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EVALUATION OF MICRO HYDRO RURAL ELECTRIFICATION PROJECTS IN THE DOMINICAN REPUBLIC

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Abstract

During the last fifteen years, the GEF Small Grants Programme (SGP) in the Dominican Republic has been promoting off-grid micro-hydropower systems (MHS) managed by the local communities. Currently, thirty-six MHS are in operation, providing electricity to rural isolated populations in the country. This thesis presents the results of a field survey conducted in the Dominican Republic, where four MHS were evaluated (Paso de la Perra, Arroyo Frio, Montazo-Vallecito, and Arroyo Majagua), in order to analyze their socio-economic stability, the status of the micro-hydro system, possible environmental changes, the level of community involvement in the project and the users' perception.

Quantitative and qualitative analyses were used based on data collected through interviews, surveys, observations and document reviews. The main outcome of this evaluation was an analysis of the strengths, weaknesses, opportunities and threats in each project. Those projects have a total installed capacity of 315.4 kW providing access to electricity to around 450 households. However, there is a significant surplus of electricity that is being wasted and the productive use of the hydroelectricity is still minimal. Therefore, five proposals were done in order to increase the capacity factor in each system: a health pot facility and a computer center with internet access, intended to improve the life quality of the inhabitants in terms of health, communication and education, and an ecotourism center, a sawmill and a cacao enterprise, as income generating activities that will give more possibilities of employment for young people in the community.

Keywords: micro hydro; electricity; renewable energy; capacity factor.

Resumen

Durante los últimos quince años el Programa de Pequeños Subsidios (PPS) en República Dominicana ha estado promoviendo sistemas micro hidroeléctricos descentralizados gestionados por las comunidades locales. Actualmente treinta y seis sistemas están en operación suministrando electricidad a población rural aislada en el territorio nacional. Esta tesis presenta los resultados de una investigación de campo realizada en República Dominicana, en la cual se evaluaron cuatro sistemas micro-hidroeléctricos (Paso de la Perra, Arroyo Frio, Montazo-Vallecito, and Arroyo Majagua). El objetivo fue analizar la estabilidad socio-económica, el estatus del sistema micro-hidroeléctrico, los posibles cambios ambientales que conlleva, el nivel de involucramiento de la comunidad y la percepción de los usuarios.

Se realizaron análisis cualitativos y cuantitativos tomando como referencia información recolectada mediante entrevistas, encuestas, observaciones y revisiones de documentos. El resultado principal de esta evaluación fue un análisis de las fortalezas, oportunidades, debilidades y amenazas en cada proyecto. Aunque estos proyectos tienen una capacidad instalada de 315.4 kW, suministrando acceso a la electricidad a alrededor de 450 hogares, hay un excedente significativo de electricidad que se está desperdiciando. Por lo tanto, se plantearon cinco propuestas con el fin de incrementar el factor de planta en cada sistema: un centro de salud y un centro de cómputo con acceso a internet con el fin de mejorar la calidad de vida de los habitantes de la comunidad en términos de salud, comunicación y educación; y un centro eco-turístico, un aserradero y una empresa de procesamiento de cacao, como actividades generadoras de ingreso que van a aportar más posibilidad de empleo para jóvenes en la comunidad.

Palabras claves: micro-hidroeléctrica, electricidad, energía renovable, factor de planta.

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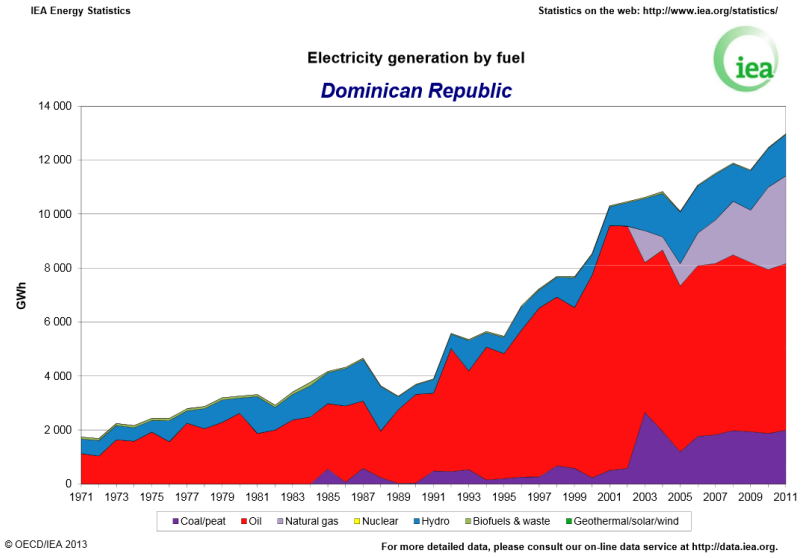
1 Introduction

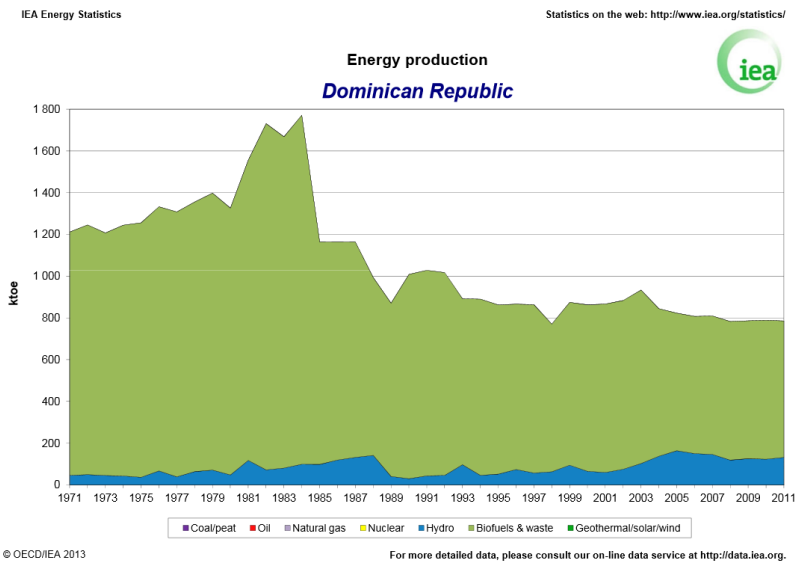
1.1 Background

According to the World Bank, over 70% of the world's population and 73% of the people classified as poor, live in middle income countries (MIC) [1]. Most of the countries in Latin America & the Caribbean are classified as Upper-middle-income economies. They have showed an increase in the economic activity through the last years. Nerveless, this increase has conducted to a rising energy demand, being the problems in the energy management one of the main factors that is affecting their development potential. One example is the Dominican Republic, where the energetic sector is a bottle neck for its development. About the 90% of the primary energy in Dominican Republic is imported [2], making them dependent on fluctuations in the value of a barrel of oil worldwide.

Since 2007, the Dominican Republic government approved the law 57-07 which target is to cover the 20% of the national energy consumption by renewable energies by 2020, in order to reduce its dependence on imported oil and other liquid fuels. However, so far, the renewable energy production is not representative in the energetic panorama of the country. For instance, the IEA statistics present the trend scenario of the last four decades. The graph 1 "total primary energy supply" depicts a trend in the primary energy imports to increase since 2004, while the graph 2 "Energy Production" shows that country's energy production doesn't have a significant increase. It should be noted that the graph 2 scale is 4 times smaller than the graph 1 scale. Moreover, not all the energy production can be called renewable energy.

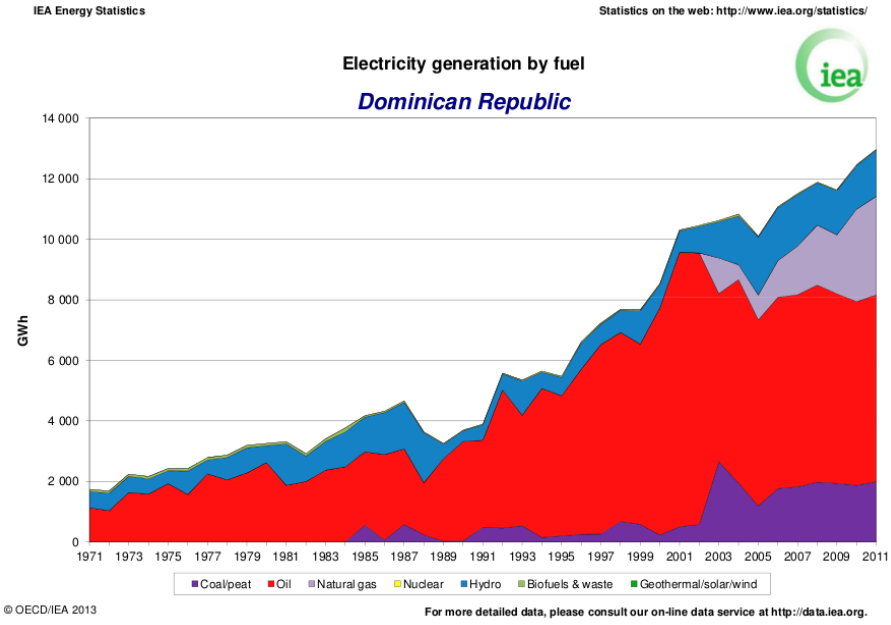


Graph 1. Total primary energy supply in Dominican Republic from 1971 to 2011 [2]



Graph 2. Total energy production in Dominican Republic from 1971 to 2011 [2]

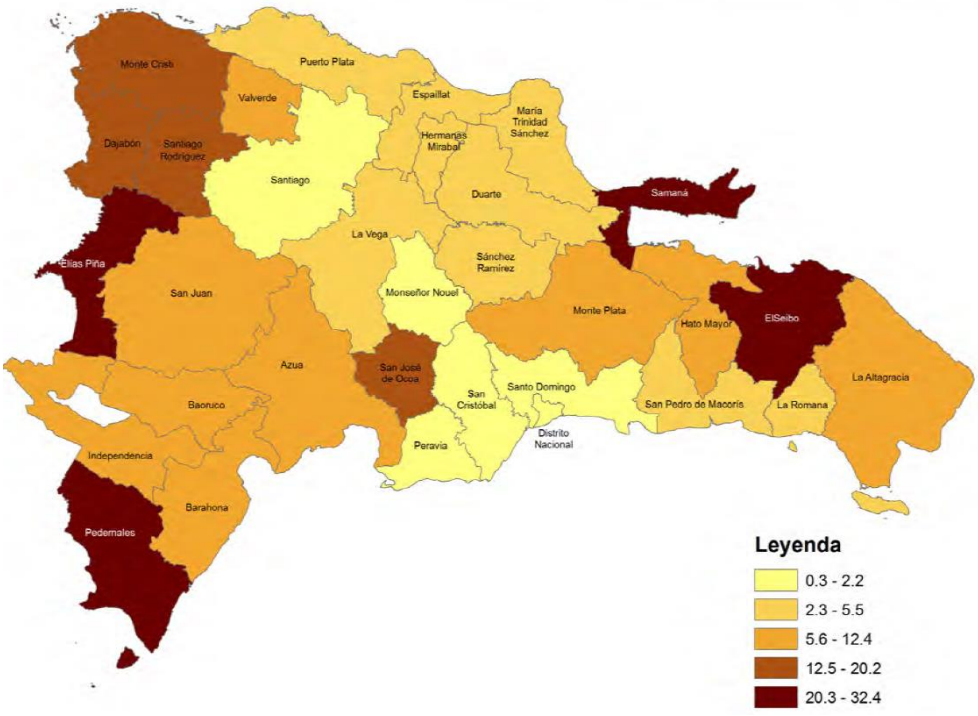
As an effect of the increasing energy demand of the country, generation of electricity has also increased. In spite of the hydropower has been playing a bigger role in electricity generation, covering approximately 11.5% of country's production (see Graph 3), the oil fuels, the natural gas and the coal continue as the leaders [2].



Graph 3. Electricity generation by fuel in Dominican Republic from 1971 to 2011 [2]

But not only is the dependence on fuel imports a problem for Dominican Republic. One of the most striking aspects of their energetic problem is the network system distribution losses. The country has one of the highest indexes of distribution losses in the world, close to 38% in 2010 [3]. In a study of the "Economic and Commercial Office of the Spain Embassy in Santo Domingo" in 2012, it was showed that the main factors of these big losses are: First, the limited electricity price, so when the oil world price is higher that the stipulated price, the government subsides the difference. Second, the electricity robbery; only the 60% of island residents are legal connected. Third, the blackouts. And finally, the inadequate investment in capacity upgrades and the limited regulatory capacity. This instability in the electricity grid corresponds to approx. the 3.4% of the national GDP. For this reason, even when there is supposed to be a 92% of population access to the electricity (in and out of the network), the quality of the service is low.

The problems mentioned previously have as a consequence a big among of population non grid connected. The map of the national grid showed a big proportion of the national territory without connection (see annex, map 4). The national average of population in rural areas without national grid electricity access is 12.28%. However, it can be seen that in some states the regional value can reach 32.4% households without national grid connection. The following map shows the results of the survey about the percent of households without access to the electricity national, done by the census 2010 [4].



Map 1. Percent of population without electricity access [4]**.**

Furthermore, due to its location, Dominican Republic has a good solar an hydro potential for energy generation, as well as a considerable good biomass and wind potential [3]. Moreover, since 2007, the Renewable Energies Incentive Law 57-07 promotes incentives for renewable energies. The benefits are, for example, an exemption from import duties, value-added tax and income tax for up to ten years until 2020; a 5% tax reduction on interest on foreign financing of renewable energy projects; a single tax credit of up to 75% on the cost of capital equipment; and a 75% financing of the total cost for small-scale renewable energy projects destined for community use, up to 500 kW [5].

By way of summarize, in one hand, Dominican Republic is an example of a developing country with serious energy management problems. On the other hand, Dominican Republic has the potential and the legal framework to promote a self-energy generation strategy. Using these resources, people living in remote regions that are currently excluded could access to the electricity. From the perspective of sustainable development, the promotion of electricity generation from renewable energy sources under an integrated approach, that goes from the local to the global and which considers social, environmental, political and economic dimensions, can lead to environmental and social benefits to those off grid village.

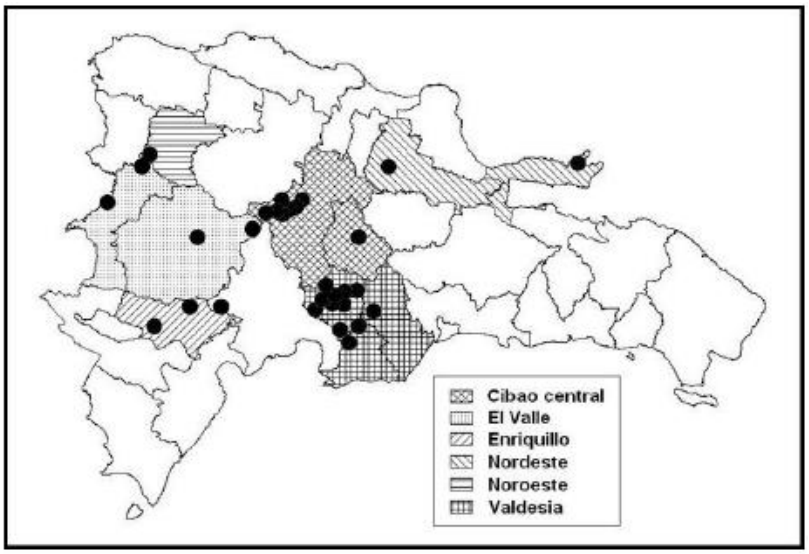
The Small Grants Programme (SGP) of the United Nations Development Programme (UNDP), which is an initiative of the Global Environment Facility (GEF), intended to support non-refundable administrative and technical assistance to civil society in the development of community activities in favor of global environment and attract well-being of local people [6]. This program has been supporting micro-hydro community projects for rural electrification in the Dominican Republic. The community would receive and administrate the electrical system (collection, distribution, and maintenance). Their idea is to use the projects to promote empower and strengthen the community structure. However, despite the large number of projects being implemented in this country (36), there are few studies in-depth evaluations of the effects of these projects on the sustainable development of the communities after it conclusion. This kind of analysis is crucial to identify the main factors conditioning the outcomes of the projects, in order to diffuse them in other context.

Taking the Dominican Republic experience as an example, this research proposes to carry out an assessment of some of the community based project for rural electrification in the Dominican Republic assisted by the Small Grants Program, in order to learn about them, identify their status quo and give some advices for a more efficient use of the energy.

1.2 State of the art

“The Small Grants Programme (SGPDR)” of the “United Nations Development Programme (UNDP)” have support a total of 36 micro hydroelectric power systems in Dominican Republic and Haiti with a capacity between 5 and 150 KW. Around 3.350 families in 55 rural communities in the mountain

area got access to the electricity with these projects. The following map shows the location of those micro hydro projects.



Map 2. Location of the communities according to the state in the Dominican Republic [7]

1.2.1 Main actors behind the projects

Rural communities: by local development and improvement of their living conditions. The rural communities are selected by 3 criteria main criteria [7]:

- poverty level: inhabitants lived under the poverty line,
- lack of access to the national grid: no intentions to connect them to the grid in short and medium term,
- potential for the development of a renewable energy source

Government: in their policies to combat poverty, strategies for reducing the dependence on imported oil and in the promotion of national development.

Local NGOs: in the promotion sustainable development in their areas of advocacy.

International Cooperation: in the funding contribution to the achievement of the Millennium Development Goals, for instance the European Union and the UNDP.

The following table shows the different stakeholders that provided the inputs to the Project, its functions and the scale where they were acting [7].

Actors	Scale			Function in the Project	Organization
	Global	National	Local		
United Nations Development Programme (UNDP)	X			Supervision, economic and financial management of the Programme	UNDP-United nations
European Commission, Inter-American Foundation, Among other sponsors	X			Funding	-
GEF Small Grants Programme Dominican Republic (SGP DR)		X		Execution unit: coordinate and implement with the partners all aspects related to the execution of this program.	SGP-UNDP-United nations
Advisory Committee (CA)		X		Guidelines for implementing the program: participation on the board of the Cooperatives Association. It will consist of a representative of all institutions involved in the action.	-
National Institute of Water Resources (INDRHI)		X		technical and institutional support	Government
				Ensure sustainability after the time of program execution is completed.	
NGO CAREL			X	technical advice, specifically for their experience in promoting renewable energy participatory approach at community level	Non-profit organization.
NGOs and community-based organizations (OCBs)			X	Implement each community projects, coordinating with beneficiary communities the execution of planned activities.	Non-profit organization.
Local community			X	unskilled labor force required for the execution of the project	Non-profit organization.
community cooperatives			X	direct management of their projects and subsequent handling of the installed systems	community-based organizations
				billing for the service and maintenance of the energy system	
National Energy Commission (CNE)		X		legal framework	Government
Dominican Corporation of Electric State Companies (CDEEE)		X		Experience in Rural and Suburban Electrification Unit (UERS). Official electricity sector	Government
Unidad de Electrificación Rural y Suburbana (UERS-CDEEE)		X		Mini Grid, materials for the construction, pipelines and technical assistance.	Government

Table 1 Stakeholders that provided the inputs of the Project, its functions, the percent of funding and the scale where they were acting

1.2.2 Input in the projects

- non-refundable funds and supports
- Technical assistance to civil society in the development of community activities
- Unskilled labor required for the execution of the project (provided by each community).

1.2.3 Outputs of the projects

1) 36 renewable micro-hydro energy systems installed and running with a capacity between 5 and 132 KW
2) microenterprise community systems established based on the use of different renewable energy sources
3) A national association of cooperative management of energy systems established based on principles of mutual support, solidarity and cross subsidy.

1.2.4 Activities done in the projects

1.2.4.1 Output 1

- Feasibility studies and system design
- Participatory planning workshops in targeted communities
- Construction and installation of the system
- Training and community education (workshops about climate change, electricity, and basic plumbing)
- Training workshops on the design, implementation and management of renewable energy systems.
- Reforestation campaigns
- Establishment and operation of brigades for the control of forest fires.

1.2.4.2 Output 2

- Microenterprise integrated production system of candies, cheeses and marketing of fish.
- Marketing and commercialization of production
- Implementation of a national campaign to promote replication Integral System
- Identification and formulation of community entrepreneurship

1.2.4.3 Output 3

- Constitution of 36 community micro enterprises (cooperatives) for the management of the systems
- Continuous Training: Courses and workshops on Management and Accounting
- Continuous Training: Workshops on rational use of energy and tariff systems.
- Socialization Program in the local government level
- Establishment of a National Association of cooperatives: agreements between community cooperatives, NGOs, local governments, and government institutions.

- Establishment of a solidarity fund with contributions from the profits of each community cooperative.
- Development of a strategic plan for the promotion and use of renewable energy sources.
- Implementation of the plan.

1.2.5 Outcomes of the project

- The develop among the users of a culture of payment for the energy service
- A reduction in the technological and communicative gap with the rest of the world
- Long distance training and new educational opportunities to compensate the shortcomings of the current education system
- A strengthening of the internal organization of the communities, stimulating their ability to develop projects and making concrete the possibility of acting
- Conservation and/or restoration of the native forest cover in the river basin
- Promotion of a sustainable land use in mountain areas
- Development of business initiatives that add value to their production systems

1.2.6 Expected impacts

- Improvement in the life quality of the communities
- Socio economic development in the communities
- Reduction of the oil dependency
- A critical group of people able to continue with future initiative and with the potential to contribute to the energy policies in Dominican Republic in order to archive sustainable solutions.
- Ensure the availability of raw materials required by the renewable energy systems
- Contribution to the conservation of biodiversity
- Reduction of the social and environmental local vulnerability to the threat of climate change
- Reduction of the emigration rate to the cities and other countries
- Reduction of about 40000 tons of CO2 emission
- More gender equity

1.3 Research Questions

What is the status quo of the community based micro-hydro electrification projects in rural areas in Dominican Republic in the sector of effectiveness of the system and sustainable development of the community?

1.4 Objectives

1.4.1 General objective

Evaluate some of the community based micro hydro project for rural electrification in Dominican Republic.

1.4.2 Specifics objectives

- Identify the main stakeholders and their role in some of the community based micro hydro project done by the Small Grants Programme UNDP
- Develop an indicator framework to evaluate the projects and apply it to the cases of study.
- Analyze the results and identify the status quo of the project according to the indicator framework.
- Develop a capacity analysis for a more efficient use of the energy resources.

2 Methodology

2.1 State of the art: methodologies for evaluation of rural electrification projects

2.1.1 Multi criteria analysis

The multi criteria analysis is the most common used methodology for evaluation of sustainability in rural electrification projects. Some recognized international organizations such as the International Atomic Energy Agency, part of the United Nations Department of Economic and Social affairs, as well as the International Energy Agency, Eurostat and European Environment Agency, have develop a list of "Energy Indicators for Sustainable Development" in social, economic and environmental dimensions. Many different projects use those indicators as the base for their evaluation. According to each case, more dimensions or more indicators are added.

Social Dimension	
SOC1:	Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy
SOC2:	Share of household income spent on fuel and electricity
SOC3:	Household energy use for each income group and corresponding fuel mix
SOC4:	Accident fatalities per energy produced by fuel chain
Economic Dimension	
ECO1:	Energy use per capita
ECO2:	Energy use per unit of GDP
ECO3:	Efficiency of energy conversion and distribution
ECO4:	Reserves-to-production ratio
ECO5:	Resources-to-production ratio
ECO6:	Industrial energy intensities
ECO7:	Agricultural energy intensities
ECO8:	Service/commercial energy intensities
ECO9:	Household energy intensities
ECO10:	Transport energy intensities
ECO11:	Fuel shares in energy and electricity
ECO12:	Non-carbon energy share in energy and electricity
ECO13:	Renewable energy share in energy and electricity
ECO14:	End-use energy prices by fuel and by sector
ECO15:	Net energy import dependency
ECO16:	Stocks of critical fuels per corresponding fuel consumption
Environmental Dimension	
ENV1:	Greenhouse gas (GHG) emissions from energy production and use, per capita and per unit of GDP
ENV2:	Ambient concentrations of air pollutants in urban areas
ENV3:	Air pollutant emissions from energy systems
ENV4-1:	Contaminant discharges in liquid effluents from energy systems
ENV4-2:	Oil discharges into coastal waters
ENV5:	Soil area where acidification exceeds critical load
ENV6:	Rate of deforestation attributed to energy use
ENV7:	Ratio of solid waste generation to units of energy produced
ENV8:	Ratio of solid waste properly disposed of to total generated solid waste
ENV9:	Ratio of solid radioactive waste to units of energy produced
ENV10:	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste

Table 2. Example of a multi criteria analysis using "Energy Indicators for Sustainable Development" [8]

2.1.2 The Demand-Oriented Approach

The demand-oriented approach was developed by the Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) [9]. This approach is divided in two parts: a participatory assessment and a socioeconomic impact survey. The participatory assessment works at the community, institutional, and policy levels, and its goal is to evaluate the role of: gender, poverty, energy demand, participation, and sustainable energy service delivery in rural electrification projects. The second part, the socioeconomic impact survey, is created with the intention of understand and quantify the socioeconomic benefits of rural electrification interventions. Those benefits are related to education, health, productivity, convenience, security, and entertainment.

This methodology claims that a participatory approach is important, because it allows the participants identify problems and solutions. As a consequent, they will be more likely to own the outcomes and more satisfice with them. Participatory assessment tools such as wealth classification, community mapping, focus group discussion, among other, are recommended. In terms of the socioeconomic impact survey, this methodology emphasis the need of a cross-

sectional comparisons. This comparison can be either in different period samples during the project life or by a survey of households in a project area with and without electricity.

Finally, the methodology shows examples of monitoring and evaluation indicators divided in the following dimensions of analysis:

- Effectively sustained (System quality, Effective functioning, Financial viability of service provider, Effective management)
- Equitable access and use (Access, Affordability, Service use, Demand-responsive service)
- Degree of change in cross-sectorial social development indicators (Education, Health care and safety, Domestic productivity, Income-generating activities, "Strategic" needs, Access to information and communications, Convenience/comfort)
- Division of costs and benefits
- Participation in service establishment and operation
- Policy support for gender and poverty
- Institutional support for gender and poverty

One main difference between this methodology (the demand-oriented approach) with the one mentioned before (the multi criteria analysis), is the use of the participatory assessment tools for the data collection. More or less, the indicators are organized in different categories, but they cover the same topics. However, topics as the users comfort and entertainment, the weight of the stakeholders in term of funding and benefits with the project, and the policy and institutional support are new.

2.1.3 Participative Approaches

The Master Thesis of Shradha Upadhayay from the San Jose State University about the evaluation of the effectiveness of micro-hydropower projects in Nepal, proposed an additional participative approach to counteract the information get by using normal indicators [10]. In this methodology, not only the framework for evaluation of micro-hydro projects is studied, but also de conceptual framework for understanding public participation in those projects. In other words, the research aims to evaluate the effectiveness of the micro-hydro project in meeting the electricity needs of the community and its relationship with the public participation. The way the public participation is evaluated, is by carrying out semi structured interviews. An example of the criteria and indicators is showed in the table below.

Operationalization of participation model (Adapted from Butterfoss 2007. Used with permission)

Criteria	Indicators	Tool
1. Opportunities and Levels of Decision-making	Participating but not voicing opinions Consulted/informed but not involved in decision-making Directly involved and have full control over decision-making	Semi-structured interview See Appendix A: PC (a)
2. Degree of Local Ownership Perceived	Level of participation in community meetings Providing financial/technical/social support	See Appendix A: PC (b)
3. Satisfaction with the Process of Participation	Recognition in community meetings Voice heard at meetings	See Appendix A: PC (c)
4. Diversity of Participants	Ethnic, social, gender and economic diversity	See Appendix A: PD (d)
5. Benefits and Challenges of Participation	Knowledge/Involvement in vital projects affecting the community Ability to make informed decisions Improved quality of life Difficulty in participation due to lack of self confidence and social barriers	See Appendix A: PC (e)

Table 3 Criteria and Indicators presented by Shradha Upadhayay [10]

The information of the interviews was compared with the data from questionnaires face to face about the effectiveness of the micro-hydro project (see table 4) in three different scenarios: an ideal scenario where each indicator has an equal importance when considering the success of the project; a community-based scenario where each indicator is weighted based on what the community views; and an expert-based scenario, based on the experts view.

Operationalization of Adams and Ghaly's Evaluation Model

Criteria	Indicators	Tools
1. Adequacy of Funding	Total capital construction cost Percentage of loans and grant Tariff collection Operation and maintenance cost List of funders and donars	Appendix B (PP 1 to 13)
2. Technical Performance and project efficiency	Power output No. of households served Repair and maintenance Skill of operators and managers	
3. Technology Transfer	Replication of program to nearby villages	
4. Environmental Effects	Regulations associated with the micro-hydro project	
6. Social Stability	Increase in mills for grinding Satisfaction with the project	
7. User Satisfaction	No complaints about the system Reliable electricity for domestic and/or industrial use Improvement in education and health	Appendix A PU (7)

Table 4 Criteria and Indicators presented by Shradha Upadhayay [10]

2.1.4 Case of study Ba'Kelalan, Malaysia

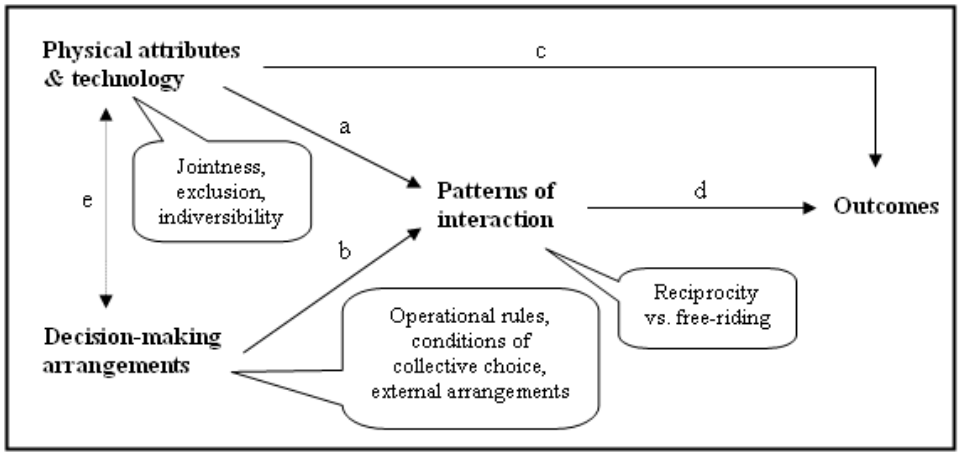
In the article "Learning from experience: A survey of existing micro-hydropower projects in Ba'Kelalan, Malaysia" [11], the methodology use three specific dimensions for comparing micro hydro projects:

- Socio-economic: household income and expenditure, current energy use pattern and peak load and daily consumption
- Current status of micro-hydro systems: type of MHS, funding, level of community involvement in the project, electricity tariff and operation and maintenance arrangements
- Impacts: users' perceived impacts of micro-hydropower on social life

What makes this methodology different from the others is the way the impacts are measured. Instead of comparing socio-economic indicators after and before the projects, it is asked to the people what they perceived has changed. The reason of the modification of the information source is to reduce the uncertainty while measuring impacts, due to the many different factors that may affect them beyond the access to electricity.

2.1.5 Local institutional analysis in community-based organizations

This methodology assumes the key to success in decentralized mini grids as the local institutional arrangement on who invests, develops, owns and operates the systems [12]. It is focus in community-based organizations, since it is the most common business model for renewable energy mini grid systems in developing countries. In that case, the use of electricity will be characterized as a common-pool resource (CPRs). Therefore, the success of the project will be highly dependent on the collective action of the users in order to avoid a 'selfish' use of the common resources, also known as the "The Tragedy of the Commons"[13]. For this reason, it is proposed to evaluate the decision-making arrangements, and if they match to the system's technical/physical characteristics. The graph below shows a diagram of the four different evaluation dimensions.



Graph 4. Framework for Analysing Common-Pool Resources[12]

The methodology defines those dimensions as:

Physical attributes and technology: available electricity, the quality of the construction, the equipment's age, the risk of natural hazards, the size of the scheme in terms of the length of the channel and the extent of the grid, the quality and quantity of the water, the used equipment and its age, and many others factors. All these factors have different impacts in influencing the benefit the community gains from the projects as well as the costs it has to bear for the operation and maintenance.

Decision-making arrangements: rules that structure individual and collective choices with respect to the commons. The attributes are:

- operational rules: to limit the users' behavior in the interest of maintaining the commons
- conditions of collective choice: how the group decides to modify operational rules
- external arrangements: decision-structures outside the community that influence the use and organization

Those decision-making arrangements depend on the social context: Differences in the number of electrified households, distinctive religious and ethnic-linguistic settings, different numbers of clans with varying relationships, socio-economic heterogeneities, personal jealousies and conflict potentials make different demands on the regulating institutions.

Patterns of interaction: result of the comparison of the costs and benefits of alternative actions. That can be seen as a 'collective action', such as contributing to the maintenance of the MHS, or to "free-ride" and look only at one's own individual self-interest.

Outcomes: result of the combination of the patterns of behavior and the physical characteristics of the resource, in regards to a MHS a reliable and adequately powerful flow of electricity.

2.2 Evaluation framework for this project

Based on the main factors described in the methodologies mentioned above, an indicator framework was proposed, taking into account the time available for the data collection (3 month) and the accessibility to the information.

2.2.1 Project Context for each case of study

Before the field visit to the projects, some general information will be collected:

Physical and technology context: Available water flow, design flow and head, turbine manufacturer, turbine type, nominal capacity, numbers of turbines, generator type, generator rated capacity, risk of natural hazards, length of the channel, extent of the grid , year the construction started, year the construction ended, initial project cost.

Socio-economical context: Number of families/houses/people in the community, number of schools, health centers, small-scale industry, drinking water potable plant, irrigation or any other commercial/medical facilities in the community, predominant economic activities within the community, division in the village by incomes groups, distinctive religious and ethnic-linguistic settings (if relevant), socio-economic heterogeneities.

2.2.2 Indicator framework

The next table shows the dimension of analysis selected for the evaluation, the criteria and indicators for each one. The first dimension (socio-economic stability) aims to evaluate if the users have an equitable access to the electricity, if they can pay for it, and what are they using it for in their normal life. With the second dimension (status of the micro-hydro system) is intended to give an overview of the system management. It evaluates the tariff system, the quality of the services, the quality of the equipment operation and its maintenance. The next dimension (environmental changes) focus in identify if there are relevant implications in the environment due to the project. The fourth dimension (level of community involvement in the project) seeks to understand how the participation of the community during and after the project execution was and the sense of belonging to the system they are managing. Finally, the last dimension (users' perception) attempt to recognize the main impacts of the project in the users' life quality from their perspective.

dimension	criteria	Indicators	no.	components
Socio-economic stability	Equitable access	Share of population with access to electricity	S1	Total number of households with electricity
				Total number of households
		Share of public areas, health centers and schools with access to electricity	S2	total public areas and services in the village
				public areas with electricity
		Distribution of electricity client households in income groups categories	S3	income groups in the village
				Households with electricity (for each income group)
	Affordability	Share of household income spent on fuel and electricity	S4	Household income spent on fuel and electricity before and after
				Household income
		Coverage of installation/connection costs	S5	cover of installation/connection cost
				price of a new installation/connection
	Current energy use pattern	changes in the households fuel mix	S6	Corresponding fuel mix (for each income group) (candles, kerosene, gas) - before and after

		Choices in services, appliances, and equipment offered	S7	type of appliances (according to income group)
				main hours of use of the appliances
				appliances expected per household in the planning of the project
		Peak load	S8	peak load value
				peak load hours
Current status of micro-hydro systems	Electricity tariff system	fee/tariff structure	M1	Profitability
				Operational and maintenance costs
				Tariff collection per month
				Levelize cost of energy
		Tariff collection pattern	M2	Existence of different tariff according to income group
				Person(s) in charge of the management of the collection
				Timeliness of payments
		re-investment	M3	Share of profit set aside for re-investment in electricity service business
	Effective functioning of MHS	Capacity Factor	M4	actual output
				potential output
		Plant Factor	M5	Running hours
				Total possible running time
		Quality of Power	M6	Fluctuations in voltage
	Quality of the MH power plant	Quality of design	M7	appropriate sized for the daily use
		Quality of components	M8	problems with manufacturer guarantees
		Quality of installation.	M9	properly sited
				proper wire sizing and connections
				safe and accessible for maintenance
	Operation and Maintenance arrangements	Existence and implementation of maintenance schedule	M10	Existence of maintenance schedule
				maintenance plan followed
				existence of trained daily operators in the village for O&M
Environmental changes	Actions for protection and conservation	New activities for conservation (reforestation) and/or protections	E1	New activities for conservation
				New activities for protections
	land use changes	land use	E2	land use changes
Level of community involvement in the project	Degree of local ownership	communities involvement in funding	L1	users contribution
		communities involvement in site works, ongoing operation and maintenance.	L2	Working days contributed to activities related to the implementation, installation or

				other related to the MHP
		participation and voice hear at the meetings	L3	number of households who feel their opinion was take into account in the meetings
		gender and economic diversity in the meetings	L4	share of participants in the meeting according to gender and economic diversity
	Level of decision-making	Level of decision-making	L5	Number of households participation but without voting option
				number of households consulted/informed but not involved in decision-making
				number of households directly involved and have dull control over decision making
Users perception	Users' perceived impacts on social life	perceived impacts in education	U1	perceived impacts in education
		perceived impacts in health care	U2	perceived impacts in health care
		perceived impacts in safety	U3	perceived impacts in safety
		perceived impacts in domestic productivity	U4	perceived impacts in domestic productivity
		perceived impacts in income-generating activities	U5	perceived impacts in income-generating activities
		perceived impacts in comfort and entertainment	U6	perceived impacts in comfort and entertainment
	Users' satisfaction	Number of complaints about the system/operation/service	U7	complaints about the system/operation/service
		Perception about the service costs (financial Equity)	U8	Perception about the service costs (financial Equity)

2.3 Sample size calculation

The selection of the data sample size was done according to the next equation [14]:

$$n = \frac{K^2 pqN}{e^2(N-1) + K^2 pq}$$

Where

N: is the population size (in this case, the total of households)

K: is the Z-score. It is a constant value depending on the confidence level and measures the amount of uncertainty that can be tolerated. In this case the selected confidence level is 95%, so Z would be 1,96.

K: is the margin of error. It is the amount of error that can be tolerated. In this case it would be +/- 15%.

p: is the standard of deviation. It is 0.5

q: $1 - p$

2.4 Methodology for sampling

This research is based on quantitative and qualitative data collected through interviews to the community leader, to one of the integrant of the MHS committee and one operator of the system, as well as through face to face questionnaires to a determined number of households.

Each micro hydroelectric project supplies electricity to a group of small communities. Therefore, the sample was distributed between the communities according to the percent of population connected to the grid in each of them. One household was selected randomly, and the following households were interviewed following the snowball method.

3 Case of study description

3.1 Physical and technology context:

From a total of 36 micro hydro systems that are currently working in Dominican Republic developed under the SGP methodology, four projects were selected for this research. The criteria were:

1. The two bigger size projects: Arroyo Frio (120 kW) and "Montazo-Vallecito" (132 kW)

2. Two projects with long time working compared to the others: Paso de la Perra (5 years) and Arroyo Majagua (4 years)

The table below presents an overview of the main physical and technology information.

Project	No. Of families	Turbine		Generator		Head [m]	Rated flow [gpm]
		Type	Capacity [kW]	Type	Capacity [kW]		
Arroyo Frio	207	Two Nozzle Turgo	120	synchronous AC. 3 phase	150	90	5000
Paso de la Perra	181	Pelton	45	synchronous AC. 3 phase	53	167, 6	650
Montazo-Vallecito	122	Cross flow	132	synchronous AC. 3 phase	200	25,5	12000
Arroyo Majagua	38	Two Nozzle Turgo	18.4	synchronous AC. 1 phase	22	37,7	998

Table 5 Information about the projects

Map 3. Location of the projects in Google earth

The first two projects, Paso de la Perra and Arroyo Frio, are part of the municipal district of Manabao (La Vega, Dominican Republic). Manabao is located in the Central Cordillera, in the upper basin of the "Yaque del Norte" River, between 1000 and 1250 meters above sea level. The national grid passes through this province and the Manabao town has access to grid electricity. However, the grid is 6 km away from the communities surveyed. The climate of the area is defined as temperate highland tropical climate (Cfb), being characterized by abundant rainfall (over 1100 mm per year). The average annual temperature is 18.1 °C. There are two wet peaks in the year in the months of May and September-October and the driest period in the month of February (annex A.1 graph 39, annex A.4 map 5). The projects were visited for one week at the end of March 2015.

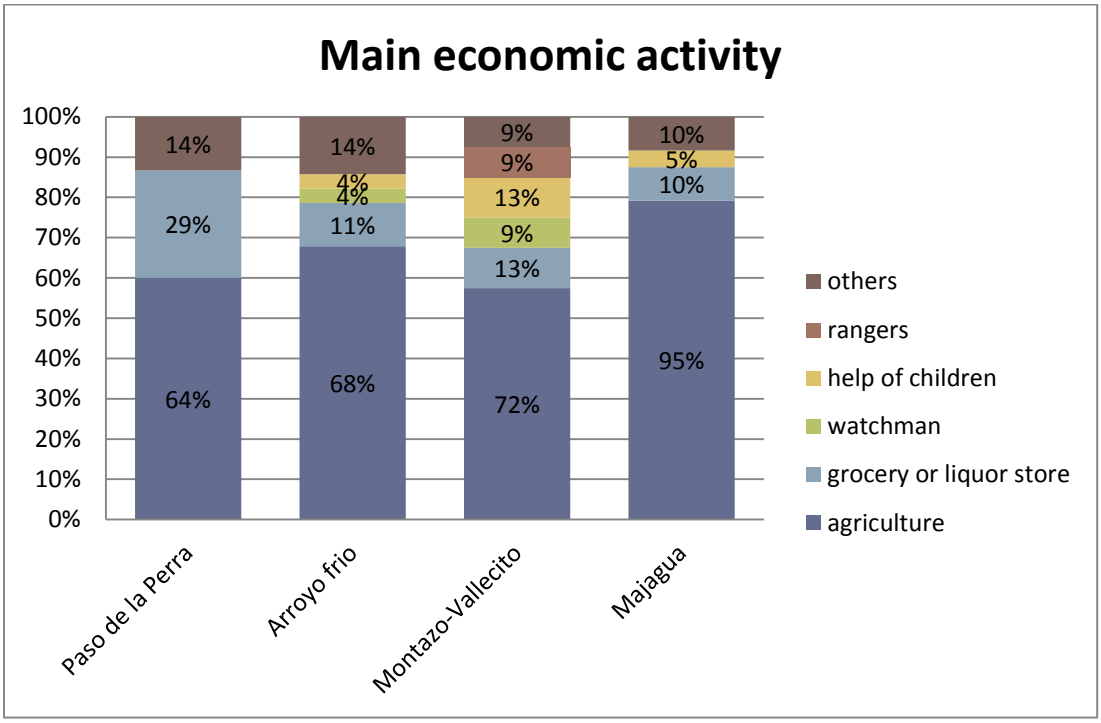
The communities of Montazo and Vallecito are located in the municipality of Sabaneta (Santiago Rodriguez, Dominican Republic) between 480 and 540 meters above sea level, in the north side of the central cordillera. Sabaneta has a tropical wet and dry climate (Aw). It has a pronounced dry season in winter with much less rain than in summer. The two wet peaks are in the May and September-October, and the driest period from December to March. The average annual temperature in Sabaneta is 26.8°Ca, and the average rainfall per year is 1268 mm (annex A.1 graph 40, annex A.4 map 6). The projects Montazo-Vallecito was visited for one week at the middle of April 2015.

The community of Arroyo Majagua is located in the municipality of Yamasá (Monte Plata, Dominican Republic) between 160 and 200 meters above sea level. The climate in Yamasá is

classified as tropical rainforest climate (Af). There is rainfall throughout the year (over 2100 mm per year); even in the driest month it exceeds the 60 mm. The driest period is in winter and the average annual temperature is 25.8 ° C (annex A.1 graph 41, annex A.4 map 7). The project was visited for 3 days at the beginning of May. This year, May was the driest month due to the El Niño Southern Oscillation (ENSO) that delayed the onset of the rainy season.

3.2 Socio-economical context:

The predominant economic activity in all the communities is the agriculture. In Arroyo Frio and Paso de la Perra the main crop is tayota, whose production is mainly intended for sale on the domestic market and for export to Haiti, through an organized system of sale and transfer of the products. Additionally, there are greenhouses where vegetables are cultivated predominantly intended for sale. Other agricultural products such as beans, cassava, bananas, plantains, among others, are for local consumption. In Montazo-Vallecito, the main products are tubers for local consumption and to sale in the farmers markets in the towns and cities close. Majagua is dedicated to the cultivation of organic cacao. They have agreements with companies that buy the cocoa beans already dried.



Graph 5. Main economic activities in the communities, data collected in interviews

In terms of infrastructure, all the communities have access to potable water through a community aqueduct. Each community has a primary school, but students should move to the nearest town for high school education or to the city if they want to have access to university degrees. Only the community of Vallecito has a health facility which provides basic medical consultation services.

4 Results

4.1 Sample size:

Micro hydro Project	Total Families connected to the project	Communities	No of families per communities	Sample size per Community
Arroyo Frio	181*	Arroyo Frio	28	4
		Caña Seca	48	7
		Los Ramos	34	4
		El Arraijan	38	5
		Boca de los Rios	33	4
Paso de la Perra	120*	Paso de la Perra	12	2
		La Peñita	36	4
		Joya de Ramon	37	4
		La Cotorra	35	4
Montazo-Vallecito	122	Montazo	82	21
		Vallecito	40	10
Arroyo Majagua	38	Majagua	38	20

Table 6. Sample size.

***For the sample size calculation, the population of the projects Arroyo Frio and Paso de la Perra was taken as a whole since their communities are overlap and the future plan is to be connected to one grid**

4.2 Socio economic stability

4.2.1 Equitable access

SE1. Share of population with access to electricity

Indicator description:

Indicator Name	SE1: Share of population with access to electricity
research question	Which proportion of the population has access to electricity?
Dimension	Socio Economic Stability
Theme	Equitable access
Components	Total number of households with electricity
	Total number of households
Calculation	(# households with electricity)*100/(# households)
Measure Unit	number
Unit for comparison	**%** population with access to electricity
Sources	**Relevant interview question**
interview to Local MHS committee	How many families do not have access to the electricity because they did not participate in the project?
interview to community leader	How many households does the village have?
	What is the number of families/houses/people supplied with the electricity?
interview to project managers and Local MHS committee	What is the number of families/houses/people supplied with the electricity?

Result:

Project	Total Families	Families w/electricity from the MHS	Indicator value	Description
Paso de la Perra	126	120	**95%**	3 cottages use panels, and 3 families did not want to participate into the project.
Arroyo Frio	263	207	**79%**	According to the secretary, 207 families are connected, yet there are 263 rights to light sold.
Montazo-Vallecito	127	122	**96%**	2 families did not participate in the project. 3 families did participate but are not connected since they are isolated.
Arroyo Majagua	56	38	**68%**	Some families are connected to the national grid.

Table 7 Result indicator share of population with access to electricity

According to the information from the interviews, all the inhabitants of the communities had the chance to participate in the project. However, there are some families in each community that decided to do not have access to the electricity of the micro hydro system. This decision was mainly based on the fact that they were either using other electricity sources (e.g. the cottages with solar panels and the households connected to the national grid), or they did not wanted to be part of the brigades.

SE2. Share of public areas, health centers and schools with access to electricity

Indicator description:

Indicator Name	SE2: Share of public areas, health centers and schools with access to electricity
research question	Do the public services have access to electricity?
Dimension	Socio Economic Stability
Theme	Equitable access
Components	total public areas and services in the village
	public areas and services with electricity
Calculation	# public areas and services with electricity*100/total public areas and services
Measure Unit	Number
Unit for comparison	**%** public areas with access to electricity
Sources	**Relevant interview question**
interview to project managers and local MHS committee	Does it provide services for schools, health centers, small-scale industry, drinking water, irrigation or any other commercial / medical facilities?
Observation and visit to the places	total public areas and services in the village

Result:

Project	Total of public areas	Public Areas w/electricity from the MHS	Indicator value	Description
Paso de la Perra	2	2	**100%**	Church and school
Arroyo Frio	2	2	**100%**	Church and school
Montazo-Vallecito	4	4	**100%**	Church, school, and community health center
Arroyo Majagua	2	2	**100%**	Church and school

Table 8. Result indicator share of public areas, health centers and schools with access to electricity.

There is a 100% cover to the public areas/buildings available in the communities. For those places, the electricity is free of price. Nonetheless, they have a breaker of 3 amperes in Paso de la Perra, Arroyo Frio and Arroyo Majagua, and one of 6 amperes in Montazo-Vallecito.

SE3: Equitable distribution of electricity

Indicator description:

Indicator Name	SE3: Equitable distribution of electricity
research question	Is there an unequal access to electricity?
Dimension	Socio Economic Stability
Theme	Equitable access
Components	income groups in the village
	Households with electricity per income group
Calculation	# households with equitable electricity *100/ total inhabitants
Measure Unit	Number
Unit for comparison	% households with an equal access to electricity
Sources	**Relevant interview question**
interview to community leader	Is the village divided by incomes groups? Does it influence the access to electricity?
interview to Local MHS committee	I understand there is a different tariff in the community. Is this correct? If so, how many families are in each tariff group? How much electricity can they use?

Result:

Project	Users with priority or disadvantage	Total of users	Indicator value	Description
Paso de la Perra	0	120	100%	No problems so far
Arroyo Frio	1	207	99,5%	Problem with a cottage that has no breaker. It belongs to one of the wealthiest persons in the country.
Montazo-Vallecito	3	122	98%	Problem with 3 very distant homes that could not be connected even though they were part of the brigades.
Arroyo Majagua	0	38	100%	No problems so far

Table 9. Result indicator equitable distribution of electricity

On the one hand, Arroyo Frio has a case of a user with priority. The owner of a cottage had connection without breaker; however, they already got an agreement. Since they have a surplus of energy, they will allow the connection, yet the user will have to pay more for electricity. On the other hand, there is the opposite case in Montazo-Vallecito. Due to the insolate location of three families, the cost of the grid was too high, and they could not be connected, although they participated in the brigades. The solution so far was to offer them the option to be connected if they decide to move their houses closer to grid.

4.2.2 Affordability

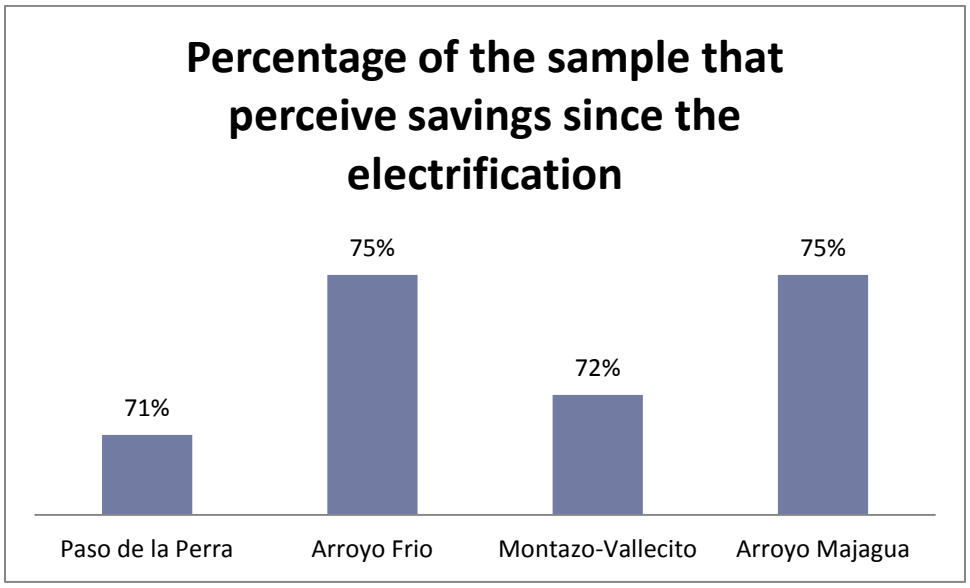
SE4: Share of household income spent on fuel and electricity

Indicator description:

Indicator Name	SE4: Share of household income spent on fuel and electricity
research question	Is the price of the service affordable? Did they reduce the expenditures?
Dimension	Socio Economic Stability
Theme	Affordability
Components	Household income spent on fuel and electricity before and after
Calculation	[(expenditures on energy before) - (expenditures on energy after)]
	% incomes for energy
Measure Unit	Pesos/month
Unit for comparison	% reduction expenditures
Sources	**Relevant interview question**
indirect calculation from face to face questionnaires	How do you distribute your current monthly expenditures and how did you do it before the MHS?
	Which one are your family main income sources? What kind of crops do you have in your land? How much do you produce in a month?
face to face questionnaire to households	Since using the new light and/or electricity, have you save Money? How much?

Result:

There were two different ways to calculate this indicator. On the one hand, there was a direct question during the face to face questionnaire to the households about their savings since they are using the new light and/or electricity. This question was seldom answered. The reasons are either that they do not want to talk about their incomes with strangers, and/or that they do not have an idea of how much they spend per month; most of them are dedicated to the agriculture, their incomes are not regular, neither their expenditures. As a result of this situation, it was possible to know if they perceive they are paying less for light than before the project. However, it was no possible to get a real value.

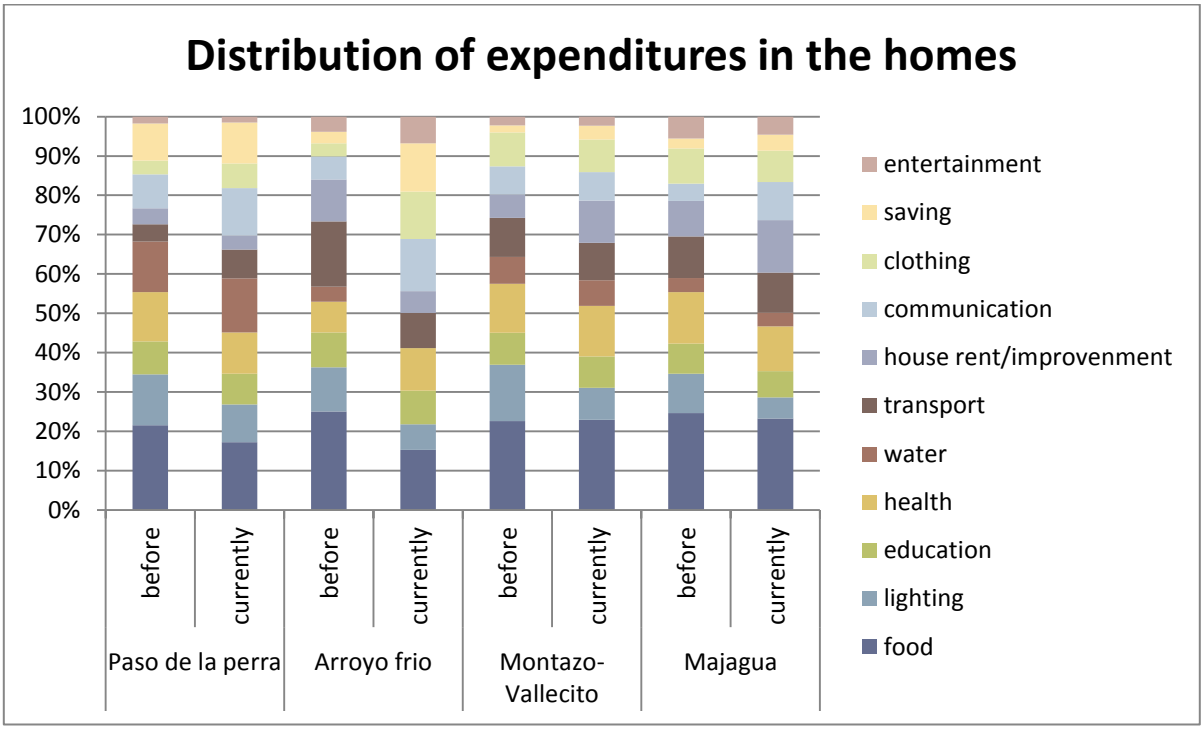


Graph 6. Percentage of the sample that perceive saving since the electrification

On the other hand, an indirect calculation was done in a dynamic way. It consists in color cards with the name and draw (for those who are analphabet) of the different kind of expenditures families have in a month: food, lighting, education, health, water, transport, housing, communication, clothing, saving and entertainment. The interviewee will receive an amount of seeds, in this case corn, representing their total incomes. Thereafter, the interviewer will have to distribute them over the different cards according to the amount of money they spend on each one. This activity is done for two different times: expenditures before and after the electricity access.

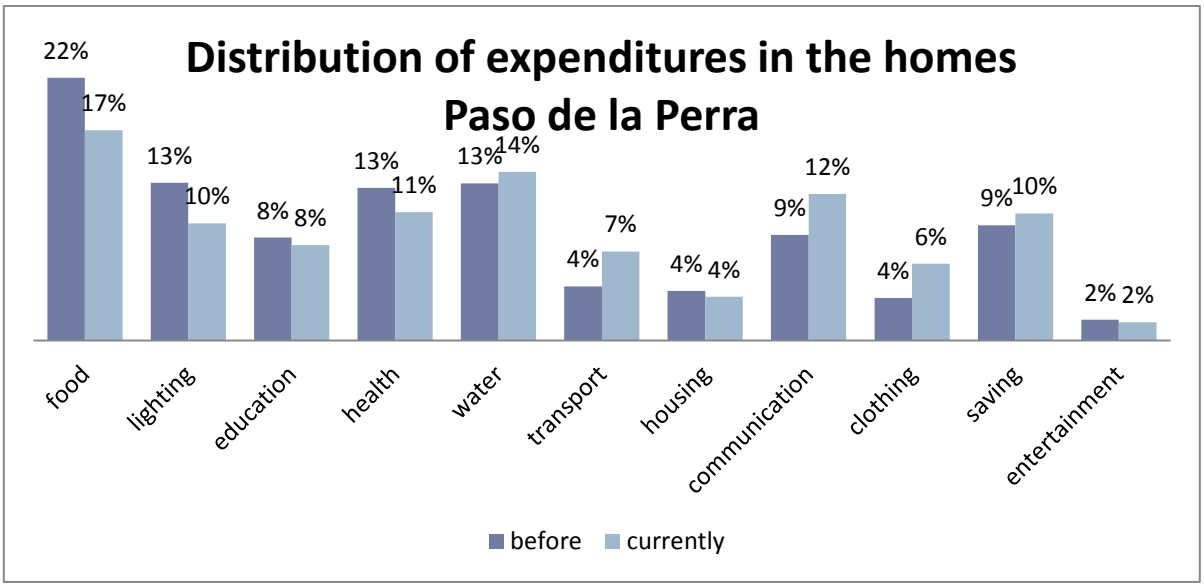
Photo 1. Activity for analysis of expenditures

After counting the number of seeds over each card, it was possible to calculate the percent of the total incomes that each card represents. That information is not only useful to know how do the distributes their expenditures and what are their priorities, but also to understanding if a family is reducing their expenses in lighting after the access to electricity from the MHS, and what are they using the savings for.



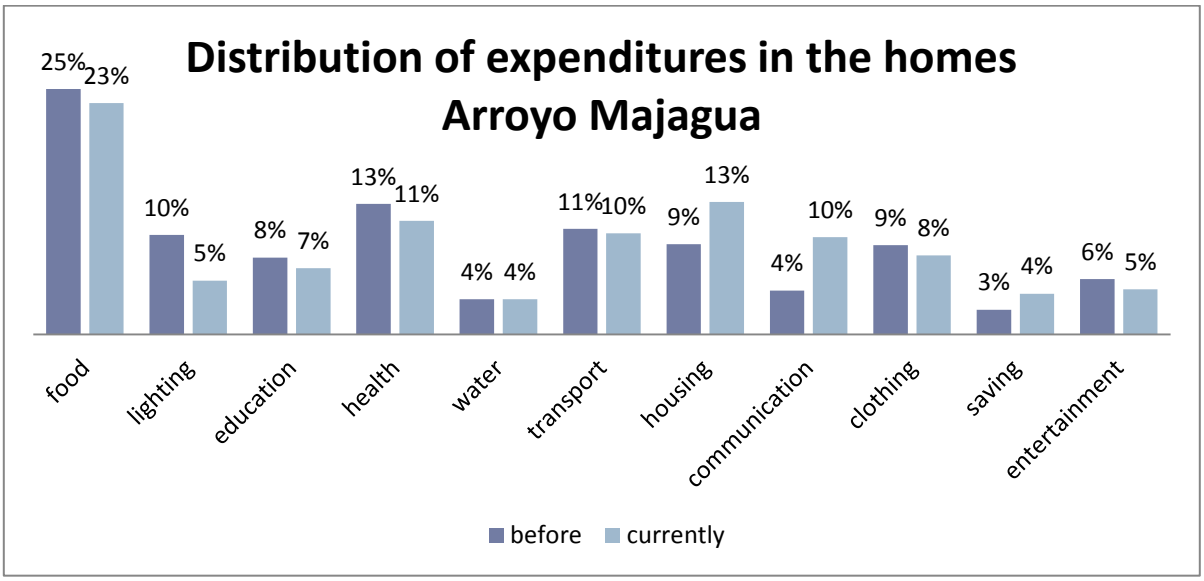
Graph 7. Distribution of expenditures in the homes

Paso de la Perra: After 5 years since electrification, the main changes in the distribution of the expenditures are savings in food and light. The savings in food are an indirect consequence due to the use of fridges. The money saved is been used for secondary necessities such as transportation, clothing and communication. The increase of expenditures in communication could be caused by the fact that currently, most of the families have at least one cellphone at home, although the cellphone signal there is weak. Before the electricity connection, it was not possible to charge the cell phones, so they needed to travel to the closest town in order to make a call.



Graph 8. Distribution of expenditures in the homes in Paso de la Perra

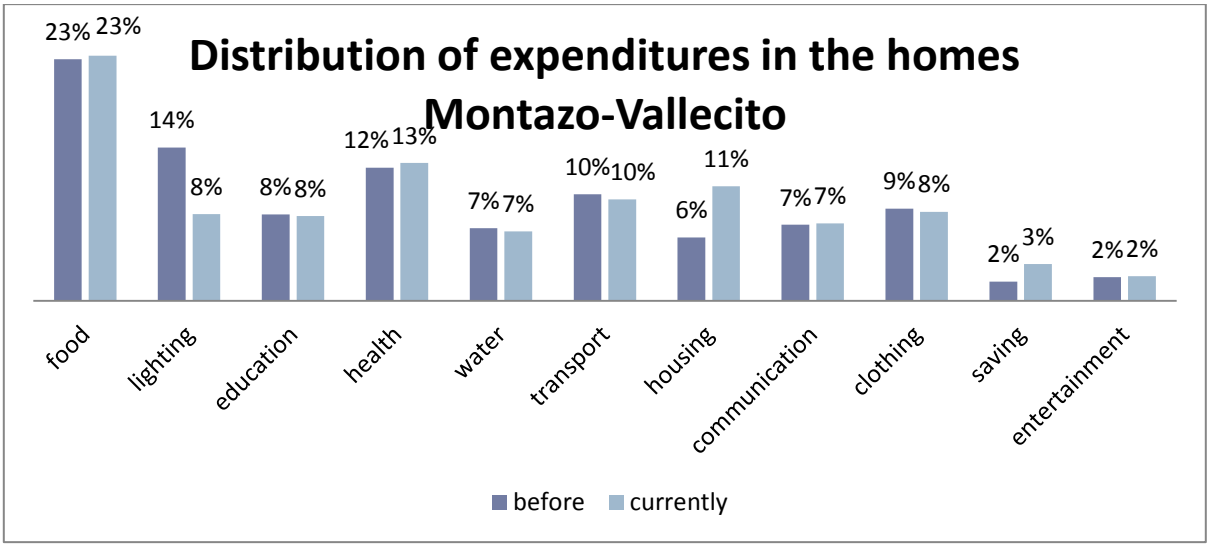
Arroyo Majagua: In the case of Arroyo Majagua, after 4 years, the main savings are due to lighting. The money saved is been used to buy new appliances as well as savings fund. It is meaningful to mention that saving is an activity that was not commonly practice there, different from Paso de la Perra.



Graph 9. Distribution of expenditures in the homes in Arroyo Majagua

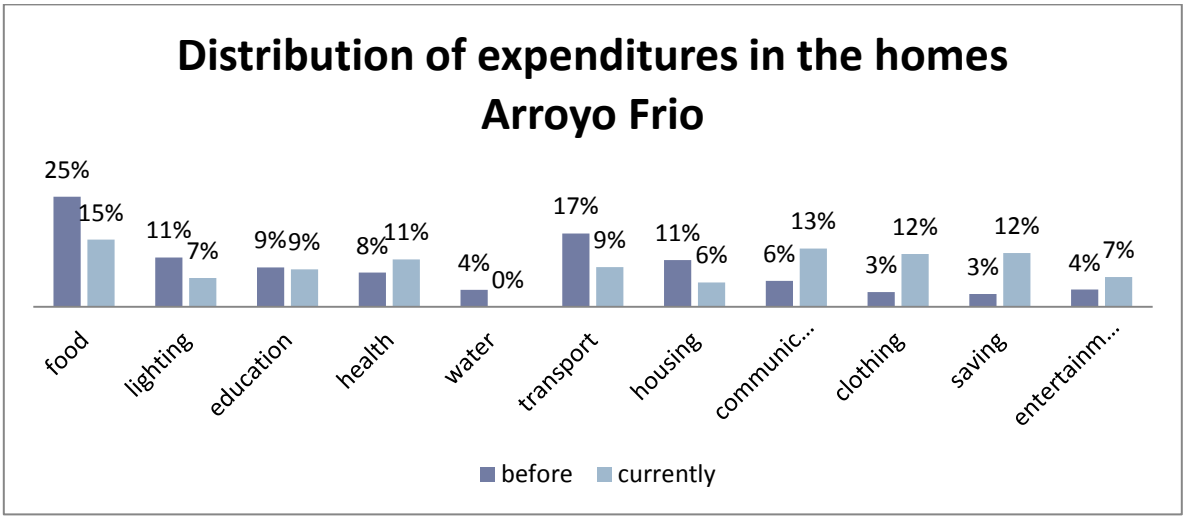
Montazo-Vallecito: The community of Montazo-Vallecito has been connected to the light for one year. For this reason, the majority of their savings is been used to buy new appliances for the home, which imply more expenditures in housing. The money use for saving funds has increase as

well, and the situation is similar to Arroyo Majagua; saving money for the future is a new activity. In the other aspects, there have not been relevant changes in the short time the project has been running.



Graph 10. Distribution of expenditures in the homes in Montazo-Vallecito

Arroyo Frio: Although the micro hydroelectric in Arroyo Frio had only 2 month since the inauguration at the moment of the visit, there is a community that used to be part of Paso de la Perra and now is connected to Arroyo Frio. That community was the only one able to explain the changes since they have had electricity for 5 years. Those households have been saving in lighting, and indirect expenses as food, house improvements and transportation. This money is being reinvested mostly in secondary expenditures such as communication, clothing, entertainment and savings.



Graph 11. Distribution of expenditures in the homes in Arroyo Frio

On the whole, it can be seen that there was a significant reduction in the expenditures for lighting since the communities have access to the micro hydroelectricity. Besides, there is a trend for the inversion of this money. For those communities that have a short time after the electrification, the mainly use of that money is to buy appliances for the house; meanwhile the communities with more than 5 years use them for secondary necessities (e.g: clothing, transportation and communication).

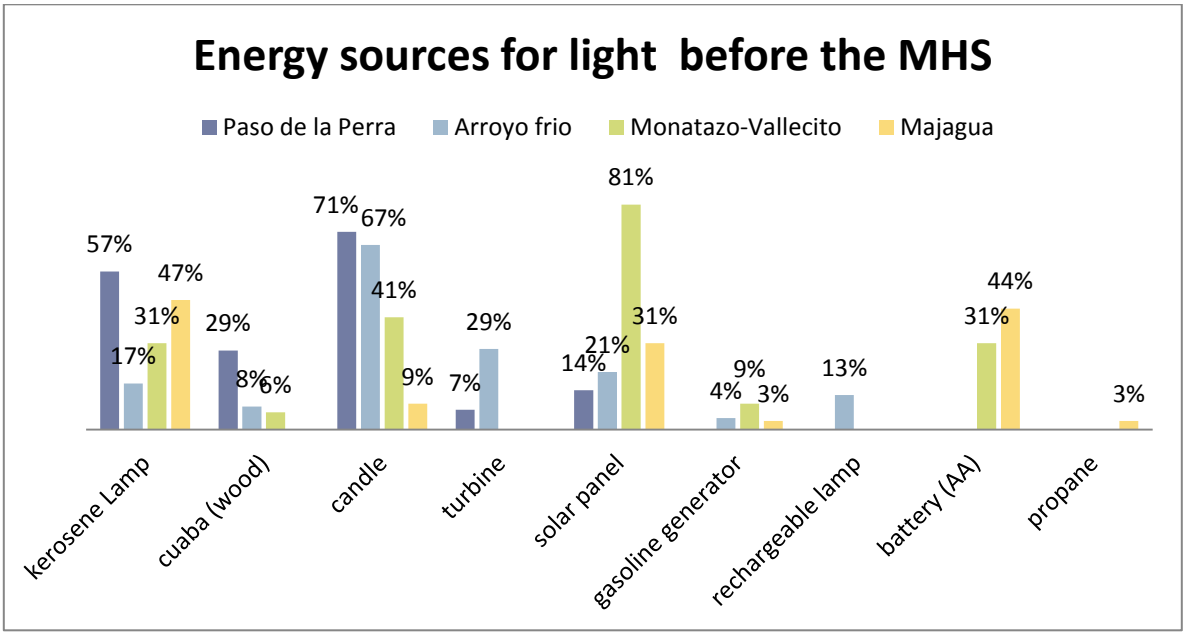
Equally important is the habit of saving that the project entails. Before paying a monthly tariff for electricity, most of the households did not know how much money they were spending for having light. Now, they know they must save money during the month to pay for the electricity, and in many cases, they even starting saving money for other future uses.

SE5: changes in the households fuel mix

Indicator description:

Indicator Name	**SE5: changes in the households fuel mix**
research question	Did they reduce the amount of other energy sources for light due to the project? Does the differences in the use of mixed fuels are related with income groups?
Dimension	Socio Economic Stability
Theme	Equitable access
Components	Corresponding fuel mix for light (for each income group) (candles, kerosene, gas) - before and after
Calculation	# households that used each fuel/ Total inhabitants interviewed
Measure Unit	Number, gallons/month
Unit for comparison	% user per each fuel mix
Sources	**Relevant interview question**
face to face questionnaire to households	Before being connected to the MHS, what fuel sources did you use?
	Has the electricity and/or light provided through the MHS served as a substitute for it?

Result:



Graph 12.Energy source for light before the Micro hydro system

In Paso de la Perra, 6 years ago, the poorest houses where using cuaba (wood) as light source. However, kerosene lamps and candles were the most common used light sources. Only few households had a turbine-generator in an irrigation channel or a solar panel.

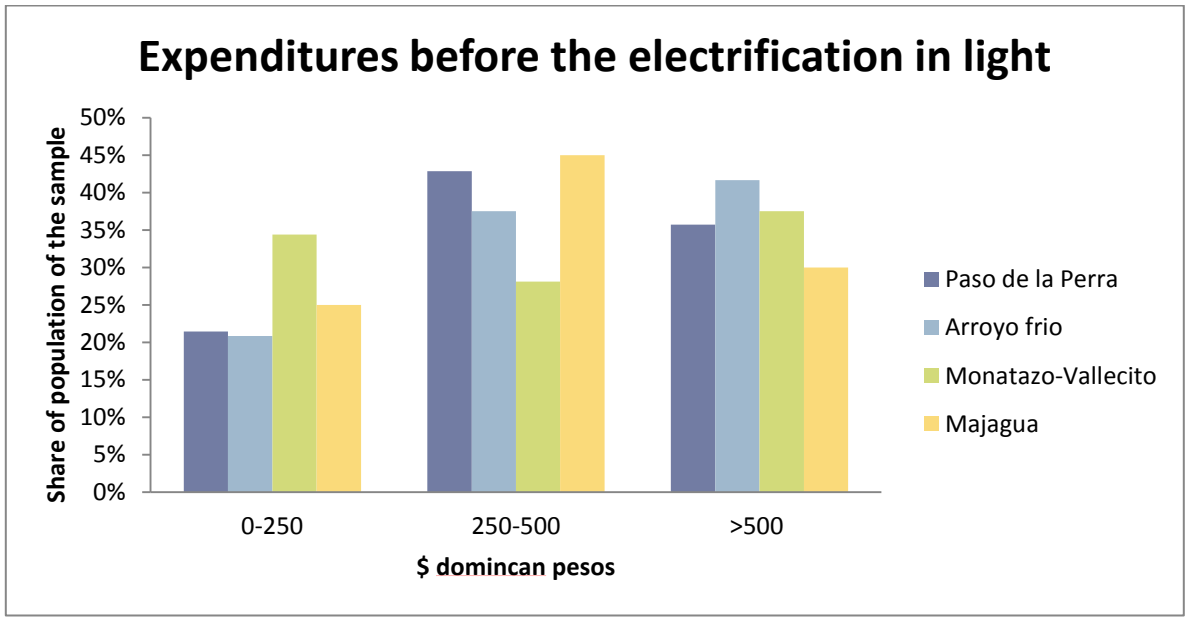
In the case of Arroyo Frio, one of the communities had a turbine-generator in the irrigation channel close to where the power house is currently located, and it was supplying only light (2 light bulbs per house) for around 20 households when possible. However, most of the people were using candles.

The community of Montazo-Vallecito was part of previous program a couple of years before the MHS, where the government gave them solar panels for free, so most of the households used to have one. The solar panels where enough for lighting and a radio, but not more than that. The replacement of the battery had to be done by the user.

Households in Arroyo Majagua were using mostly kerosene lamps and candles. Some of them where part of a program in the 90s, where they rent a solar panel. They were paying a monthly fee, and after some time they had the opportunity to buy it.

In some communities, they were using batteries (AA) for the flashlights and it is the only sources that is still been used.

Taking into account the kind of source and the quantity each household was using before the MHS, an approximate value of the total monthly expenditures was calculated. The next graph split the sample in three different groups taking as a reference the current tariff of electricity for households is $250 Dominican pesos/month (except for "Paso de la Perra where they are currently paying $200 Dominican pesos/month).



Graph 13. Expenditures before the electrification in light

The first group represents the population that is not saving money or paying the same ($0-250 Dominican pesos/month). Most of the people that was expending less than the current tariff, were those using cuaba (wood) and/or kerosene lamps.

The second group corresponds to the population that is saving money but not more than the double ($250-500 Dominican pesos/month).

Finally, the last group are those who are saving more than two times what they pay now for the electricity (>$500 Dominican pesos/month).

4.2.3 Current energy use pattern

SE7: Choices in services, appliances, and equipment offered

Indicator description:

Indicator Name	SE6: Choices in services, appliances, and equipment offered
research question	What are the energy needs and usage patterns of the villagers? Are those according to the plans?
Dimension	Socio Economic Stability
Theme	Current energy use pattern
Components	type of appliances (according to income group)
	main hours of use of the appliances
	appliances expected per household in the planning of the project
Calculation	graph KW vs. hours
Measure Unit	Number and specification
	hours/day
Unit for comparison	daily load profile
Sources	**Relevant interview question**
face to face questionnaire to households	Which of the following electrical appliances do you own? At what time do you normally use them? Light, TV, Radio, Refrigerator, Washing machine, Electric fan, Cell phone, Other.
interview to project managers	When the system was designed, what were the expected appliances per household? Do you have any studies about the expected demand curve?
	Do you think the plan was followed? And how do you control it?

Result:

Main appliances used in the Dominican Republic houses:

Appliance	Consumption [W]
light bulb	15
TV	90
radio	40
washing machine	350
fridge	220
cell phone	5
blender	350
fan	100
freezer	220
toaster	500
iron	1000
hairdryer	800

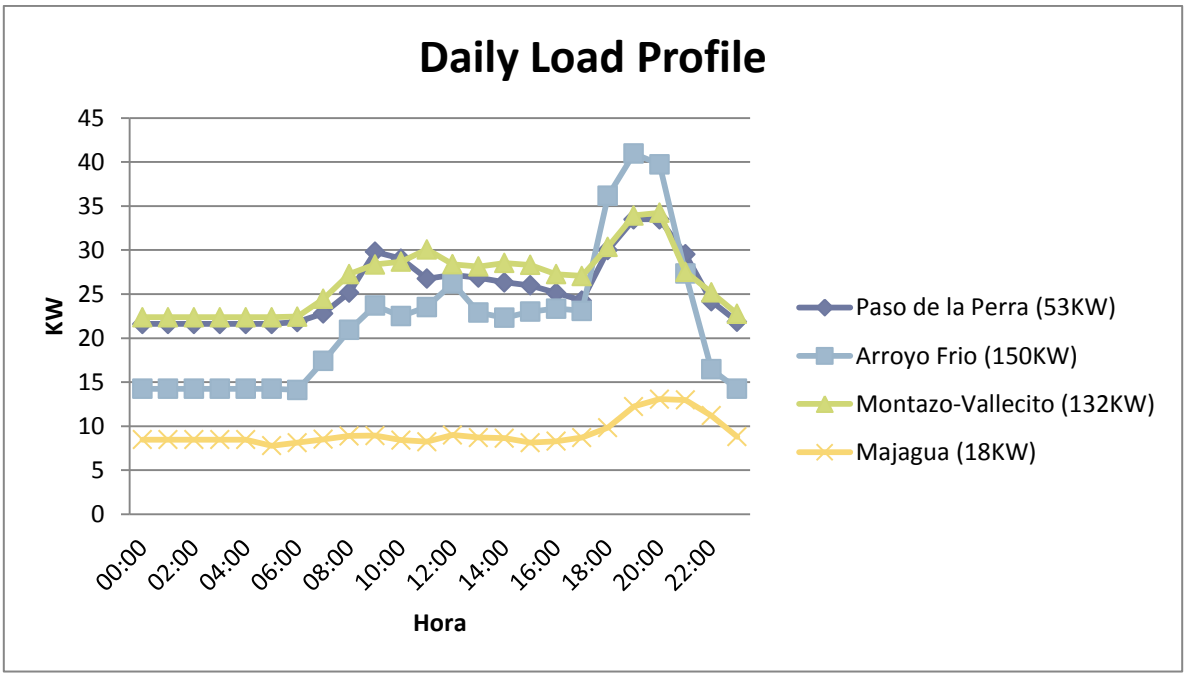
Table 10. Main appliances used in Dominican Republic

Since its planning, there is a restriction in the use of the electricity according to the type of user (household, business or public areas). This electricity is limited through a breaker. Paso de la Perra is the only community where each user has an electricity meter, so the household, for instance, have a full price of $200 Dominican pesos per month (approx. 4,45 dollars/month) if they consume less than 100KWh per month. So far, it has never happened that a household exceed this value. The following table shows the consumption limits in each project.

Paso de la Perra	**No.**	**Breaker [A]**	**Consumption Limit [KW]**
Households	120	3	360
Grocery store and other business	30	6	720
school/church	2	3	360
Arroyo Frio	**No.**	**Breaker [A]**	**Consumption Limit [KW]**
Households	263	3 o 4	360
Grocery store and other business	18	6	720
Cottages	13	9	1080
school/church	4	3	350
Montazo-Vallecito	**No.**	**Breaker [A]**	**Consumption Limit [KW]**
Households	122	3 o 6	720
Grocery store and other business	8	10	1200
school/church/community health center	4	6	720
Arroyo Majagua	**No.**	**Breaker [A]**	**Consumption Limit [KW]**
Households	38	3	360
Grocery store and other business	3	6	720
school/church	2	3	360

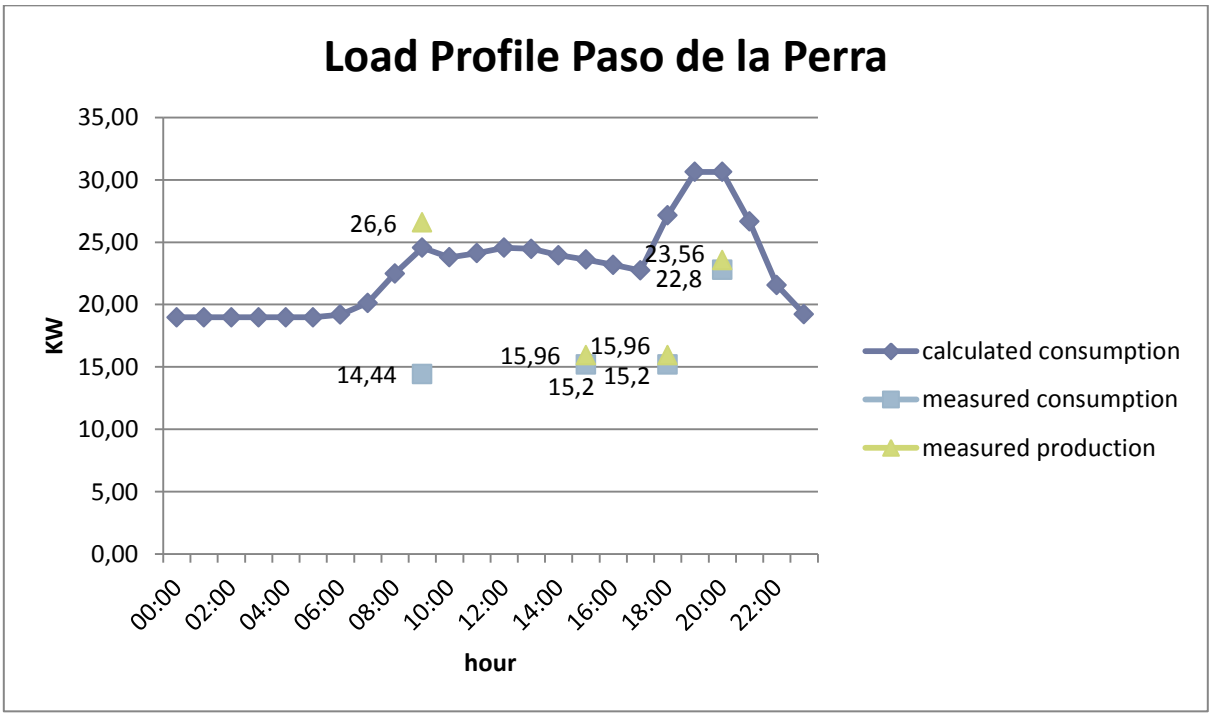
Table 11. Consumption limits for the users in each project

A daily load profile was calculated according to the information from the face to face questionnaires.

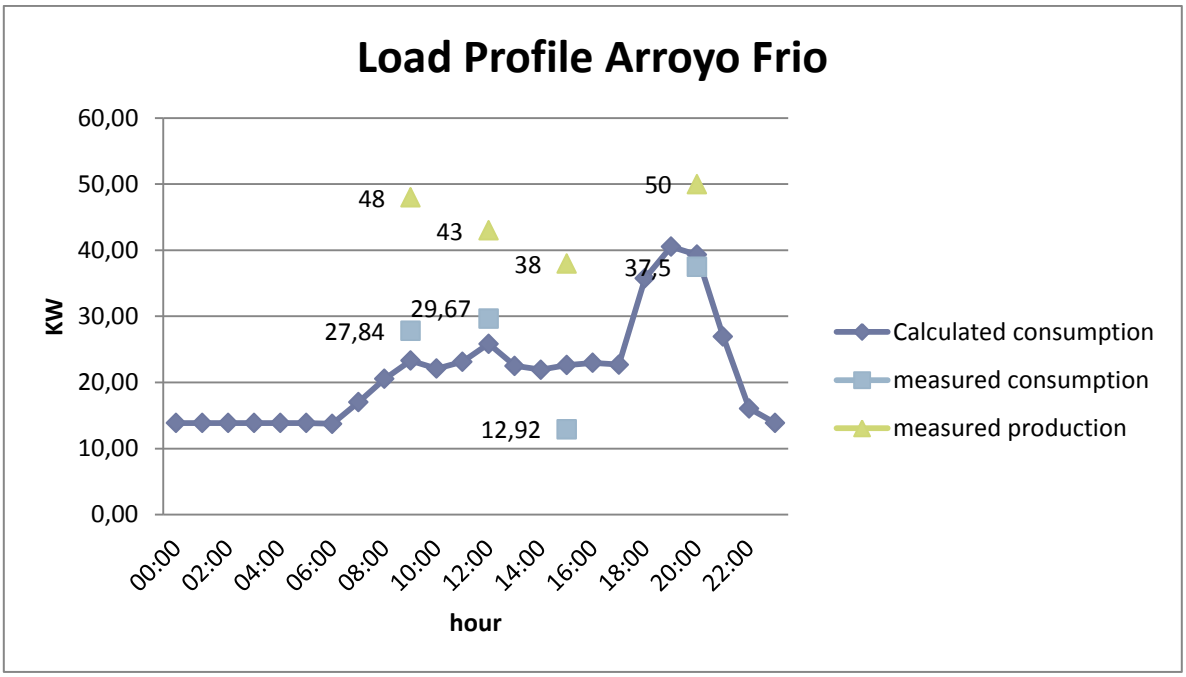


Graph 14. Daily Load Profile for the projects

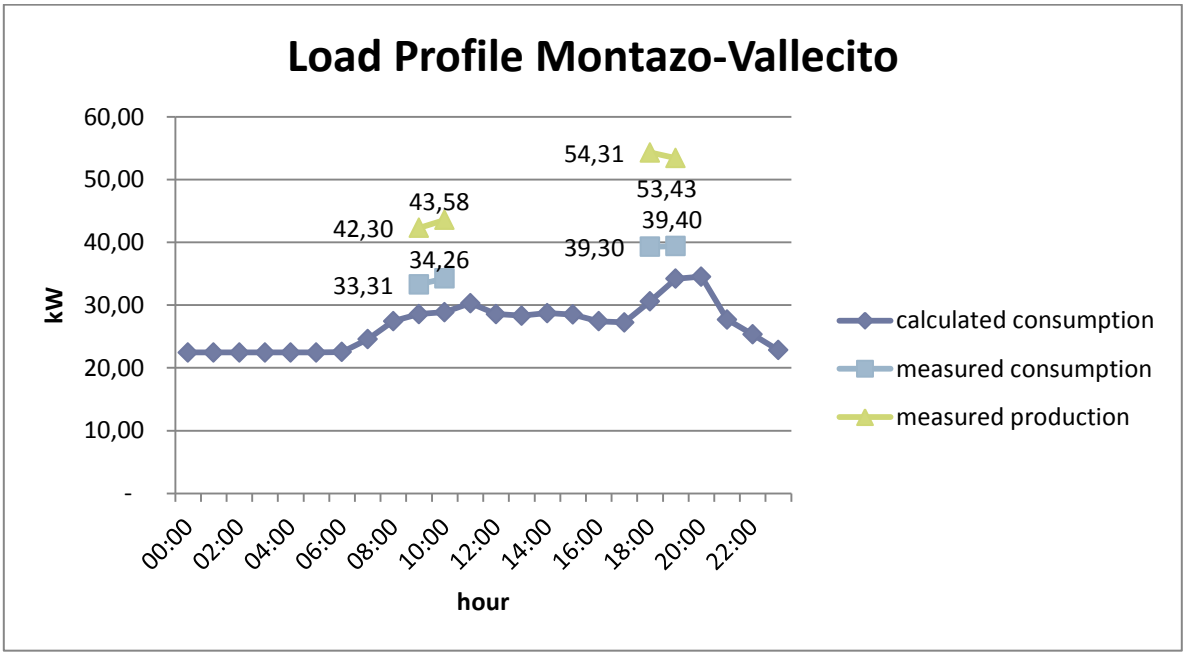
Additionally, measurements in the power house where done in order to compare the calculated values with the real one.



Graph 15. Load profile for Paso de la Perra vs measure information

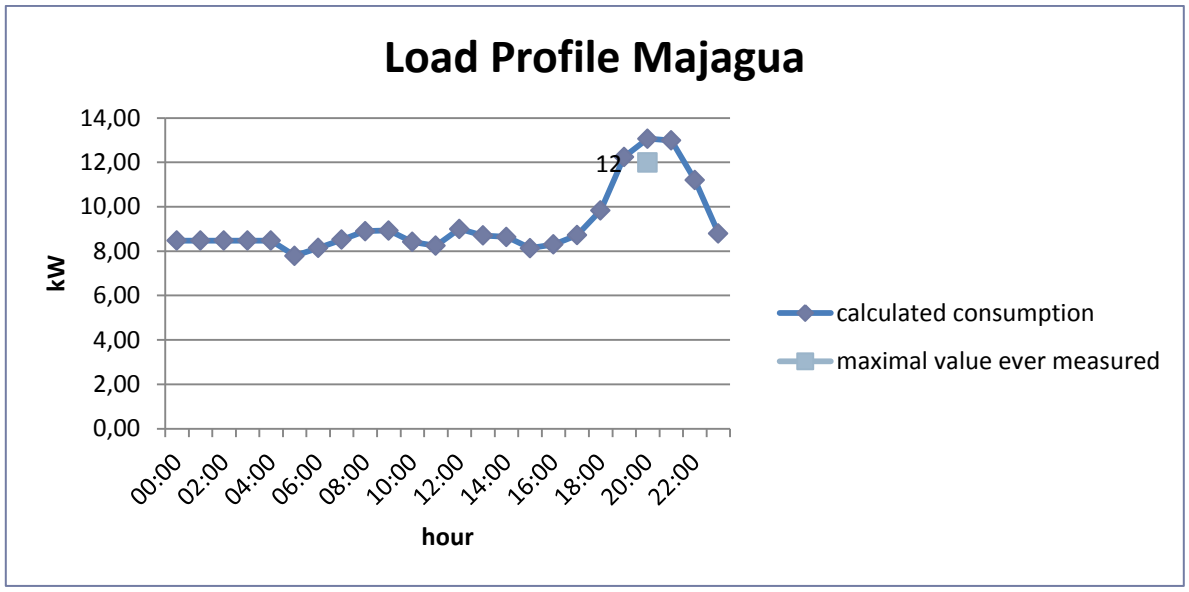


Graph 16. Load profile for Arroyo Frio Vs measure information



Graph 17. Load profile for Montazo-Vallecito vs measure information

In Arroyo Majagua, the amperimeter was not working. Therefore, it was not possible to have in situ real information. The operator says that the maximal value ever measured with an voltmeter was 12 kW at the evening.



Graph 18. Load profile Arroyo Majagua vs measure information

SE8: Peak load

Indicator description:

Indicator Name	SE7: Peak load
research question	When and how big is the peak load compare with the capacity?
Dimension	Socio Economic Stability
Theme	Current energy use pattern
Components	peak load value
	peak load hours
Calculation	graph KW vs hours
Measure Unit	KW
	hours/day
Unit for comparison	peak load curve/day
Sources	**Relevant interview question**
interview to O&M	What is the daily average peak load registered?
	At what time does it usually occurred?
	What is annual/monthly peak load, and what is the average?

Result:

The next table presents the peak hour data for each project:

Data	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Rated Capacity	53 kW	150 kW	132 kW	18 kW
Calculated Peak Load	33,49 kW	40,95 kW	34,25 kW	13,07 kW
Hour	19:00-21:00	19:00-20:00	20:00-21:00	20:00-21:00
Measured production	23,56 kW	37,5 kW	53,43 kW	12 kW*
Measured consumption	22,8 KW	50 kW	39,4 kW	No data
Hour	20:15	21:40	21:15	evening

Table 12. Result indicator Peak load

4.3 Micro hydro system status

4.3.1 Electricity tariff system

M1: Fee/tariff structure

Indicator description:

Indicator Name	**M1: fee/tariff structure**
research question	What do they do with the money collected? Can the tariff system cover the cost of installation, operation and maintenance, system expansion and eventual replacement of major parts? Is the electricity metering effective?
Dimension	Current status of Micro Hydro System
Theme	Electricity tariff system
Components	Profitability
	Operational and maintenance costs
	How much is the salary of an operator?
	Levelize cost of energy
Calculation	LCE=total expenditures/ total consumption
Measure Unit	$ Pesos/month
Unit for comparison	$ Pesos/KW
Sources	**Relevant interview question**
interview to Local MHS committee	How much is the salary of an operator? How much is the electricity tariff? How much (in total) do you collect per month? What is the Operation/Maintenance cost per month? What are the total operation, repair, maintenance costs since installation of the plant?
interview to project managers	What was the initial project cost? Who financed it? Is there a study on the cost of the kWh required to cover the initial investment and operating and maintenance expenses?
interview to O&M	How much electricity is generated annually? (last year) Do you have a record of the electricity generated to date? How much is it?

Result:

The levelize cost of energy (LCOE) was calculated using the following equation [15]:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + R_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

n is the lifetime of the system. For micro hydro systems the common value is 15 years.

I_t are the investment expenditures.

M_t are the operation and maintenance expenditures per year. Only the salaries where assumed as the fixed operation and maintenance expenditures.

R_t are the expenditure on repairs per year. The value corresponds to all the money each project has spent in repairs so far, divided by the number of years working since its inauguration.

E_t is the total electricity consumed per year. It was calculated based on the load profile. Therefore, the final (LCOE) value will be higher than the normal values in literature; it takes not only the energy production into account, but also the transmission losses and wasted energy.

r is the discount rate. A value of 13,75 was assumed taking as a reference the default values for the expected return on equity for energy distribution and energy demand in Dominican Republic [16].

Project Investment				
Projects:	**Paso de la Perra**	**Arroyo Frio**	**Montazo-Vallecito**	**Arroyo Majagua**
total cost of the project [$ pesos dom.]	13.885.621,90	48.018.724,08	45.878.159,65	10.463.000,00
total paid by the community [$ pesos dom.]	3.031.304,92	3.780.400,00	4.957.500,00	2.100.000,00
No. Of HH	181	207	122	38
Turbine capacity [kW]	45	150	132	18,4
Cost per KW [$pesos dom/kW]	308.569,38	320.124,83	347.561,82	568.641,30

Table 13. Project Investment

Calculation of the operation and maintenances expenditures

O&M expenditures				
Projects:	**Paso de la Perra**	**Arroyo Frio**	**Montazo-Vallecito**	**Arroyo Majagua**
O&M monthly expenditures [$ pesos dom.]	14.000,00	19.000,00	16.000,00	0,00
O&M per year [$ pesos dom.]	168.000,00	228.000,00	192.000,00	0,00

Table 14. Operation and maintenances expenditures

Calculation of the repairs expenditures

Repairs expenditures				
Projects:	**Paso de la Perra**	**Arroyo Frio**	**Montazo-Vallecito**	**Arroyo Majagua**
repairs so far [$ pesos dom.]	300.000,00	20% of total recollected	78.530,00	178.068,37
operation time	5 years	2 months	1 year	44 month
repairs per year [$ pesos dom.]	60.000,00	169.200,00	78.530,00	48.564,10

Table 15. Repairs expenditures

The first value corresponds to the LCOF for all the investment expenditures. The second value only takes into account the money gave by the community since the other part are nonrefundable funds.

Levelize Cost of Energy					
Projects:		**Paso de la Perra**	**Arroyo Frio**	**Montazo-Vallecito**	**Arroyo Majagua**
LCOE whole projects	Total Expenditures per year [$ pesos dom.]	2.505.625,33	7.815.116,26	7.230.088,69	1.620.375,71
	annual electricity consumed [kWh]	217.117,64	202.864,03	234.449,01	80.654,63
	[$ pesos dom./kWh.]	5,31	17,74	14,20	9,25
	[$ US dollar /kWh][1]	0,12	0,39	0,32	0,21
LCOE part paid by community	Total Expenditures per year [$ pesos dom.]	934.063,69	1.409.991,61	1.305.318,01	409.523,84
	[$ pesos dom./kWh.]	**1,98**	**3,20**	**2,56**	**2,34**
	[$ US dollar /kWh][1]	**0,04**	**0,07**	**0,06**	**0,05**

Table 16. Levelize Cost of Energy

[1] 45 pesos dom. = 1US dollar

Additionally, the price charged per kWh was calculated dividing the average money recollected per month by the monthly electricity consumed in kWh.

price charged per kWh				
Projects:	**Paso de la Perra**	**Arroyo Frio**	**Montazo-Vallecito**	**Arroyo Majagua**
Average recollected per month [$ pesos dom.]	30.666,67	70.500,00	36.550,83	9.000,00
Electricity tariff for Household [$ pesos dom.]	200	250	250	250
monthly electricity consumed [kWh]	18.093,14	16.905,34	19.537,42	6.721,22
[$ pesos dom./kWh.]	**1,69**	**4,17**	**1,87**	**1,34**
[$ US dollar /kWh] [1]	**0,04**	**0,09**	**0,04**	**0,03**

Table 17. Price charged per kWh

It can be noted that Montazo-Valleito and Aroyo Majagua have lower values of money collected per kWh than the LCOE for the part of the investment paid by the community. However, the biggest part of the money gave by the community corresponds to the working hours. Therefore, those communities are actually saving money each month.

Utilities				
Projects:	**Paso de la Perra**	**Arroyo Frio**	**Montazo-Vallecito**	**Arroyo Majagua**
Total money in the bank account [$ pesos dom.]	600.000,00	no info so far	109.950,00	217.931,63
money in parts for replacement [$ pesos dom.]	100.000,00	no info so far	0,00	0,00
Debt [$ pesos dom.]	0,00	0,00	23.990,00	0,00
Average recollected per month [$ pesos dom.]	30.666,67	70.500,00	36.550,83	9.000,00
Utilities per year [$ pesos dom.]	**120.000,00**	**448.800,00**	**109.950,00**	**60.818,13**
Utilities per year [$ US dollar] [1]	**2.666,67**	**9.973,33**	**2.443,33**	**1.351,51**

Table 18. Utilities per project

M2: Tariff collection pattern

Indicator description:

Indicator Name	M2: Tariff collection pattern
research question	How is the money collected and by whom?
Dimension	Current status of Micro Hydro System
Theme	Electricity tariff system
Components	Existence of different tariff according to income group
	Person(s) in charge of the management of the collection
	Timeliness of payments
Calculation	subjective indicator classification (creation of an index)
Measure Unit	classification and description
Unit for comparison	%
Sources	**Relevant interview question**
interview to Local MHS committee	Do you have different tariff in the community?
	How are tariffs collected?
	Do some households in the community have timeless of payments?
	How is the committee selected? How are decisions made?

Tariff collection pattern INDEX	
Person(s) in charge of the management of the collection	
independent hydroelectric committee	0%
committee as a dependency of the organization or institution legally constituted	100%
	V1
Timeliness of payments	
there is a timeliness because the people doesn't want to pay for electricity	33%
there is a timeliness because the people can't pay for the electricity	67%
there is not timeliness	100%
	V1
Existence of different tariff according to income group	
same price	33%
different according to consumption	67%
different according to consumption and incomes	100%
	V3
Same tariff for households and business	25%
Different tariff for households and business	100%
	V4
Total value	**[V1+V2+V3(V4)]/3**

Table 19. Tariff collection pattern INDEX

Result:

Project	Person(s) in charge of the management of the collection		Timeliness of payments		Existence of different tariff according to income group			Indicator Value
	description	V1	description	V2	description	V3	V4	
Paso de la Perra	There is non-association legally constituted.	50%	because the people can't pay for the electricity	50%	different according to consumption	67%	100%	**56%**
Arroyo Frio	"Asociación Divino Niño"	100%	No information so far		same tariff	33%	100%	**67%**
Montazo Vallecito	"Asociación Sagrado Corazón de Jesús"	100%	because the people can't pay for the electricity	50%	same tariff	33%	100%	**61%**
Majagua	"Asociación La Esperanza"	100%	because the people can't pay for the electricity	50%	same tariff	33%	100%	**61%**

Table 20. Result indicator Tariff collection pattern

All the projects allow a timeliness of payments, because it is usual that some people can't pay for the electricity at that moment. Nevertheless, it doesn't mean that the tariff is not affordable. In occasions, the families have not gotten the money for the agriculture products their sell at the beginning of the month, so they pay as soon as they get it. There are strict rules for those who do not pay within the extra time allowed: the electricity is cut until they pay plus a penalty for reconnection.

M3: Re-investment

Indicator description:

Indicator Name	M3: re-investment
research question	What do they do with the money collected?
Dimension	Current status of Micro Hydro System
Theme	Electricity tariff system
Components	Share of profit set aside for re-investment in electricity service business
Calculation	%
Measure Unit	%
Unit for comparison	%
Sources	**Relevant interview question**
interview to Local MHS committee	Which percent of the profit set aside for re-investment in electricity service business?
interview to community leader	Do you have future plans to reinvest the money you have saved?

Result:

Project	Utilities per year US$	Indicator Value	Description
Paso de la Perra	$ 2.667,00	**0%**	They would like to give loans but without guarantees it is not possible
Arroyo Frio	$ 475.200,00	**0%**	They want a bigger savings fund. They would like to give loans with collateral.
Montazo-Vallecito	$ 2.443,00	**0%**	They want a bigger savings fund.
Arroyo Majagua	$ 1.351,51	**0%**	They have not think about it,

Table 21. Result indicator Re-investment

4.3.2 Effective functioning of MHS

M4: Capacity Factor

Indicator description:

Indicator Name	M4: Capacity factor
research question	Does the system provide the expected amount of electricity?
Dimension	Current status of Micro Hydro System
Theme	Effective functioning of MHS
Components	actual output
	potential output
Calculation	actual output/potential output
Measure Unit	kW
Unit for comparison	%
Sources	Relevant interview question
interview to O&M	What was the year energy yield for last year?

Result:

The capacity factor was calculated based on the electricity consumption of the community, so it includes the transmission and distribution losses.

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
calculated consumption [kWh day]	594,84	555,79	642,33	220,97
potential output [kWh day]	1080	2880	3168	432
capacity factor	**55%**	**19%**	**20%**	**51%**

Table 22. Result indicator Capacity Factor

M5: Plant Factor

Indicator description:

Indicator Name	M5: Plant Factor
research question	Is there a lack of service due to system malfunction?
Dimension	Current status of Micro Hydro System
Theme	Effective functioning of MHS
Components	Running hours
	Total possible running time
Calculation	running hours/total possible running time
Measure Unit	hours
Unit for comparison	%
Sources	Relevant interview question
interview to O&M	How many supply interruptions do you experience per month?

Result:

Project	days it stops in one month	hours of black out	Total hours it stops per month	running hours	total possible running time	**plan factor**	description
Paso de la Perra	10	2	20	700	720	**97%**	It used to stop in the dry season. Since they have fewer houses, it doesn't happen anymore.
Arroyo Frio	2	2	4	716	720	**99%**	it doesn't stop regularly
Montazo -Vallecito	3	12	36	684	720	**95%**	It stops in the rainy season due to rubbish in the channel
Arroyo Majagua	30	13	390	330	720	**46%**	During the drought: 11 working hours (controlled blackouts). Out of the dry season it doesn't stop regularly

Table 23. Result indicator Plan Factor

M6: Quality of the power

Indicator description:

Indicator Name	**M6: Quality of Power**
research question	Is the system reliable?
Dimension	Current status of Micro Hydro System
Theme	Effective functioning of MHS
Components	Fluctuations in voltage
Calculation	subjective classification
Measure Unit	1 to 5
Unit for comparison	%
Sources	**Relevant interview question**
face to face questionnaire to households	Have you noticed that the intensity of electricity varies?

Quality of Power Score	
Fluctuations are too high and electricity is not useable	0%
Fluctuations exist continuously and affect the usability of appliances occasionally	25%
Fluctuations exist during peak hours but are just influencing sensible appliances	50%
Fluctuations exist during peak hours but are generally irrelevant	75%
No perceived voltage fluctuations	100%

Table 24. Quality of Power Score

Results:

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Indicator Value	100%	100%	100%	75%

Table 25. Result indicator quality of power

4.3.3 Quality of the MH power plant

M7: Quality of the design

Indicator description:

Indicator Name	**M7: Quality of design**
research question	Has the energy system been appropriately sized for the daily use?
Dimension	Current status of Micro Hydro System
Theme	Quality of the MH power plant
Components	appropriate sized for the daily use
Calculation	daily demand and future demand vs system capacity
Measure Unit	yes/no and reason
	calculation based on load profile
Unit for comparison	%
Sources	**Relevant interview question**
interview to project managers	What are the available water flow in the river and the design flow? Who did the measure?
	Based on which factors did you select the size of the system?
	Do you think it was appropriate sized for the daily use?
interview to Local MHS committee	How was the study of the river flow conducted? Who performed the measured? Do you have a record of the data?
	How many users did you have initially?, how many users are currently connected? and how many users want to be connected?

Quality of design score	
Since its planning, the system capacity cannot meet the demand	20%
The system is oversized	40%
The system would meet the demand if consumption patterns were the expected	60%
The system meets the current demand but cannot meet future demand or new users	80%
In its planning the system took into account the future demand (short and medium term) without being oversized	100%

Table 26. Quality of design score

Results:

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Indicator Value	60%	40%	40%	100%

Table 27. Result indicator quality of designe

When the project in Paso de la Perra was planned, there were more users than the capacity, so a system of community center for watching cloth and a community cine where the people could see the TV, was the proposal. However, this never happened and they used to have blackouts, especially in the dry season, because of the high energy demand. Currently that problem is not happening anymore, because some houses are now connected to Arroyo Frio. Taking as a reference the capacity factor, both project, Arroyo Frio and Montazo-Vallecito are oversized. In spite of those projects are new, and the households do not have many appliances, the amount of wasted electricity is high. There is an opportunity to implement other productive activities that demand energy.

M8: Quality of components

Indicator description:

Indicator Name	**M8: Quality of components**
research question	Do the machines have manufacturer guarantees?
Dimension	Current status of Micro Hydro System
Theme	Quality of the MH power plant
Components	problems with manufacturer guarantees
Calculation	subjective classification
Measure Unit	yes/no and reason
Unit for comparison	%
Sources	**Relevant interview question**
interview to project managers	Have you have problems with the brands or the manufacturer guarantees?
interview to Local MHS committee and interview to O&M	What kinds of problems have arisen regarding the machines since the project started? Does the local operator fix them?, or has it been necessary to call experts?

Quality of components score	
Problems with the machinery and warranties	
no problems	100%
there have been some problems that the warranty covers	50%
there have been some problems that the warranty does not cover	0%

Table 28. Quality of components score

Result:

Project	Equipment	description	Pipeline	description
Paso de la Perra	100%	No problems so far	100%	No problems so far
Arroyo Frio	50%	When the equipment arrived, the circuit diagram was wrong.	100%	No problems so far
Montazo -Vallecito	50%	When the equipment arrived, one PLC (Programmable logic controller) had a wrong installation	100%	No problems so far
Arroyo Majagua	100%	No problems so far	0%	The PVC pipes came out of poor quality and are not covered by warranty.

Table 29. Result indicator quality of components

M9: Quality of installation

Indicator description:

Indicator Name	**M9: Quality of installation**
research question	Was the system properly sited? does it have proper wire sizing and connections?, is the system safe and accessible for maintenance?
Dimension	Current status of Micro Hydro System
Theme	Quality of the MH power plant
Components	properly sited
	proper wire sizing and connections
	safe and accessible for maintenance
Calculation	subjective classification
Measure Unit	yes/no and reason
Unit for comparison	%
Sources	**Relevant interview question**
interview to O&M	Do you think the system is safe and accessible for maintenance?
	How many accidents have happened since installation? How many workers have been injured in O&M?
observation	

Quality of Installation INDEX	
Grid	
Poorly designed with unregulated expansion and improvised house connection	0%
Systematic grid design with parallel distribution lines but no standardized house connection	50%
Well-designed according to energy demand with safe standardized connectors	100%
	V1
Properly sited	
Not properly sited with problems due to the location	0%
Not properly sited, no problems so far	50%
Good location	100%
	V2
Safe and Accessible for Maintenance	
There have been accidents due to the design of the system	0%
No accidents but not easy to access for maintenance	50%
No accidents and easy to access	100%
	V3
TOTAL value	**(V1+V2+V3)/3**

Table 30. Quality of installation INDEX

Result:

In the annex A.3 (A.3.1. System Installation) there is a list of photos taken in each project describing the parts of the systems and its condition. Based on those observation, the value of the indicator was selected.

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Indicator Value	100%	100%	100%	100%

Table 31. Result indicator quality of installation

M10: Existence and implementation of maintenance schedule

Indicator description:

Indicator Name	M11: Existence and implementation of maintenance schedule
research question	Are the repairs timely? Is there as maintenance schedule? Is it followed?
Dimension	Current status of Micro Hydro System
Theme	Operation and Maintenance arrangements
Components	Existence of maintenance schedule
	maintenance plan followed
	existence of trained daily operators in the village for O&M
Calculation	subjective classification
Measure Unit	yes/no and reason
Unit for comparison	%
Sources	**Relevant interview question**
interview to O&M	Is there a Maintenance program in place? If yes, how is it implemented?
	How many community members have been trained in MHP use and maintenance?
	What kinds of problems have arisen regarding the machines since the project started? Does the local operator fix them? Or has it been necessary to call experts?

Existence and implementation of maintenance schedule INDEX	
Maintenance Schedule	
There is no maintenance schedule. Workers are not trained.	0%
There is no maintenance schedule. Workers were trained to give solution to problems when their appear	25%
Maintenance schedule was fairly prepared. Irregularly followed. Workers were trained to give solution to problems when their appear	50%
Maintenance schedule was well prepared. Workers are well trained. But maintenance activity is not strictly followed.	75%
Maintenance schedule was well prepared, clear and strictly followed	100%
	V1
Repairs	
Repair by an outside expert	0%
replacement of the machinery	33%
Repair by an expert in Dominican	67%
Locally repair	100%
	V2
Total value	**(V1+V)/2**

Table 32. Existence and implementation of maintenance schedule index

Result:

Project	Maintenance Schedule		Record of maintenance		Repairs		Indicator Value
	description	**V1**	**description**	**V2**	**description**	**V3**	
Paso de la Perra	yes	100%	There is not an organize record of maintenance activities	50%	Locally repair	100 %	**83%**
Arroyo Frio	yes	100%	There is not an organize record of maintenance activities	50%	Repair by an expert in Dominican	67 %	**72%**
Montazo Vallecito	Maintenance schedule was fairly prepared. Irregularly followed. Workers were trained to give solution to problems when their appear	50%	yes	100%	Locally repair	100 %	**83%**
Arroyo Majagua	Workers were trained to give solution to problems when they appear. There is no maintenance schedule. However, they have a "mental schedule" based on empirical experience	38%	There is not an organize record of maintenance activities	50%	Repair by an expert in Dominican the first time, after that they learn to do it locally	84 %	**57%**

Table 33. Result indicator existance and implementation of mantenance schedule

4.4 Environmental changes

4.4.1 Actions for protection and conservation

E1: New activities for conservation (reforestation) and/or protections

Indicator description:

Indicator Name	**E1: New activities for conservation (reforestation) and/or protections**
research question	Are there changes in the conservation and protections of the river basin due to the project?
Dimension	Environmental changes
Theme	Actions for protection and conservation
Components	New activities for conservation
	New activities for protections
Calculation	no need
Measure Unit	Number and specification
Unit for comparison	Number
Sources	**Relevant interview question**
interview to environment managers	How many new projects were created for preservation and/or protection after the hydroelectric?

Result:

Project	Number of activities for protection or conservation related to the project	[Ha] reforested	type of tree
Paso del la Perra	1	700	Creole Pine
Arroyo Frio	1	1500	Creole Pine
Montazo-Vallecito	1	0	Creole Pine
Arroyo Majagua	1	0	Organic Cacao

Table 34. Result indicator new activities for conservation (reforestation) and/or protections

The size of the protected area depends on the size of the river basin. In the case of Paso de la Perra and Arroyo Frio it was necessary the reforestation of this area, in the other cases, there is a compromise done by the community to protect the area and do not cut the trees. As a consequence, the river basin area visited (from the power house until the water uptake walking through the pipeline) presented an optimum vegetation cover, and there was no evidence of big sedimentation. Photos are presented in Annex A.3.2

4.4.2 Land use changes

E2: Land use

Indicator description:

Indicator Name	E2: Land use
research question	Are there land use changes due to the project?
Dimension	Environmental changes
Theme	land use changes
Components	land use changes
Calculation	% interviewees
Measured Unit	classification and description
Unit for comparison	% by classification
Sources	**Relevant interview question**
face to face questionnaire to households	What kind of crops do you have in your land?
	How much do you produce in a month?
	Have you had changes in the use of your land due to the project?

Results:

Project	Land use changes	Main land use	Main crop	Use
Paso del la Perra	no	agriculture	Tayota	Export to Haiti
Arroyo Frio	no	agriculture	Tayota	Export to Haiti
Montazo-Vallecito	no	agriculture	Tubers	For self-consumption. Surplus is sold in town markets
Arroyo Majagua	no	agriculture	Organic Cacao	Sold to companies to export

Table 35. Result indicator land use

4.5 Level of community involvement

4.5.1 Degree of local ownership

L1: Community involvement in funding

Indicator description:

Indicator Name	L1: Community involvement in funding
research question	What kinds of contributions were given by the community? Are those contributions adjusted to their capacities to pay?
Dimension	Level of community involvement in the project
Theme	Degree of local ownership
Components	users contribution
Calculation	contribution from the community*100/project price
Measure Unit	Dominican pesos $
Unit for comparison	%
Sources	**Relevant interview question**
interview to Local MHS committee	How much money did the community give to the project? How were the funds collected?
interview to project managers	What percentage of the cost of the project was provided by the community?
interview to households	Did you give any financial support to the project? How much did you contribute?
	Did you help to raise funds for the project? Which kinds of activities were performed?

Result:

The table 36 shows the percent of contribution from the community to the total project value. Also, it can be seen the percent of the total value covered by the community from their own funds, and the percent corresponding to working hours, food and collected money from activities or other sponsored.

Project	Total Value	Users' contribution					
	Total	Total Users' contribution		Community own funds		Working hours, food and collected money.	
	US$	US$	%	US$	%	US$	%
Paso de la Perra	308.569,38	67.362,33	22%	1.955,56	1%	65.406,78	21%
Arroyo Frio	67.082,76	84.008,89	8%	11.688,89	1%	72.320,00	7%
Montazo-Vallecito	1.019.514,66	107.944,44	11%	2.711,11	0,3%	105.233,33	10%
Arroyo Majagua	232.511,11	46.666,67	20%	1.688,89	1%	44.977,78	19%

Table 36. Result indicator users' contribution

L2: Participation and voice hear at the meetings

Indicator description:

Indicator Name	L2: Participation and voice hear at the meetings
research question	Does the community feel that their opinions where taking into account?
Dimension	Level of community involvement in the project
Theme	Degree of local ownership
Components	number of households who feel their opinion was take into account in the meetings
Calculation	number*100/total interviewers
Measured Unit	number
Unit for comparison	%
Sources	**Relevant interview question**
face to face questionnaire to households	Do you participate in community meetings?
	Do you feel you opinion was take into account in the meetings?

Result:

Project	Assistance during the project development	Assistance after project completion	Time of project construction	% feeling that their opinion was take into account in the meetings
Paso de la Perra	86%	79%	5 years	100%
Arroyo Frio	100%	88%	2 month	100%
Montazo-Vallecito	94%	78%	1 year	97%
Arroyo Majagua	95%	90%	4 years	100%

Table 37. Result indicator Participation and voice hear at the meetings

L3: Gender and economic diversity in the meetings

Indicator description:

Indicator Name	L3: Gender and economic diversity in the meetings
research question	Are those meetings inclusive to all community members?
Dimension	Level of community involvement in the project
Theme	Degree of local ownership
Components	share of participants in the meeting according to gender and economic diversity
Calculation	number*100/total
Measured Unit	number
Unit for comparison	%
Sources	**Relevant interview question**
interview to Local MHS committee and to community leader	What issues were discussed at the meetings? Who participated in these meetings? Do you have an idea of the percentage of women? Is there any record of participants? Do you still hold meetings?
interview to project managers	How many training sessions have been conducted? How many people have been employed in the project? Are there local people? What is the percentage of women employed in the project?

Result:

For this indicator, information about the participation in the meetings was collected. However, the percent was calculated based on the local MHS committee, since this is the entity that takes the main decisions related to the project. In the case of Montazo-Vallecito, the women participation seems to not be so high. Nevertheless, in this community, the president of the committee and the treasurer (the most important positions in terms of decision making) are women.

Project	Local MHS committee			% men participation	% women participation
	Total	**Men**	**Women**		
Paso de la Perra	7	4	3	57%	43%
Arroyo Frio	7	5	2	71%	29%
Montazo-Vallecito	12	8	4	67%	33%
Arroyo Majagua	6	5	1	83%	17%

Table 38. Result indicator gender and economic diversity in the meetings

4.5.2 Level of decision-making

L5: Level of decision-making

Indicator description:

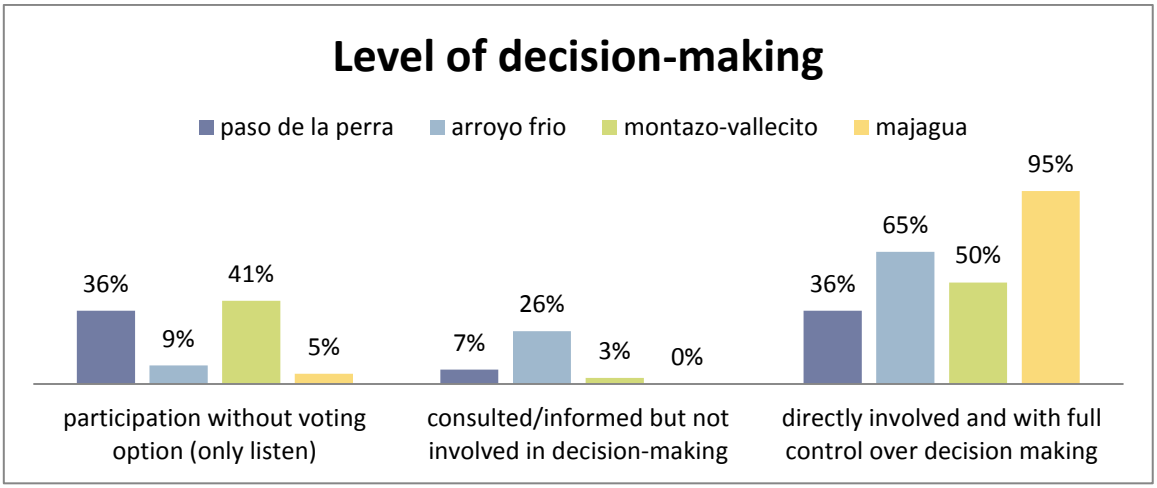
Indicator Name	L4: Level of decision-making
research question	Are those meetings inclusive to all community members?
Dimension	Level of community involvement in the project
Theme	Level of decision-making
Components	Number of households participation but without voting option
	number of households consulted/informed but not involved in decision-making
	number of households directly involved and have dull control over decision making
Calculation	number of households*100/total
Measure Unit	number
Unit for comparison	% according to each classification
Sources	**Relevant interview question**
interview to households	How involved are you in decisions? -Participation but without voting option -Consulted/informed but not involved in decision-making -Directly involved and have dull control over decision making

Result:

Most of the people that does not participate (only listen) is because they decided not to do it. It is more common in women. The reason is that they consider the people who have more knowledge about the MHS should opine. Especially in Paso de la Perra, the project have been working for 5 years with the same committee, so many people said they trust in their decisions.

Those who said they were consulted/informed but not involved in decision-making are users that go to the meetings, vote when it is necessary, but they do not like to talk in public. Their role is to wait what other people propose and then take a side.

Finally, the interviewees that claim to be directly involved in the decision-making are the majority. In the meetings they are active, they ask for information about the functioning of the system and make proposals.



Graph 19. Level of decision-making

4.6 Users' perception

4.6.1 Users' perceived impacts of MHS on social life

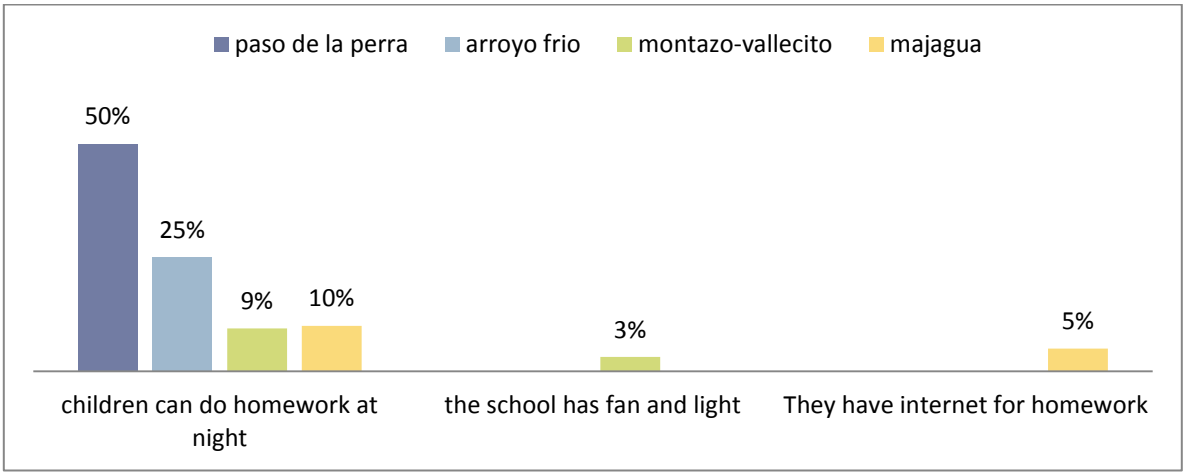
U1: Perceived impacts in education

Indicator description:

Indicator Name	**U1: Perceived impacts in education**
research question	Are there perceived impacts in education by the community?
Dimension	Users perception
Theme	Users' perceived impacts of MHS on social life
Components	perceived impacts in education
Calculation	classification
Measure Unit	Description
Unit for comparison	% impacts by classification
Sources	**Relevant interview question**
face to face questionnaire to households	What have been the main differences in your daily activities since receiving electricity?
	What have been the main differences in your sons' daily activities since receiving electricity?
	What have been the main differences in your wife's daily activities since receiving electricity?
	What have been some changes you have noticed in your neighbors or your community since electrification?
interview to community leader	What have been some changes you have noticed in the community since electrification? What about the access to information and communication with the outside? Have you noted changes in terms of education?

Result:

The information listed in the graph 23 corresponds to the answers after asking the parents how the life of their children has changed after electrification.



Graph 20. Changes in children activities

U2: Perceived impacts in health care

Indicator description:

Indicator Name	U2: Perceived impacts in health care
research question	Are there perceived impacts in health care by the community?
Dimension	Users perception
Theme	Users' perceived impacts of MHS on social life
Components	perceived impacts in health care
Calculation	classification
Measure Unit	description
Unit for comparison	% impacts by classification
Sources	**Relevant interview question**
face to face questionnaire to households	Do you think that the health of your family has improved since access to electricity?
interview to community leader	What have been some changes you have noticed in the community since electrification? Have you noted changes in terms of health care?

Result:

The first question was if they think that the health of the family has improved since access to the electricity. The table 39 shows the answers.

The health has improved	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Yes	86%	100%	78%	75%
No	14%	0%	22%	25%

Table 39. Result indicator perceived impacts in health care

Those who perceive an improvement were asked to describe the reasons. The information is presented in the next table.

impacts in health care	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
due to no more smoke (fewer respiratory problems)	43%	75%	28%	40%
due to wash machine (no more body pain or fungus in their hands)	14%		31%	30%
due to savings (buy medicine or medical insurance)			6%	
due to electricity (home refrigerated medicines and spray apparatus at home)			6%	
due to the lighting at night (to help sick people, to go out in case of emergency, no more falls or stumbling)	7%		3%	5%
due to no more candles (no more burns)	7%			
indirect impact: more hygiene	14%	25%		
indirect impacts: children no longer play much with ground		25%		
indirect impacts: due to happiness, less health problems			3%	

Table 40. Percived impacts in health care

The most common impacts in all the communities are related with less respiratory problems since there is no more smoke from candles and kerosene lamps and the use of wash machine instead of going to the river and do hand-wash. In the case of Paso de la Perra and Arroyo Frio (only for the community that used to be part of Paso de la Perra), after 5 years they mentioned a relevant improvement in terms of hygiene and waste collection.

U3: Perceived impacts in safety

Indicator description:

Indicator Name	U3: Perceived impacts in safety
research question	Are there perceived impacts in security by the community?
Dimension	Users perception
Theme	Users' perceived impacts of MHS on social life
Components	perceived impacts in safety
Calculation	classification
Measure Unit	description
Unit for comparison	% impacts by classification
Sources	**Relevant interview question**
face to face questionnaire to households	Do you feel that your household is safer since using the new light and/or electricity?
	What have been some changes you have noticed in your neighbors or your community since electrification?
	Do you feel your community is safer since using the new light and/or electricity?
interview to community leader	What have been some changes you have noticed in the community since electrification? Have you noted changes in terms of security?

Result:

The table 41 shows the percent of interviewers that perceive an impact in terms of safety after the electrification. In Arroyo Majagua they have never had problems of safety, so there are no perceived changes. In fewer cases people answered that they feel insecure because before they did not have anything at home, now they have appliances that can be robbed.

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
the house is safer	100%	100%	100%	75%
the community is safer	100%	100%	100%	80%

Table 41. Result indicator perceived impacts in safety

U5: Perceived impacts in income-generating activities

Indicator description:

Indicator Name	U4: Perceived impacts in domestic productivity
research question	Are there changes in the domestic productivity since electrification?
Dimension	Users perception
Theme	Users' perceived impacts of micro-hydropower on social life
Components	perceived impacts in domestic productivity
Calculation	classification
Measure Unit	description
Unit for comparison	% impacts by classification
Sources	**Relevant interview question**
face to face questionnaire to households	What have been the main differences in your daily activities since receiving electricity?
	What have been the main differences in your sons' daily activities since receiving electricity?
	What have been the main differences in your wife's daily activities since receiving electricity?

Result:

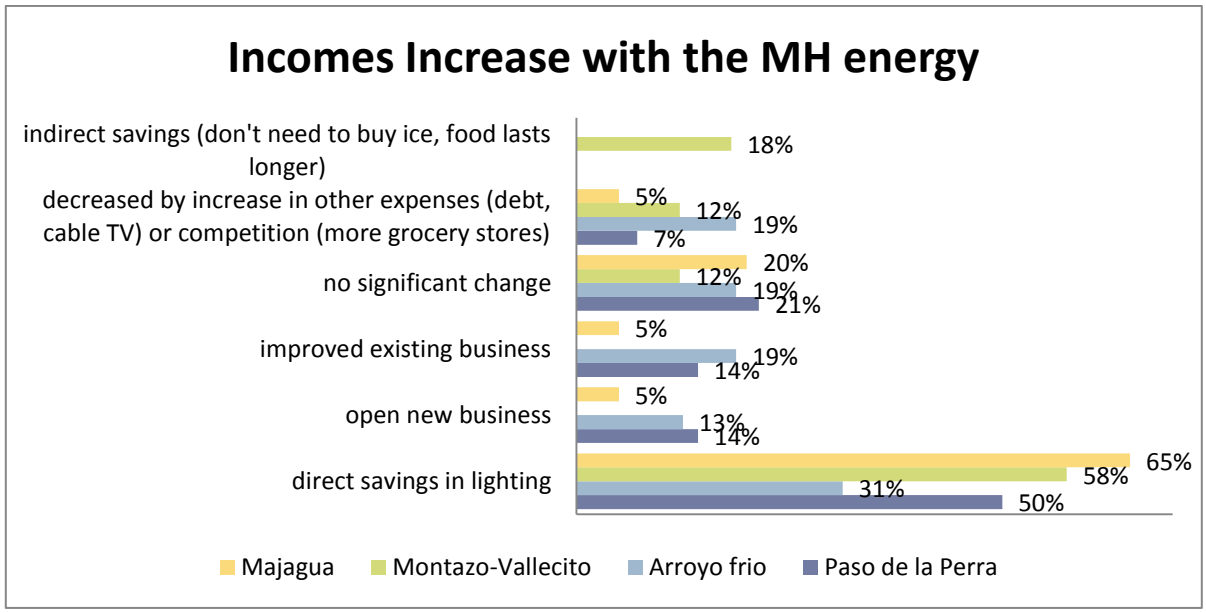
Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Incomes increased after the MHS	71%	75%	72%	75%
Open a new business	21%	8%	0%	45%

Table 42. Result indicator perceived impacts in income-generating activities

It was asked if they feel they increased their income since electrification. Although not all increased their income after the MHS, the 100% claimed to have better "living conditions". In the Montazo-Vallecito, none of those interviewed claimed to have opened a new business. However, in the community they have opened two grocery stores and a beauty salon.

In most cases, they ensure cost savings related to lighting. However, many users use the savings to buy appliances. Therefore, they do not perceive significant changes in their income. In other cases, they have even acquired debts, which imply a decline in earnings.

For those who had a grocery store before, electricity can lead to higher profits by diversifying the products offered. Yet, on other occasions, this implies losses by declining sales, as there are new stores, and in some cases, many of the products that were previously sold can be preserved today in refrigerators in homes.



Graph 21. Incomes Increase with the micro hydro energy

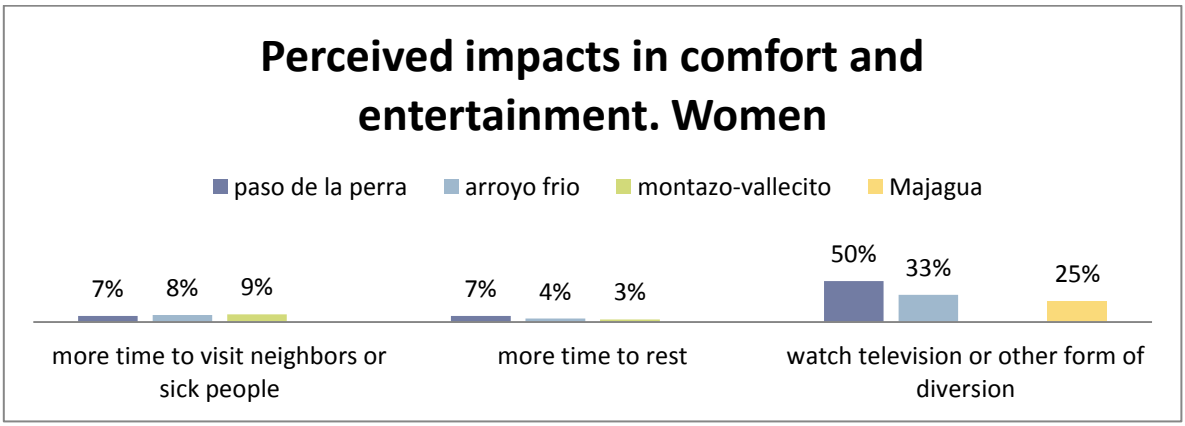
U6: Perceived impacts in comfort and entertainment

Indicator description:

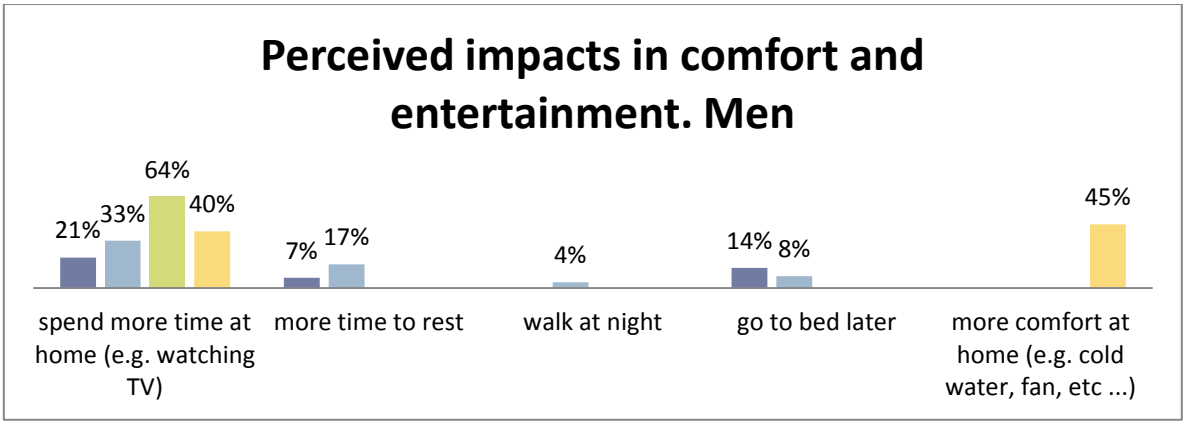
Indicator Name	**U6: Perceived impacts in comfort and entertainment**
research question	Are there perceived impacts in comfort and entertainment by the community?
Dimension	Users perception
Theme	Users' perceived impacts of micro-hydropower on social life
Components	perceived impacts in comfort and entertainment
Calculation	classification
Measure Unit	description
Unit for comparison	% impacts by classification
Sources	**Relevant interview question**
face to face questionnaire to households	What have been the main differences in your daily activities since receiving electricity?
	What have been the main differences in your sons' daily activities since receiving electricity?
	What have been the main differences in your wife's daily activities since receiving electricity?
	Do you feel that the community has come together more after the project?

Result:

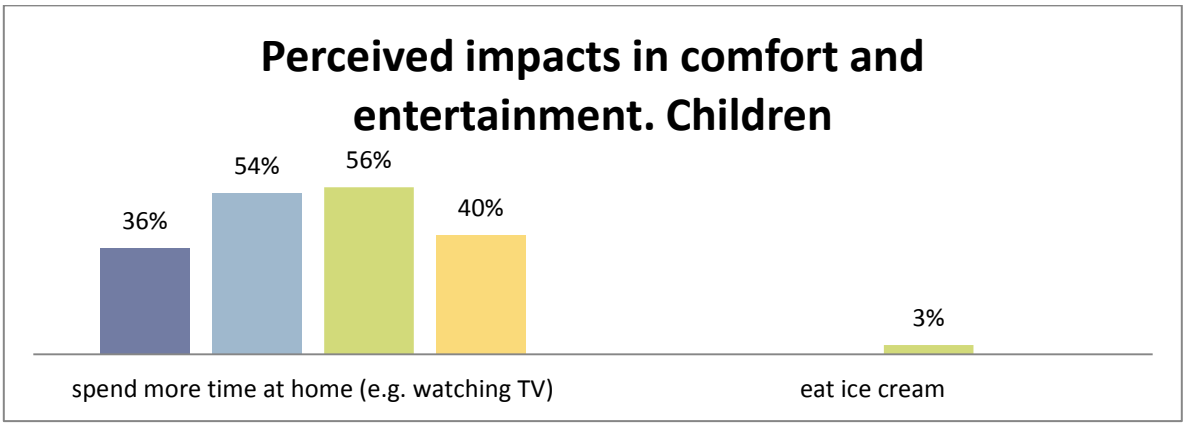
According to the answers about the new activities each one in the house does different after the electrification, those related with comfort and entertainment were clustered. In all the cases, watching TV is the new preferred activities.



Graph 22. Perceived impacts in comfort and entertainment for women



Graph 23. Perceived impacts in comfort and entertainment for men



Graph 24. Perceived impacts in comfort and entertainment for children

4.6.2 Users' satisfaction

U7: Complaints about the system/operation/service

Indicator description:

Indicator Name	U7: Complaints about the system/operation/service
research question	Are there complaints about the service?
Dimension	Users' perception
Theme	Users' satisfaction
Components	complaints about the system/operation/service
Calculation	number
Measure Unit	number and description
Unit for comparison	% complaints by classification
Sources	**Relevant interview question**
face to face questionnaire to households	Are you satisfied with the management performance? Yes or no, why?

Result:

In none of the Projects, the interviewees had complains about the system. For instance, in situations that have involved an unplanned suspension of the service for repairs, or a limitation on the electricity available by drought, the community claims to be informed about the reasons, to understand the circumstances of this problems and is able to organize themselves to take an active role in the search for solutions without blaming the system managers.

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Satisfaction with the MHS committee	100%	96%	100%	100%

Table 43. Result indicator complaints about the system/operation/service

U8: Perception about the service costs (financial equity)

Indicator description:

Indicator Name	U8: Perception about the service costs (financial equity)
research question	Are the household members satisfied with the tariff system?
Dimension	Users perception
Theme	Users' satisfaction
Components	Perception about the service costs (financial Equity)
Calculation	classification
Measure Unit	classification and description
Unit for comparison	% opinions by classification
Sources	**Relevant interview question**
face to face questionnaire to households	Have you noticed changes in terms of equity / equality in the community due to electrification?
	Do you find the electricity cost fare? Yes or no, why?

Result:

The majority are satisfied with the price of the service. In few cases some people find it expensive.

Project	Paso de la Perra	Arroyo Frio	Montazo-Vallecito	Arroyo Majagua
Satisfaction with the tariff	93%	92%	91%	100%

Table 44. Result impact perception about the service costs (financial equity)

5 Discussion and Interpretations

5.1 SWOT Matrix

In order to analyze the information from the indicator framework, a SWOT matrix was elaborated for each project where the strengths, weaknesses, opportunities and threats were listed.

5.1.1 Paso de la Perra

Strengths	Weaknesses
• Well trained operator: One of the advisors nationwide. • High level of confidence in the committee and satisfaction with their decisions • Organized community with high levels of participation in the meeting (79% after 5 years) • Experience in community management of project • Around 2.700 US$ of utilities per year	• There is no record of system maintenance. • Afraid to reinvest the money saved. • Monocropping of tayota. • Most of the food consumed bought in the nearest town. No food self-sufficiency. • Use of fertilizers and other chemicals to cultivate.
Opportunities	**Threats**
• The road to highest peak of the country is close. **Attractive for ecotourism**. • A river passing by with clear-water and mountain landscape. **Attraction for ecotourism.** • Surplus of electricity (only use 55% of their capacity)	• A health center in the community. They need to travel to "Manabao", about 5 km away in an unpaved road. • Internet and computer center • Equipment for the schools. They only have light and fans. • Only primary education available. Young people have to move to the city to further study. • New employment opportunities for young people different than agriculture. • Reduce the use of agrochemicals.

5.1.2 Arroyo Frio

Strengths	Weaknesses
• Organized community with high levels of participation in the meeting (88% after 2 years) • Around 10.000 US$ of utilities per year. • Experience in community management of project	• Operators are still insecure • There is no record of system maintenance. • Afraid to reinvest the money saved. • Monocropping of tayota. • Most of the food consumed bought in the nearest town. No food self-sufficiency. • Use of fertilizers and other chemicals to cultivate.
Opportunities	**Threats**
• The road to highest peak of the country is close. **Attractive for ecotourism**. • A river passing by with clear-water and mountain landscape. **Attraction for ecotourism.** • Surplus of electricity (only use 19% of their capacity).	• A health center in the community. They need to travel to "Manabao", about 7 km away in an unpaved road. • Internet and cellphone signal. • Equipment for the schools. They only have light and fans. • Only basic education available. Young people have to move to the city to further study. • New employment opportunities for young people different than agriculture or guide to climb Pico Duarte. • Reduce the use of agrochemicals.

5.1.3 Montazo-Vallecito

Strengths	Weaknesses
• Organized community with high levels of participation in the meeting (78% after 1 years) • Around 2.400 US$ of utilities per year. • Other community projects did not work before but now they have experience in community management of project • Some young people continue in the community. • Diversity of crops. Mainly tubers	• Afraid to reinvest the money saved. • They do not believe in community projects for income generation. • The system shuts down during the rainy season and windy days for the lack of a filter for the sand removal. • Difficult access to the powerhouse
Opportunities	**Threats**
• They used to have a **community sawmill.** Still in operation but is controlled for private profit. Gasoline generator used. • They used to have a community project for **greenhouses organic cocoa** but it was at the same time that the MHS construction,	• There is a health center in the community but they only have light, a fan and a computer. • Internet and cellphone signal. • Equipment for the schools. They only have light and fans.

so the people abandoned it. • Surplus of electricity (only use 20% of their capacity). • There are communities close without electricity access.	• Only basic education available. Young people have to travel to other town for high school or move to the city to further study. • New employment opportunities for young people different than agriculture.

5.1.4 Arroyo Majagua

Strengths	Weaknesses
• Organized community with high levels of participation in the meeting (90% after 4 years) • Around 1.300 US$ of utilities per year. • Reforestation with organic cacao (useful for income generation)	• Afraid to reinvest the money saved. • They need to organize programed black out during the day in the dry season.
Opportunities	**Threats**
• They produce organic cacao and sell the sell raw material, but they could give it an additional price using the electricity. • Surplus of electricity (only use 52% of their capacity) except for the dry season.	• A health center in the community. • Internet and cellphone signal. • Equipment for the schools. They only have light and fans. • Only basic education available. Young people have to move to the city to further study. • New employment opportunities for young people different than cultivation of cacao.

5.2 Proposal

5.2.1 Health facility

The provision of a suitable health service for all the population, especially the improvement of the maternal health and the reduction of child mortality, is a priority for the Millennium Development Goals (MDGs) of the UNDP. As it can be seen in the SWOT Matrix, rural health facilities are necessities in all the projects. Only Montazo-Vallecito has a doctor's office without any medical equipment. Furthermore, there are many stories about people who had an accident and did not have enough time to go to the closed hospital, or people who doesn't go to the doctor because they do not have money to pay the transport to the town. Equally important, there is a lack of knowledge about family planning methods, having as a result teenager's pregnancy.

The surplus of electricity generated by each project could provide enough electricity to match the main loads of the medical equipment. According to the IEA, a rural health facility can be classified as health posts, health clinics and health centers, depending on their size [17]. Health posts are

the smallest size health facility. They do not have permanent working team, and their main function is to provide basic treatment for emergency cases such as first aid. This is the kind of facility which will be proposed for those communities. A detailed inventory of all possible loads is described:

- **Lighting**: The light availability is important to improve medical emergency interventions. In this case, efficient light bulb will be in the rooms and an additional exam light beside the stretcher.
- **Vaccine refrigeration**: This equipment is important for immunization programs. The refrigerator will help to preserve the vaccine against diseases such as tuberculosis, hepatitis, polio, diphtheria, pertussis, tetanus, measles, and rubella, among other. In order to keep the internal temperature constant, it has to be running the 24 hours.
- **Microscope:** It is important for diagnosis diseases, for instance, HIV, syphilis, malaria, and anemia.
- **Radio.**
- **Fan:** for communities such as Montazo-Vallecito and Arroyo Majagua, where the temperature reach high levels.
- Other equipment such as centrifuge (to analyze blood samples), a spectrophotometry (to diagnosis of diseases at earlier stages) or a sterilization autoclave (to sterilize medical tools and surgical equipment) could be including in a future.

The table shows the estimations of energy consumption per medical equipment and the number of hours use per day. In Paso de la Perra and Arroyo Frio, the fan is not including in the load profile. In Montazo-Vallecito, there is already a doctor office, so only the vaccine refrigerator and the microscope are added.

Equipment	Quantity	Power [W]	Hours Used per Day	Energy Used [Wh]
Lighting	2	15	2	60
Exam light	1	20	2	40
Vaccine Refrigerator	1	60	24	1440
Microscope	1	30	1	30
Fan	1	100	3	300
Radio	1	40	5	200
TOTAL Consumption per day				**2070**

Table 45. Equipment for a health pot

5.2.2 Computer center

Although there have been communication improvements since the electricity access due to the use of appliances such us television and radio, most of the communities still have not cellphone signal and none of them has internet access. Regarding to the schools, they offer basic primary

school, but in most of the cases, students have to travel to the towns for high school and to the city if they want to have technical or university education.

A computer center with internet access could bring many different services for the community. It will not only give the possibility of surfing in internet to the students, teachers, local residents and possible tourists, but it can also give them the possibility to have an e-mail account, telephone services, online education, telemedicine, they could create a forum in the network of Micro Hydro Systems to exchange experience, they can transfer money and share some publicity to attract more tourist.

In terms of the connectivity, there are different types. I can be either wired or wireless connectivity. The first one needs a telephone line or a broadband service. The second option normally requires wires of antenna or a set of equipment procured from an Internet Service Provider. The most common wireless connectivity are: WiFi as an indoor technology, WiMax for long range system covering many kilometers, Portable Satellite Terminal when there is no electricity or access to any other connectivity infrastructure, and the satellite or VSAT, which is the most commonly used for insolated areas, yet it is expensive and provides only slow upstream speeds [18].

The community of El Limón in Dominican Republic has internet access since 1998 [19]. From their experience, they recommend using Wi-Fi or Wi-Max due to its very low cost, reliable, and relatively easy installation and maintenance compared to other technologies. If the place where the repeater (antenna) is installed is far away from a grid, it would be necessary to add a solar panel and a battery. Additionally, the must be a line-of-sight between antennas. Otherwise, the use of VSAT could be fundable if there is also a community telephone call center.

The table shows the estimations of energy consumption per equipment and the number of hours use per day.

Equipment	Quantity	Power [W]	Hours Used per Day	Energy Used [Wh]
Lighting	4	15	2	120
Desktop computer and monitor	10	300	11	33000
video projector (Beamer)	1	200	4	800
	TOTAL Consumption per day			**33920**

Table 46. Equipment for a computer center

5.2.3 Eco-Tourism Center

The projects Paso de la Perra and Arroyo Frio are located close to the start point of the road to the highest peak of the country (Pico Duarte). Also, there are clear-water Rivers flowing through the communities and a beautiful mountain landscape**.** All of this makes it attractive for ecotourism.

The creation of a community ecotourism center could be an income generating option and a source of employment. The inconveniences in this idea are that there are already some ecotourism centers in the area that offer the same or even more sport activities. Moreover, in those communities there is a monocropping of tayota and a lot of greenhouses that use fertilizers and other chemicals, which can be felt while breathing. One example of a different ecotourism offer could be a community based agritourism enterprise. This is not only a way to generate incomes but also to promote more sustainable land use and food self-sufficiency in the community. In Latin America, Costa Rica has experience in those kinds of rural community based tourism strategies.

The estimation of appliances was divided according to the rooms/areas where they would be used. Initially, 5 cottages are proposed to host tourist, a common area where they can have dinner or listen some music, a kitchen, a cleaning area to wash clothes and dirty sheets, and an office.

Appliance	Cottage x 5			Common area			Kitchen			cleaning area			office		
	qty.	Power (W)	TOTAL (W)	qty.	Power (W)	TOTAL (W)	qty.	Power (W)	TOTAL (W)	qty.	Power (W)	TOTAL (W)	qty.	Power (W)	TOTAL (W)
Lighting	2	15	150	4	15	60			0			0			0
connection for charging cellphones and cameras	2	5	50			0			0			0			0
Fan	1	100	500			0			0			0			0
Stereo (radio)			0	1	60	60			0			0			0
fridge			0			0	1	220	220			0			0
freezer			0			0	1	220	220			0			0
blender			0			0	1	350	350			0			0
washing machine			0			0			0	1	350	350			0
Desktop computer and monitor			0			0			0			0	1	300	300

Table 47. Appliances for a Eco Tourism Center

5.2.4 Sawmill

In Vallecito, there used to be a community sawmill. It is still in operation but is controlled for private profit, and the equipment is using a gasoline generator. The recovery of this place under a community approach and using electricity from the micro hydro system could be an opportunity for income generation and employment.

The most basic equipment for a small sawmill are a circular saw to cut long distance pieces and a crosswise feeding edger to cut thicknesses [20]. Taking as a reference the engines used to run this equipment in a research done by the "Department of Forest and Mobile Technology, Faculty of Environmental and Manufacturing Technology, Technical University in Zvolen, Zvolen, Slovakia", an estimation of the energy consumption was done .

Equipment	Engine	Power [kW]	Hours Used per Day	Energy Used [kWh]
Circular Saw	3 phases asynchronous electrical motor	7,5	7	52,5
Crosswise feeding edger	electrical motor	5,5	7	38,5

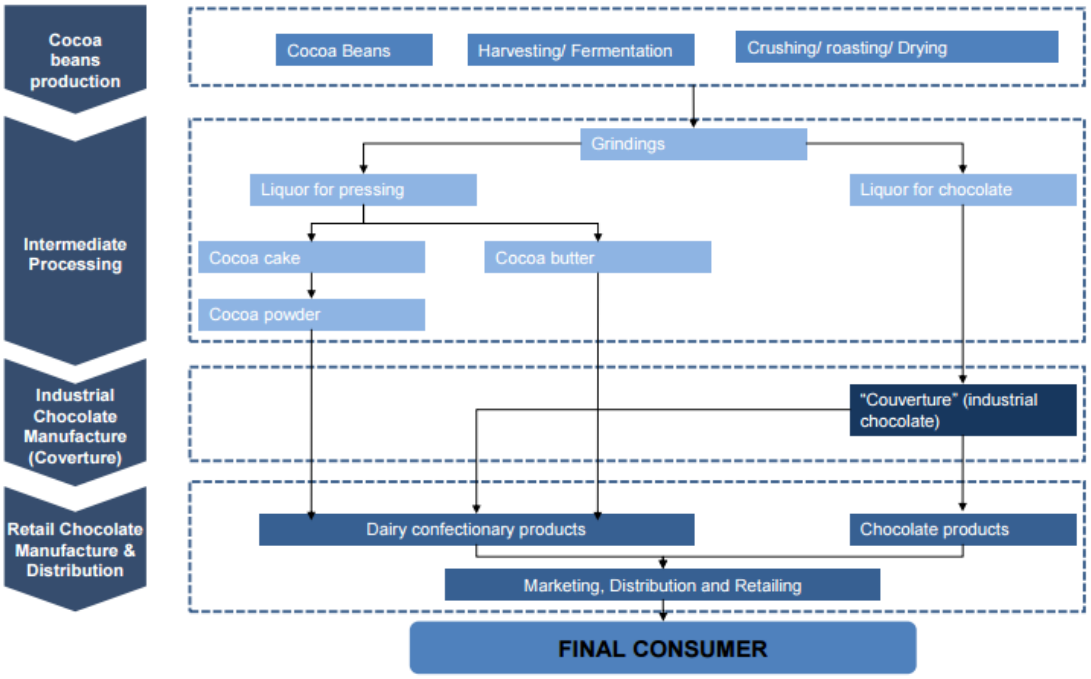
Table 48. Equipment for a Sawmill

5.2.5 Cacao enterprise

The main economic activity in the community of Arroyo Majagua is planting cocoa, drying the beans and selling there to big enterprises. Also, the communities of El Montazo-Vallecito have a climate suitable for planting cocoa, and there was a project for cocoa greenhouses that even though it is not working anymore, it serves as an example to highlight the potential in the area.

In a research made by the African Center for Economy Transformation, an analysis of the coca value chain was done [21]. Normally, the production of cocoa beans is undertaken by the smallholder farmers. They describe them as those farmers with less than 5 hectares of land, which is the case of most of the inhabitants of Arroyo Majagua. Those farmers are classified as 'price takers', since they have a little influence over the price. As it can be seen in the graph, there are in the lowest part of the cocoa value chain.

FIGURE 1: THE COCOA VALUE CHAIN



Graph 25. Cocoa Value Chain [21]

A local value addition to the cocoa using the surplus of electricity could be an attractive opportunity for those communities. By integrating the intermediate chocolate manufacturing step, the money the farmers will get per Kg of product will be higher. This step is known as the grinding of the cocoa beans. The intermediate agri-commodities gotten at the end of this process are cocoa butter, cocoa powder and liquor for chocolate, a mixture of cocoa powder and butter that remains.

After the beans are roasted, they will go to a winnowing machine in order to remove the shells and obtain cocoa nibs. Those nibs are milled to create the cocoa liquor. Next, the liquor is pressed to extract the coca butter, which is mainly use in the manufacture of the chocolate, and the cocoa presscake is broken into small pieces that are later pulverized to form the cocoa powder [21].

For a small scale grinding enterprise a winnowing machine, a cocoa mill and a press would be necessary. The last one could be manual for a starting point. The values of capacity and power consumption were selected based on commercial machines sell in internet.

Montazo Vallecito					
Process step	**Machine**	**Capacity [Kg/h]**	**Power [kW]**	**Hours Used per Day**	**Energy Used [kWh]**
shell remove	winnowing machine	400	2,2	7	15,4
grinding	cocoa mill	350-500	5	7	35

Table 49. Equipment for a cacao enterprise in Montazo-Vallecito

The cocoa mill for Arroyo Majagua has a lower capacity since the surplus of electricity in this project is lower than in Montazo-Vallecito

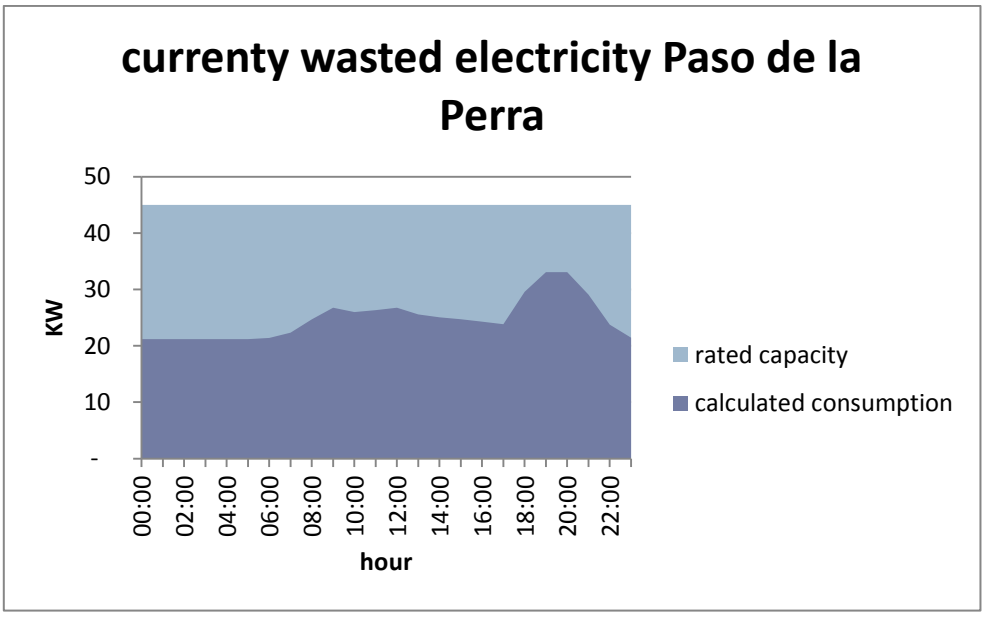
Arroyo Majagua					
Process step	**Machine**	**Capacity [Kg/h]**	**Power [kW]**	**Hours Used per Day**	**Energy Used [kWh]**
shell remove	winnowing machine	400	2,2	4	8,8
grinding	cocoa mill	150-300	2,2	8	17,6

Table 50. Equipment for a cacao enterprise in Arroyo Majagua

5.3 Future scenario

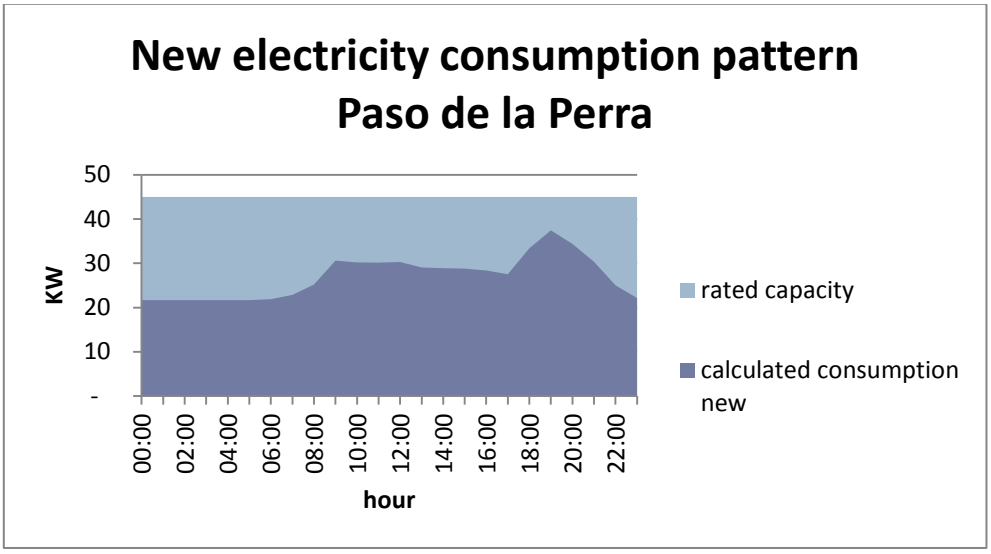
5.3.1 Paso de la Perra

Currently, Paso de la Perra uses only 55% of its capacity (comparing rated capacity and the calculated average consumption).



Graph 26. Currently wasted electricity Paso de la Perra

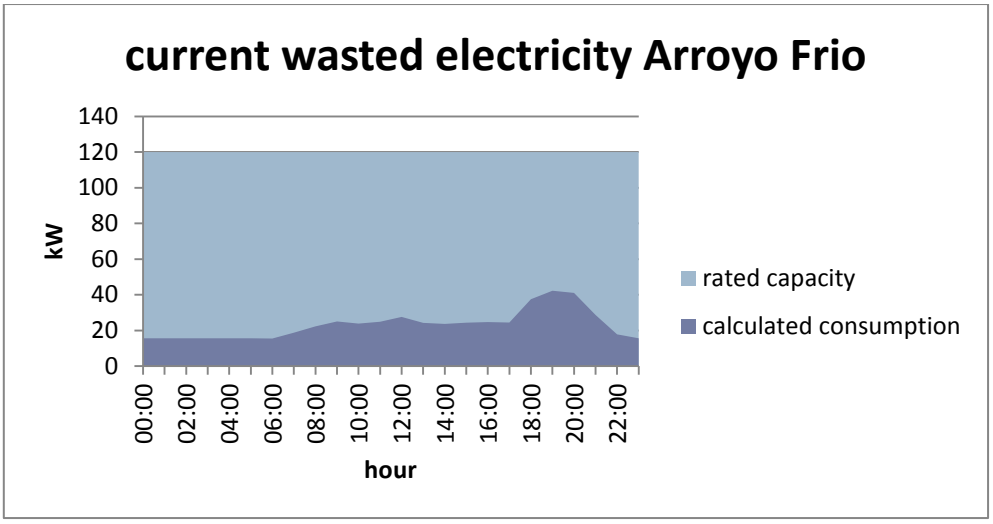
The proposal is to include a health pot facility, a computer center with internet access and an ecotourism center. The two first options are intended to improve the life quality of the inhabitants in terms of health, communication and education. The second one aims to be an income generating activity that will give more possibilities of employment for young people in the community and will promote a more sustainable land use. After including the load of all the appliances and equipment needed, the capacity factor would increase in a 5%. In other words, it means a new capacity factor of 60%.



Graph 27. New electricity consumption pattern Paso de la Perra

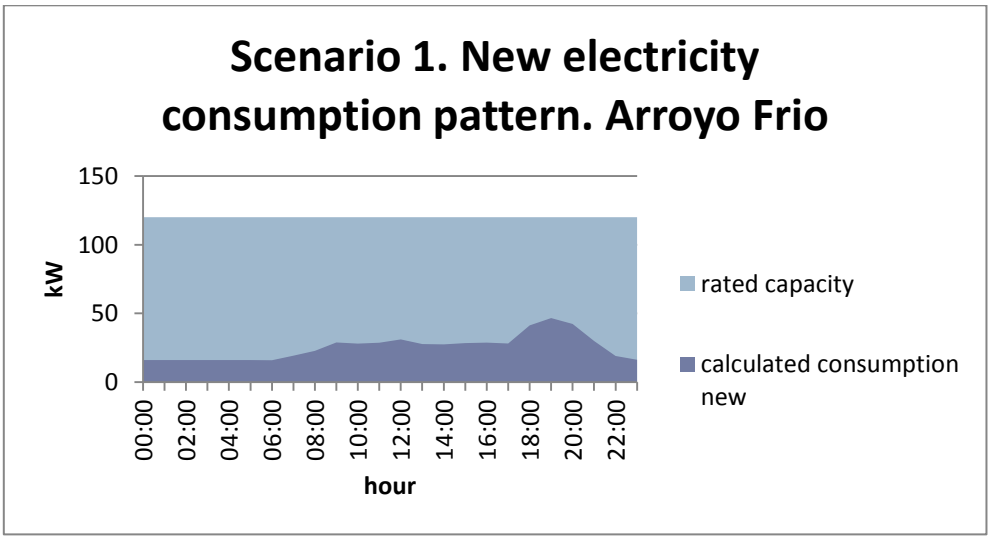
5.3.2 Arroyo Frio

Arroyo Frio uses only 19% of its capacity (comparing rated capacity and the calculated average consumption).



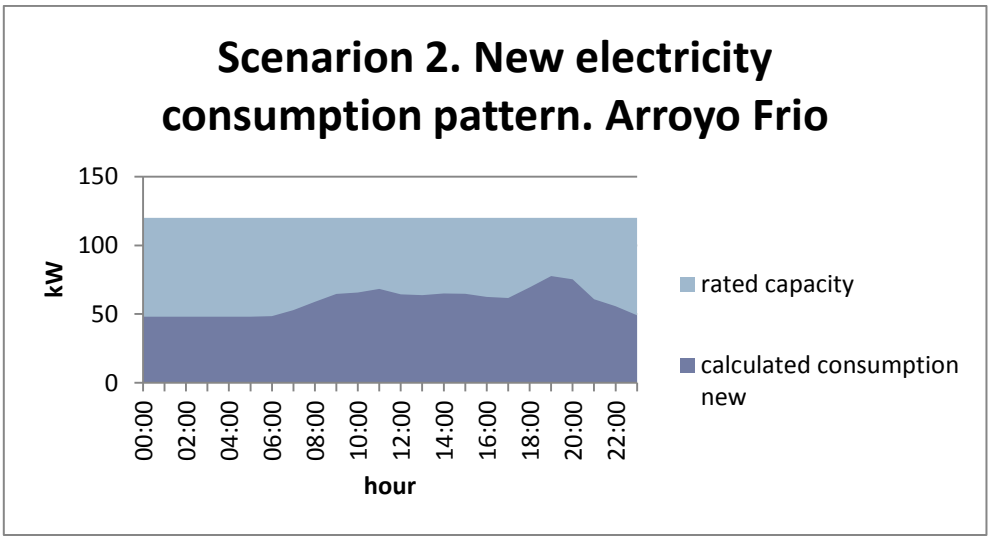
Graph 28. Current wasted electricity Arroyo Frio

Similar to Paso de la Perra, the proposal is to include a health pot facility, a computer center with internet access and an ecotourism center. For this first scenario, after including the load of all the appliances and equipment needed, the capacity factor would increase in a 2%. The new capacity factor will be 21%.



Graph 29. Scenario 1. New electricity consumption pattern. Arroyo Frio

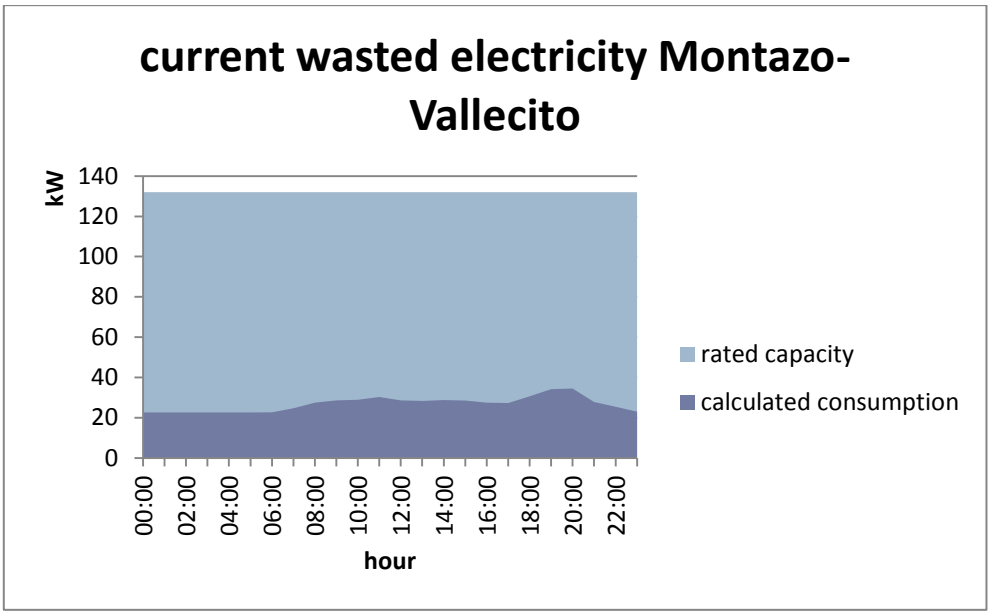
It is important to mention that Arroyo Frio was visited only 2 month after its inauguration. Therefore, there were still 56 rights to the connection from people who paid and worked in the project brigades but have not built the house. Furthermore, each household had fewer appliances than in other project that have been working for longer, so there is a high possibility that the households could buy more appliances in a future. For this second scenario, it was added not only the proposals from the first scenario (health pot, computer center and eco-tourism center), but also an energy average consumption per household equal to the one in Montazo-Vallecito for all the current and future houses with a right to the connection (263 Households). In this scenario, the capacity factor would increase in a 29%. The new capacity factor will be 49%.



Graph 30. Scenario 2. New electricity consumption pattern. Arroyo Frio

5.3.3 Montazo-Vallecito

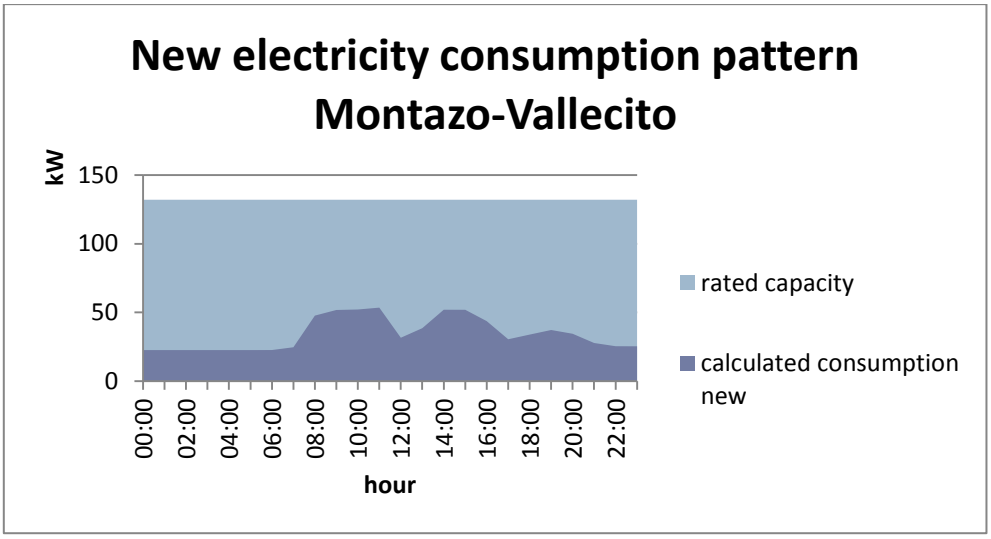
Montazo-Vallecito uses only 20% of its installed capacity (comparing rated capacity and the calculated average consumption).



Graph 31. Current wasted electricity Montazo-Vallecito

The proposal is to improve the health pot facility by buying medical equipment, install a computer center with internet access, retrieve the sawmill under a community approach, reopen the cocoa greenhouse and install a cocoa enterprise. After including the load of all the appliances and equipment needed, the capacity factor would increase in a 6%. In other words, it means a new

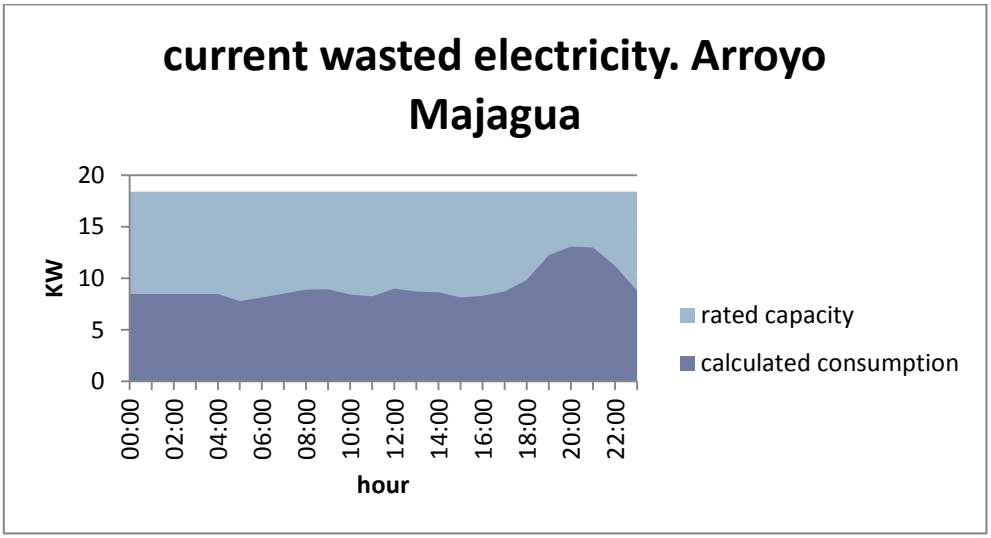
capacity factor of 26%. There is still a big amount of electricity available for other productive uses. Also, there are communities close to the project that could be connected to the grid, since the surplus of electricity is quite high. This is a good point to be considered.



Graph 32. New electricity consumption pattern Montazo-Vallecito

5.3.4 Arroyo Majagua

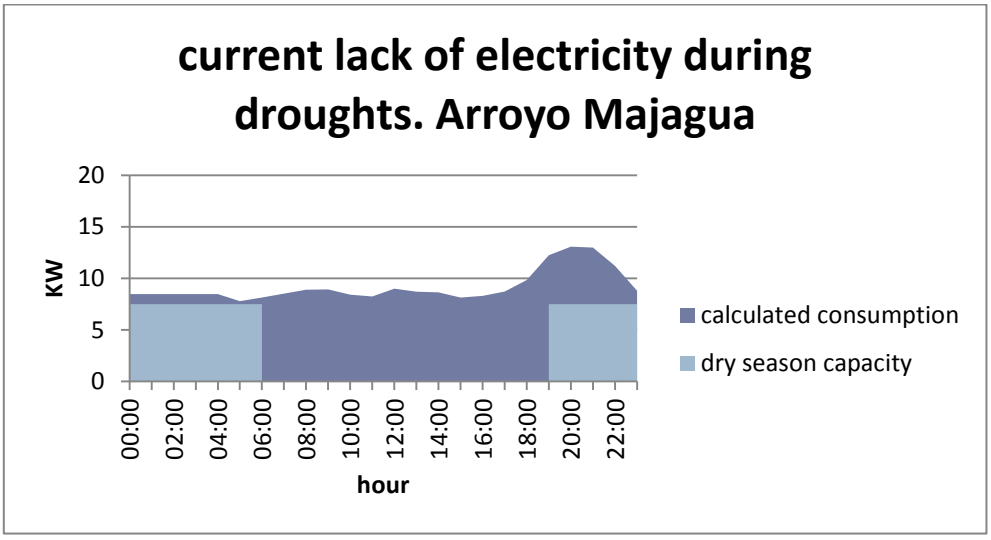
Currently, under normal conditions, Arroyo Majagua uses only 55% of its capacity (comparing rated capacity and the calculated average consumption).



Graph 33. Current wasted electricity Arroyo Majagua

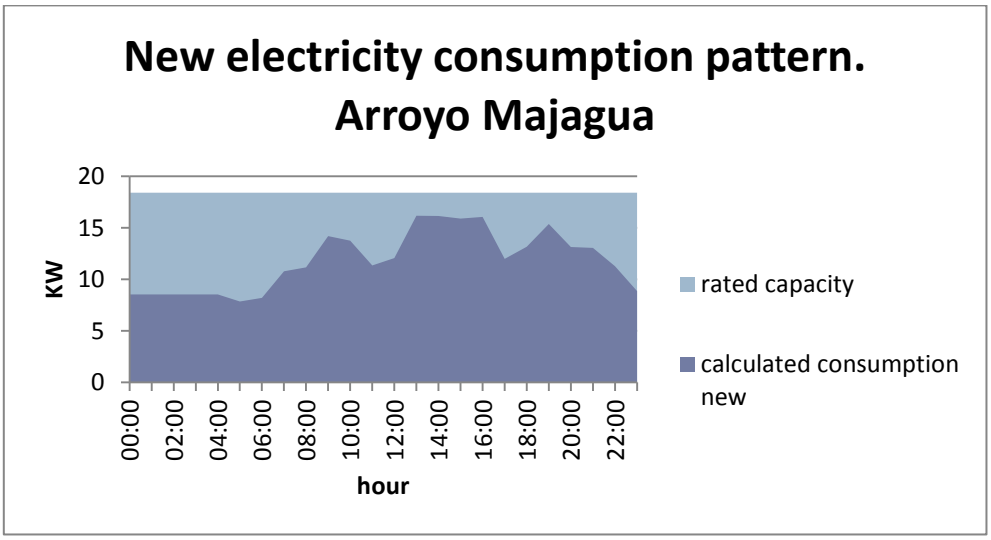
The moment of visit matched with the effects of El Niño Southern Oscillation (commonly called ENSO) in the island, thus they were going through one of the major droughts in 20 years. In fact,

the water flow in the river decreased drastically, so planned blackouts where organized in order to dam water and generate electricity at night. The average generation capacity was around 7.5 kW, which is a lower value than the normal demand, as it can be seen in the following graph. As a result, the community organized their consumption patterns, for instance, they disconnected the fridges while watching TV or listening Radio.



Graph 34. Current lack of electricity during droughts. Arroyo Majagua

The proposal for this community includes a health pot facility, a computer center with internet access and a cocoa enterprise, in order to give an added value to the main agriculture product. After including the load of all the appliances and equipment needed, the capacity factor would increase in a 14%. In other words, it means a new capacity factor of 66%. It is important to keep in mind that the cocoa enterprise cannot work under drought conditions.



Graph 35. New electricity consumption pattern. Arroyo Majagua

6 Conclusion

In the Dominican Republic, four micro hydro power plants projects were surveyed. With a total installed capacity of 315.4 kW they provide access to electricity to around 450 households.

There is an evident reduction in the expenditures for lighting and other indirect savings due to the access to the electricity from the micro hydro projects. Nevertheless, approximately 70% of the interviewees perceive savings after the electrification. The reasons are specific to each context; however, the results showed a trend in the use of the money they save, which could be a relevant influence for this perception. Normally, in the first years after the project inauguration, many users answered that they were spending the same or even more since they were buying appliances for the house, which in many cases implies debts. For communities with more than 5 years with electricity, the main use of the money they save is for secondary necessities like new cloth, transportation and communication, which they could not afford before. It should be noted that all of them made it clear that regardless of whether their expenses have increased or not due to the electrification, there was a significantly improved quality of life. Furthermore, over 90% agree that the tariff they are paying is fair and affordable.

Equally important is the new habit of saving that the project entails. Before paying a monthly tariff for electricity, the main sources for lighting were candles and kerosene lamps with some exceptions in Montazo-Vallecito, where solar panels were used. These panels were provided by a former project. The candles were bought per unit and the gas per half-liter bottles in stores. Most of them did not realize the total consumption at the end of the month, neither how much they were paying for that. A fixed tariff has forced users to save money during the month. Each community established sanctions and reconnection fees for those who do not pay in the limit of time allowed. Moreover, the analysis of the change in the distribution of the expenditures due to the electricity access showed that in many cases, the communities have started saving money for other future uses.

The levelized cost of energy (LCOE) to recover all the investment expenditures for the projects in Paso de la Perra, Arroyo Frio, Montazo-Vallecito and Arroyo Majagua is 12¢, 39¢, 32¢ and 21¢ dollar cents respectively, and 4¢, 7¢, 6¢ and 5¢ dollar cents to recover only the investment made by the community since the other part are nonrefundable funds. A life time of 15 years and a discount rate of 13,75 were assumed. In fact, the calculated LCOEs are higher than the normal values in literature. The reason is that it takes into account not only the energy production, but also the transmission losses and wasted energy.

In terms of user contributions, the biggest part of the money provided by the community corresponds to the working hours, which will not be paid back to them. Therefore, those communities are actually generating utilities each month. Paso de la Perra, Arroyo Frio, Montazo-

Vallecito and Arroyo Majagua save approximately $ 2700, $ 10000, $ 2400 and $ 1300 US dollars per year respectively. Nevertheless, there is a refusal to reinvest that money.

The current capacity factors of the projects Paso de la Perra, Arroyo Frio, Montazo-Vallecito and Arroyo Majagua are 55%, 19%, 20% and 51% respectively. Basically, the electricity use is mainly for households, some grocery stores, a church and the schools. 21% of the interviewees in Paso de la Perra and 8% in Arroyo Frio have opened a new business since the access to the electricity, corresponding mainly to new grocery stores, a beauty salon and a barbershop. In the case of Arroyo Majagua, the value is higher, a 45%, because many housewives are selling ice cream. However, the productive use of the hydroelectricity is still minimal, and each project has significant surplus of electricity that is being wasted.

Through an analysis of the strengths, weaknesses, opportunities and threats in each project, five proposals were done in order to have a more efficient use of the electricity: a health pot facility and a computer center with internet access, intended to improve the life quality of the inhabitants in terms of health, communication and education, and an ecotourism center, a sawmill and a cacao enterprise, as income generating activities that will give more possibilities of employment for young people in the community. After including the load of all the appliances and equipment needed for those proposals, the new capacity factor for Paso de la Perra, Arroyo Frio, Montazo-Vallecito and Arroyo Majagua would be 60%, 49%, 26% and 66% respectively.

Those projects were executed under a “learning by doing” methodology. As a consequence, the people in charge of the operation and maintenance of the systems are well trained to give solution to possible problems locally. There is also a network for all the micro hydro projects where the operators in those projects with more years of experience could give support to new projects in terms of repairs and extraordinary incidents if necessary. Notwithstanding, the training has been mainly empirically. Although the systems have not presented significant drawbacks so far, there is a lack of detailed written information and/or reports on the incidents/repairs done. This creates dependency on the maintenance staff making them indispensable for the correct functioning of the system. A journal of the maintenance activities is also necessary to estimate the lifetime of parts and create the basis for a program of preventive maintenance.

There are not perceived impacts on the environment as a result of the project beyond the conservation and reforestation (if necessary) of the river basin. However, the population has increased their awareness about the necessity of protecting the plant coverage in the river basin and the pipeline, in order to ensure the service.

The main perceived impacts related to health improvements were mentioned by the interviewees that used to use candles or kerosene lamps as lighting sources. The most common answers related to the change in the kids’ activities after having hydroelectricity was the time they spend watching TV, followed by the fact that they can do the homework in the evening. There is an improvement

in terms of communication due to the use of televisions and radio; however, those appliances are mostly used to see soap operas and rarely news. The biggest change is seen in the quality of life of housewives. Although they are not equally active as men in terms of participation in the decision-making, they have more comfort in their daily activities and, sometimes, free time for other activities.

Finally, the micro hydro systems developed under the SGP methodology have shown to be very effective in terms of continuity. The involvement of the community during all the steps of the project as labor force in the construction and installation of the system, as well as main actors in the decision-making, has subsequently generated a high degree of sense of belonging among users. Each community has demonstrated their capacity to shape their own development processes and management structure, according to the cultural and territorial context. All this is reflected in the high degree of satisfaction with the tariff system, the hydroelectric committee that represents them and the decisions taken.

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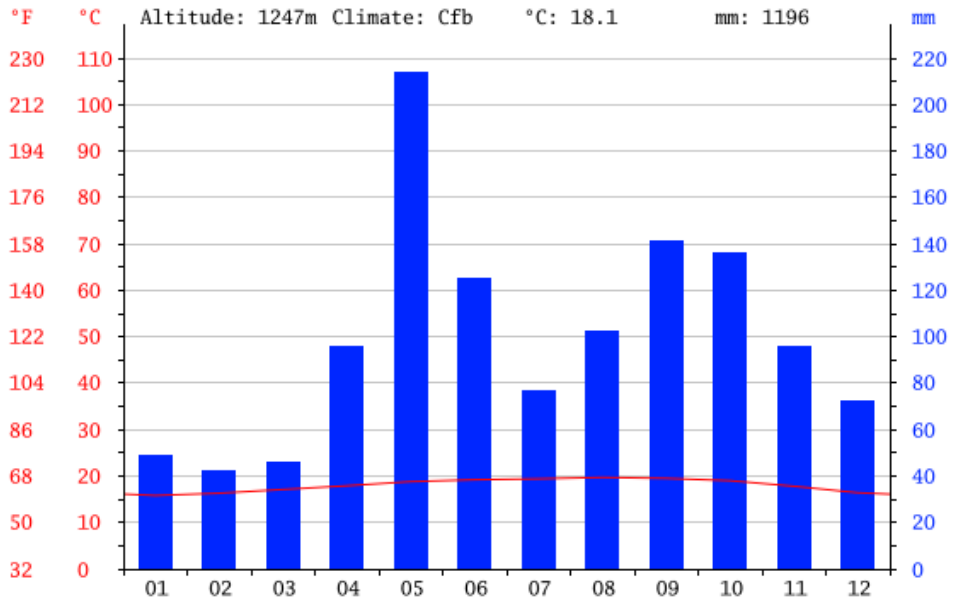
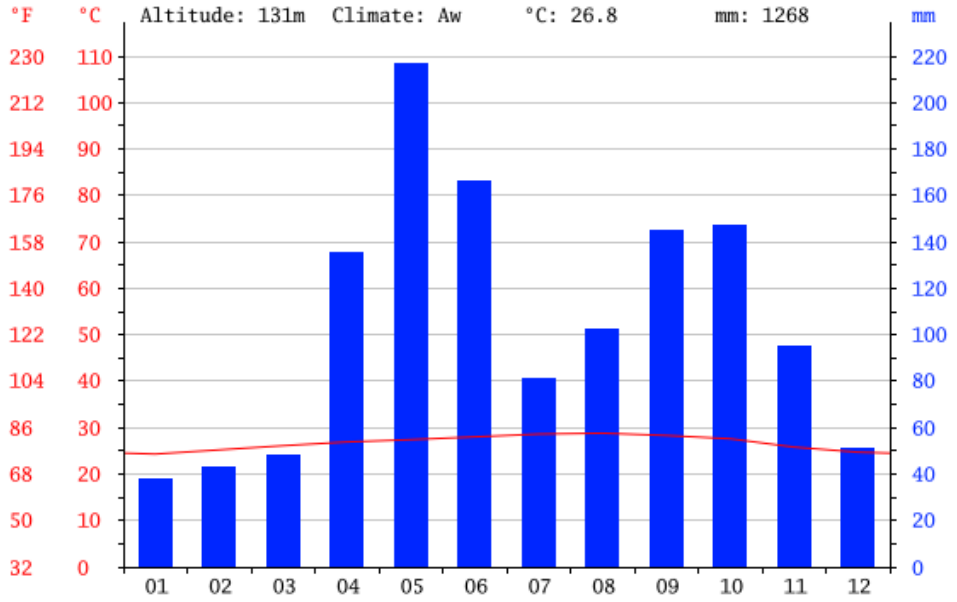
Annex

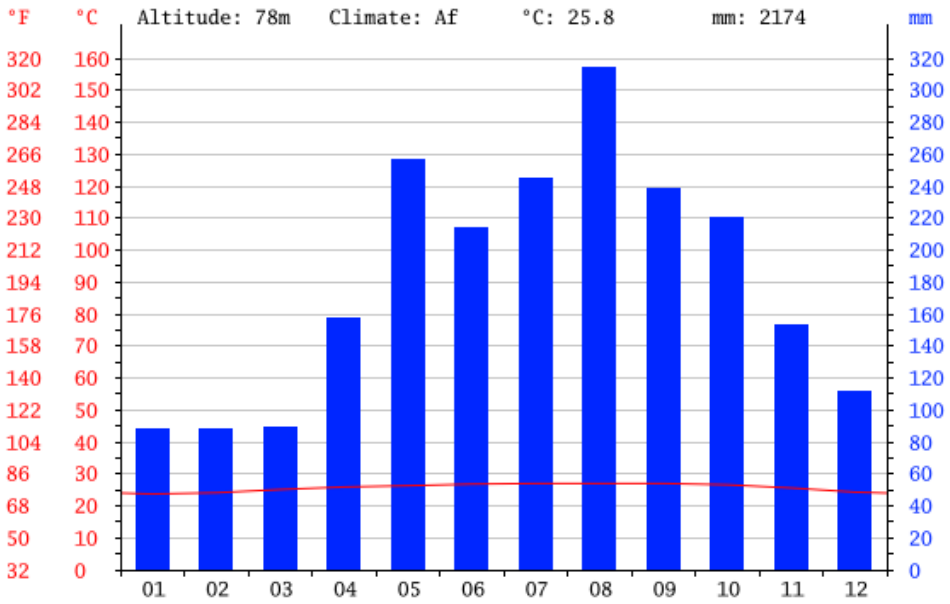
A.1. Climograms



Graph 36 Climogram. La Cienaga, Manabao, Jarabacoa, Dominican Republic. Location 877266. [22]



Graph 37. Climogram Sabaneta, Santiago Rodríguez, Dominican Republic. Location 25806. [22]



Graph 38 Climogram Yamasá, Monte Plata, Dominican Republic. Location 3906. [22]

A.2 Interviews

A.2.1 Community leaders interview

1. How many households does the village have?
2. What are the predominant economic activities within the community?
3. How many households have access to electricity?, Why?
4. How many public areas and services buildings does the village have? And How many of them have access to electricity?
5. Is the village divided by incomes groups?
   Does it influence the access to electricity?
6. What have been some changes you have noticed in the community since electrification? What about the access to information and communication with the outside? Have you noted changes in terms of education?
7. How many jobs/new businesses have been created through MHP (electricity)?
8. Do you have future plans to reinvest the money you have saved?

A.2.2 Project managers interview

1. What is the number of families/houses/people supplied with the electricity?
2. Does it provide services for schools, health centers, small-scale industry, drinking water, irrigation or any other commercial / medical facilities?
3. When the construction started and when did it end?

4. What are the available water flow in the river and the design flow?
5. What was the initial project cost?
6. Turbine manufacturer:
   Turbine type:
   Nominal capacity:
   Numbers of turbines:
   Generator type
   Generator rated capacity:
7. Are there any plans for asset upgrade/transmission extension? If yes. Who cover the installation/connection cost for a new house? And how much does it cost?
8. When the system was designed, what were the expected appliances per household?
9. Do you have any studies about the expected demand curve? Do you think the plan was followed? And how do you control it?
10. Based on which factors did you select the size of the system?
11. Do you think it was appropriate sized for the daily use?
12. Have you have problems with the brands or the manufacturer guarantees?
13. Has the MHS been replicated in nearby villages? If not, what are major obstacles (e.g. lack of investment incentives)?

A.2.3 Operation and Maintenance interview

Name of the responsible for plant operation

1. When the construction started and when did it end?
2. What are the available water flow in the river and the design flow?
3. Turbine manufacturer:
   Turbine type:
   Nominal capacity:
   Numbers of turbines:
   Generator type
   Generator rated capacity:
4. Have you have problems with the brands or the manufacturer guarantees?
5. What is the daily average peak load registered?
6. At what time does it usually occurred?
7. Do you have a record of the electricity generated? How much is it?
8. What was the year energy yield for last year?
9. How many hours does the plant operate per day?
10. How many supply interruptions do you experience per month?
11. Do you think the system is safe and accessible for maintenance?

12. How many accidents have happened since installation? How many workers have been injured in O&M?
13. Is there a Maintenance program in place? If yes, how is it implemented?
14. How many community members have been trained in MHP use and maintenance?
15. What kinds of problems have arisen regarding the machines since the project started? Does the local operator fix them? Or has it been necessary to call experts?

A.2.4 Micro Hydro System local managers interview

1. What is the number of families/houses/people supplied with the electricity?
2. Does it provide services for schools, health centers, small-scale industry, drinking water, irrigation or any other commercial / medical facilities?
3. When the construction started and when did it end?
4. How many hours does the plant operate per day?
5. How many supply interruptions do you experience per month?
6. Does the local operator (Do you) fix problems or experts from outside have to be called?
7. How much is the salary of an operator?
8. How much is the electricity tariff?
9. I understand there is a different tariff in the community. Is this correct? If so, how many families are in each tariff group? How much electricity can they use?
10. Do you have different tariff in the community?
11. How are tariffs collected?
12. Do some households in the community have timeless of payments?
13. How much (in total) do you collect per month?
14. How is the committee selected? How are decisions made?
15. What is the Operation/Maintenance cost per month?
16. What are the total operation, repair, maintenance costs since installation of the plant?
17. Are there any plans for asset upgrade/transmission extension? If yes. Who cover the installation/connection cost for a new house? And how much does it cost?
18. Which percent of the profit set aside for re-investment in electricity service business?
19. How many community members have been trained in MHP use and maintenance?
20. How was the study of the river flow conducted? Who performed the measured? Do you have a record of the data?
21. How many users did you have initially? how many users are currently connected? and how many users want to be connected?
22. What kinds of problems have arisen regarding the machines since the project started? Does the local operator fix them? or has it been necessary to call experts?
23. How many jobs/new businesses have been created through MHP (electricity)?

24. What issues were discussed at the meetings? Who participated in these meetings? Do you have an idea of the percentage of women? Is there any record of participants? Do you still hold meetings?

A.2.5 Community Members Face to Face Questionnaires

1. How many people live in your house?
2. Do you currently have access to electricity in your household?
3. How many hours per day do you get access to electricity?
4. Before being connected to the MHS, what fuel sources did you use?
5. Has the electricity and/or light provided through the MHS served as a substitute for it?
6. Which of the following electrical appliances do you own? At what time do you normally use them?
   Light, TV, Radio, Refrigerator, Washing machine, Electric fan, Cell phone, Other.
7. Since using the new light and/or electricity, have you save Money? How much?
8. How do you distribute your current monthly expenditures and how did you do it before the MHS?
9. Have you noticed that the intensity of electricity varies?
10. Have you had changes in the use of your land due to the project?
11. Did you give any financial support to the project? How much did you contribute?
12. Did you help to raise funds for the project? Which kinds of activities were performed?
13. Do you participate in community meetings?
14. Do you feel your opinion was take into account in the meetings?
15. How involved are you in decisions?
    -Participation but without voting option
    -Consulted/informed but not involved in decision-making
    -Directly involved and have dull control over decision making
16. Do you think that the health of your family has improved since access to electricity?
17. Do you feel that your household is safer since using the new light and/or electricity?
18. What have been some changes you have noticed in your neighbors or your community since electrification?
19. Do you feel your community is safer since using the new light and/or electricity?
20. Has having electricity allowed you to increase your family income? If so, how?

21. Have you set up a home business or Income generating activity since receiving electricity?
22. What have been the main differences in your daily activities since receiving electricity?
23. What have been the main differences in your sons' daily activities since receiving electricity?
24. What have been the main differences in your wife's daily activities since receiving electricity?
25. Do you feel that the community has come together more after the project?
26. Has the electricity and/or light provided through the MHS served as a substitute for it?
27. Are you satisfied with the management performance? Yes or no, why?
28. Have you noticed changes in terms of equity / equality in the community due to electrification?
29. Do you find the electricity cost fare? Yes or no, why?

A.3 Photos

A.3.1 System installation

Paso de la Perra

Photo 2. Equipment Paso de la Perra

Photo 3. Water going out of the turbine Paso de la Perra

Photo 4. Valve in the pipeline Paso de la Perra

Photo 5. Pressure redactor Paso de la Perra

Photo 6. Grit removal Paso de la Perra

Photo 7. Water intake Paso de la Perra

Photo 8. Water intake Paso de la Perra

Photo 9. Grid (House connection) Paso de la Perra

Photo 10. Consumption meters in each house Paso de la Perra

Arroyo Frio

Photo 11. Equipment. Turgo-horizontal Arroyo Frio

Photo 12 Power house Arroyo Frio

Photo 13. Transformers Arroyo Frio

Photo 14. Columns to hold the pipe Arroyo Frio

Photo 15. Valve in Pipeline Arroyo Frio

Photo 16. Joints and section changes Arroyo Frio

Photo 17. Joints iron-PVC pipeline Arroyo Frio

Photo 18.Grit removal Arroyo Frio

Photo 19. Water intake Arroyo Frio

Photo 20. Water intake (ecological flow)

Photo 21. Grid (house connection) Arroyo Frio

Photo 22. Grid (house connection) Arroyo Frio

Montazo-Vallecito

Photo 23. Equipment Montazo-Vallecito

Photo 24. Powe House Montazo-Vallecito

Photo 25. Water going out of the turbine Montazo-Vallecito

Photo 26. Transformers Montazo-Vallecito

Photo 27. Joint Iron-PVC pipeline Montazo-Vallecito

Photo 28. Not valves but holes Montazo-Vallecito

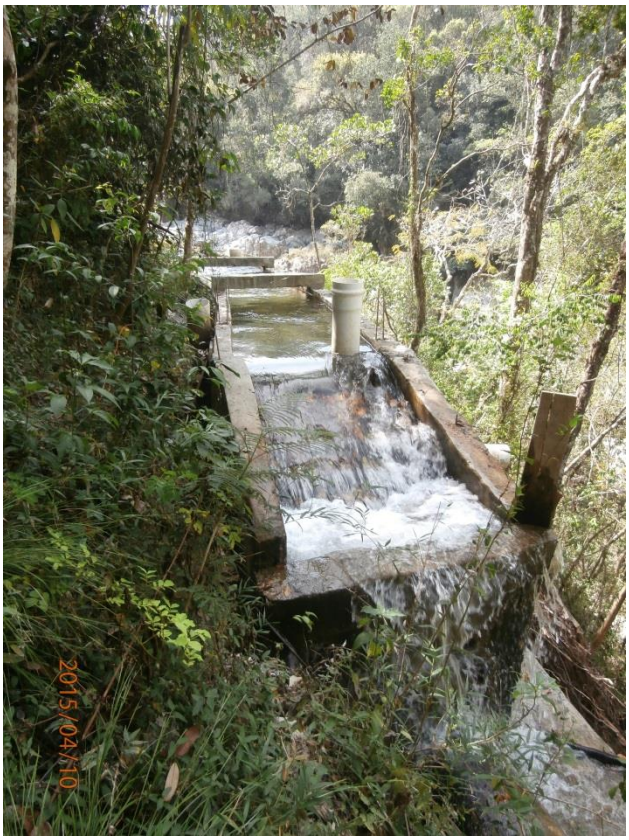


Photo 29. Grit removal (before cleaning) Montazo-Vallecito

Photo 30. Grit removal (after cleaning) Montazo-Vallecito

Photo 31. Water intake Montazo-Vallecito

Photo 32. Water intake (Ecological flow) Montazo-Vallecito

Photo 33. Grid lamppost in areas accessible by car Montazo-Valleicto

Photo 34. Grid where it is not accessible by car Montazo-Vallecito

Photo 35. House connection Montazo-Vallecito

Arroyo Majagua

Photo 36. Equipment Arroyo Majagua

Photo 37. Power house Arroyo Majagua

Photo 38. Water going out of the turbine Arroyo Majagua

Photo 39. Joint iron-PVC pipeline Arroyo Majagua

Photo 40. Columns to hold the pipe Arroyo Majagua

Photo 41. Grit removal Arroyo Majagua

Photo 42. Water intake (channel) Arroyo Majagua

Photo 43. Water intake Arroyo Majagua

Photo 44. Grit Arroyo Majagua

Photo 45. Grid (house connection) Arroyo Majagua

A.3.2 River Basin conditions

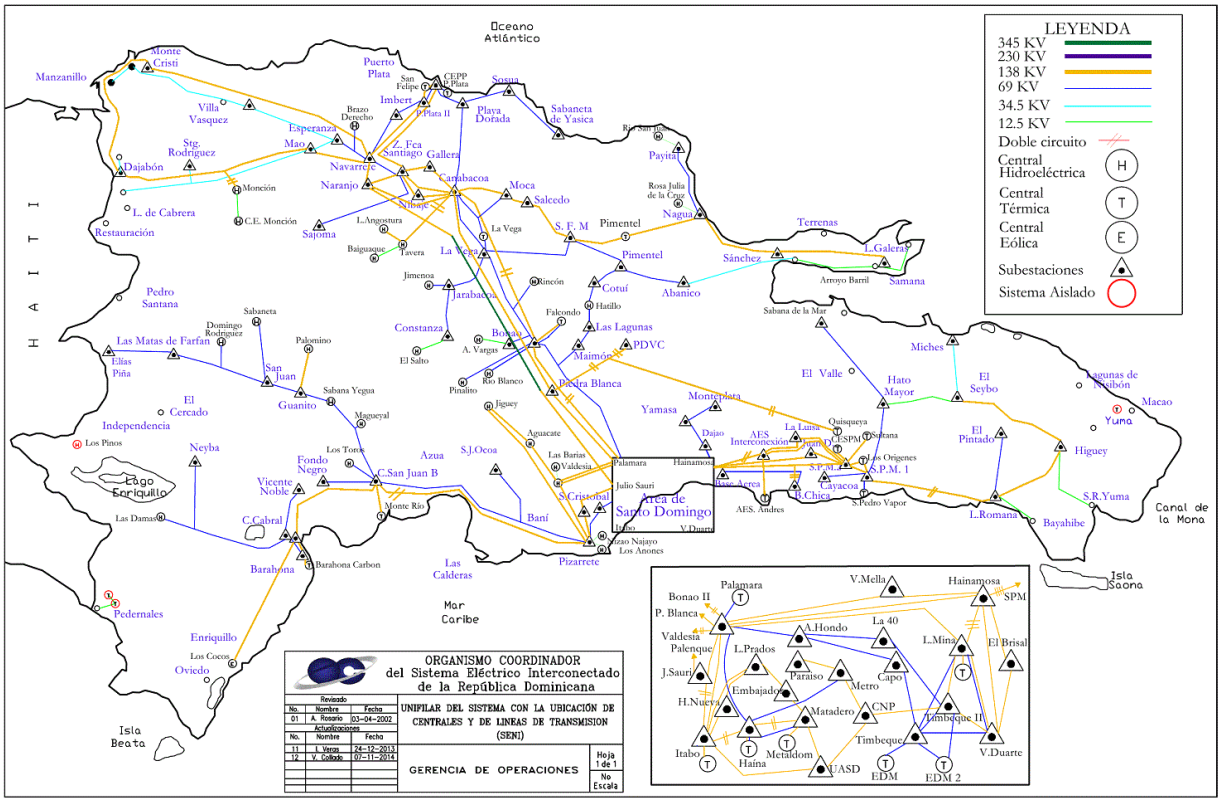
Photo 46. River basin conditions Paso de la Perra

Photo 47. River basin conditions Arroyo Frio

Photo 48. River basin conditions. Montazo-Vallecito

Photo 49. River basin conditions Arroyo Majagua

A.4 Maps



Map 4 Dominican Republic national grid [23].

Map 5. Location of the projects Paso de la Perra, Arroyo Frio and the nearest town in Google earth

Map 6.Location of the communities of Montazo and Vallecito and the nearest town in Google earth

Map 7. Location of the projects Arroyo Majagua and the nearest town in Google earth