THE MICRO-HYDRO POWER SISTEM OF THE COMMUNIT OF SAN MIGUEL DE LA TIGRA, SAN CARLOS, COSTA RICA

EXECUTIVE SUMMARY

Some rural communities in Costa Rica, as is common in other developing countries, remain isolated from centralized power grids. Economic activities which require a dependable energy source are stymied, and if energy needs are not satisfied, residents will tend to abandon these communities, looking for comfort and employment in urban areas. Given this situation, many individuals and communities look for ways to supply their energy needs independently. The current Case Study tells the story of the solution found by the small Costa Rican community of San Miguel de La Tigra to their energy needs, and the role of the Regional Office for Central American and the Caribbean of the Biomass Users Network (BUN-CA) in improving the efficiency of that system.

The history of San Miguel de la Tigra, in Costa Rica's north central province of Alajuela, is similar to that of many isolated rural communities, reflecting periods of growth, of decline, and questions about the future From 1986 to 1990, a series of events reduced San Miguel to a group of about 15 families. Those that remained, however, were determined to stop the town's decline, retain the current residents, and hopefully attract new ones. The installation of electrical power was the strategy that was chosen to lead the movement toward a better standard of living and new economic opportunities.

The most viable alternative to connecting with an external system, to which the community did not have access, was to install a small hydro powered generator.

Construction of San Miguel's hydro-power plant and connecting power lines was carried out over a two month period in 1989, without significant outside assistance. During this time, the participants worked 12 hours a day in construction and installation of the water intake facility, powerhouse, electrical grid, and other basic components. Thus, 12 houses within a one mile radius of the generator began receiving electrical power for the first time, benefitting a total of 70 people. The plant has potential to supply 35 Kw of power, sufficient for residential use and light industrial activities.

The hydro-power plant operated for almost two years with no technical or professional assistance, but problems were beginning by 1991, when José Maria Blanco, BUN-CA Director, visited San Miguel for the first time. The effort exemplified BUN's interest in appropriate renewable energy technology at the community level. The resulting project's objective was to increase the efficiency of the existing electric system in all its phases; generation, transmission and end use of the electricity. By supporting the efforts of this community group, BUN intended to document and share grass roots "know-how" in small renewable hydro-electric energy.

Initially, four working phases were planned:

a. Rebuilding of the Water Intake Facility
b. Redesign and Retrofitting of the Transmission System
c. Minor Modification to the Generating Unit, and

d. Elaboration of a program for electricity consumption management

Several principal problems were identified by BUN staff and consultants in the design and function of the existing installation, including that:

- The intake area was not capturing all of the water available from the source, reducing its potential efficiency.
- The intake area was frequently blocked by leaves and other debris, impeding the passage of water to the turbine which affected the quality of electrical output, and caused often the system to shut down.
- The power lines leaving the power house were low to the ground and not securely fastened, and the transformer was directly next to the generator, creating an immediate danger to people visiting the site, as well as to wildlife.
- The posts supporting the power lines were old and deteriorating. If one had fallen, it could have caused death by electrocution and/or made the generator and transformers inoperable.

Through the BUN-CA project with the community, modifications including the following were carried out:

1. The height of the intake tanks was increased by 30 centimeters (12 inches) to increase the volume of water which is directed to the turbine. This effectively increases efficiency of water use by 10%.
2. Two chambers for cleaning the water at the source were constructed.
3. To reduce the problem of blockage from forest matter, the forbay was covered with a steel mesh grill, in a steep inverted V shape.
4. Taller and stronger posts were placed along the transmission route.
5. The power lines were transferred to the new poles, equipped with new transformers, and tensed accordingly

With the completion of the project, the time invested by the participants in routine maintenance has been significantly reduced. The improved electrical power system has made possible a variety of economic activities for the seven families which now remain in San Miguel. In addition, BUN's willingness to spend time and money to support their project motivated residents to undertake projects on their own to improve the road, the school, the communal facilities, and begin planning for a town-wide potable water system. Another benefit of the BUN-CA project in La Tigra has been an increased recognition by other regional organizations of the value of the community's efforts in renewable energy.

COMMUNITY HYDRO-ELECTRIC FACILITY SAN MIGUEL DE LA TIGRA

INTRODUCTION

Some rural communities in Costa Rica, as is common in other developing countries, remain isolated from centralized power grids. Residents of these areas cannot take for granted the simple act of flipping a switch to illuminate a darkened room, much less refrigeration, electric ovens, or the other household appliances common in much of the world. Economic activities which require a dependable energy source are stymied. If energy needs are not satisfied, residents will tend to abandon these communities, looking for comfort and employment in urban areas. As the United States Agency for International

Development recognizes, "One of the major obstacles to economic development in villages in developing countries has been the lack of power for basic services, including lighting, water pumping, and health care." (USAID, 1992)

Given this situation, many individuals and communities look for ways to supply their energy needs independently. Several options exist for community and household energy production. Each method has its advantages and disadvantages as an energy source:

Biomass: Biomass refers to plant materials and animal wastes used to produce some type of usable energy. Biomass resources include wood, charcoal, animal manures, crop wastes and weeds, among others. These materials are often freely available in the environment, or are byproducts of other productive activities. They can be "burnt directly for heat, to generate steam or gases for producing electricity, fermented to alcohol fuels, extracted as oils from plants as diesel substitutes, anaerobically digested to biogas, or gasified to produce high energy gas." (BUN, 1991) Simple or complex technologies can be applied to household, farm and industrial uses. Biomass is a renewable energy source when properly managed, accounting for needed inputs of land, water and labor. Mismanagement of some of these resources, however, such as wood and other plant materials, may contribute to deforestation and desertification.

Solar: Photovoltaic solar cells and solar thermal technologies convert sunlight into electricity or heat. In solar electric technology, simply put, "Some materials exhibit a property, known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current result can be used as electricity." (Shepperd and Richards, 1993) These systems provide low-cost, dependable energy under almost any climatic condition, but may require significant investments in equipment and installation.

Small Generators: Some households and rural businesses (such as restaurants and small hotels) use individual fossil fuel-based generators to provide electricity for lighting, cooking, and refrigeration. These generators are noisy, need frequent maintenance, and their fuels (diesel, kerosene and fuel oil) must be purchased and brought into the area over often undependable transportation routes. Due to the costs of these systems, they generally operate only a few hours each day.

Wind: Wind turbines can be used to produce electricity and to pump water for community, industrial and irrigation uses. The resource is eternally renewable, and energy production no contaminating. Windmill technology is simple, but has been less frequently applied than other alternative energy sources. Lack of available appropriate technology in developing countries with energy shortages is a stumbling block to small wind energy projects.

Hydro-electric: A hydraulic turbine connected to a generator can be used to convert natural water flows into electricity. Applications of this technology vary greatly; from a micro plant providing power to one house, to larger installations

which supply communities or regions. Hydro-electric generating systems require stable water flow rates and careful maintenance.

The current Case Study tells the story of the solution that the small community of San Miguel de La Tigra found to their energy needs, and the role of the Regional Office for Central American and the Caribbean of the Biomass Users Network (BUN-CA) in improving the efficiency of that system.

BUN-CA

The Biomass Users Network (BUN) is a non-profit organization which works internationally to facilitate the sustainable use of biomass resources and improve living conditions of rural populations in developing countries. BUN established a presence in Costa Rica in 1988, and consolidated its Regional Office for Central America and the Caribbean (CR) in 1991. The organization supports local groups already working in projects within BUN-CA's principal areas of interest; organic agriculture, renewable energy and information exchange. The projects should demonstrate direct social as well as environmental benefits, and offer a model which could be replicated by other groups facing similar problems, be they in the same country or elsewhere in Central America. Without assuming control of a project, BUN-CA offers small scale financial support in critical moments, and facilitates the exchange of practical technical information appropriate to project needs. Technical specifications and procedures used in all projects are available to the public in the Costa Rica office, and are disseminated through publications, presentations and seminars.

Renewable Energy Area

Within its general framework, BUN-CA has prioritized three areas in which to concentrate its efforts: organic agriculture, electronic information systems and renewable energy. The Renewable Energy Area focuses on promoting projects which improve energy efficiency and/or take advantage of local sources of renewable energy, such as wind, biomass, photovoltaic, and small hydroelectric plants. BUN-CA assists rural organizations or communities to improve the energy efficiency of projects which are already underway, through providing technical expertise, funding for materials and by facilitating contacts with other organizations and information exchange.
The renewable energy project being carried out in the village of San Miguel de la Tigra is an ideal example of the benefits of micro hydroelectric plants, and of how an external organization can facilitate community development.

SOCIAL CONTEXT: San Miguel de La Tigra

The history of San Miguel de la Tigra, in Costa Rica's north central province of Alajuela, is similar to that of many isolated rural communities, reflecting a periods of growth, of decline, and questions about the future. The existence of a dependable energy source may be the determining factor in future development.

Origin and growth of the community

In recent generations, individuals and families have entered largely inaccessible areas of the country, to establish claims on the land and seek their fortunes in a pioneer lifestyle. This is the origin of San Miguel de la Tigra, as well. When Tranquilino Vásquez arrived in the zone in 1956 with his wife Esperanza (6 months pregnant) and several small children, there were only a few houses scattered through the hillsides. There were no roads, and the family had to walk several days carrying everything they would have to start their new life. At that point, the area was known by its nickname PocoSol, but Vásquez chose the official name which would stay with the new community. Don Tranquilino and Doña Esperanza cleared the land, planted coffee, food crops, attended cattle, raised 18 children, and participated in San Miguel's development.

The village is located approximately 5 kilometers (3.5 miles) from the town of La Tigra (see Figure 1). With an altitude of 1527 meters (5008 feet) above sea level, it receives about 3,000 mm (118 inches) of rain per year. The area is catalogued as a Very Humid Low Forest, mostly suitable for forest preservation.

Over the years, other large families established themselves in San Miguel, along with individual farmers, and the community grew steadily, reaching its maximum population around the year 1974. Eight extended families had settled in the area, bringing the population to well over 100.

Throughout the decades of the 1960's, 70's and 80's, standing forest was viewed mainly as an obstacle to productive activities by most rural residents, including those in San Miguel. After "cleaning" the land of much natural vegetation, most of the farmers cultivated coffee, raised some dairy cattle, and grew food crops for personal consumption. Coffee provided virtually the only source of cash income for farmers in San Miguel throughout a ten to twelve year prosperous period. Most residents owned some land, but many also worked as day laborers on other farms, the only source of employment.

It was during this time that the first primary school opened in the community; previously, the children walked several hours a day to the town of San José de la Tigra. Few were able to complete more than three or four years of primary school, as their labor was needed on-farm. In recent years, there have been greater opportunities to receive a basic education close to home, but young people must still leave San Miguel to attend secondary school.

During this high point in the community's development, the first rudimentary road was put in, improving access to the outside world. The area still lacked most basic services, however, which severely limited opportunities to improve the standard of living. Homes were still lit with kerosene and candles, food was prepared over wood stoves, there was no community infrastructure, communications and transportation were difficult, and little processing of agricultural products was possible.

Hard times ahead: Population Decline

Approximately 8 years ago, in 1986, San Miguel's growth began to turn to decline. Around this time, production in the coffee plantations began to decrease, coinciding with falling prices in the international market. Suddenly, the major source of cash income was threatened, with no immediate alternatives immerging.

To additionally complicate matters, San Miguel and its surrounding area is located within the buffer zone of the Monteverde Cloud Forest Reserve, and is directly on the border of the approximately 19,000 hectare Children's Eternal Rainforest Reserve (see Figure 1), meaning that human activities such as farming, cattle ranching, construction and road building can effect the resources within the protected areas; drainage basins, biological diversity, and species preservation. The easiest way to limit the effects of human communities is to gain legal control over land use. To this end, in 1988 the Monteverde Conservation Association and other international environmentalists began purchasing land in the PocoSol sector of the Children's Eternal Rainforest Reserve, which included part of the area making up San Miguel (Monteverde Conservation Association, 1992).

In contrast to land purchases for officially designated national parks, no farmer could be obligated to sell. For this reason, the Association paid a good price for the land, often more than these isolated farms would have brought on the national market; as much as $250 per hectare (Monteverde Conservation Association, 1992). This offer was very attractive to many residents, who were struggling to survive without their traditional cash income from coffee. One land holder after another began selling and moving away, and thus began an exodus which decimated the community's population.

The situation has generated resentment on the part of some of San Miguel's residents. Gerardo Vásquez, for example, criticizes the project for protecting nature without considering the effects on the human neighbors. "Who do they think lives here, monkeys?" he asks. His father Tranquilino, however, approaches the problem more philosophically. While he questions some of the methods used to buy the land, he feels that, "The reserve is a good idea, if you're thinking about the future. It's important to protect the rivers and everything".

Other families outside the Reserve's area of interest lost an important source of paid work when these landowners left, and were unable to sell their land at a price which would allow them to buy elsewhere. Many of these did not sell, but simply moved away leaving large areas of unused land and unoccupied houses. The opportunity of obtaining a plot in government sponsored settlement projects also proved attractive to some residents. The decline of agricultural incomes, the lack of amenities such as electrical power, and the increasing isolation brought by outmigration, provided reason enough for many residents to abandon the community to look for employment in urban centers. Of Tranquilino and Esperanza's 18 children, for example, only three still live in San Miguel.

From 1988 to 1990, this process reduced San Miguel to a group of about 15 families. Those that remained, however, were determined to stop the town's decline, retain the current residents, and hopefully attract new ones. The residents of San Miguel were not accustomed to carrying out communal projects, but rather attended to individual interests. Differing working styles and personalities have made it difficult for groups to come together toward common ends.

The installation of electrical power, however, was a need which almost everyone agreed on, and was the strategy that was chosen to lead the movement toward a better standard of living and new economic opportunities.

PROJECT HISTORY

The idea of bringing electricity to San Miguel was not a new one when the project got underway in 1988. For several years, community members had been exploring the possibility of connecting with an existing power grid. The town is located within the area of influence of the Rural Electrification Cooperative of San Carlos (COOPELESCA), a regional organization which began supplying power to the area in 1965. The power lines had arrived within 3 kilometers of San Miguel, but to connect the village to the system, the residents would have had to pay about US $30,000 in advance. This kind of investment was clearly out of the question for the struggling farmers.

The community, however, was committed to bringing in some kind of electrical power system. With dependable power, household life could be nearly as easy as in the city, with modern kitchen and entertainment apparatus, and the safety and comfort of nighttime illumination in the house and street. Community services could be improved, such as lighting for the school and social center. Electric power would also permit refrigeration of perishable food products to be sold outside the community, as well as items brought in for local consumption. A variety of other economic activities depending on machinery would also be possible. With this service functioning, San Miguel would have a chance to notably improve standards of living and retain residents.

The most viable alternative to connecting with an external system was to install a small hydro powered generator. The people of San Miguel had seen such systems functioning in other communities, and a few had even tried installing their own small generators for household use. With this background, the idea of establishing a larger system serving the entire community did not seem too farfetched.

Two community leaders, Gerardo Vásquez and Juan José Rojas, along with members of the González family, took on the responsibility for developing the project. The first problem they encountered was that the residents were strictly farmers, with little experience in the technical aspects of electrical power. The answer was to look for people with the appropriate knowledge, and find out what they needed to know. Vásquez and neighbor Miguel Rodriguez arranged for advisors to evaluate the proposed water source, a small tributary of the Peñas Blancas River. They concluded that the centrally located site provided an adequate hydraulic fall and a constant year round flow of water.

With the appropriate location chosen, Juan José Rojas took charge of the technical details of installing the system, while Vásquez organized and motivated the participation of other community members. Rojas visited other projects, and talked with technicians who knew this type of generating system. He basically asked, "How does it work? How do you set one up?" With these answers, he designed the system himself without the benefit of any formal training. Rojas has a natural ability with technical matters, and is oriented toward getting the job done with as little fuss as possible. He has no patience, however, for the politics and tact necessary for working in groups or with institutions. Vásquez filled this gap by contributing his natural leadership abilities to the project.

The next obstacle to overcome was economic. The group calculated the cash cost of purchasing a used generator and installing the system a t a approximately US $8,000. This amount was divided into seven quotas of about US $1,145 each, to be paid by the participants. While some, like Tranquilino Vásquez, were able to pay the amount out of their income from coffee production, most had to obtain loans to cover their portion. Juan José Rojas and his wife Damaris Vásquez, for example, took a loan from his sister, originally intended for improvements to their home, to finance their quota. Others also took out formal and informal loans, paying them off over a four to five year period. Some community members could not pay the entire amount under any circumstances, but wished to participate anyway, so several families joined together to pay one part. Those who could not pay cash, supplied materials, the labor and food during construction were considered as their contribution[1].

Construction of San Miguel's hydro-power generator and connecting power lines was carried out over a two month period in 1989. During this time, the participants abandoned their other productive tasks, working 12 hours a day in construction and installation of the water intake facility, powerhouse, electrical grid, and other basic components.

Gerardo Vásquez and Juan José Rojas (front, left to right), and visitors climb down to the generating facility.

The location of the water source made getting in and out of the construction site a daunting task. At first the participants were discouraged at having to climb up and down the severe mountain slope carrying heavy materials on their shoulders. Determined to continue, instead of lightening their loads, they increased them in order to reduce the number of trips to be made. Several people ended up falling head over heels down the steep hillside, but miraculously no one was seriously injured.

After the two month period, the system was installed (see Technical Aspects below). An acquaintance from the town of Grecia visited the project at the end to check the installation and connect the generator to the transformer, which the

[1] All of the 12 families which were eventually connected to the network contributed in some way to its construction. Others in the area who did not wish to participate during the establishment of the system will not be included unless they pay a similar quota.

townspeople felt was too dangerous for them to attempt. Thus, 12 houses within a one mile radius of the generator began receiving electrical power for the first time, benefitting a total of 70 people. The plant has potential to supply 15 Kw of power, sufficient for residential use and light industrial activities.

Since 1989, the generator and distribution system has worked relatively smoothly, with infrequent shutdowns for maintenance and repairs. Over time, however, the use of electrical appliances has increased in each household, straining the system's supply capability. If electric irons were used in several houses at the same time, for example, the quantity of electricity available in all the houses would drop. Over the years, the increase in demand along with deterioration of the infrastructure made it obvious that the original system needed to be overhauled.

BUN-CA Collaboration

If this community problem is approached through a sustainable development perspective, it is clear that the San Miguel experience offers an opportunity to promote the use of appropriate technology and capture valuable knowledge that could be re-applied in other communities in Costa Rica and Central America.

The hydro-power plant operated for almost two years with no technical or professional assistance, but problems were beginning to present themselves in 1991, when by chance José Maria Blanco, BUN-CA Director, visited San Miguel for the first time. The project exemplified BUN's interest in appropriate renewable energy technology at the community level, in addition to the town's sensitive location in the Monteverde Reserve's buffer zone. Community members requested any help that BUN could offer in improving their energy system, but it was not until 1992 that funding was secured from the Joyce Mertz Gilmore Foundation, to initiate a joint BUN-CA / San Miguel project called "Optimization of a Rural Hydro-power System". All the activities described below were carried out with only $2,000 in cash funding, plus donated time and materials. BUN-CA staff salaries and expenses were not charged to the project budget.

The project's objective was to increase the efficiency of the existing electric system in all its phases; generation, transmission and end use of the electricity. By supporting the efforts of this community group, BUN intended to document and share grass roots "know-how" in renewable hydroelectric energy.

The specific project objectives were:

1. To evaluate the existing system and provide the technical recommendations needed to guarantee adequate operation.
2. To collaborate in the optimization of the existing infrastructure.
3. To implement an educational campaign and set up an energy end-use saving program.
4. To encourage the local spirit of association among the neighbors, in order to re-apply their group motivation in other activities.
5. To use BUN's communication resources to disseminate the benefits and success of this non-conventional renewable energy source to local and international communities.

As a first step in the San Miguel project, BUN-CA, through its small power system consultants, prepared a preliminary technical report on the mechanical condition and electrical operation of the system. This evaluation allowed the definition of a program of technical assistance which would be carried out in phases as funding permitted.

PROJECT DEVELOPMENT

Initially, four working phases were planned:

A. Rebuilding of the Water Intake Facility

UN-CR's technical consultants reviewed the existing intake system, and suggested design modifications (see Technical Aspects below) to improve the efficiency of the water flow utilization. In carrying out the modifications, BUN provided part of the materials, and the community carried out all construction. Once again, the rocks, sand, cement mix, steel bars, cement blocks and other construction materials were carried in on the shoulders the participants. Work on this phase of the project was completed in October, 1993.

The effect of the divergence of water on stream-side vegetation has proven to be minimal. The water is removed from its course for only a short distance before being returned, and overflow assures continual moisture in the original streambed. This is one of the main advantages of small projects as sources of renewable energy. There is no need to create damns for water storage or in any way significantly effect the environment.

B. Redesign and Retrofitting of the Transmission System Technical consultants supplied by BUN-CA studied the hardware and placement of transmission lines, and designed their retrofitting (see Technical Aspects below).

This type of hydro-electric project is by nature capital intensive, requiring investment in materials and equipment. Since the financing available for this phase of the project didn't cover the cost of all needed materials, BUN-CA set out to obtain total or partial donations; to make "zero cost" investments when possible.

Over several months, BUN-CA negotiated the purchase of used transmission poles at a nominal price and the donation of two street lights and some minor miscellaneous materials from COOPELESC A. BUN also a ranged to cheaply buy more used poles and porcelain insulators from the National Power and Light Company (CNFL), the country's main power distribution utility. The Cartago Electrical Service Administrative Board (JASEC) agreed to sell two used transformers to the project at about US $20 each. In this way, and by canvassing used equipment "junk" yards, BUN staff succeeded in obtaining most of the materials without cost or at a discount, so that purchase of new equipment at retail price was minimal. While this method reduces cash costs considerably, it does require a time investment on the part of project or assisting organization staff.

In 1993, the community placed the new poles following the technical consultant's suggestions. The power lines were transferred from the old poles to the newly installed ones, and the new transformers were installed in June, 1994. COOPELESCA carried out this sensitive and dangerous task, sharing the cost of the work equally with the community and BUN.

C. Minor Modification to the Generating Unit

Although several problems were identified with the installation of equipment in the powerhouse (see Technical Aspects, below), as the project progressed, it became clear that BUN's contribution of resources could be better used in the first two phases mentioned above. Modifications such as the installation of a functioning electronic control panel to increase the efficiency of the generating unit and the readjustment of the valve regulating water flow entering the turbine have been identified for eventual completion by the community.

Original water intake facility

D. Elaboration of a program for electricity consumption management

In July, 1992, BUN staff completed a study of current and projected energy demand within San Miguel, comparing it with actual and potential energy output of the hydro-electric plant. The original intention was to carry out an educational campaign in the community to reduce consumption of electricity, but it turned out that with the modifications to the system, the supply of energy will far exceed the demand for the foreseeable future (the generator's output capacity is 15Kw, while current demand is only 3.5Kw). It was decided that the moment was not opportune for this phase of the project, though it could be revived if more houses are added to the system.

TECHNICAL ASPECTS

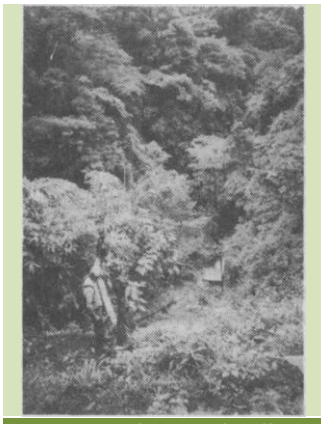
Basic system design

The San Miguel micro hydro plant is a "run of the river" scheme, which does not stop a river's flow by building a damn, but diverts part of the water's flow through the turbine before returning it to the stream bed. This approach is low cost, and results in little environmental disruption.

San Miguel's original system, as installed by the community, had the following basic characteristics:

1. The water intake facility was made up of a concrete block tank and two steel bar grids. The system received a water flow of 50 liters (13 gallons) per second, at a constant rate throughout the rainy and dry seasons.

2. A concrete pipeline approximately 20 meters (67 feet) long and 35 centimeters (14 inches) in diameter, connected the tank with a steel pipeline 46 meters (150 feet) long and 30 centimeters (12 inches) in diameter, called the "penstock", which drops the water from the source to the turbine, incresing the water pressure and energy potential. The fall, called the "head", is of about 25 meters (82 feet), which provides a maximum potential hydraulic output of 35 Kw.



'Penstock" pipeline descends to powerhouse

3. The water flow is regulated manually by means of a 4 inch hatch type valve, installed at the entrance of the turbine.

4. A 35 centimeter (14 inch) diameter Pelton type turbine, with 15 buckets, was mounted over a highly unstable 7.5 centimeter (3 inch) steel bar and steel bearings. The water entering the turbine hits buckets on a turning wheel, which converts the energy from hydraulic to mechanical. The wheel is connected to a generator by means of a shaft and a rubber belt. The unit operates non-stop 24 hours a day.

5. A15 KVA D-l 1E Stanford generator (230-115 volts, 65- 130 amperes, 61 Hertz, monophase of 1800 rpm) then converts the energy from mechanical to electric. The consulting electrical engineer estimated that the maximum power outlet of this unit is 10 Kw, which represents a total efficiency of 64.13%.

6. A set of pulleys and belts with a speed ratio from 237.5 rpm to 1800 rpm(2).

7. A control panel, which was in poor condition and inoperable, contributed to surges which could damage electronic equipment.

8. A 15 KVA transformer elevated the voltage from 230 volts at the generator outlet to 2400 volts.

9. The protection system consisted of a blade type breaker of 200 amperes located near the generator.

10. The transmission system was about one mile long, and consisted of 2 mounted copper wires, plus three monophase transformers which transformed the voltage from 2400 to 230-130 volts at the household level.

11. Most of the poles were made of wood, with five made locally of concrete. The insulators were made simply of PVC tubes.

Analysis of the problems

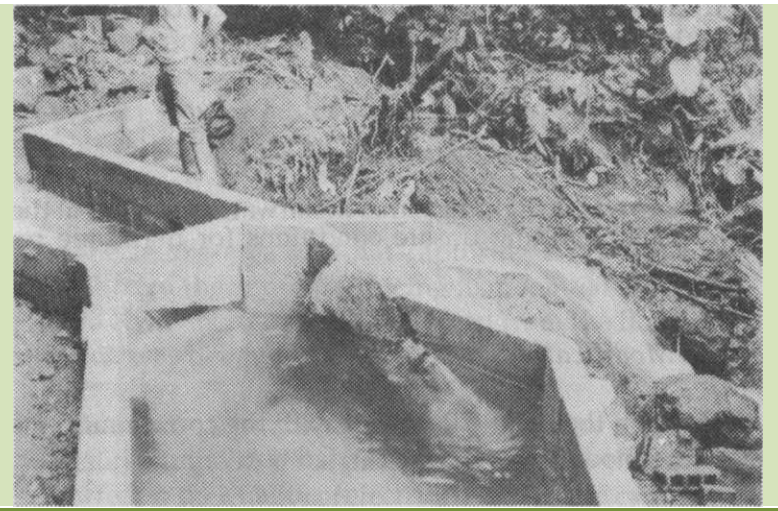
Several principal problems were identified by BUN staff and consultants in the design and function of the existing installation.

- The intake area was not capturing all of the water available from the source, reducing its potential efficiency. Of the 35 Kw which could be generated from the flow, only about 19% was being used.
- The intake area was frequently blocked by leaves and other debris, impeding the passage of water to the turbine which affected the quality of electrical output, and caused the system to shut down. One of the community members had to go down to the intake site at least once a day to keep the grating clear.
- The leaves, sand and other materials that passed the intake grating were abrasive within the turbine, causing deterioration.
- The valve regulating the entrance of water from the tube to the turbine was poorly adjusted, greatly effecting the efficient use of the water's energy.
- The power lines leaving the power house were low to the ground and not securely fastened, and the transformer was directly next to the generator, creating an immediate danger to people visiting the site, as well as wildlife. The transformer converts 240 volts into 2,400 volts, which flows out through the exposed wires.
- The posts supporting the power lines were old and deteriorating. If one had fallen, it could have caused death by electrocution and/or made the generator and transformers inoperable.
- The transmission system lacked ground wires, to protect from lightning damage and ensure the correct functioning of the insulation components.
- Wire tension had slackened off.
- The houses lacked circuit breakers.
- There was no lighting either at the water source or at the powerhouse, creating unsafe conditions for nighttime repairs.

System Modifications

Through the BUN-CA project with the community, the following modifications were carried out:

1. The height of the intake tanks was increased by 30 centimeters (12 inches) to increase the volume of water which is directed to the turbine. This effectively increases efficiency of water use by 10%.



Redesigned "settling tank", background, "forbay", foreground, and overflow spillway.

2. Two chambers for cleaning the water at the source were constructed from cement blocks and metal bars.

The first chamber facilitates gravel and debris clearance. First, a board (called a weir) across the opening through which the stream enters the tank breaks the force of the entering flow. As water collects in the "settling tank", it allows gravel and sand to settle to the bottom, later to be cleaned through a resealable aperture. A slightly inclined grill is also placed in front of the main exit point, to strain out leaves, twigs and other materials brought in by the stream. The force of the water as it moves through the tank pushes the materials up the incline of the grill, where they are expelled through a small overflow spillway.

The second tank, the "forbay", serves a similar purpose. Sedimentation of abrasive sand is again expelled through a valve at its base. Another grate clears the water of debris one last time before it begins its journey to the turbine through the "penstock".

3. To further reduce the problem of blockage from forest matter, the forbay was covered with a steel mesh grill, in a steep inverted V shape, which allows rainwater to enter, while preventing leaves from blowing into the open tank.
4. The base over which the pelton was mounted was strengthened to reduce movement and wear on the shaft.
5. Taller and stronger posts were placed along the transmission route.
6. Inadequate hardware, such as insulators, was replaced.
7. Two transformers were replaced.
8. Ground lines were added to stabilize transmission posts.
9. Circuit breakers were installed at main power transmission points.
10. The power lines were transferred to the new poles and tensed accordingly.

Mesh grill keeps leaves from clogging "forbay"

Juan José Rojas, left, shows the new, taller and stronger transmission poles, alongside the old ones, to BUN Director José María Blanco and consultant Gustavo Jiménez.

With the improvements made in the intake facility and power line infrastructure, the BUN estimates that the system is now reaching close to 50% efficiency, which is sufficient to supply the community's power needs.

FUTURE PLANS

The BUN-CA / San Miguel de La Tigra project terminated with the installation of the power lines on the new posts. Both parties, however, hope to continue developing other projects together. One possibility is to replace the current turbine with a larger, more efficient model. Another is to build additional generating facilities directly below the first one, in order to sell the excess production to the national power company as a money making enterprise (which would require interconnection to the national grid). For now, how-ever, the community will concentrate on maintaining the newly completed improvements.

SOCIAL AND ECONOMIC RESULTS OF THE BUN-CA / SAN MIGUEL PROJECT

Efficiency in Maintenance

With the completion of the project, the time invested by the participants in routine maintenance has been significantly reduced. Previously, family members had to climb down to the water intake site at least twice a day to clean away debris. Now, each family rotates responsibility for this maintenance task weekly, visiting the facility at most twice during that period. This frees people up for other productive activities, contributing to the sustainability of the project.

The group has also increased emphasis on following a plan of ongoing equipment maintenance, rather than wait for problems to occur. The cost in replacement and overhaul of worn parts is more than offset by avoiding major repairs. Each family benefiting from the electrical power pays about US $2 a month into a maintenance fund. The design and hardware improvements, especially in the transmission system, have greatly increased the safety of the people maintaining the system, as well.

Economic Opportunities

The expense and the work involved in construction and maintenance of the hydro-electric power system demonstrates the high value placed on electricity by community residents.
The electrical power system has made a difference in San Miguel not only in terms of the convenience of light bulbs and household appliances, but by making possible a variety of economic activities. The most notable example of new enterprises is the sewing workshop that Damaris Vásquez and Juan José Rojas have installed in their home.

Shortly after the installation of the original generator, Rojas became gravely ill with peritonitis, and had to be hospitalized. Damaris, now 38 years old, desperately needed a way to support her five children through this crisis. Thanks to the availability of electricity she was able to fulfill a long held desire to

use her sewing skills to generate income. She bought a used sewing machine from Juan Jose's sister, and began producing children's undershirts. Since his illness, Rojas, 44, is no longer able to manage the hard physical labor involved in farming, so the two work together assembling children's underwear which is then sold to distributors. As a result of stable electrical power, the couple is able to use electric sewing machines and work during the evening and nighttime hours. They have developed such a successful business that they were able to pay off debts, remodel the house, and help their children pay for high school and college expenses.
Another neighbor has installed a refrigeration system which enables him to store and market dairy products as an important income source.

While Damaris admits that other residents have been slow to take advantage of the economic options offered by electricity, where before the community lacked the means to reach its development potential, now the possibilities are there for when people choose to take them. For example, with electric power more comfortable conditions could be offered to eco-tourists, which could still become an important source of income.

Population Stability

So far, the fortification of the electrical system has not contributed to attracting new residents to the area. Nor has it been able to completely stem the loss of population. In 1991, when the power was shut down to permit major repairs to the generator and the turbine, people were discouraged by the fragility of the system, and three families moved away. By early 1994, two more families had gone, leaving seven households (50 people) in the community.

Those seven families, however, stay in San Miguel as a result of the project carried out with BUN-CA to improve the electrical power system. Gerardo Vásquez, for instance, states that if the power had failed definitively, he and his family of eleven would certainly have moved to the city. Damaris Vásquez affirms that this is true for all the residents. "BUN's support was incredible valuable. With their help, the problems were resolved just at the right moment. If they hadn't come, and the electrical system had failed, there wouldn't be one person left in this town." Even she and her husband were at the point of giving up, and moving out like the others.

The people that remain in San Miguel, however, are committed to staying and developing the community despite the setbacks. Gerardo Vásquez says, "I haven't given up!" He points out that since many of the people who left the area have not sold their land, they could return at any time. Or, they could sell to someone who wants to move in and work the farms.

Community Motivation

Before BUN-CA began collaborating with San Miguel's hydro-electric project, one of the factors which kept the residents from pursuing social improvement projects was a belief that in reality, maybe the community wasn't worth the trouble. After all, no public or private institutions had ever really shown interest in their situation, or given any concrete assistance. But when the BUN was

willing to spend time and money to support their project, they began to feel that maybe the town was worth the effort. This motivated them to undertake projects on their own to improve the road, the school, the communal facilities, and begin planning for a town-wide potable water system. They saw that it was possible to ask for and attain assistance from outside organizations, and that it was worthwhile investing in their community.

External Contacts

Another benefit of the BUN-CA project in La Tigra is an increased recognition by other regional organizations of the value of the community's efforts in renewable energy. Through the contacts made by BUN, organizations such as the National Light and Power Company (CNFL), the Cartago Electrical Services Administrative Board (JASEC) and others have become aware of the project, and willing to support it with materials and services. COOPELESCA was willing to share the cost of transferring the power lines to new poles, and is even interested in eventually purchasing electricity from the project, a notable change in attitude over a few short months. San Miguel has gone from an isolated, struggling community to one which can access international (BUN), national and regional sources of support for their self-directed development.