Photovoltaic Powered Water System for an Indigenous Community in the Ecuadorian Amazon Rainforest

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ABSTRACT: This paper presents the commissioning and start-up phases of a project to allow the indigenous community of Santa Rosa, Ecuador gain access to fresh water, with pumped storage provided by a photovoltaic (PV) system. The project used the initial design prepared by a non-profit organization as the basis for construction as well as materials from an industry funded grant. The work involved two faculty and four students from the California Polytechnic State University, San Luis Obispo (Cal Poly) National Electrical Contractors Association (NECA) and Mechanical Contractors Association of America (MCAA) Student Chapters to complete the installation of a clean water system. This included PV panels, electrical distribution and overcurrent protection, piping connections to a direct current submersible pump, water storage tanks, and distribution piping/connections to each village household. Although the initial design was a vital part of the project, much of the details were resolved in the field with a design-build approach.

Keywords *Photovoltaic, Water Distribution, Santa Rosa, Reach Beyond, Cal Poly*

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1. INTRODUCTION

This paper presents student perspectives during the commissioning and start-up phases of a project to help an indigenous community in Ecuador gain access to fresh water by means of photovoltaic power. Duffy (2008) describes similar student service learning projects in Guatemala where students designed and installed two different solar-powered water supply and drinking water purification systems; one using a spring and gravity to provide water and another which pumps water from a river to an elevated tank. Our project used an initial design for a spring-fed, solar-powered, elevated tank pumped water system prepared by Reach Beyond, a non-profit organization, as the basis for construction. Reach Beyond involved students and faculty from California Polytechnic State University, San Luis Obispo (Cal Poly) to assist with a clean water distribution system. ELECTRI International's Student Passport Initiative grant provided incentive and partial funding for the project to provide a clean water distribution system for the village of Santa Rosa, Ecuador, in the Amazon rainforest.

2. BACKGROUND

Santa Rosa is located on the banks of the Rio Pastaza in Ecuador. The community is not served by electric power and lacks the ability to pump water. Although fresh water is available from an underground spring that feeds the river, the community must bucket water over long distances. The community has seventeen homes along with a community house, soccer field, volleyball court, and audience stands. A portion of the community is shown in Figure 1, presenting an overview from our plane approach. The large dirt area is the village soccer field and behind that resides the community households.

Figure 1. View of Santa Rosa Village

The community elects its own President who is in charge of leading the village as well as being the representative to the Ecuadorian government. Once the need for a service project is identified, the community develops this into a request, then community members travel from their village to the city to reach a potential funding organization such

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as Reach Beyond. Reach Beyond then works with the community and government to design and install the project. In many cases they also work with other religious or educational institutions to complete the project.

Reach Beyond involved students and faculty from Cal Poly's National Electrical Contractors Association (NECA) and Mechanical Contractors Association of America (MCAA) Student Chapters for a clean water distribution system. This included a photovoltaic panel array, electrical distribution and overcurrent protection, piping connections for a direct current submersible pump, water storage tanks, and distribution piping/connections to each village household. Reviews of the research, demonstrations, and case studies since 2001 indicate that solar energy can be a viable solution for the provision of power throughout the world, especially to electrify rural off-grid locations as an eco-friendly and cost-effective solution (Akikur 2013).

3. KEY PROJECT FACTORS

3.1 Project Coordination

With so many entities involved in an international project, we scheduled weekly meetings that included students, faculty, and Reach Beyond to discuss the best dates to execute the project. Once potential dates for the trip were identified, day-by-day milestones were developed. We kept a running action-items log to coordinate international paperwork, changes in design and equipment, and a preliminary work plan.

3.2 Budget

We were awarded a $20,000 (USD) grant and funds were secured, enabling us to develop a project budget. Budget items included system materials, participant travel, and contingencies for unforeseen events. Each of these subcategories was further developed in line-by-line specifics.

3.3 Schedule

A proposal was submitted in May 2015, we were selected as finalists in June 2015, and invited to present to the ELECTRI Council meeting in July 2015. Award was made at the end of July 2015. Creating a schedule for the project involved the consideration of various long-lead items. Completing the shipping paperwork started immediately since shipping time was estimated to take up to three months.

4. EXECUTION

4.1 Pre-Departure

The trip was planned to occur during Cal Poly's winter break, from December 11 to December 21, 2015. We planned to fly into the jungle on December 14, 2015 and work continuously until the project was completed and water was available to every community member. Prior to our departure, we worked to ensure we would have all materials and equipment needed to complete the project while we were on-site.

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4.2 Installation

The first day involved immediate integration into the community. We met some of the villagers along with the village President. After a quick lunch we installed the pump in the concrete cistern (Fig. 2). The pump was raised above the bottom of the tank on a bed of rocks to keep it from pumping sediment that could collect at the bottom of the tank. It is enclosed within a 6-inch piece of PVC pipe to provide protection while operating.

Figure 2. Installation of the submersible pump

While one group of students was installing the water distribution system, another group installed the PV system (Fig. 3) to provide power to the cistern pump. After the PV panels were secured, we installed a circuit breaker and ground rod. Prior to connecting the wiring, palm leaves were placed on the panels to prevent power from being generated.

Figure 3. PV panel installation

By the end of the day, we connected the pump and piping, as well as the wiring for the solar panels. The next morning began at sunrise with a test of the pump to verify the PV

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and piping connections functioned correctly to supply water to the tower storage tanks. Once we determined everything was successfully installed, after lunch we began installing the piping connections between the water storage tanks as seen in Figure 4. The two water storage tanks were connected using ball valves that would allow the villagers to shut-off the flow from one or both of the tanks. We installed two extra lines for future use and there was physical space to add two more tanks if needed.

Figure 4. Interconnection of the water storage tanks

By the end of the day the pump was delivering water into both storage tanks, with a valve preventing it from loading the community piping. The next day, we stared work early to test the water pressure by filling the pipes with the water stored overnight. After the piping was full, we began installing the final connection points at each household. This involved a hose bib, shower, and meter connection so that each villager has easy access to the water. The meter allows the President of the village to control water usage if people don't pay the monthly fee for using it. This connection can be seen in Figure 5, when we were completely finished and had water running through the system. The water points have been completely installed and we were able to get a strong flow of water through the hose bib and shower connections.

Figure 5.   Water delivered to household

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4.3 Post construction analysis

Following installation, Cal Poly will have the ability to monitor the energy generation and water distribution over time. The Santa Rosa site will be equipped with a satellite monitoring system to capture and transmit data. An example of the water distribution and system monitoring showing the flow of water and amount of available sunlight for a similar PV power system is shown in Figure 6. Comparing data from multiple locations will allow for a comprehensive study of photovoltaic/water distribution systems across ranges of geography, humidity, elevation, and ecological conditions.

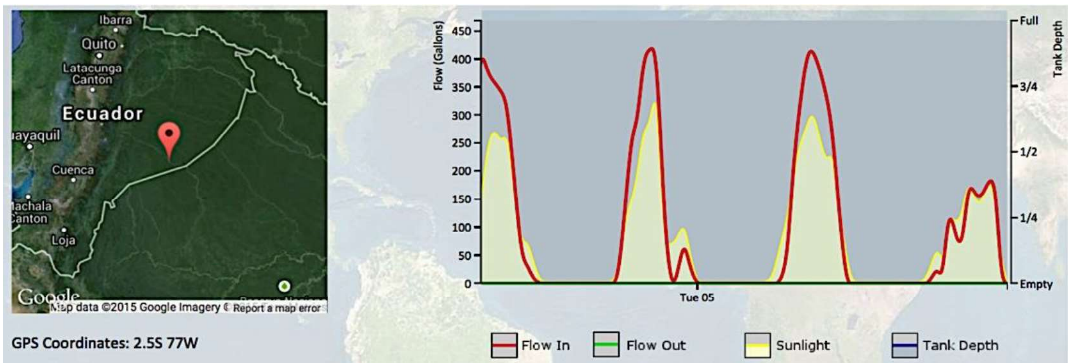

Figure 6: Water distribution and system monitoring for a similar system installation

5. NEW KNOWLEDGE

New knowledge that developed as a result of the project initially focused on the differences between USA and Ecuador codes and industry standards. The local codes were much more lenient; the original design that was per domestic codes could be executed by easier means and less expensive methods. As a result, more time could have been allocated to coordinating international material deliveries rather than on design specifics.

New knowledge was also gained in the area of fund allocation. Project-based student projects typically are often difficult to pursue because they must be non-profit, without out-of-pocket payment. However, there are various grant-funded programs that are structured toward towards these types of goal-specific projects. For students looking to pursue future projects, these service learning projects could be designed and executed to meet the specific requirements of a particular grant. In this particular case, a goal-specific grant made project planning narrow and well defined.

Service learning is a form of experiential education in which students work with others, applying what they have learned to solve community problems (Eyler 2002). The project presented a unique perspective to students in several ways. Much of the materials and equipment had to be outsourced from other countries since Ecuador didn't have access to as wide variety of materials as available in the USA. This brought new and unique challenges that students had to confront. The plumbing system was different due to the simplicity of a gravity-fed system. Other new knowledge included discovering the optimal design to get a pump to send water up a hillside and into storage tanks mounted on an elevated tower. This type of gravity-fed system had to be mounted high enough to develop sufficient head pressure to feed the water distribution system. If it were not high enough

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above the water points, it would not supply enough pressure to produce adequate flow throughout the system.

6. MATERIAL AND EQUIPMENT

The electrical power and water distribution systems materials and equipment principally included the PV panels, conduit and wiring, pump system, water storage tank piping, distribution piping, and hose bib/shower connections. Both systems progressed very smoothly with few setbacks; all issues that developed were able to be resolved in the field. A list of principal materials and equipment is shown in Table 1; the total cost was approximately $21,000 USD. Some of these costs were associated with grant funds; the remainder were collected from donors and local government authorities.

Table 1. Final costs for material and equipment

Equipment/Material	Quantity	Cost (USD)	Shipping (USD)	Total (USD)
PV Panels	2 each	$ 500	$ 500	$ 2,000
Electrical Cable	300 feet	500	$ 0	$ 500
Pump	1 each.	$ 3,300	$ 0	$ 3,300
Storage Tanks	2 each	$ 400	$ 200	$ 1,200
Piping	1 lot	$ 12,000	$ 0	$ 12,000
House Connections	17 each	$ 100	$ 0	$ 1,700
			Total:	$ 20,700

7. LESSONS LEARNED

A key lesson that resulted from the project is that the planning of an actual project is perhaps the most knowledge-promoting experience that a student can go through while in school. In order to make these opportunities achievable, it is important to remember and research what grant funding is available to deserving projects.

Many of the lessons learned came from the practical nature of the fieldwork. For example, the project team came across issues in the field from mistakes or miscalculations. By working with the materials that we had available and developing solutions we were able to overcome every obstacle. Much of the lessons learned included incorrectly measuring piping. Fortunately, the piping was very forgiving and easy to work with (as our team had little prior experience with its installation).

One last lesson learned- international paperwork processes are very lengthy and often create holds on a project that cannot be avoided.

8. APPLICATION OF NEW KNOWLEDGE

The students strongly encourage and promote organizations to offer funding to projects that meet specific criteria. By providing these opportunities, students are given the chance to spearhead projects and assume the role of a project manager while still in school. This allows them to acquire real-world experiences and knowledge before entering the

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workforce. Projects that entail attention and dedication open a door to new knowledge that cannot be taught in a classroom. This type of project-based approach enables students to practice self-directed learning, to find solutions to design problems that are sustainable, and to recognize that they are part of a global community (Savage et al. 2007).

The new knowledge that developed could be applied to many future installations. This system design could be utilized for any project involving a need for clean water collection from an underground spring. Studies have concluded that service work encourages students to become more socially responsible, committed to serving their communities, empowered, and committed to their education (Borg 2008).

9. CONCLUSION

This project was an overall success and the amount of work our team was able to accomplish in such a short time was outstanding. The project itself was the experience of a lifetime with much hands-on work. It also was impactful to provide a clean water source to a village that had limited accessibility. Our team was very fortunate to work with an organization and partake in a project at the completion phase. Altogether, this project could not have been accomplished without the dedication from all parties involved.

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