Comparing Renewable Energy Sources in Rural Ecuador

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The aim of my research was to compare the abilities of a biodigester, solar panel, and water heating system through the lens of a rural community in Ecuador. Each renewable energy system was analyzed from an economic, environmental, and health perspective. My research was conducted at La Hesperia Biological Reserve, located in the Pichincha province of Ecuador. The reserve functioned as both a conservation site as well as a farm. Situated in a secondary and cloud forest, the reserve worked around and often through the rain. My research took place during the rainy season (December-April), where it typically began to rain all throughout the afternoon and evening. The sun was generally out however during the morning hours of about 8 am to 12 pm. The variability in the weather was a large factor to consider when analyzing each of the energy systems.

The first stage of my research was spent getting an understanding for each of the systems and their uses. I was able to learn more about each system in this stage that could have only been possible through user observation. The next stage involved recording the data for each of the systems. This process was a bit more difficult than anticipated because of the limited access of Internet and tools. After obtaining enough data to produce sufficient results, I looked at ways to optimize each of the systems. Lastly, I reevaluated each system to see if any of the adjustments produced lasting improvements. The life cycle calculations were based on a 25-year cycle, the average lifetime of a solar panel. A 5% interest rate was used, based on market values at this present time. The remainder of the report is organized based on the energy system, starting with the solar panel.

The solar panel was used to provide electricity for a small preschool that was affiliated with La Hesperia. The electricity was used only for lighting, leaving the panel underutilized. The school was used only 100 days out of the year, so the panel was not even used the majority of the time. The power output of the solar panel was determined to be approximately 200 watts. This number is based on the premise that the panel was able to power between 6-7 30-watt light bulbs. The cost of the panel (360 USD) is also similar to the cost of 200-watt monocrystal panels in the United States. Based on these values, the solar panel had a payback period of 23 years and annual savings of $14.60 USD. The net present worth (present worth benefits = present worth benefits – present worth costs) of the panel was $2043.41 USD after a 25-year period. These values assumed maximum usage of the panel, 365 days a year for 5 hours a day; the results would have not been competitive if the calculations were based on its current utilization. The benefits were calculated based on the kilo watts produced a day times the cost of electricity from the national grid ($.04 / kwh). As the Ecuadorian government plans to limit energy subsidies, this price is likely to increase in coming years.

User observation indicated that the panel would benefit from the morning sun during the rainy season. This meant situating the panel on the opposite side of the roof, where it could face more to the east. The relocation of the panel did not necessarily produce definitive results although the light bulbs seemed to be better lit. While the system did not necessarily have the best payback period, it provided a reliable source of electricity. Electricity is still available even during blackouts, which are common occurrences in this region of Ecuador.

The plastic bottle water heating system was a unique design that could provide hot water for showers. This system was not built when I arrived, so part of my project involved designing and constructing the system. Durability, sufficient water pressure, and cost were all factors considered in construction. The bottles were painted with black paint and the frame below the plastic bottle system was layered with tetra packs to maximize solar absorption. A 250 L tank was used to store the hot water, the largest size available without compromising circulation. The initial cost of the system was $100 USD with an estimated annual maintenance of $20 USD. With a water temperature increase from 10°C to 20°C, 2.9 kW of power is produced. Assuming this process occurs once a day, $42.44 USD of electricity is saved annually by not using electric shower heaters. Incorporating these calculations as well as replacements, a present worth net balance of $216.29 USD is made over a 25-year span with a payback period of 3.45 years.

This system proved to be a unique way of both recycling plastic bottles as well as producing hot water from cheap materials. Improvements could be made by adding another hot water tank and more piping to produce more hot water. The system during the dry season is likely to produce hotter water, as there will be more sun out. When this is the case the panel should be adjust to lie flat on the group, where it will be perpendicular to the sun when it is the strongest (noon).

The last system analyzed in this report was the biodigester. The system involved the highest degree of daily maintenance as well as the largest initial cost. With 25 diary cows however, this system had the highest availability of naturally reoccurring energy (manure). Manure was collected each day after the cows were milked. Only a portion of the cow's daily manure output could be calculated because it was not feasible to retrieve manure each day from the grazing field. The collected manure was eventually mixed with 4 parts water to produce an appropriate mixture for the digestion phase of the biodigester. The capital cost of the system was $4320 USD with annual maintenance of $50 USD and complete system replacement 15 years into the 25-year life cycle assessment. Data was accumulated by weighing one portion of excretion and multiplying by the number of cows. The m^3 of biogas produced daily was then calculated through several conversions. Computation indicates that 5.05 m^3 or 5054 liters of biogas is produced daily.

Based on these results, $163 USD could be saved a year. The biodigester also produces a highly effective fertilizer. Based on other studies, a biodigester of similar size could provide $260 USD worth of fertilizer. The value of energy benefits was calculated according the price of Congas methane tanks, which cost $2 USD for 15 kg of gas. With these calculations the payback period is 5.75 years with present worth net benefit of $3352. The cost of gas tanks however, is heavily subsidized so this same set of calculations was done to the real cost of the gas tanks. The Ecuadorian government has plans to stop subsidizing gas tanks, so this value is perhaps more relevant. The new results indicate a payback period of 2.7 years with present worth net benefits of $9784.9 USD. The results also took environmental impact into consideration. By analyzing the greenhouse gases displaced by using a renewable energy source as well as the methane released from cow manure, an average of $35 USD can be saved. This improves the payback period to 2.6 years.

Many other factors must be considered when analyzing the biodigester. Based on the limited access of gas tanks, rural communities occasionally struggle to have consistent supplies of gas. A biodigester allows rural farming regions to have consistent supplies of cooking gas in addition to effective waste removal. While it was harder to calculate any health factors associated with the biodigester, it can be assumed that the quality of the surrounding water is improved by preventing contamination. Negative factors to consider are the reliability and practicality of the biodigester system. Although the system may be easy to initially construct, there are certainly going to be technical difficulties along the way that many farmers may not know how to address. Overall however, the biodigester is the most lucrative renewable energy system at La Hesperia reserve.

Many of the challenges of the research project were finding ways to relate each of the energy systems and make the results relevant from a broader perspective. In doing so, I have presented only the basic relatable results, but have created an excel sheet that considers other factors involved in a cost-benefit analysis. For example, one might compare the results based on individual consumption factors or other values of energy. From user observation and the end results, I would consider the plastic bottle water heater the safest investment, and best bet if there are limited initial funds. I would consider the biodigester the best investment, but the highest risk. During my 9 weeks spent at the La Hesperia reserve, the biodigester had to be fixed several times. Problems occurred from debris entering the digestion tank, to inadequate gas pressure to supply the stove. Weather was another obstacle that existed throughout my project. The constant rain made considering durability a rather important factor. The weather also demonstrated the need for having reliable supplies of energy; because of rainstorms, landslides were a monthly occurrence on the highways, preventing the transport of gas. Rainstorms often disrupted power lines, shutting down electricity for days at a time.

Conducting this research project allowed me to gain valuable in-field experience and learn the realities of conducting individual research. I was able to see first-hand how important a renewable energy system could be. In a country like Ecuador, commodities such as hot water would not exist if it were not for low-cost energy systems. After presenting at the research symposium, I am also going to contact several organizations, such as Engineers without Borders and Peace Corps to discuss how my results relate to their line of work. I am confident that I will continue to work with renewable energy projects in developing countries in future years.