Developing a Net-Zero Biological Field Station in Costa Rica

Dow Distinguished Award Project 2019

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Executive Summary

This project seeks to establish a net-zero carbon research and education center in Costa Rica so both University of Michigan (UM) and local Costa Rican students, faculty, and staff can engage in international and interdisciplinary work in environmentalism. This team's objective was to create a plan for carbon-neutral energy. The team constructed a detailed energy forecast that included present and desired electricity demand, gathered data on local renewable energy resources including solar, biomass residues and hydrokinetic resources, and created a model to determine how energy could be most-efficiently harnessed from bordering agricultural operation residue. Furthermore, the team compiled data for necessary sustainable water management. The result is a blueprint for a microgrid system that will allow the station to become carbon neutral, and to serve as a demonstration for faculty and students.

The Taboga Forest Reserve protects tropical dry forest in the Guanacaste Province of Costa Rica. It is home to a variety of wildlife including threatened Jabiru, Crested Guan, and Laughing Falcon species. University of Michigan faculty from the Psychology and Ecology and Evolutionary Biology Departments have been collaborating with researchers at La Universidad Técnica Nacional (UTN) in studying cognition and behavior of White-Faced Capuchins, initiating the need for the station. We share an inspiration in revamping the facilities of this 297-hectare reserve to create an international, interdisciplinary biological field station, fostering further international collaboration. In the heart of a unique ecosystem surrounded by commercial plantations, the Taboga Forest Reserve will be able to serve as a novel opportunity for advancing sustainable energy, agriculture, ecology, and fishery research and studies.

The facilities at the Taboga Reserve had been gifted to UTN in recent years, but most buildings are in disrepair after not being used the past decade due to funding deficiencies. UTN leadership is excited about the recent collaboration with the University of Michigan, and is eager to arrange for Costa Ricans to study sustainability through the onsite fishery, sugarcane and rice fields, and dense dry forest. A house that used to serve as faculty housing is being renovated, which will provide lab space and living quarters as we realize the field station and school vision.

While the team was in the field, a technical energy study was performed to gather information required to model required energy generation and demand. An optimized energy model was created for the living quarters and research lab using HOMER energy modeling software. Results show the most feasible model for the current electrical demand and the budget required solely solar power, interconnected to the Costa Rican electric grid. Interconnection and net-metering requires utility permitting, and the necessary communications for this effort are underway. Meanwhile, the renovation is continuing under the assumption that the microgrid will be tethered to the national electric grid.

As a proof of concept, 1.5 kW of solar capacity were installed on the current laboratory's roof at the field station. Research activities will be moved to the newly renovated building upon its completion. Frequent power outages have jeopardized the state of frozen samples used in monkey hormone research for the Capuchin project, so a microgrid of ten solar panels and eight batteries was installed to provide energy security. This demonstration project has led to a better understanding of solar material suppliers in Costa Rica, as well as the local energy resource. Preliminary studies into hydrokinetic and biomass potential were also performed.

Progress

The first milestone in this project was to design a microgrid using HOMER energy modeling software. To do this, the team gathered data on the current energy demand in both the living quarters and the lab. A survey of all in-use electrical devices was done, including the extent of daily use. This was used to create a bottom-up model of electricity demand, including quantity of devices, the power draw, and estimated time in-use throughout the day. This data was extrapolated into weekly, monthly, and yearly estimates of electricity demand, which will be used to inform the sizing of the microgrid system. We also took a preliminary survey of the electrical appliances that would be used in the lab and housing for the final field school.

Our model assumes there would be four field workers at the biostation, and that it would be a weekday in the dry season. These considerations take into account the variability in fan use between seasons and workdays to weekends, as fans are used considerably more often in the dry season—therefore, the microgrid model is conservatively sized to for the greatest demand. The bottom-up demand model was completed May 16th, within the established timeline in our Seed Grant proposal. This data will be projected to meet the energy demands of the eventual field school. This would cover additional dormitory buildings to consider when the facility is at full capacity. It has been calculated in this phase of the project that the field station will require 15,600 kWh of electricity annually, with the capability of providing 13.2 kW at peak.

The team measured the flow rate of the river that cuts through the reserve to determine if it was a viable resource for a hydrokinetic turbine. A volumetric flow rate was calculated by multiplying the cross-sectional area by the velocity of the water. The potential energy resource was determined to be insignificant to serve as a viable source of power for the biostation. Uncertainty in the seasonal variation of the flow rate in addition to the sheer distance from the most viable site on the river to the biostation's activities would have made a hydrokinetic turbine prohibitively expensive. Nearby wells that draw from the local aquifers were assessed and found to have not been maintained properly. Historical rainfall data was reviewed in addition to creating an ongoing log for on-site rainfall, which will assist in the biostation securing a sustainable supply of fresh water. This information provides a base for the future project team that will create models for water demand and determine how best to supply that water.

The team investigated the use of biomass gasification as a sustainable energy resource. A Biomass Harvesting and Gasification (BHAG) model was constructed over the summer to gain energy insights from local field sizes, crop yields, residue-to-product ratios, harvesting procedures, and the machinery used in nearby rice and sugarcane fields. The BHAG model will complement the expanding microgrid system upon future trips to Taboga. An estimate for further equipment costs in constructing the gasifier is included in our proposed budget.

We were able to construct a working model of our planned solar array on the roof of the existing lab. Pictures of the installation process and the completed array are included in the Appendix. We used ten 150W solar panels in series to provide energy security for the lab freezer. The wiring schematic for the off-grid freezer is included in Figure 1 of the Appendix, in addition to gauge measurements that will be particularly useful when the system is moved to the renovated building. A manual for system maintenance and data collection was left at Taboga to clarify what the controller and the combination box should be doing if the system is in working order, including a log to record the percent charge, voltage and amp-hours of the system. Preliminary demand curves from our bottom-up model are also included in the Appendix.

<u>Future Work Timeline</u>

September 2019 - December 2019: Analyze data, complete demand and optimization curves for full-capacity field school, finalize financial cost of implementing solar and biomass at scale

January 2020: Recruit new team members from SEAS, College of Engineering, and those interested in joining Sustainability Without Borders who will travel to Taboga

January - April 2020: Transition between teams, create field work plan for Phase 2

May 2020: On-site field work in the reserve: oversee installation of solar panels, construct biomass gasifier, begin renovations on a second house

June - December 2020: Create models determining water demand, determine optimal methods for sustainably securing water

January 2021: Recruit new team members who will carry on with Phase 3 of the project

January - April 2021: Transition between teams, create field work plan for Phase 3

May 2021: On-site field work in the reserve: oversee installation of sustainable water methods (i.e. water catchment from building roofs, etc.), gather data on sustainable waste options, begin renovations on third and final house, as well as the large dorm building

June - December 2021: Determine methods for achieving net-zero waste for the biological station

January 2022: Recruit team members to finalize the realization of a net-zero field station and school

January - April 2022: Transition between teams, create field work plan for finalizing the project

May 2022: On-site field work in the reserve: finalize any remaining work to create a sustainable biological station whether it be through the energy, water, or waste aspects. Begin renovations on the big dorm building if not already underway/finished.

June - December 2022: Reporting of sustainability metrics for Taboga Operations, development of monitoring activities to ensure sustainability

January - April 2023: Reassess the state of operations at the station and determine what additional sustainable demonstrations are feasible

<u>Milestones/Project Success</u>

Most of the team members on this project are pursuing graduate degrees through the School for the Environment and Sustainability. Many students opt to pursue a 1.5-year Master's Project, and there has been strong interest among students in continuing this project. Due to the limited amount of time each group of students has with the project, there will be multiple groups of students working through each phase of this venture. The project will continue to be supervised by advisors Dr. Jose Alfaro, Dr. Thore Bergman, and Dr. Jacinta Beehner, allowing for smooth transitions between project teams. This project is open to all students at the University of Michigan. These students often learn of this project through the Sustainability Without Borders student group or the Master's Project Process.

The phases of this project are intuitively setup to be the completion of certain sustainable facets of the biological station. The first phase will be completed April 2020, when the current project team has finalized demand curves and optimized for the most cost-effective microgrid to supply sustainable energy for the completed research station. The second phase will involve finishing a model for a sustainable water supply. The third phase will focus on the aspect of producing net zero waste. The final phase will be the culmination of the previous three into establishing the fully functioning net-zero biological station and field school accurately reporting a plethora of sustainability metrics. The success of each portion of this project will be measured through various reports to involved bodies (Sustainability Without Borders, Dow Seed Grants, School for Environment and Sustainability, etc.) as well as through capstone presentations that must be presented in April by each team. Further milestones will be measured by the completed renovations of each building on-site.

As can be seen in the projected future work timeline, this project is currently estimated to be finished in 2023. This timeline is subject to change, but the desired progression of the project is accurately outlined.

<u>Additional Funding Requested</u>

Our team is requesting an additional $50,000 in funding to help renovate and establish the multi-building biological field station and field school, install gasification technology, and investigate carbon sequestration objectives. The money will be utilized towards the items in the estimated budget included in the Appendix.

Skill Gaps

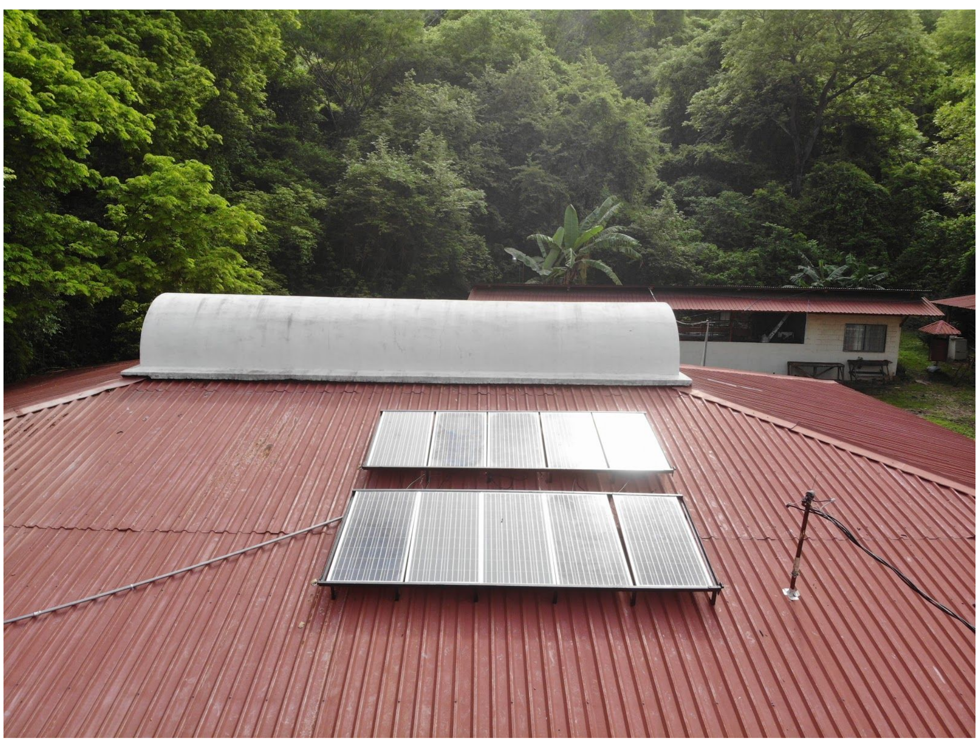
Through this project's unique ability to have a different composition of team members each year, skill gaps can be recognized and easily filled by the next incoming team. As this was the pioneer year for the project, the team learned more about what challenges will be faced for the completion of this project and gained a better understanding of the skills that future teams should have to meet those challenges. Moving forward, the current team will be involved in the selection process of the next team in order to fill the major skill gaps that were experienced over the past year. Following teams will be comprised of students who have some/both of the following two skills: Further Spanish proficiency, and a background in engineering (mechanical and chemical). These positions will be filled by master's students from the growing SEAS student body, with a focus on recruiting from the Sustainable Systems track.

Additional Engagement and Potential Impact

One of the main objectives of this field station will be bringing together scientists and students from both the United States as well as Costa Rica. The field station will provide researchers with a place to investigate topics that involve ecology and sustainability. Likewise, students from international and local schools will be able to learn about sustainable systems, ecology, and biology. As an initial step towards this goal, faculty advisors for the team have initiated a collaboration scheme supported by UTN deans. It involves grantsmanship workshops and site visits from UTN professors and students.

Appendix

Picture 1: solar array being installed



Picture 2: Completed solar array

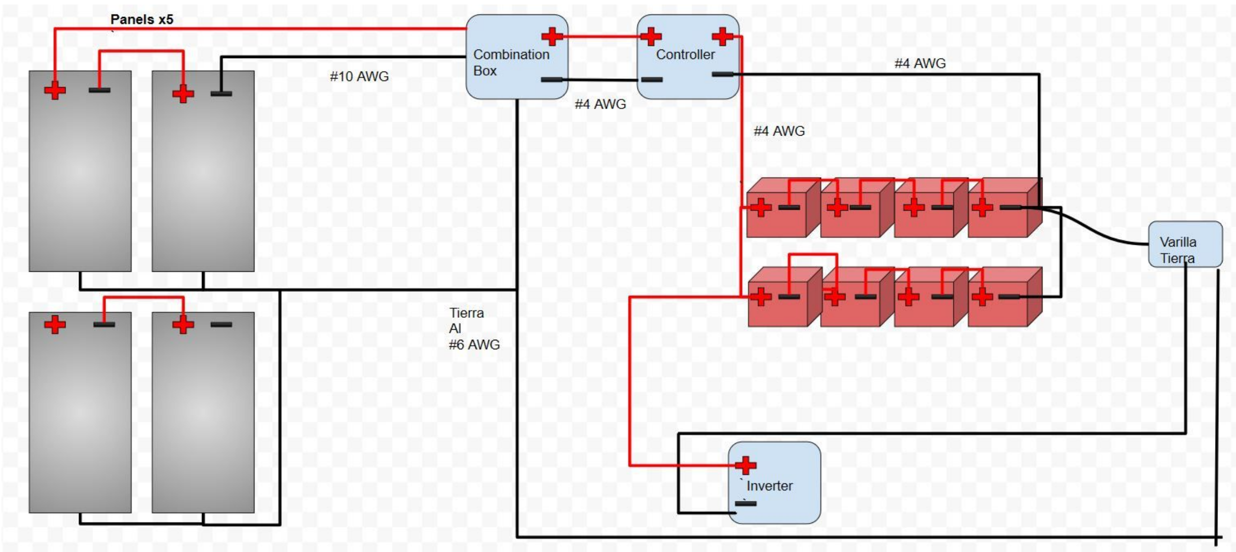


Figure 1. Schematic of Proof-of-Concept Microgrid Supporting Laboratory Freezer.

Figure 2. Photo of Combination Box, Controller, and 8 Lithium Ion Batteries.

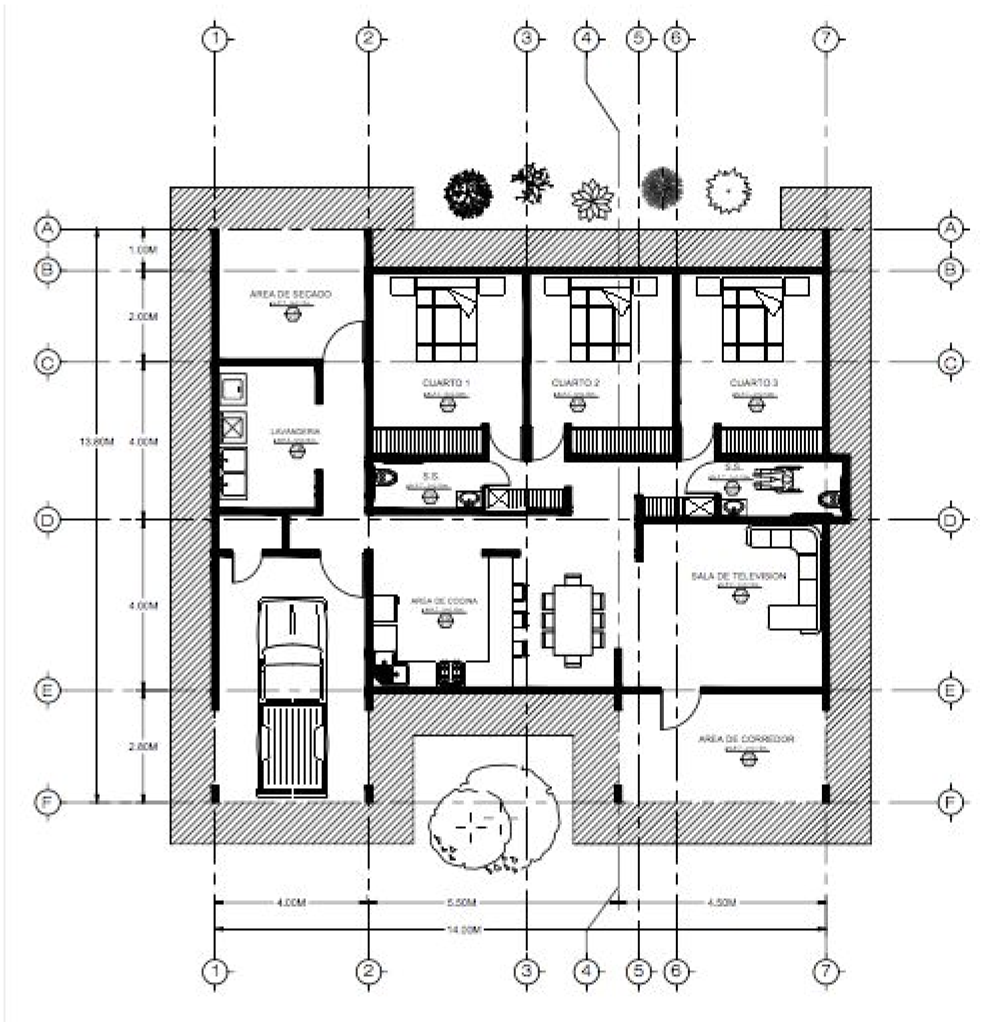
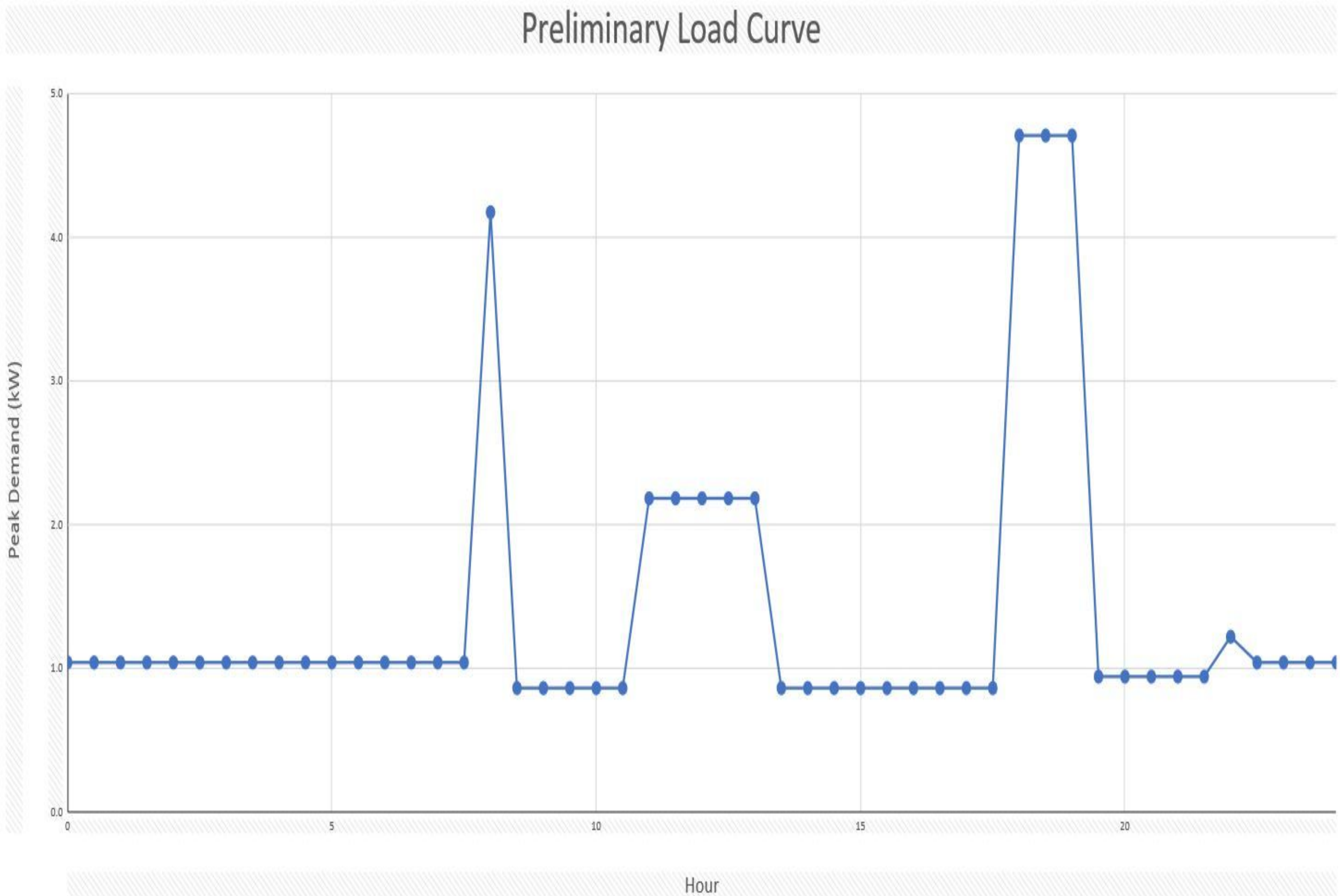


Figure 3. Floor Plan for Faculty Houses.


Preliminary Load Curve
Peak Demand (kW)
0.0
1.0
2.0
3.0
4.0
5.0
0
5
10
15
20
Hour

Estimated Project Budget

Estimated Project Budget (modify sample text below)		
Item	**Description/Examples**	**Cost**
Equipment	150 Additional Solar Panels @ $95 each	$14,250
Equipment	10 Combiner Box @ 140 each	$1,400
Equipment	2 Grid Controller $75 each	$150
Equipment	30 1kWh Lithium Ion Batteries @ $375 each	$11,250
Equipment	Materials and equipment for a ~3kW Biomass Gasificaiton System	$10,000
Meals	Groceries to use in on-site kitchen for two months ($15x4person/day)	$3,600
Travel	8 round-trip flights to Liberia, Costa Rica	$7,350
Travel	Two months of rental car + tolls	$2,000
Lodging	Hosted on-site	$0
	Total Budget	**$50,000**

Estimated 50% Project Budget- Reduces solar and eliminates biomass gasifier

Item	**Description/Examples**	**Cost**
Equipment	100 Additional Solar Panels @ $95 each	$9,500
Equipment	5 Combiner Box @ 140 each	$700
Equipment	1 Grid Controller $75 each	$75
Equipment	25 1kWh Lithium Ion Batteries @ $375 each	$9,375
Equipment	Sense Electric Meter- Solar	$350
Meals	Groceries to use in on-site kitchen for two months (~$10/person/day)	$1,000
Travel	4 round-trip flights to Liberia, Costa Rica	$3,000
Travel	One month of rental car	$1,000
Lodging	Hosted on-site	$0
	Total Budget	**$25,000**