Project Title: Producing Solar Ice in Ghana

Abstract:

There is a current opportunity for Cal Poly students to collaborate with SunDanzer Refrigeration Inc. (the world's largest solar powered refrigeration company) to customize and implement a new solar-powered freezing system to be used in off-grid locations while additionally testing and implementing a small scale, low-cost thermoelectric ice maker created here at Cal Poly. With the support of Baker Koob, Cal Poly students would have the resources and equipment needed to apply the learn by doing approach to this project. In the next 6 months here at Cal Poly, the team will focus on building and optimizing a specialized solar array, customizing a SunDanzer freezer unit for ice production and fish freezing, and finishing a dozen small prototypes thermoelectric ice makers to be tested in the field. Once complete, these systems will be shipped to the rural fishing village of Agbokpa, Ghana, for installation scheduled for early September, 2019. Dr. Heston, one of the teams faculty advisors who lived near to this village from 2010-2014 will be traveling to Ghana in July to begin preparations with other faculty and team members joining him in September.

Fishermen in Agbokpa, Ghana face a problem common in many remote villages around the world. Lack of access to ice results in spoilage causing food insecurity, loss of revenue, and over-fishing. Both SunDanzer's new product line, and the one developed at Cal Poly are designed with the intention of using the free energy from the Sun to solve this problem, with the thermoelectric ice makers targeting a small-scale personal solution and SunDanzer's new unit providing a solution that would be used as community-wide resource. This project will allow us to learn about challenges of implementing technology in poor communities, develop working collaborations in Ghana, learn a about a very different way of life, and fully understand the needs, barriers, and responsibilities necessary for a successful real-world project.

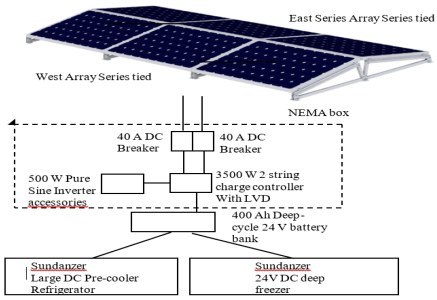
With plans and sponsorship for implementation in September of 2019, funds are still necessary to optimize both systems before installation. Recent contributions of $19,000 have been secured to cover the majority of travel costs, yet funding from Baker Koob would be of major value for our team to expand our relationship with SunDanzer, while also working to refine our own thermoelectric ice maker. The goal is to create a lasting system that not only changes the lives of the community, but opens doors for scaling with potential global impact.

Objectives:

- Determining the best method of preservation by performing a comparative life cycle cost analysis: independent freezer systems versus refrigeration; comparing battery storage versus thermal storage with increased insulation and phase change materials.
- Minimize necessity and usage of batteries.
- Determining actual power loads necessary to cool 150 lbs of fish per day.
- Construction of a customized East-West array (construction management students) where angles and sizes are optimized to minimize battery costs and maximize direct drive.
- Designing, fabricating and testing customized racks and molds for the internal refrigeration compartments to maximize cooling COPs.
- Finish building a dozen prototypes of thermoelectric ice makers that can be field tested.
- Minimizing required daily maintenance from community members.

Methodology:

Ghana lies in Western Africa with a land mass about the size of Oregon and a population of about 28 million, equaling that of Texas, the second most populous US state. Lake Volta lies within Ghana and is the world's largest manmade lake (by surface area) occupying 3,300 square miles. It is one Ghana's largest natural resources, providing vast amounts of food, revenue, and hydroelectric energy to the country, yet the full economic potential of Lake Volta is far from realized. Irrigated farming, transportation, and especially the fishing industry, are poorly developed due to the lack of grid electricity on most of the lakefront. Ghana's electric grid only attaches to Lake Volta on the southern (more economically developed) side leaving thousands of miles of coastline, and copious off-grid fishing and farming villages without electricity. Providing refrigeration to these off-grid communities would have a huge economic impact. Not only would it allow them to increase their output and consequently their return on investment, but it would benefit their economy, consequently increasing health, education, and wellbeing of the community.



Fresh fish can only last a couple hours when unrefrigerated, but when properly stored, they can last up to 10 days, which is more than enough time to get them to market every week. Our goal is to provide the community of Agbokpa with a way to store their fish throughout the day on their way to market, and longer term during days when the market is not going on. Shorter term storage can be accomplished by freezing the 500 mL filtered water sacks which are readily available throughout Ghana and using them as thermal batteries in coolers. These water sacks can be reused and refrozen in the deep cycle freezer. Longer term storage will be in either the deep cycle freezer or a separate refrigeration cabinet again utilizing thermal batteries.

The idea of preserving fish with ice is not a new one and using solar energy to generate the ice is a common goal that is hard to realize. The Cal Poly team learned this first hand in 2016 when they built their first prototype solar ice shed on campus. Typical refrigeration and ice generation systems use AC compressors which are not easily compatible with DC solar power. Systems end up needing large and costly battery systems and expensive electrical inverters to convert the DC power into AC. The battery banks are common failure points and rarely last beyond a few years. Once such system the team studied was built in Mexico in 1999 and lasted less than two years before batteries began failing. Where Sundanzer and Cal Poly's approach is different is that both of our systems run from DC power. SunDanzer sells a DC deep freezer, which they have invited Cal Poly students to both customize for use in Ghana as well as design and build a small solar power system to run. With help from Brian Jensen (SunDanzer engineer and Cal Poly alumni) we will explore the most efficient methods for preserving fish and produce, maximizing efficiency, and minimizing costs.

The entire design will be prefabricated and tested in the Cal Poly Simpson Strong Tie Lab alongside NECA sponsored Construction Management team members, giving students a hands-on educational experience in a design and build scenario. Once testing and optimization is complete, all necessary materials, students, and faculty will travel to Ghana to collaborate with the local people to install the system. Two other Cal Poly student projects are also planning on traveling simultaneously to this region of Ghana, thus providing the opportunity to reduce costs, share transportation expenses and assist one another in the three projects. Nathan Heston's

network in Ghana and close relationship with the village of Agbokpa, will greatly facilitate housing, transportation, obtaining resources and many other factors that often complicate working abroad.

On top of the SunDanzer project, this is an opportunity for our team to integrate our own small scale photovoltaic-powered thermoelectric ice maker. The current prototype is capable of making 2.0 kgs of ice a day with a single 100 W solar panel with a coefficient of performance near 0.4. Coupling the deployment of this prototype with the SunDanzer freezer provides a means to compare utility in a rural village and will likely lead to continued collaboration with SunDanzer. Research will continue to explore ways to lower costs and increase efficiency and joint publication could provide a model for other villages locally and globally.

Timeline:

Tasks/Activities	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	2020
Comparative Life Cycle Cost Analysis														
Aquiring of customized SunDanzer refrigeration unit														
Refining and Finalizing Load Calculation														
Matching solar array with necessary battery/compressor systemloads														
Testing custom ice making racks and molds														
Fabrication of solar mounting system														
Complete prefabrication of entire system														
Testing and optimizing entire system														
Shipment of entire system to Ghana														
Heston travels to Ghana														
Pre-Installation American Solar Energy Society Conference 8/5/2019														
Team members travel to Ghana and installation occurs														
Data collection and performance information for publication														
Final project report completion														
Preperation of Manuscript on performance														Spring 2020
Post-Installation American Solar Energy Society Conference 8/5/2020														8/5/20

Final Products and Dissemination:

Throughout the completion of this project, data will be recorded and analyzed for a paper with 8-10 student authors. An in-depth project film will also be created to document the process. During and after installation, performance information data will be collected for comparison with initial calculations for a final report and manuscript. Patents will be published if found applicable. Team members will also present work at professional conferences such as the American Solar Energy Society (ASES) Conference as we did in 2017 to present initial results from tests completed during prefabrication on campus.

Budget Justification:

The majority of the budget will be split between two main parts. $2,000 will be to cover the travel costs of one mechanical engineering student to travel to Ghana to assist in the installation and collection of data of the system. $1,800 of which will be used for airfare, the other $200 to cover in country transportation costs. The other $3,000 will go towards covering the equipment costs that will be necessary to purchase the freezer, compressor, and a data logger. As of now, the SunDanzer DCF390 DC freezer ($1,549 before tax and shipping) will be used. The CASCADE17-0342Y3 CASCADE0006 (estimated $624.89) is an upgraded compressor that would be necessary to handle higher freezer loads. A new data logger capable of running six thermocouples simultaneously, and running 2 inputs of current and voltage simultaneously is necessary for us to continue collecting reliable data. This piece of equipment would aid in not only data collected in this project, but many other projects run by Dr. Heston and Dr. Schwartz in their research facilities. The proposed logger is the DL-1080 Universal Data Logger ($1,595 before tax and shipping). The full Baker Koob funding wouldn't fully cover these costs but will greatly supplement the purchase of this necessary equipment.

Student Applicant(s):	Casey Smith Michael Klee
Faculty Advisor:	Nathan Heston
Project Title:	**Requested Endowment Funding**
Travel *subtotal*	$2,000
Travel: In-state	$
Travel: Out-of-state	$
Travel: International	$2,000
Operating Expenses *subtotal*	$ 3,000
Non-computer Supplies & Materials	$
Computer Supplies & Materials	$3,000
Software/Software Licenses	$
Printing/Duplication	$
Postage/Shipping	$
Registration	$
Membership Dues & Subscriptions	$
Multimedia Services	$
Advertising	$
Journal Publication Costs	$
Contractual Services *subtotal*	$
Contracted Services	$
Equipment Rental/Lease Agreements	$
Service/Maintenance Agreements	$
TOTAL	$5,000