MECS-TRIID Final Project Report (public version)

Project: *Thermal Storage with Phase Change Materials*

Organisation: *California Polytechnic State University, San Luis Obispo*

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For: DFID and Loughborough University

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Executive Summary

The $35,000 we received from MECS was primarily used for two purposes:

1) Improving and developing Insulated Solar Electric Cooking (ISEC) technology; in particular by adding Phase Change Thermal Storage (PCTS). Our most recent prototype boiled 2.5 L of water for 2.5 hours after being disconnected from power for three hours.

2) Establishing SolarElectricCook (SEC, see www.SolarElectricCook.com), a company in Kumasi, Ghana to build and disseminate ISEC and study the adoption process. The company is run by Ghanaian nationals and uses locally-produced as well as imported parts and materials. Our disseminated efforts were stalled by the Coronavirus lockdown after the dissemination of 10 ISEC in a local community.

The funding was used for salaries of staff in California (44%) and Ghana (26%), hardware, materials and supplies for use in Ghana (15%), overhead from Cal Poly (14%), and ETHOS conference attendance (1%).

Over the past decade and in particular in the past year, we've established collaborations and built university synergy that leverages university and community support to both improve student education while promoting ISEC technology and dissemination. This network includes:

- Martin Osei, who established SEC in October 2019, and managed it until coming to Eastern Illinois University in January 2020 on a scholarship for an engineering master's degree. He plans on making ISEC development his thesis before returning to Ghana.

- Emmanuel Kweku: presently managing SEC in Kumasi, Ghana, since January, 2020.

- Nexleaf (www.nexleaf.org), Los Angeles NGO, dedicated to the study of adoption of improved cooking technologies enthusiastically welcomed us as their first electric cooking technology, providing valuable guidance and 20 of their "Trek" temperature data loggers to document use of ISECs in Ghana.

- Cal Poly research students. More than 10 students are engaged each year in laboratory research dedicated to ISEC development:

    - ~ 3 full time summer research students funded by Bill Frost through Cal Poly's College of Science and Math,

    - ~ 3 students engaged in year-long senior projects (usually physics majors),

    - ~ 2 year-long engineering senior project groups ~ 4 students per group.

- Cal Poly service learning classes dedicated to collaborative poverty mitigation (http://appropriatetechnology.peteschwartz.net/about-us/) whereby a multidisciplinary group of ~4 students develop technology, businesses, and educational resources with different community partners ranging from California to Africa and Asia. These classes have fostered more than six international partners interested in developing ISEC production capacity.

- SNV, a Dutch NGO (www.SNV.org) in Ghana expressed an interest to support a pilot study as soon as we have a prototype that we can produce in moderate numbers, which we now have.

- SOWTech (http://www.sowtech.com/) is developing a control module to power a resistor-heated ISEC. We are sharing hardware and knowledge.

We have established a laboratory off campus, so that much of the research and management can be done independent of the university. With continued funding, we are well positioned to take the next step: to develop ISEC technology, to adapt ISEC technology to a variety of locations, and to study the dissemination process, all to be done collaboratively with present partners. In particular we would like to:

- Bring Martin Osei to Cal Poly for this summer which may cost about $5,000 for total expenses. This will leverage considerable university funding and resources, leaving Martin with an advanced degree and expertise in ISEC technology in particular.

- Provide ongoing employment for a project manager in San Luis Obispo. This recent graduate and ISEC expert provides the necessary connection between the beneficial university activities, the laboratory development, and the international outreach for about $20/hr that Pete Schwartz is unable to provide as fully-engaged university professor.

- Provide continued funding to support salary (~ $1.50/hr) and resources for SEC in Ghana.

- Provide resources to support pre-existing businesses in poor countries develop ISEC construction capacity.

We also describe herein the many mistakes made and lessons learned in starting a business for the first time in a continent we'd never before visited.

In retrospect when we received the MECS award, we were not ready to start a business. However, in prematurely meeting people, setting up a business and involving about 40 Cal Poly students, we learned many valuable principles and skills toward establishing ISEC as a sustainable solution to the cooking/electrification challenge experienced by the global poor. These lessons along with the past year's technology improvements will serve us well in supporting others to build ISEC construction / distribution capacity.

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1. Introduction

1.1 In 2015, we invented and have since developed Insulated Solar Electric Cooking (ISEC) whereby a solar panel is directly connected to an insulated, electrically-heated cookpot. In 2018, we explored using diode heaters rather than resistive heaters because diode heaters more effectively couple power from a solar panel under a wide range of solar intensities. Typically, we use a 100 W solar panel, capable of heating 5 kg of food to boiling in the course of the day. If people want more power and/or want to cook in the evening after the sun has set, we developed phase-change thermal storage capability using Erythritol, with a melting point of 118°C that is capable of storing about ½ kWh over the course of the day. The cookers can deposit much of this energy in a short period of time after external power has been disconnected, providing many times more power than 100 W. The simple phase change thermal storage unit could be used with applications other than ISEC, and is a simple design built from less than $20 in materials.

1.2 *References are provided at the end of this document*

Aims of the project

1.3 The aims of the project are to improve the design, share knowledge with African partners, collaboratively disseminate the technology, and study the technology adoption process. Our dissemination model is to support local enterprises in constructing and innovating ISEC products for local sale. Our efforts and finances are leveraged by student participation in service-learning classes and in the laboratory as part of their education.

Objectives of the project

1.4 Objectives:

- Improve the design of the PCTS cooker
- Establish connections in Ghana
- Study the use of ISEC by Ghanaians
- Set up a business in Ghana and to manufacture the cookers
- Disseminate the cookers for a pilot test
- Study community adoption
- Disseminate results to and provide support for local production by companies, NGOs, or governments.

2. Methodology

2.1 The project develops through the coordinated effort of business and technology work at a designated company in Kumasi, Ghana, research groups at Cal Poly, and service-learning classes directed by Pete Schwartz.

Outline of the concept

2.2 Using existing technologies in a novel way, ISEC (Insulated Solar Electric Cooking) is a fundamental disruption of the use of solar electricity (Watkins 2016), providing a radically inexpensive and simple way to extract heat and electricity from a solar panel at near optimum efficiency (Gius 2019). The innovation we sought funding for is to improve, refine, and disseminate Phase Change Thermal Storage (PCTS) with a Phase Change Material (PCM), allowing the user to cook after electrical power is disconnected, and to have access to greater power by discharging the stored heat over a shorter period of time. This PCTS capacity could be used with grid electricity and other energy sources as well as with solar electricity. Electrical power can also be drawn off the diode chain to charge cell phones or lighting systems, which is a high-demand feature for many of the global poor.

2.3 We develop this phase change thermal storage (PCTS) in tandem with other ISEC improvements in Insulated Solar Electric Cooking. We developed our first PCTS design in spring 2019 with a student group in the Appropriate Technology Class, based on the design of our direct-heating ISEC. Over the course of this grant, we have redesigned it several times and now use the model shown below (Fig. 1, 2, 3).

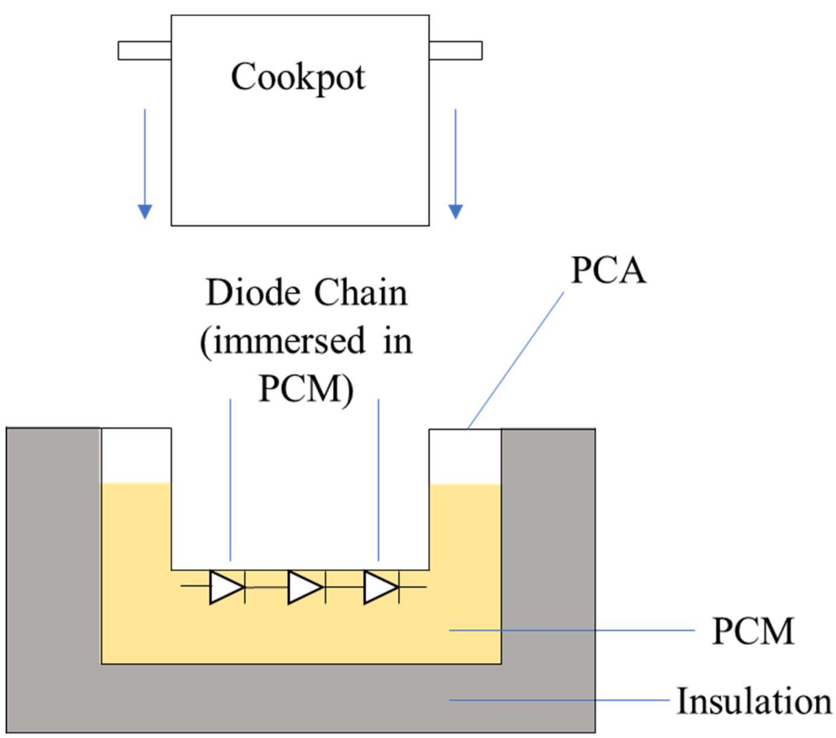

Figure 1. Schematic of the current PCTS design.

The PCA (Phase Change Assembly) refers to the container of PCM (Phase Change Material). Further insulation is placed on top of the cookpot after it is placed inside the PCA. The orange material in Fig. 2 below is a spray foam that (for this prototype) seals the PCM inside the PCA. The diode chain of 17 diodes is immersed in the PCM, attached to the underside of PCA's inner pot as shown. A standard PCA contains 2.5 kg of erythritol.

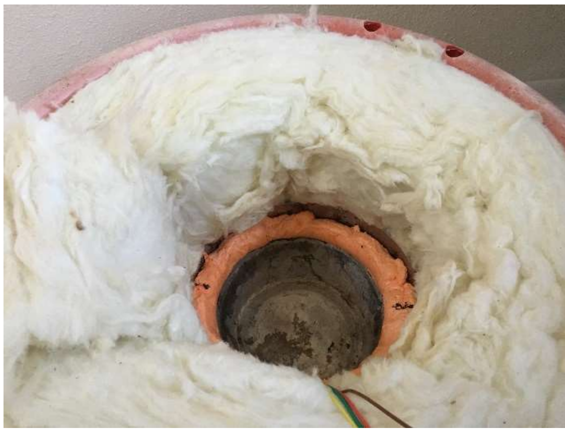

Figure 2. Image of the top of the PCA within insulation.

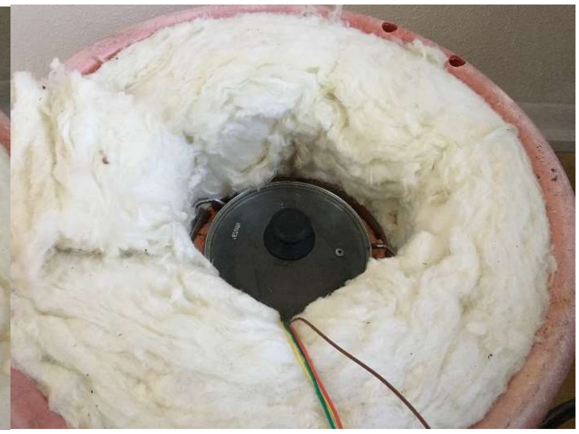

Figure 3. Image of a cookpot inside the PCA.

Intellectual Property Rights

We wish to keep any innovations we are responsible for as open source, in the public domain.

Assumptions made

We assume that maintaining open access to the IP we develop will optimize the speed of development and dissemination of the technology. Additionally, it will allow us to dedicate our creative energy to further product development rather than engaging in the competitive process of intellectual property defence.

3. Implementation

We visited Ghana August 2019 (days after learning that we received the MECS award) with the intention of developing university and government collaborations. There we spent time in the community of Agbokpa on Lake Volta, where we cooked with local people using ISEC and studied its compatibility with their cooking methods. We established local connections with recent engineering graduates, and agreed to build a business dedicated to manufacturing and disseminating ISEC cookers, both the direct-heating slow-cooker model of ISEC as well as models with PCTS. Manufacturing, dissemination, and adoption studying are all currently continuing with some delays due to COVID-19. We have also been studying and improving our PCTS technology here at Cal Poly.

The work conducted

3.1 *Operations in Ghana*

We spent Aug 7- Aug 27 in Ghana visiting the rural, off-grid community of Agbokpa and developing connections with skilled technical workers, government organizations, NGOs, and companies with the intention of establishing a sustainable company in Ghana, which is now located in Kumasi. Martin Osei (with a Mechanical Engineering BSc from KNUST, Kumasi, Ghana) founded SolarElectricCook, LLC with the help of Dr. Schwartz and Cal Poly students. We met with Domod Aluminium Company (link below), a cookpot factory in Accra who agreed to make pots to our specifications. A considerable amount of work has gone into sourcing parts and materials to SEC, LLC. Materials include pots (produced in Accra at Domod Aluminium Company) are produced locally, to erythritol (the phase change material) which must be imported from China. We import by sea when possible due to the lower carbon cost.

http://domod.com/da/aboutus.html

During the manufacturing process, Emmanuel visited several communities until he found an on-grid and off-grid community that were adequately close to Kumasi. With help from the town's pastor, Emmanuel delivered 10 direct-heating ISEC cookers to the on-grid community of Kojo-Nkwanta as a preliminary pilot test, installed them in people's homes, and gave them complimentary bags of rice.

After two weeks of using ISECs, we surveyed the users, asking the following questions (over the phone, as at this point the COVID-19 quarantine had begun in Ghana):

1. What do you like about it?
2. What do you dislike about it?
3. How many times have you used ISEC in the course of the week?
4. Do you have any challenges in using the stove?
5. Do you have any other stoves or cooking appliances in your home other than the ISEC we gave you?

6. In the last 3 days, what foods did you prepare with ISEC?
7. In the last 3 days, what foods did you prepare other ways?
8. Did you cook any meals where you use both stoves at the same time? What are they? Why?
9. Is there anything you want to tell me that changed from before?

We also gave a second, similar survey and are developing another.

<u>Operations at Cal Poly, PCTS Development</u>

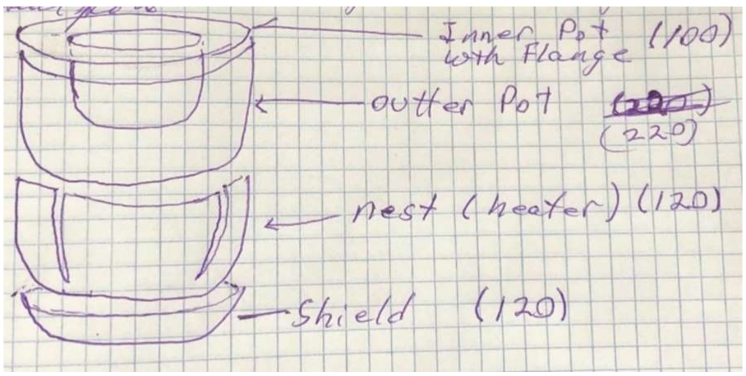

Figure 4. Schematic of the nested heater PCTS design.

Figure 5. Image of the nested heater PCTS design.

We began with the PCTS design we collaboratively created in Kumasi in August 2019 (Fig. 4, 5). This design was functional but caused several inconveniences due to the PCM being within the walls of the same pot that contained the food:

- The cookpot was very heavy and difficult to hold with one hand, making it difficult to fill, empty and clean.
- There was risk of burning oneself while emptying it of food, as the PCM would still be hot.
- Having to pull the PCM out of insulation to empty food caused heat loss in the PCM, delaying future cooking.

We redesigned the cooker so that the PCM would remain in an insulated container, into which we would “dip” a cookpot to cook food. The schematic is shown in the previous Methodology section (Fig. 1).

Lack of thermal conductivity between the food and PCM limited the deliverable power of this prototype. The erythritol closest to the cookpot solidifies first, acting as a thermal barrier for heat from the still-molten erythritol near the bottom and sides. We added aluminium shavings to the erythritol to improve the thermal conductivity. Preliminary results indicate that adding aluminium shavings at a mass ratio of 5 to 1 (erythritol to aluminium) reduces the temperature difference across the PCM from about 30 ºC to about 15 ºC.

Experimenting with different insulation and ultimately increasing the insulation was the last step towards the current model (Figs 2, 3).

Also, a great deal of time was spent at Cal Poly running various tests on equipment that would be used in Ghana, such as thermal switches, charging systems, lighting systems, diodes, nest designs, and erythritol.

3.2 The idea of local manufacturing of the technology is central to both Schwartz's research and appropriate technology classes.

As described in the application, local manufacture achieves the following goals:
- Decreases dependence on foreign supply lines.
- Employs local people, improving local standard of living and providing labour at a reduced cost.
- Brings the industry closer to the people, making the technology more adaptable to local needs and wants. The feedback loop formed by the user giving input to what changes they want in the product and the producer making those changes is shorter. A local business can adapt to consumer demands quicker and with more insight than a foreign business.
- Provides a model for other countries to establish their own production and dissemination.

3.3 *Delay of project start because of university negotiation.*

Settling the contract to make funding available took about two months. After this approval process, university funding would not front the money for larger purchases requiring the Ghanaian workers to go into debt to pay for supplies, and also limiting the size of purchases to that which the Ghanaian workers could borrow.

Martins departure, expertise of Emmanuel

In October, Martin was granted a scholarship to a graduate school program at Eastern Illinois University in the United States. At this point, he was the sole director of operations in Ghana and we had invested a significant amount of our time in Ghana to teaching him about ISEC.

Before he left Ghana, Martin found and trained a replacement for himself, Emmanuel. Emmanuel has been very aptly communicating with us and producing operational ISECs. However, he lacks the technical experience with the cookers that Martin has, causing more manufacturing errors and requiring more oversight.

Sourcing supplies

Many supplies are hard to find in Ghana. Electrical supplies are scarce and many specific parts cannot be found and must be imported. Erythritol for instance, was too difficult to find and had to be imported, along with many other materials.

<u>Technological Problems</u>

Corrosion

The leads between the wires and the diode chains seem to corrode over time in some cases. Matt Walker, an experienced research student who was part of the August 2019 Ghana trip is dedicating his senior project to studying this challenge.

Diode Failure

The diodes can break if they overheat, which can occur if they are not properly attached the base pot or if too much current is run through them. We are exploring the options of returning to resistive heating.

Charging/Lighting Systems

We initially built our own USB charging circuits and lighting systems. However, this involved considerable effort and troubleshooting; and these systems are inexpensively available in China. We presently import USB ports and rechargeable lights.

<u>Mutually supporting project development and service learning classes.</u>

By the time the grant was awarded, Schwartz was already committed to teach a full load of classes for the fall quarter, and he was not able to dedicate the attention to this project that it deserved/required. We had initially hoped to find a dedicated professor in Ghana, but were not able to find a committed partner. This was mitigated in January by hiring Owen Staveland, who had experience on the project and had just graduated. Moving forward, we propose a natural solution to this challenge is to help Martin continue his education in the USA with ISEC research so he can direct SEC, LLC locally in Ghana on firm technological understanding. Such an innovation would provide long-term sustainability to the continued development of the technology in country.

<u>Weather</u>

Poor weather in Ghana pushed back the dissemination day several times. Cloudy weather also resulted in difficulty with some survey questions about recent usage of ISECs.

<u>COVID-19 Disruptions</u>

We had planned to create and disseminate 40 more ISEC cookers before April 30th as well as begin construction of cookers with PCTS. COVID-19 disrupted both our supply chain as well as ability to operate within Ghana. The following are the disruptions to our project due to COVID-19:

- Our aluminium pot supplier lost access to aluminium so we could not buy pots, preventing the next round of ISECs to be manufactured.

- Erythritol was delayed. It will now arrive within a month.
- Charging circuits could not be delivered to Ghana and are stuck in transit.
- Prices for the lighting systems increased, so we postponed purchasing them.
- Emmanuel could not give surveys in person.
- Emmanuel could not visit Kojo-Nkwanta again to add Treks (cooking data collection device from Nexleaf) to the cookers or add any other improvements.
- We relocated our research lab off campus. This lab is small, so we only have one worker present at a time in order to comply with "shelter in place" orders. In order to comply with Cal Poly restrictions, all research is conducted by nonstudent research staff.

3.4 In many cultures it is the job for the women to manage all cooking. Women are freer from the burden of collecting firewood with ISEC as it requires no fuel source. This saves women time they would have spent collecting firewood, money they would have spent on it, and protects them from violence that they may be exposed to while out obtaining it. Cooking with ISEC does not require as much attention as cooking with and tending to a fire, so this is another way in which it saves women time.

The liaisons hired in the communities will also be all women, as they are more involved in the cooking process in these communities. We have yet to identify a woman liaison in Kojo-Nkwanta. However as soon as quarantine is lifted and Emmanuel can visit the community he will address this.

The project findings

3.5 It would have been better to build a strong collaboration with university and industrial partners in one place, over a long time, consolidating communication to a very small number of key players. We recognize that we didn't have this luxury, as we didn't know anyone until we arrived in Ghana. Moving forward, we will seek to continue to strengthen the connections we have.

Survey results

We disseminated 10 direct-heating (non-PCTS) ISECs in the on-grid community of Kojo-Nkwanta for free along with bags of rice. We got in touch with all but one user by phone call 4 weeks later to conduct a progress survey and found that all the ISECs were still in use. The users will continue to have the ISECs for an indefinite amount of time because of travel restrictions from COVID-19.

When asked what they like about the ISEC, most users agreed that the ISEC makes cooking easier. Specifically, one user reported that it helps save cost and energy (gas) and is less destructive, while another reported that it takes away the stress of fetching firewood. When asked what they dislike about the ISEC, two-thirds of users reported that it takes too long, while the others described other problems such as being limited to cooking when the sun intensity is adequate and having a limited range of foods that they can cook in it. Two-thirds of users also reported that their main challenge in using the stove is that it doesn't get hot enough to boil water. Throughout the survey, some users noted that the ISEC occasionally gives off an unpleasant smell, believed to be from the glue.

All users reported that they use the stove 5-7 days per week, mostly to heat water. The few users who did use their ISEC to cook stated that it was mostly used to cook rice, while they prepared food such as yam, banku, soups, and boiled cassava with other stoves. The table below describes the variety of cooking appliances in each user's home other than the ISEC.

Coal Pot	LPG Stove	Firewood	Number of households
x			2
	x		3
		x	1
x	x		1
x	x	x	1
	x	x	1

Figure 6. Table showing types of cookstoves in the houses of 10 Kojo-Nkwanta residents.

When asked if the users cooked any meals using the ISEC and another cooking appliance at the same time, most users said no, listing reasons such as lack of sunlight prohibiting ISEC use or ISEC taking too long to cook. One user said yes, they used the ISEC to cook rice while cooking stew with firewood.

3 weeks later, we conducted a follow up survey to gain more thorough information about the users and their opinions. Through this survey, we have solidified that the general opinion of the ISEC is that it makes cooking easier and saves money on fuel, but would prefer it were more powerful. Lately, many users have not been able to cook food due to poor weather conditions and low sun intensity. Because of this, only a few people use their ISEC to cook food while most people use it to heat water.

The next cookers we disseminate are powerful enough to boil water and we will use different glue, so all user concerns should be addressed.

PCTS Results

We developed a PCTS cooker that can boil 1.5 L of water for 2.5 hours after being heated with 100 W for 6 hours and then disconnected for 3 hours. The cooker has 2.5 kg of erythritol. Thermocouple data is shown below in Fig. 7. The thermocouple above the diodes (blue) is more directly heated by the diodes that the bottom of the PCA. The PCM melts between about 1.5 hours and 5 hours as indicated by the flattening of the heating curve. At 6 hours, the power is disconnected and the ISEC attains the same temperature and cools slowly through the insulation, but remains all liquid. At 9 hours, the water (yellow) is added, resulting in rapid cooling of the PCM. The water boils in about 1.5 hours and continues boiling for about 2.5 hours. By then, the PCM is all solidified again and the ISEC again attains the same temperature and cools slowly through the insulation.

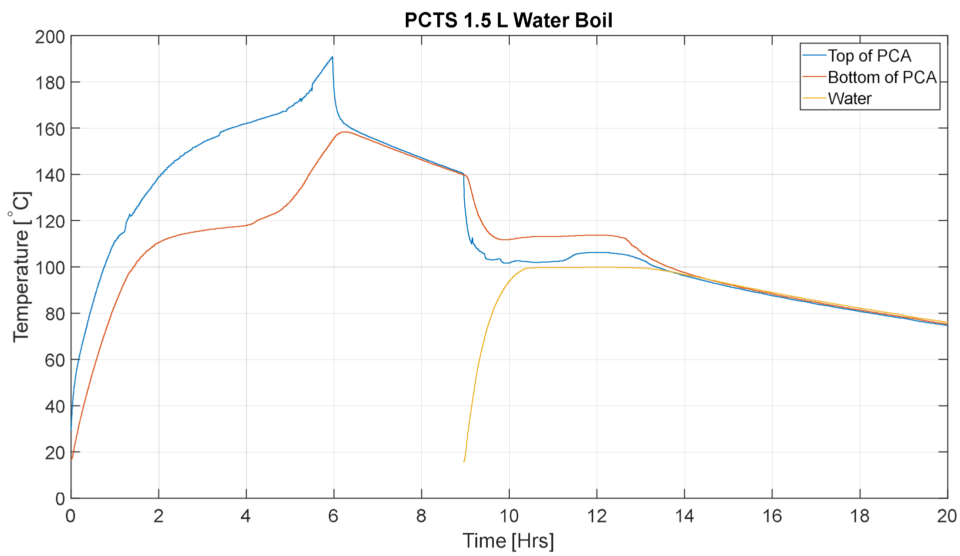

Figure 7. Thermocouple data for a 1.5 L water boil with PCTS.

Using the rate of water temperature change, we are able to calculation the power delivered to the water, below. It should be noted that this power is a lower limit, especially for higher temperatures because it doesn't include the energy flow associated with boiling the water. The 256 g of water boiled during the 2.5 hours corresponds to an additional average power output of about 50 W over this time period.

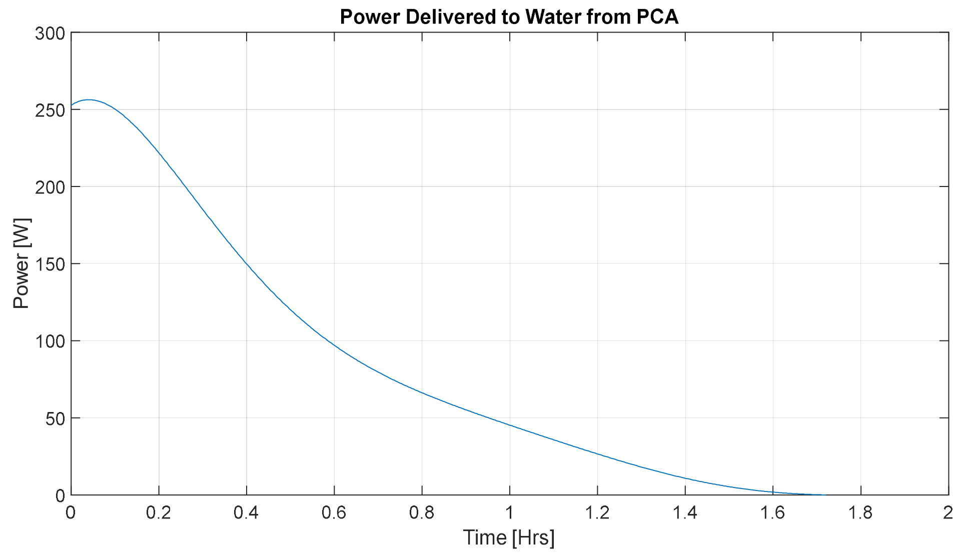

Figure 8. Power vs. Time graph for the 1.5 L water boil shown in Fig. 6.

It should also be noted that most of our experiments began with room temperature PCM. Under normal operating conditions, the PCM would still be somewhat hot from the previous day, allowing for faster cooking.

3.6 We have developed a PCTS cooker that is ready to be manufactured in Ghana and locally disseminated, answering the needs expressed in the surveys.

The survey feedback gives us insight into where ISEC fits this community and where things need to be changed. All changes we desire to make can be quickly accomplished.

We have also established a strong relationship of trust and common goals with Martin and Emmanuel, which will likely be beneficial toward long term success of this project.

Through the appropriate technology classes, we are building a working relationship with several other enterprises in Uganda (AidAfrica and Beacon of Hope School), Sierra Leone (Project Peanut Butter) South Aftrica (Solar Cookers for Africa and SunFire, www.sunfire.co.za), Nepal, and India.

Limitations of the innovation/approach/design/system

Are there any limitations on how, when, where, why, by whom this solution can be used?

The use of diodes, local production, and a small off-campus lab provide limitations.

Describe what these limitations are

Diodes

The diode heater technology is able to directly take power from solar panels more effectively than a directly-connected resistive heater. However, diodes have their drawbacks: they have a maximum operating temperature and can thus be destroyed if run above 275 C. Also, the voltage across a diode, while largely constant, depends slightly on current and temperature. Additionally, the maximum power point voltage from a solar panel also varies with temperature. Thus, it is not possible to precisely optimize power drawn from a solar panel with diodes, nor be able to optimally take power from the diode chain to power a USB port.

We will continue to use diode technology for now, but we will also continue to support development of active control measures to power a resistive heater ISEC and a USB charger from a solar panel. Presently, we will do this through collaborations at Cal Poly in Electrical Engineering as well as with universities elsewhere.

Local Production

Producing the cookers locally results in challenges regarding sourcing parts, as certain technical components cannot be found in Ghana. This can be overcome by importing parts from China, possibly all at once via a shipping container to obtain the best price.

Off-campus lab

Using an off-campus lab has allowed us to continue doing research on PCTS while Cal Poly campus has shut down and moved online. However, the size limits the amount of people in the lab at once in order to social distance and in compliance with Cal Poly rules, there are no students working in the lab. We have mitigated this by having students do safe, limited research at their own homes and providing them with materials.

4. Practical applications of the concept to the national cooking energy system (including costs)

4.1 We plan to continue producing ISECs through SEC LLC. We will provide SNV with a prototype and seek their support for continued field tests. We will also continue working with Nexleaf to study the adoption process. Lastly, we may ask MECS for continued funding. Once SEC LLC has a customer base and further-established supply lines, the need for external support should diminish considerably, and the Ghanaian Energy Commission may become interested. Ultimately, the cost of solar panels should continue to decrease such that the company should be financially self-supporting. We anticipate that this could happen within the next two years. The open-sourced availability, active publications, and proactive support through student groups should help make this transformation spread globally.

5. Next steps

5.1 Domod will receive aluminium next week and be able to supply pots for Emmanuel, who will then continue producing ISECs with recently-established improvements. A main concern from users was that it took too long to cook or was not able to boil water. We know from testing that these following improvements will solve this:

- Larger buckets that can be further insulated
- Nests that go further up the sides for greater thermal connection

Other features that we will add are:

- USB chargers, which have arrived in Ghana and should be available soon
- Treks from Nexleaf for data collection
- Lighting systems

Other potential additions that we would like to add but require further planning:

- Aesthetic improvements
- Brochure/manual/ instructive videos recorded by students in Schwartz's class.
- Temperature display

Once we can begin manufacturing improved cookers, we will disseminate them in Kojo-Nkwanta, replacing our old cookers. Once we have erythritol, we will begin manufacturing and disseminating cookers with PCTS. In Ghana we currently have enough solar panels and diodes to make 40 more ISECs and 100 kgs of erythritol should arrive soon.

5.2 Because we already have 40 panels in Ghana, the most expensive component, we seek funding to support personnel as described in the executive summary. We have recently reached out to the Rotary to help support the educational aspect of ISEC research.

5.3 As described in the executive summary:

- Martin Osei, who established SEC in October 2019, and managed it until coming to Eastern Illinois University, January 2020 on a scholarship for an engineering master's degree. He plans on making ISEC development his thesis before returning to Ghana.

- Emmanuel Kweku: presently managing SEC in Kumasi, Ghana, since January, 2020.

- Nexleaf (www.nexleaf.org), Los Angeles NGO, dedicated to the study of adoption of improved cooking technologies enthusiastically welcomed us as their first electric cooking technology, providing valuable guidance and 20 of their "Trek" temperature data loggers to document use of ISECs in Ghana.

- Cal Poly research students. More than 10 students are engaged each year in laboratory research dedicated to ISEC development:

- ~ 3 full time summer research students funded by Bill Frost through Cal Poly's College of Science and Math,
- ~ 3 students engaged in year-long senior projects (usually physics majors),
- ~ 2 year-long engineering senior project groups ~ 4 students per group.

- Cal Poly service learning classes dedicated to collaborative poverty mitigation (http://appropriatetechnology.peteschwartz.net/about-us/) whereby a multidisciplinary group of ~4 students develop technology, businesses, and educational resources with different community partners ranging from California to Africa and Asia. These classes have fostered more than six international partners interested in developing ISEC production capacity.
- SNV, a Dutch NGO (www.SNV.org) in Ghana expressed an interest to support a pilot study as soon as we have a prototype that we can produce in moderate numbers, which we now have.
- SOWTech (http://www.sowtech.com/) is developing a control module to power a resistor-heated ISEC. We are sharing hardware and knowledge.

Dissemination Plan

5.4 The dissemination plan is to locally produce and disseminate the cookers in Ghana and other countries. We found 2 communities for a pilot test: one off-grid and one on-grid. The communities needed to be close enough to where Emmanuel lives and manufactures the cookers so that he can remain in contact with them easily. Contact is through a liaison in the community who is paid to report on the cookers' usage. If problems arise with the cookers, the liaison will report it to Emmanuel, who will assist them in person or virtually.

We have different ideas for the method of dissemination within the target community. For our preliminary tests, we gave them out for free. Based on feedback, we feel confident that the next round of cookers will be desirable enough where people will pay for them. We may use a buy-in lottery system. A student at Cal Poly has been investigating the advantages of different methods.

The larger dissemination strategy is to establish a model of a business that is financially sustainable and publicize it. Additionally, we have established partnerships in several different regions where we may expand to: Sierra Leone through Project Peanut Butter and into Uganda through AidAfrica and Beacon of Hope Secondary School.

At the same time, through Schwartz's appropriate technology classes, student groups will work to support growth of new enterprises in different countries, the most prominent being Solar Cookers for Africa, a well-established NGO that has 20 years' experience building and promoting low impact cooking technologies.

Explain what dissemination you have done already or what you plan to do if you haven't done any yet. Who are you focusing on? (who is your main audience e.g. customers, politicians, standards agency etc.). What are you telling them (e.g. are you focusing on the technical benefits of the solution, the price point, how well your solution works compared to a different solution).

We have disseminated 10 cookers to the on-grid Ghanaian community of Kojo-Nkwanta. We are focusing on the poor mostly, who cook with firewood indoors.

The main selling point to the consumer is that it cuts fuel costs, is safer than traditional methods, and is easy and stress-free.

Is your audience responding to what you are telling them? – how do you know? (e.g. have you done any customer feedback? Have you been invited back for follow up conversations on your approach/product?)

While this is still early in the process, surveys have indicated that people are happy with the cookers. They enjoy how much easier it is to cook with them than traditional cooking, they appreciate the money they save on fuel, and many value the health and environmental benefits.

6. Conclusion

6.1 In our efforts to establish a financially sustainable ISEC company in Ghana with well-tested cookers and a well-studied adoption process we are behind our timeline. And yet, we have established a company with reliable collaborators, we have established supply lines, we are making ISECs and we have them in the hands of families. We are studying the adoption process and responses have been overall positive. The network of collaborators we've established through businesses and university classes may facilitate future dissemination by supporting interested start-ups globally.

There have been delays due to COVID-19, but we will soon have new and improved cookers in people's hands. We have made significant improvements to our PCTS cooker and are ready to manufacture them in Ghana for pilot tests. We have established partnerships in Ghana as well as other regions, advanced ISEC technology, and we are ready to continue with the next steps to power a cooking movement that is healthier for the people and the environment.

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Many resources can be located at our research website:
http://sharedcurriculum.peteschwartz.net/solar-electric-cooking/