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On- and Off-(micro)grid PV Electric Cooking: field data for integrated energy access in Haiti

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Executive summary

The study explores the potential of electric cooking in rural communities in Haiti by deploying electric pressure cookers and induction stoves with integrated smart meters in 20 households connected to a community scale solar PV microgrid as well as cookers and stoves supported by stand-alone solar+battery systems in 8 off-grid households.

The microgrid participants had a “SparkStove” system, while the off-grid participants had a SUNSPOT™ solar electric cooking system. Each of the systems were designed to support an electric pressure cooker (Simpot) and an induction stove. The microgrid system utilized electricity from a solar PV microgrid while the off-grid system used an individual solar+battery setup. Each device was interconnected to a smart meter that provided 15-minute interval data for customer electricity consumption. The present report shows electric cooking data for a minimum of 42 days of observation for each participant.

Participants were given hands-on training for utilizing electric cooking technology in their home and also participated in demonstrations and were given recipe and technology guides to help customers learn to cook with the new technologies and build customer excitement for electric cooking. Participants also recorded a variety of data in daily energy diaries including the number/type of meals cooked including a baseline pre-electric cooking menu, what fuel source was used (i.e. electricity, charcoal, etc.), how long they spent cooking, how many people they cooked for, and if there were any challenges for a particular meal (especially for electric cooking). All participants received free electricity for their electric cooking loads to incentivize usage and prioritize actionable data for planning electric cooking.

In the observed period, there were an estimated 3,820 electric cooking events (1,372 pressure cooker, 2,448 induction stove, 166 with both) totalling an estimated 3,713 hours of cooking and 3,979 kWh of electricity. On average, the cooking events lasted 58.8 minutes (50 minutes pressure cooker, 66 minutes induction stove, 112 minutes both) and consumed an average of 1.05 kWh (0.83 kWh pressure cooker, 1.14 kWh induction stove, 1.63 both). Cooking event data also showed significant ranges for individual customers. On average, customers used electric cooking in 79% of their observed days, but several customers used electric cooking nearly every day of the study. Overall, individual customers averaged 1.92 kWh per day. Average induction stove use was 1.58 kWh per day and average pressure cooker use was 0.79 kWh per day. Off-grid customers consumed an average of 1.18 kWh per day, while microgrid customers consumed around 2.4 kWh per day.

The electric cooking pilots added significant load to the existing microgrid operations. For example, in the month of October total average daily load increased 20% because of electric cooking load. Individual hourly consumption on the grid also increased by an average of 19%, but from 8 AM to 2 PM hourly microgrid load increased 42%-55% as a result of electric cooking highlighting that peak demand for cooking aligns with peak solar generation in rural Haiti. At the highest-level, monthly generator use increased 33% from the start of the cooking pilot in July to the end of October. On normal sunny days, the microgrid has enough extra solar + storage capacity to absorb the extra cooking load, particularly since it is aligned in the middle of the day, but when solar production is

low due to cloudy days and rain, the microgrid saw increased diesel generator usage and on a few occasions blackouts due to overdraw of the generator.

This illustrates the significant impact that electric cooking load has had on microgrid operations. In general, the additional draw on the grid is beneficial to the business model of microgrid operations because the draw coincides with the least-cost energy production. When solar energy generation is low, however, the electric cooking can be expensive or technically detrimental to the grid. As anticipated, this finding underscores the importance of 1) deferrable loads on the grid during low sun days or plans to add additional generation capacity and 2) time-of-use cooking plans to prevent instantaneous demand from exceeding supply.

The electric cooking participants were very categoric in their response: the cooking appliances are absolutely life changing. The most mentioned benefit was the amount of time saved cooking with electricity rather than using charcoal. All participants responded that electric cooking saved them time compared to status quo cooking. 78% of participants responded indicating that they used that time for relaxing, 33% for household chores, 15% for focusing on business and income tasks, 7% for self-care, and 7% for family care.

45% of participants also responded that they increased their cooking frequency as a result of the electric cooking devices. Financial savings on charcoal expenditures following electric cooking deployment ranged significantly customer to customer, but the project highlights indicative willingness to pay values for many customers at or above current microgrid tariffs. This demonstrates potential pathways for the financial viability of microgrids. The biggest challenge for the participants was the small size of the devices which limited the amount of food that could be cooked. Similarly issues with ferromagnetic pots for the induction stoves were also noted, namely that the pots were too thin and would tend to burn food if not careful.

Overall, the project is a first-step working to prove the viability, effectiveness, and attractiveness of electric cooking technologies powered by robust, reliable solar + storage energy systems supporting critical socioeconomic development outcomes in Haiti. This will help to demonstrate key demand for the solution and create actionable evidence for how to effectively design business models and frameworks to better support future electric cooking rollouts. In doing this, the project will be demonstrating viable new revenue streams and opportunities for energy access providers which will help improve assistance, service, and offerings to other communities. This will also create pathways for donors, NGOs, private sector, and other stakeholders to meaningfully develop opportunities for the expansion of clean cooking.

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1. Introduction

The present study explores the potential for electric cooking powered by reliable community-scale solar PV microgrids to provide an effective alternative to traditional cooking methods for rural communities in Haiti. Leveraging detailed smart meter consumption data and energy/food journals from 28 households equipped with electric pressure cookers and electric induction stoves, this project builds a baseline for electric cooking in Haiti and beyond; specifically by establishing a knowledge base for electric cooking awareness building, customer preferences (especially for cooking times/recipe limitations/taste), operating costs and impact on microgrid operations, key challenges and barriers, and best practices/lessons learned for electric cooking in rural Haiti.

The results will inform how microgrid operators might integrate electric cooking loads into overall microgrid system design, and how, in turn, that would impact the microgrid business model. The smart meter data will also enable EarthSpark to assess different customer engagement strategies to optimize asset utilization and overall microgrid efficiency in delivering high levels of cooking service availability to customers. Further, this data will help inform designs and business models for off-grid electric cooking providers like SUNSPOT™ who was a significant partner for the current project. By running trials in both microgrid and grid-adjacent areas, this project expands the robust functionality of microgrid smart meters to areas previously left unserved.

Figure 1: Electric cooking participant with her new setup

Overall, the project is a first-step working to prove the viability, effectiveness, and attractiveness of electric cooking technologies powered by robust, reliable solar + storage energy systems supporting critical socioeconomic development outcomes in Haiti. The project findings demonstrate demand for the solutions and create actionable evidence for how to effectively design business models and frameworks to better support future electric cooking rollouts. In doing this, the project reveals possible new revenue streams and opportunities for energy access providers which will help improve assistance, service, and offerings to other communities. The findings also create pathways for donors, NGOs, private sector, and other stakeholders to meaningfully develop opportunities for the expansion of clean cooking.

2. Approach

Overview

The study explores the potential of electric cooking in rural communities in Haiti by deploying electric pressure cookers and induction stoves with integrated smart meters in 20 households connected to a community scale solar PV microgrid as well as cookers and stoves supported by stand-alone solar+battery systems in 8 off-grid households.

The study was conducted in the rural community of Les Anglais in Southwestern Haiti which is the site of EarthSpark's first microgrid in Haiti. The microgrid itself is a 100kW solar PV hybrid microgrid serving about 2000 people.

Figure 2: Haitian spaghetti cooked with electric stove and pressure cooker

Participants

In total 20 microgrid households and 8 off-grid households were selected to participate in the electric cooking study. Participants were selected based off of a number of criteria. Unfortunately, some of this selection was complicated by COVID-19. All households were encouraged to participate through direct engagement from Enèji Pwòp staff.

For microgrid participants, the first requirement was that participants needed to be existing customers of the local microgrid operator, Enèji Pwòp. After that selection was based on a combination of:

- **Proximity/Ease of Access** – Households in the downtown area near the Enèji Pwòp store were prioritized to ease installations as well as the collection of surveys, energy journals, and other information, particularly under constrained operating procedures due to COVID-19

- **Size of household** – Given the size limitations of the cooking devices, selection focused on households that had smaller cooking requirements (i.e. number of people). In general household size ranged from 4 to 10 people.

- **Community Perception/Status** – A number of the households selected were women who ran various food businesses in town. Given the perception of barriers for electric cooking it was important to work with these stakeholders directly as their opinion/experience could help tailor future efforts and importantly frame the viability of electric cooking for the rest of the community.

- **Willingness/Ability to Participate** -To be effective, the study needed highly motivated households that would sustain participation and feedback throughout the study period. While many households theoretically could have fit this description, households that had a combination of active purchasing patterns and active interactions with Enèji Pwòp staff and past surveys/projects were prioritized.

- **Enèji Pwòp Technicians and Grid Ambassador** – The three Enèji Pwòp technicians and one grid ambassador were also included as participants (3 microgrid 1 off-grid) as it was critical for them to be able to understand and work with the devices effectively so that they could support the other participants. It also helps to establish a measure of trust in the systems for participants.

For off-grid households, Enèji Pwòp selected households in a specific neighbourhood more isolated from the rest of the town where households are not likely to be connected by the microgrid. This neighbourhood also needed to be easily accessible by truck given the installation requirements for the SUNSPOT™ **solar electric cooking** systems. The individual households in this neighbourhood were primarily selected based off of interviews which highlighted specific homes that were present, smaller in size, and not currently utilizing solar home systems. Three off-grid households were also selected to help relay the smart meter communications as described further in the technology section below.

Figure 3: SparkStove participant cooking goat

Training

Four cooking demonstrations and four trainings were held for the study participants and their families between July 2020 and November 2020. The demonstrations and trainings were conducted by Enèji Pwòp staff either in the Enèji Pwòp store or in community gathering places.

The training events specifically focused on showing participants how to use the devices safely and effectively to cook a variety of different meals as well as to answer specific questions from participants and to enable the participants to practice using the devices. Further, trainings also included how to shutoff the breakers for the electricity meters for safety and for energy conservation. Each participant household was required to attend a training event before they could get their device installed. Each participant household also received a recipe and instruction guide (see the supporting annexes). The demonstration events focused on cooking specific dishes using the pressure cookers and/or induction stoves.

Figure 4: Electric cooking demonstration and training

Electric Cooking Technology and Installations

The study participants had two different setups depending on whether they were microgrid or off-grid. The microgrid participants had a "SparkStove" system, while the off-grid participants had a "SUNSPOT" system. Each of the systems were designed to support an electric pressure cooker (Simpot) and an induction stove. The microgrid system utilized electricity from a solar PV microgrid while the off-grid system used an individual solar+battery setup. Both systems are described in detail below (see the supporting annexes). All participants received free electricity for their electric cooking loads to incentivize usage and prioritize actionable data for planning electric cooking.

SparkStove (microgrid): The SparkStove system consists of the two different electric cooking devices and three different smart meters. The induction stove and the electric pressure cooker were both connected to a 16A smart meter via a ground-fault circuit interrupter (GFCI) for surge protection which in turn was connected to a breaker box and then to a 60A smart meter for the household overall (Figure 1).

This setup was chosen to allow for individual measurement of each cooking device as well as the overall "non-cooking" electricity consumption. This helped to avoid the need for specific load disaggregation which has been a challenge for other studies.

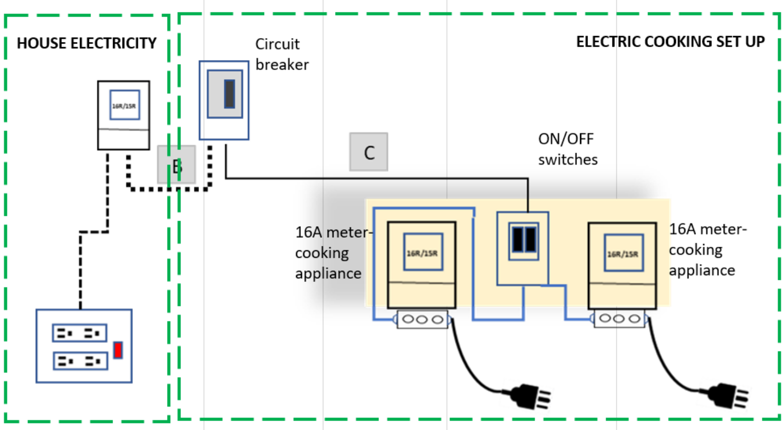


Figure 5: Electrical Setup for the Sparkstove

SUNSPOT™ (off-grid): SUNSPOT™ is a self-contained off-grid solar electric power system. The system consists of two large format PV modules (2 x 350 watts typical), a 2.5 kWh advanced lead carbon battery and dedicated power and control electronics. It is designed to supply 2 kilowatt-hours per day, which is enough energy for a family of 4-6 to cook all meals using high efficiency electric appliances such as induction cooktops or electric pressure cooker, as well as energy for LED lighting and mobile phone charging. The SUNSPOT has been engineered for local assembly and quick installation. For the current project, the SUNSPOT systems were prefabricated in the United States and then assembled locally by Enèji Pwòp staff is Les Anglais. Doug Danley from SUNSPOT also consulted on the electric cooking study design and implementation.

The SUNSPOT™ system similarly had individual metering of the cooking devices and additional outlet to allow for individual measurement of each cooking device as well as the overall "non-cooking" electricity consumption.

Figure 6: Haitian man cooking on the SUNSPOT System

Figure 7: SUNSPOT solar installation

Data Sources

The study leveraged a few different tools and technologies to collect and analyze a variety of data as detailed below:

- **Energy Diaries**: Participants recorded a variety of data in daily energy diaries including the number/type of meals cooked (both baseline menu and with electric cooking menu as discussed below), what fuel source was used (i.e. electricity, charcoal, etc.), how long they spent cooking, how many people they cooked for, and if there were any challenges for a particular meal (especially for electric cooking). These diaries were then transcribed and translated to help establish baseline cooking practices and supplement the smart-metering data. Date ranges for the diaries varied from participant to participant, but in general included 1 month of pre-electric data and 1-3 months of data after installation. A copy of the energy diary template utilized can be seen in Table 1 below.

Table 1: Template for Simple Energy Diary

Date	7/1/2020	7/2/2020	….

Cooking Start Time			
Cooking End Time			
What is the age and gender of the person who cooked?			
What food/drink did they make?			
How many people did they cook for?			
Did they cook with electricity?			
What did they make using electricity?			
Did they use the electric stove?			
What did they make?			
Was the system easy to use?			
If they used another source of energy what did you use (charcoal, wood, propane, etc.)?			
Why were you not able to use electric?			
How did people think the meal tasted?			

- **Formal Participant Surveys**: Participants completed formal surveys at the beginning and the end of the study (about 1-2 months apart for most participants). Questions focused on gathering information like cooking practices, demographics, fuel expenditures, perception of electric cooking, issues with technology, etc. A copy of the participant survey questions can be seen in the supporting annexes.

- **Informal Participant Conversations**: General feedback from participants was also gathered through informal conversations and technician/grid ambassador visits.

- **Electricity Smart Meters** – As above, all of the participants had individual electricity smart-meters from SparkMeter connected to their electric pressure cookers, induction stoves, as well as for their overall household electricity consumption from the microgrid or SUNSPOT. These meters provide 15-minute interval data on electricity consumption as well as power quality metrics like voltage, frequency, and uptime. This data is automatically pushed to the cloud.

All of the data was either gathered in person by Enèji Pwòp staff and transcribed or pushed directly to the cloud. Following this, EarthSpark researchers utilized Excel and R platforms to clean and analyze the data.

3. Presentation of Results

Overview

In total 29 participants participated in the initial electric cooking pilot (20 microgrid, 8 off-grid, and 1 R&D using the off-grid system[1]). Between July 1, 2020 and September 29th, 2020 all participants were trained on how to safely utilize the electric cooking technologies. Once trained, participants received their electric cooking installations and were able to utilize their cooking technologies in their homes. The present report shows electric cooking data for each participant household from the date interconnected to November 10th, 2020 giving a minimum of 42 days of observation for each participant.

Participant Profiles

Gender

All but one cooking participant was female. It does not mean that male members of the family did not use the cooking appliances, as cooking diaries entries did indicate the participation of male family members, though minor, in food preparation. During the training sessions as well, male members and children in the households were welcomed to attend and participate to make the cooking appliances accessible for everyone in the family.

However, the main cook in most households were identified as female, except for one off-grid household (this dynamic didn't shift much at all following the introduction of electric cooking). This reinforces the social stereotype that women are responsible for preparing food for the family and in the Haitian context, especially in rural settings, household tasks are considered to be the woman's complementary role while the men are out in the fields or doing other manual jobs. The fact that it was mostly women participating in the electric cooking project also indicates that they are the ones being the most impacted.

[1] This system was deployed at the EarthSpark field office and hosted a variety of different appliances including a small refrigerator, blender, ice machine, electric coil stove, toaster oven, etc. Since this application was so different from the other participants, we have included the data as raw data to help inform future analyses, but have excluded it from the below summaries so as to not skew results.

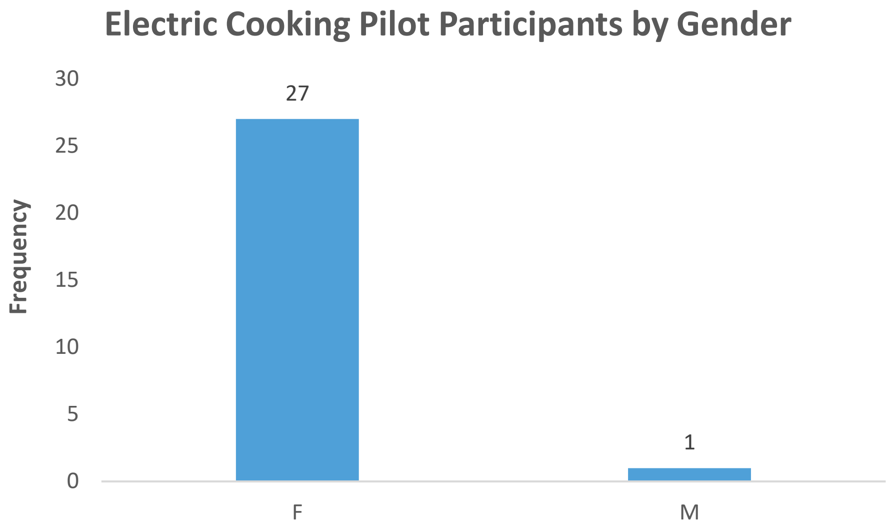


Figure 8 : Gender distribution of cooking participants

Survey results indicate that most of the cooks in the household are between 36 and 55 years old. While this figure reflects the main person who prepared food in the house, it does not mean that age groups outside of this range did not utilise the electric cooking appliances. Energy diaries entries have shown that children as young as 9 and elderly people as old as 82 did use the electric cooking appliances either for preparing meals or just boiling water.

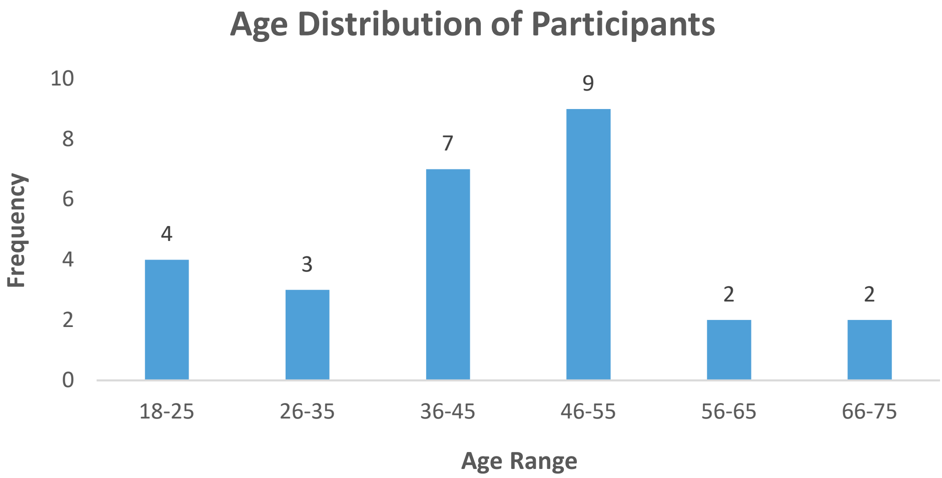


Figure 9 : Age distribution of the cooking participants

The participants were asked about what age they were when they learned to cook. The majority of them were less than 10 with 6 years old being the youngest age mentioned. Meals prepared at this young age included plain white rice and boiled root vegetables.

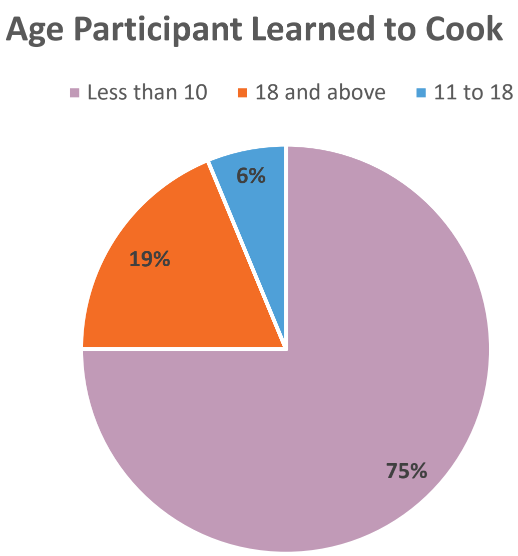


Figure 10 : Cooking learning age distribution among the participants

81% of participants learned from a maternal figure like a mother or stepmother. Two participants learned to cook at school and one even studied two years at cooking school (she is the only participant who is employed as a cook). In 100% of the cases, the person who taught the cooking skills was a woman.

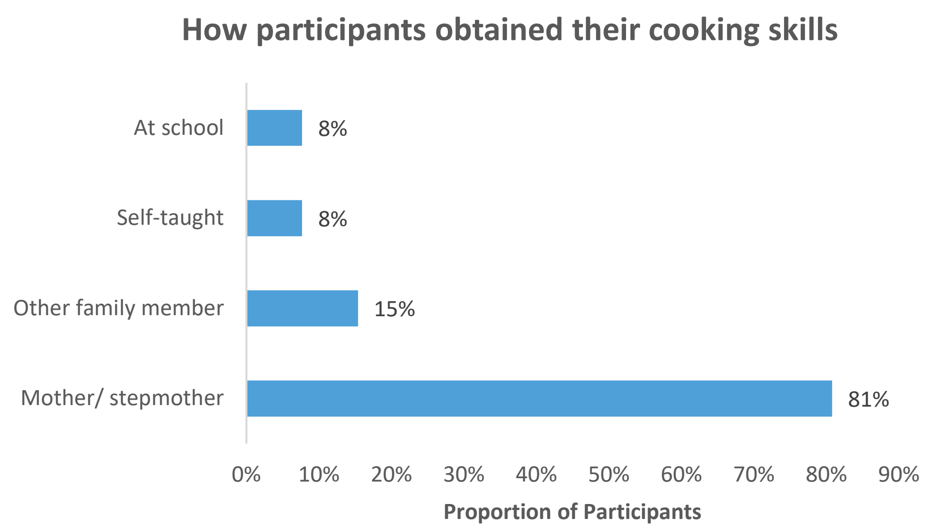


Figure 11: How Participants Learned to Cook

Haitian Meals

Baseline menus and cooking/prepping times were established from participant recorded energy diaries. Not all participants recorded energy diaries and some were more diligent about filling them out than others. Initial corrected energy/cooking diaries are included in the supporting annexes.

The participants made a variety of traditional Haitian meals over the course of the baseline and electric cooking study period. These meals mostly consist of a starch (rice, spaghetti/macaroni, cornmeal, wheat/millet, plantain, viv (boiled roots/plantain), breadfruit) and an addition of beans, meat, vegetables, eggs, and/or fish.

Figure 12: Haitian beans and rice

Mostly food is boiled or fried and rice was the most common item prepared followed by tea/coffee/hot chocolate and spaghetti/macaroni (Figure 5). Beans were the most common addition followed by fish or meat. Other additions include vegetables, legum (braised vegetables with sauce and coconut), eggs, etc (Figure 6).

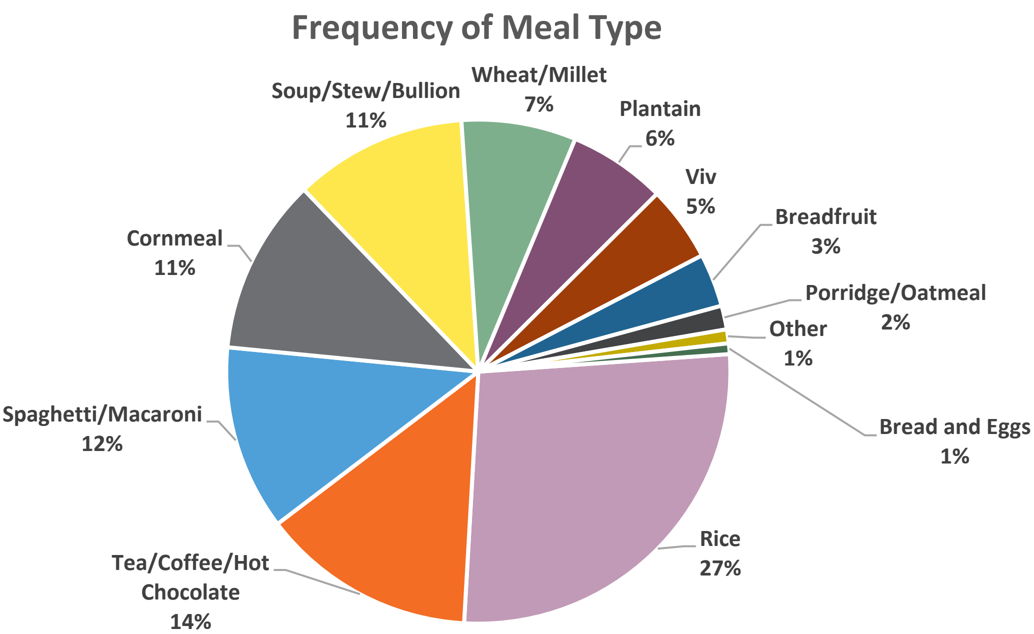


Figure 13: Frequency of Meal Type

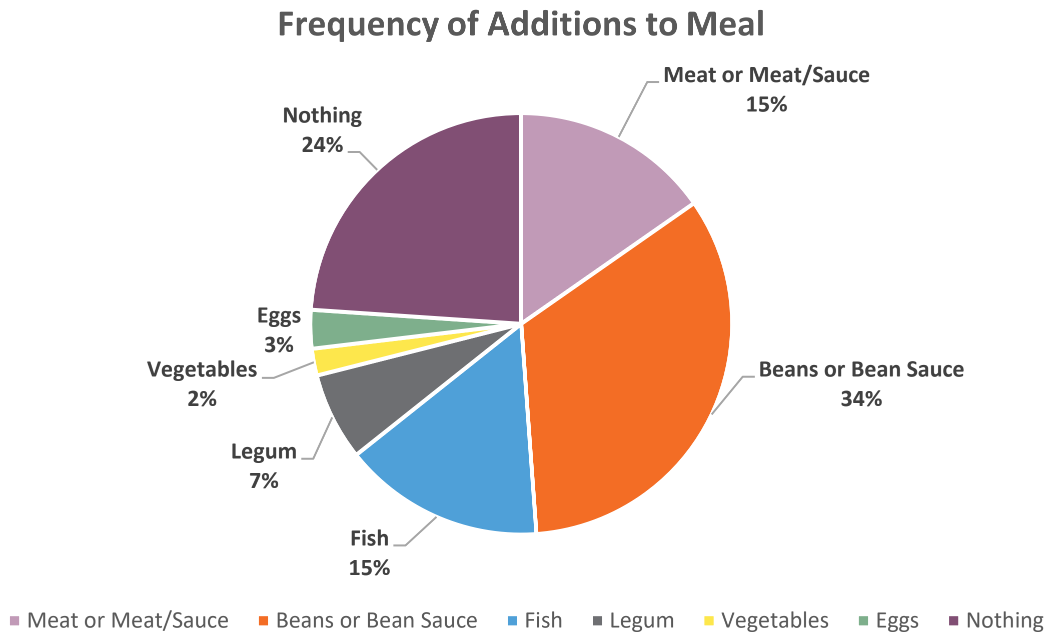


Figure 14: Frequency of Additions to Meal

Electric cooking

Participants also recorded estimated start and stop times for cooking. Despite some issues matching the energy diaries to the actual smart metering data, the diaries still highlighted changes in overall cooking/prepping times for baseline (mostly charcoal) and electric cooking. It is important to note that the times include prepping time not just cooking times and they came from participant reported start and end times which had some accuracy challenges because participants sometimes retroactively filled out their diaries, mislabelled entries (corrected where possible in review), only reported hours not hours and minutes, etc. Further, the groupings displayed below were assigned to each of the participants' entries which could have led to transcription or classification errors.

Despite these limitations, the diaries highlight a pattern that electric cooking significantly decreases cooking time, particularly for staple meal bases like breadfruit (53%), viv (51%), soup/stew/bullion (51%), wheat/millet (41%), spaghetti/macaroni (39%), rice (32%). Comparisons of participant recorded cooking/prep times can be seen in Figure 7 below.

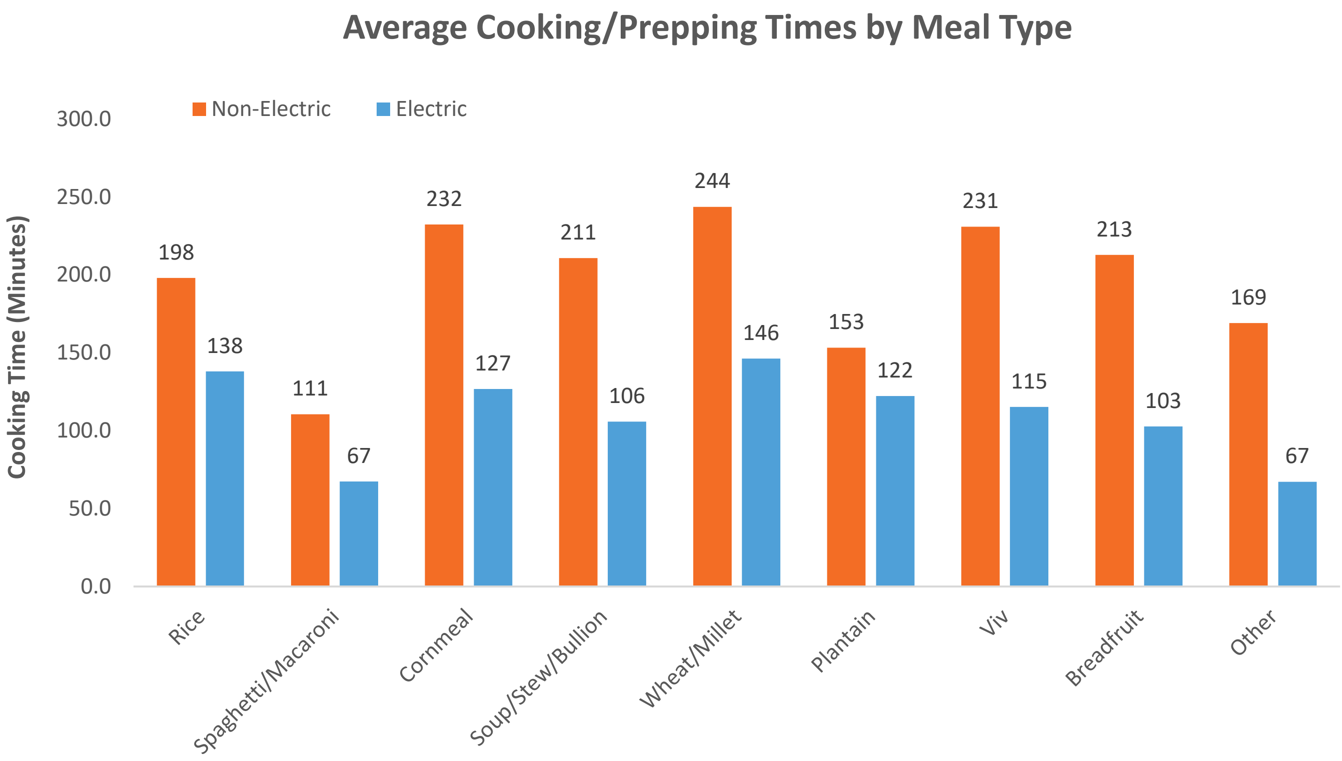


Figure 15: Average Cooking/Prep Times by Meal Type

Additional detail for meal cooking times can be seen in below. As above you can generally see a substantial decrease in cooking times for the staple meals and standard additions. With the aforementioned diary challenges, there are some comparisons that did not have observations for electric/non-electric cooking or did not have a statistically significant sample size (n>22), so those comparisons should not be viewed conclusively, but they are included for sake of completeness.

Table 2: Meal Comparisons Electric vs. Non-Electric

Meal (observations)	Average Cooking and Prep Time Non-Electric (minutes)	Average Cooking and Prep Time Electric (minutes)
Bread and Eggs (n=13)	71.00	65.00
Breadfruit (n=16)	160.42	56.00
Breadfruit w/ Fish (n=5)	286.67	127.50
Breadfruit w/ Meat or Meat/Sauce (n=2)	73.50	N/A
Breadfruit w/ Vegetables (n=6)	240.00	80.00
Bulgur Wheat (n=17)	160.80	77.92
Bulgur Wheat w/ Beans or Bean Sauce (n=32)	216.54	132.50
Bulgur Wheat w/ Fish (n=26)	232.86	111.25

Bulgur Wheat w/ Legum (n=11)	230.56	180.00
Bulgur Wheat w/ Meat or Meat/Sauce (n=11)	287.10	165.00
Chicken (n=3)	260.00	N/A
Coffee (n=98)	60.72	38.48
Cornmeal (n=40)	175.23	93.00
Cornmeal w/ Beans or Bean Sauce (n=112)	243.39	135.34
Cornmeal w/ Fish (n=34)	228.00	98.08
Cornmeal w/ legum (n=15)	258.13	200.43
Cornmeal w/ Meat or Meat/Sauce (n=14)	295.00	133.00
Eggs (n=9)	10.33	53.00
Filling (n=15)	26.33	N/A
Gratin (n=1)	250.00	N/A
Hot Chocolate (n=59)	68.94	56.60
Hot Water (n=3)	45.00	240.00
Millet (n=4)	150.00	125.00
Millet w/ Beans or Bean Sauce (n=24)	265.80	276.67
Millet w/ Fish (n=3)	345.00	N/A
Millet w/ Fruit (n=1)	N/A	60.00
Millet w/ Legum (n=1)	300.00	N/A
Millet w/ Meat or Meat/Sauce (n=10)	245.00	240.00
Pate (n=13)	200.00	68.00
Plantain (n=45)	119.66	109.88
Plantain w/ Beans or Bean Sauce (n=8)	225.00	147.50
Plantain w/ Chicken (n=2)	300.00	N/A
Plantain w/ Egg (n=13)	122.50	89.00
Plantain w/ Fish (n=24)	155.93	90.00
Plantain w/ Meat or Meat/Sauce (n=27)	193.47	172.64
Plantain with rice (n=1)	N/A	150.00
Porridge/Oatmeal (n=29)	89.14	61.75
Rice (n=66)	106.35	103.38
Rice w/ Beans or Bean Sauce (n=219)	203.17	130.18

Rice w/ Chicken (n=8)	192.50	210.00
Rice w/ Fish (n=62)	210.62	149.44
Rice w/ Legum (n=50)	213.28	147.78
Rice w/ Meat or Meat/Sauce (n=89)	225.42	190.73
Rice w/ Vegetables (n=19)	171.89	67.00
Soup/Stew/Bullion (n=189)	204.54	103.70
Spaghetti/Macaroni (n=226)	110.55	67.39
Tea (n=105)	44.88	51.57
TonmTonm (n=36)	232.26	144.00
Viv (n=6)	360.00	71.80
Viv w/ Beans or Bean Sauce (n=13)	154.83	109.86
Viv w/ Eggs (n=1)	N/A	60.00
Viv w/ Fish (n=34)	257.86	87.69
Viv w/ Legum (n=5)	200.00	120.00
Viv w/ Meat or Meat/Sauce (n=33)	221.88	153.82
Yam/Root Vegetable (n=3)	82.00	60.00

As above, there were issues matching the participants' energy diaries and recordings with the actual electricity data streams from the smart meters which resulted in electricity consumption data being presented per "cooking event[2]" as well as hourly, daily, and monthly averages as discussed below (see the supporting annexes for raw data).

[2] Defined as any time the pressure cooker or induction stove meters were recording power draw greater than 100W. Continuous 15-minute intervals represent the same "cooking event"

Figure 16: Microgrid participant cooking rice and vegetable sauce

Overall, from July 1 to November 10, project participants consumed 3,985 kWh. Off-grid participants accounted for 681 kWh and microgrid participants accounted for 3,303 kWh. This is in part because there were fewer off-grid participants and they generally were connected later than microgrid participants. Even once all participants were connected, off-grid participants only accounted for 16.6% of energy consumed. When comparing devices, the induction stoves accounted for 2,767 kWh (69.4%) and the pressure cookers accounted for 1,218 kWh (30.5%). Once all participants were online, overall daily consumption averaged 53.8 kWh (5.6 kWh off-grid, 56.0 kWh microgrid). Daily induction stove use averaged 38.0 kWh and daily pressure cooker use averaged 15.9 kWh (Figure 8) (Figure 9).

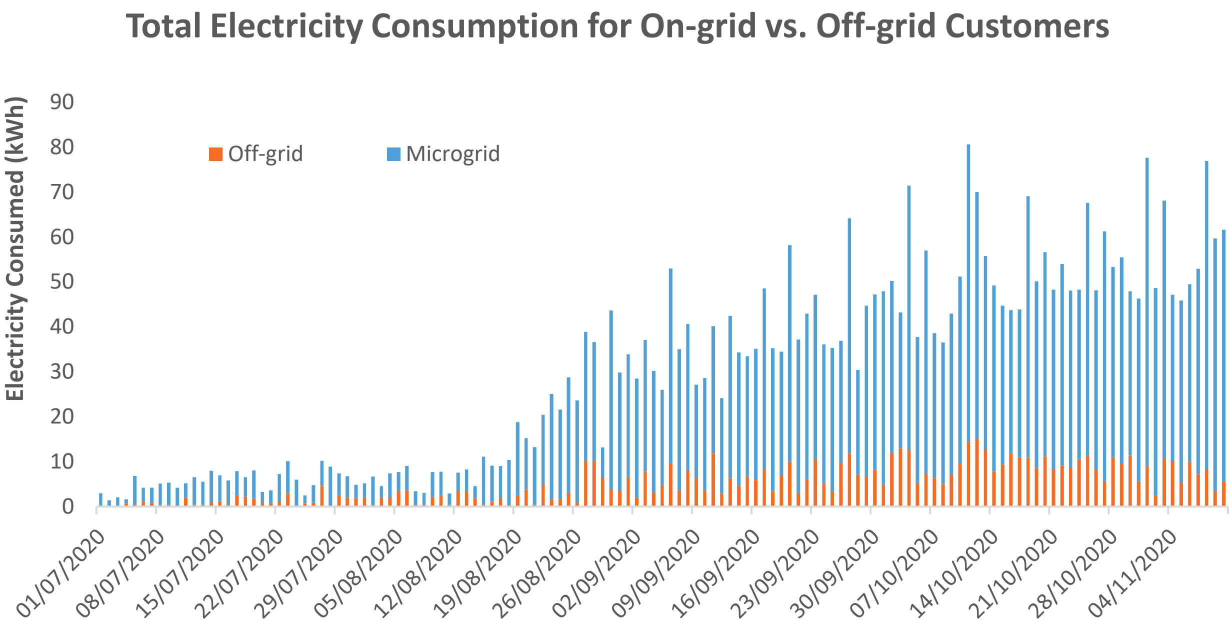


Figure 17: Total Electricity Consumption for Microgrid vs. Off-grid Customers

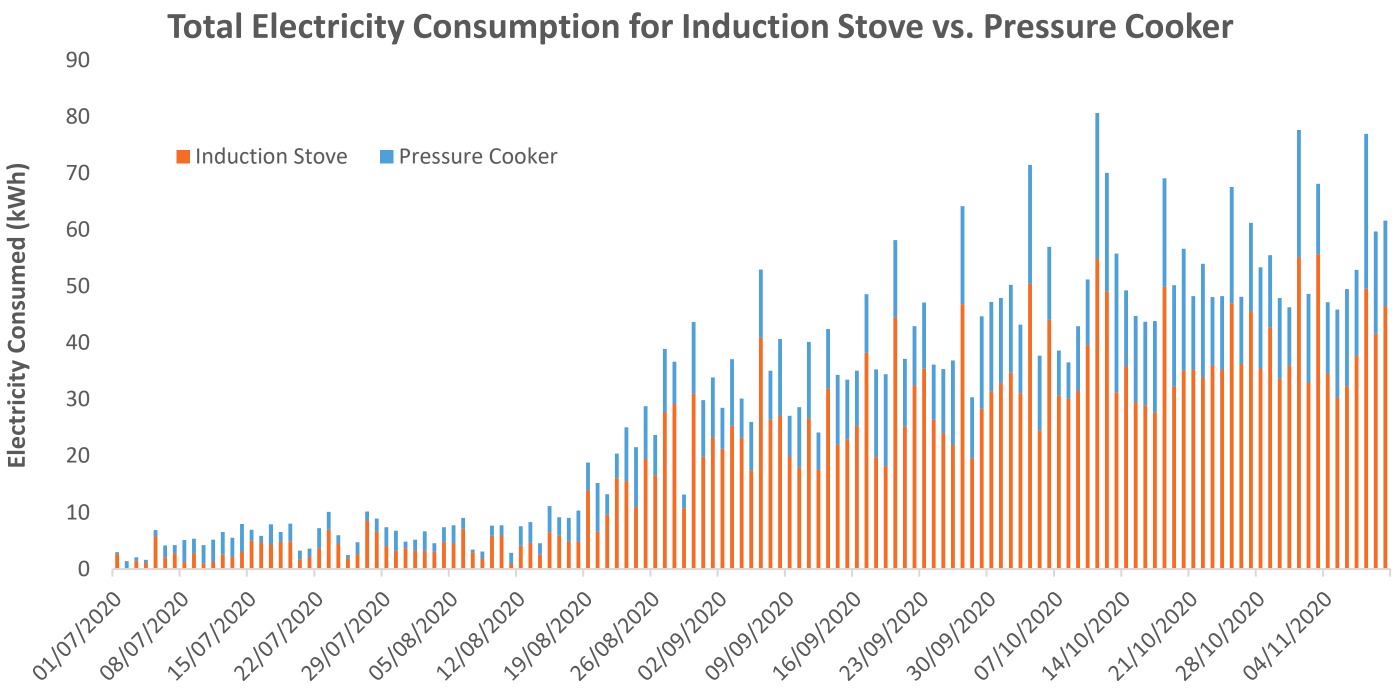


Figure 18: Total Electricity Consumption for Induction Stove vs. Pressure Cooker

Once all participants were online, average hourly consumption at the grid level was 2.26 kWh with the majority of consumption (61%) occurring between 9 AM and 4 PM. This consumption aligns with high solar production for the grid (discussed below). As above, average hourly consumption also differed by device and customer type. The induction stove averaged 1.61 kWh and the pressure cooker averaged 0.70 kWh (Figure 10)(Figure 11). Unfortunately, with instability in meter communications for off-grid meters, intervals are only recorded intermittently with single intervals accounting for the consumption in other periods. This lessened available hours to calculate true hourly averages and load profiles for off-grid participants. Consequently, the hourly averages for off-grid participants are reflected as lumpier and higher (for certain hours) than actual consumption patterns.

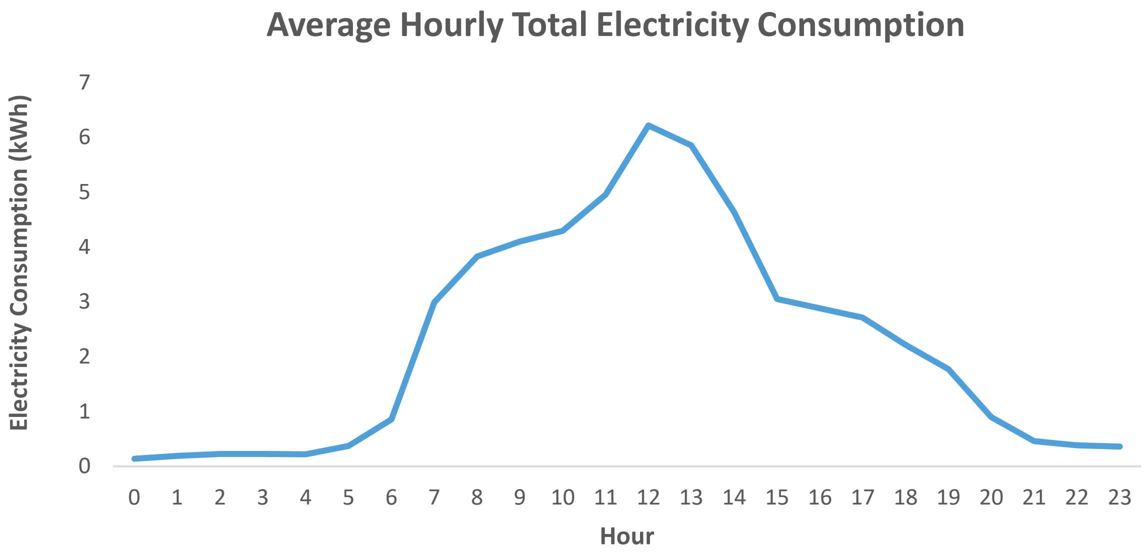


Figure 19: Average Hourly Total Electricity Consumption

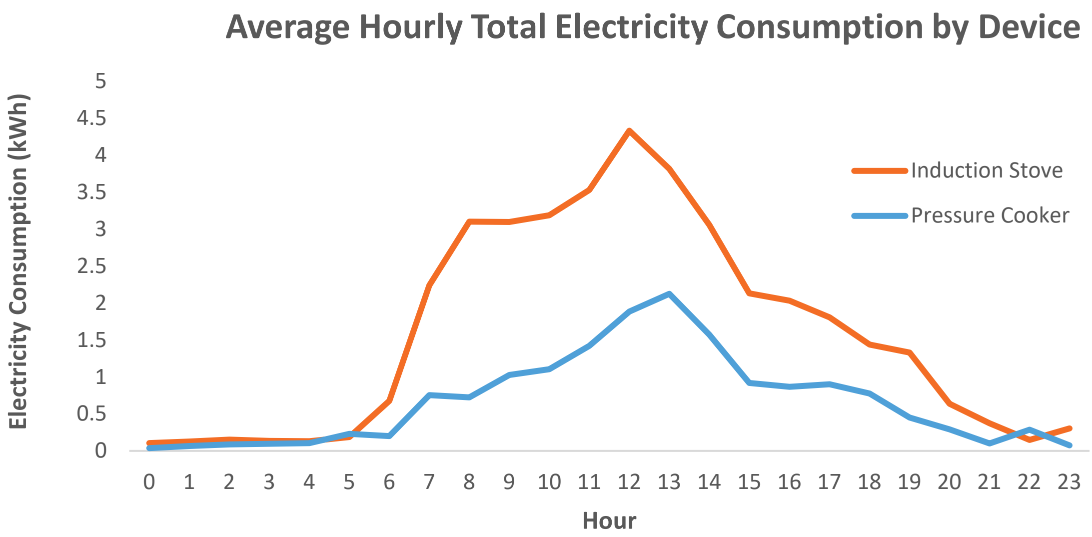


Figure 20: Average Hourly Total Electricity Consumption by Device

In the observed period, there were an estimated 3,820 electric cooking events (1,372 pressure cooker, 2,448 induction stove, 166 with both) totalling an estimated 3,713 hours of cooking and 3,979 kWh of electricity. On average the cooking events lasted 58.8 minutes (50 minutes pressure cooker, 66 minutes induction stove, 112 minutes both) and consumed an average of 1.05 kWh (0.83 kWh pressure cooker, 1.14 kWh induction stove, 1.63 both) (Table 2). As above, unfortunately, with instability in meter communications for off-grid meters, cooking events were only recorded intermittently with single intervals accounting for the consumption in other periods. That lessened the intervals recorded for calculating cooking event time. Accordingly, the cooking event comparison cannot be made effectively for microgrid vs. off-grid participants.

Table 3: Cooking Events by Device

Device	Total Cooking Events	Total Cooking Event Time (hours)	Average Cooking Event Time (hours)	Total Cooking Event Energy (kWh)	Average Cooking Event Energy (kWh)
Pressure Cooker	1,372	1,135	50.00	1,127	0.83
Induction Stove	2,282	2,271	60.23	2,583	1.14
Both	166	307	111.73	269	1.63
Total	3,820	3,713	58.79	3,979	1.05

Cooking event data also showed significant ranges for individual customers. On average, customers used electric cooking in 79% of their observed days, but several customers used electric cooking nearly every day of the study. There were some technical and equipment challenges (discussed below) that account for some of the non-use days. For the three customers with below 50% utilization, two of them were dealing with sickness in the family and/or the primary user and the third wasn't too motivated to use the electric cooking devices.

Cooking event summaries for individual participants are shown below with yellow blazes to indicate off-grid participants (Table 3).

Table 4: Electric Cooking Events by Customer

Participant	Starting Date	Total Days	Prop. of Days with Electric Cooking Use	Avg. Electric Cooking Events per Day	Avg. Electric Cooking Time per Day (hours)	Avg. Electric Cooking Energy per Day (kWh)
1	7/7/2020	126	86%	1.64	1.40	1.09
2	7/6/2020	127	95%	2.95	2.53	2.48
3	7/4/2020	129	98%	2.59	1.50	1.55
4	8/14/2020	88	74%	0.24	0.07	0.89
5	8/25/2020	77	40%	0.88	1.35	1.34
6	8/30/2020	72	78%	2.42	1.80	1.28
7	9/29/2020	42	79%	2.16	2.11	2.52
8	8/22/2020	80	99%	2.59	4.28	3.80
9	8/30/2020	72	99%	3.41	5.08	4.91
10	8/17/2020	85	73%	1.06	0.73	0.73
11	9/5/2020	66	65%	0.96	0.72	0.90
12	9/6/2020	65	88%	1.77	1.63	2.00
13	9/1/2020	70	99%	0.62	0.17	1.06
14	9/1/2020	70	74%	0.10	0.02	0.49
15	8/24/2020	78	83%	0.44	0.12	1.51

16	8/22/2020	80	94%	2.47	2.67	3.13
17	8/25/2020	77	88%	1.85	1.63	1.94
18	8/25/2020	77	51%	1.15	1.04	0.91
19	8/18/2020	84	36%	0.39	0.18	0.39
20	8/20/2020	82	98%	2.76	3.63	2.98
21	8/20/2020	82	70%	1.10	1.00	1.26
22	7/1/2020	132	97%	2.44	2.73	2.35
23	8/16/2020	86	24%	0.34	0.30	0.31
24	8/16/2020	86	99%	3.13	3.65	2.80
25	8/14/2020	88	98%	2.84	2.10	2.31
26	9/26/2020	45	84%	0.22	0.06	1.20
27	9/27/2020	44	61%	0.16	0.04	1.06
28	9/28/2020	43	74%	0.14	0.03	0.88

At the individual customer level, consumption and device preference varied significantly. Overall, individual customers averaged 1.92 kWh per day. Average induction stove use was 1.58 kWh per day and average pressure cooker use was 0.79 kWh per day. Off-grid customers consumed an average of 1.18 kWh per day, while microgrid customers consumed around 2.4 kWh per day. Average overall consumption (including non-cooking hours) for individual customers averaged 0.30 kWh per hour in a day. Individual customers' induction stove usage averaged 0.28 kWh per hour in a day, while their pressure cooker usage average 0.15 kWh per hour in a day (Figure 12)(Figure 13).

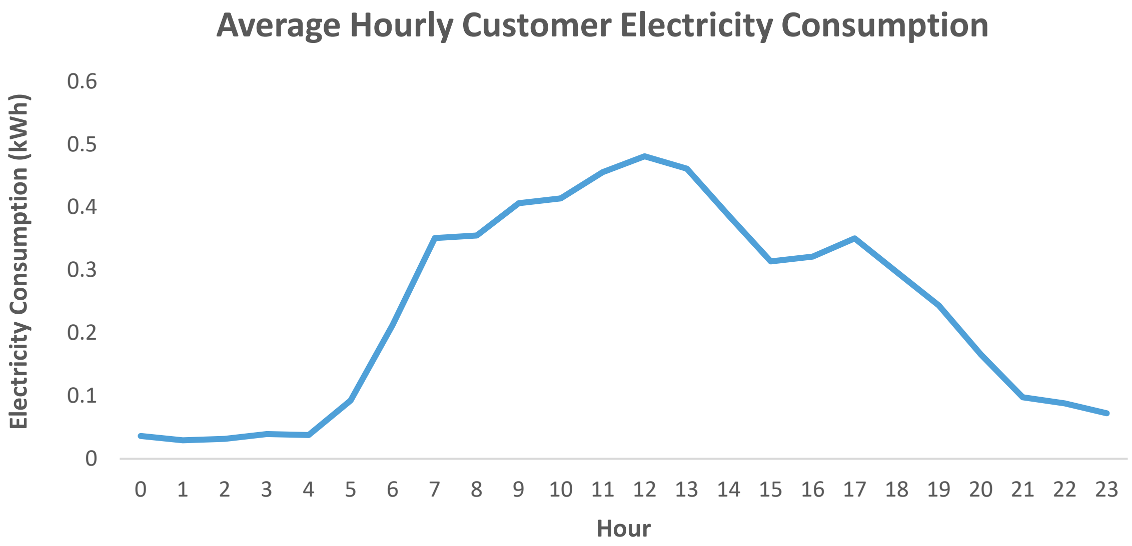


Figure 21: Average Hourly Customer Electricity Consumption

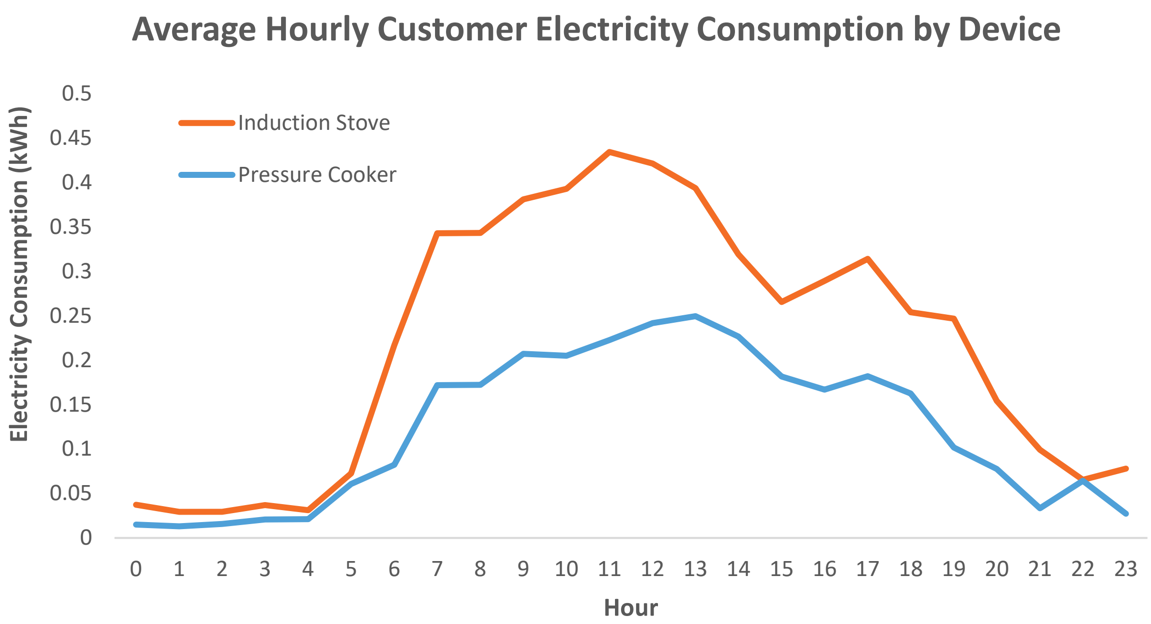


Figure 22: Average Hourly Customer Electricity Consumption by Device

Microgrid operations and power quality

The electric cooking pilots added significant load to the existing microgrid in Les Anglais. For example, in the month of October total average daily load increased 20% because of electric cooking load. Individual hourly consumption on the grid also increased by an average of 19%, but from 8 AM to 2 PM hourly microgrid load increased 42%-55% as a result of electric cooking (Figure 14)(Figure 15).

On normal sunny days, the microgrid has enough extra solar + storage capacity to absorb the cooking load, particularly since it is aligned in the middle of the day, but when solar production is low due to cloudy days and rain, the microgrid has seen increased diesel generator usage and on a few occasions blackouts due to overdraw of the generator. At the highest-level, monthly generator use increased 33% from the start of the cooking pilot in July to the end of October. It should be noted that other significant loads were added to the Les Anglais system in July 2020 when the electric cooking pilot started, in particular two telecommunications towers which were themselves a significant draw on the system, so the increase in generator use is not fully attributable to electric cooking.

This illustrates the significant impact that electric cooking load has had on microgrid operations. In general, the additional draw on the grid is beneficial to the business model of microgrid operations because the draw coincides with the least-cost energy production. When solar energy generation is low, however, the electric cooking can be expensive or technically detrimental to the grid. As anticipated, this finding underscores the importance of 1) deferrable loads on the grid during low sun days or plans to add additional generation capacity and 2) time-of-use cooking plans to prevent instantaneous demand from exceeding supply. In the future it may also be possible to integrate weather conditions into cooking tariffs (i.e. sunny day tariffs for electric cooking).

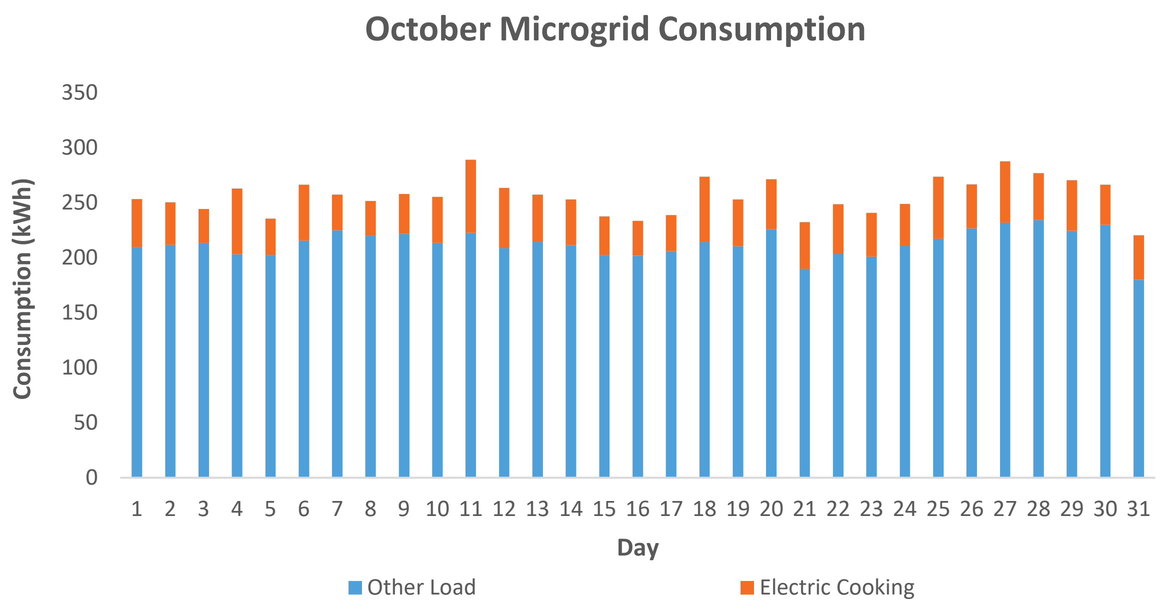


Figure 23: October Microgrid Consumption by Day

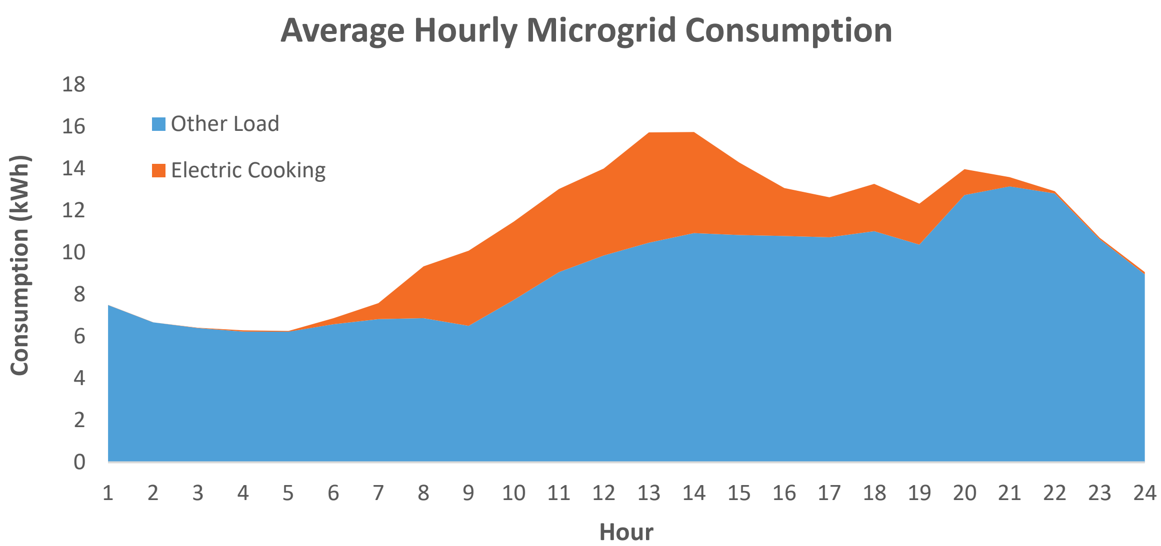


Figure 24: Average Hourly Microgrid Consumption

Electric cooking did seem to have some impact on delivered voltage, particularly on certain distribution lines, but overall delivered voltage stayed within normal +/- 5% ranges to the customer devices. The histograms below show a number of 0 readings at the left tail of the histogram which were mostly the result of meters being left on with no electric cooking load (Figure 16) (Figure 17).

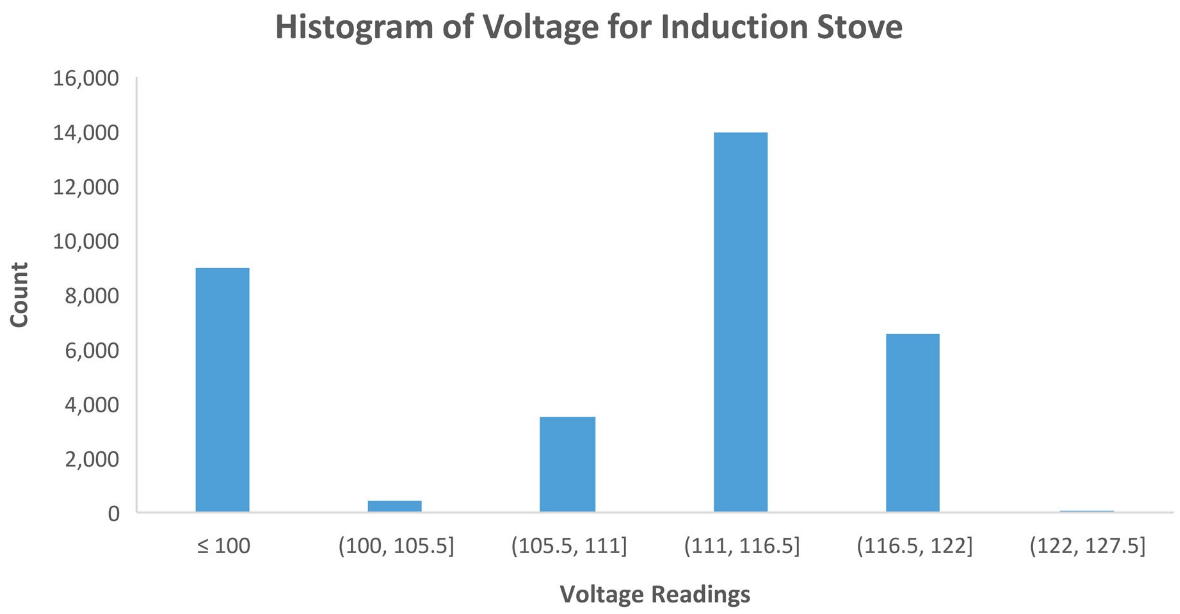


Figure 25: Histogram of Voltage Recordings for Induction Stoves

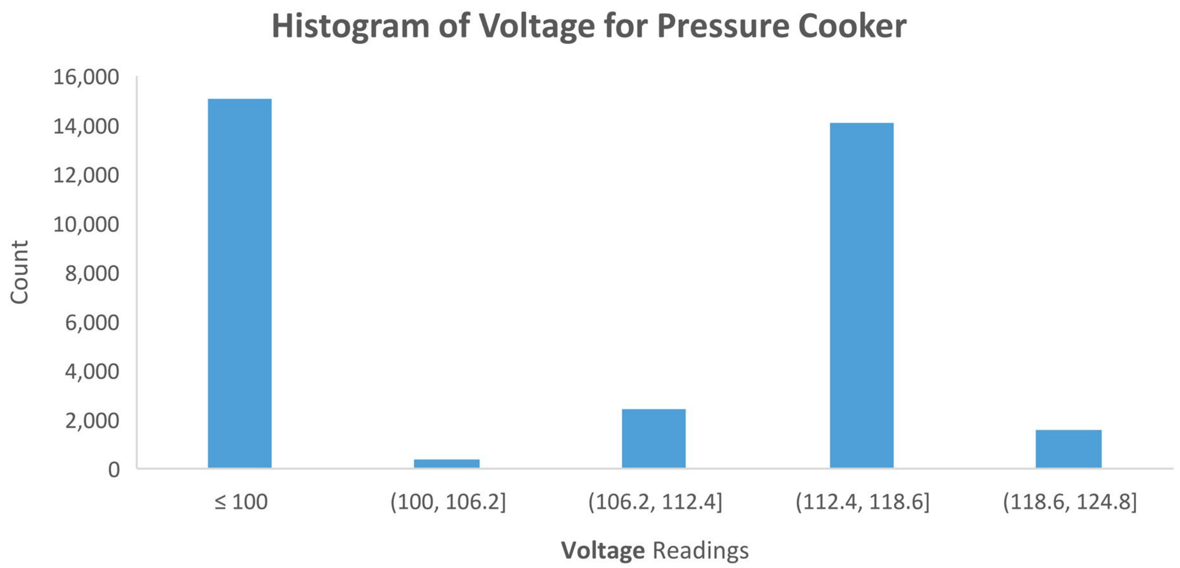


Figure 26: Histogram of Voltages for Pressure Cookers

Customer Surveys

Customer satisfaction surveys were conducted for each of the participants. Participants were asked a variety of questions about charcoal consumption, cooking frequency, free time, etc. before and after electric cooking. Additional discussion of the findings can be seen in the “Changing the narrative section” below. A template for the surveys and the raw survey data is included in the supporting annexes.

The electric cooking participants were very categoric in their response: the cooking appliances are absolutely life changing. The most mentioned benefit was the amount of time saved cooking with electricity rather than using charcoal. Beans are very present in Haitian cuisine and it can take at least two hours to get the dry beans ready for the meals. With the use of the electric cooking appliances, this time has been reduced by more than half. Cooked for about 30 minutes in the Simpot, dry black beans can be ready for consumption. The same beans would take at least 1.5 to 2 hours on charcoal including the time to get the charcoal hot enough to be able to cook food.

Figure 27: Microgrid electric cooking participant in her kitchen

Some participants mentioned how sometimes the charcoal that is available at the market is not good enough and doesn't even last a long time. This brings us to the next benefit mentioned, which is the amount of money saved from not having to purchase or from purchasing less charcoal. Responses from some participants stressed the ever-increasing price of charcoal, which represents a big expenditure for the household. It is interesting to note how a higher percentage of microgrid participants reported saving money on charcoal than off-grid participants. The reason for this is because the off-grid participants' SUNSPOT might not allow them to cook on it if it has been raining for many days in a row. Under this circumstance, the off-grid participants always needed to have a supplementary fuel source.

Some off-grid participants mentioned the additional benefits of having lighting and a power outlet in their homes with the SUNSPOT. Some of them would normally use kerosene lamps or rechargeable lights for their homes but they now have a light point with the system, that works even when the weather is too bad for electric cooking to be possible. The ability to charge phones for themselves and some people in their family and neighbourhood has been mentioned and this allows the participants to save more money as they no longer need to go to phone charging businesses to have their phone batteries charged (Figure 18).

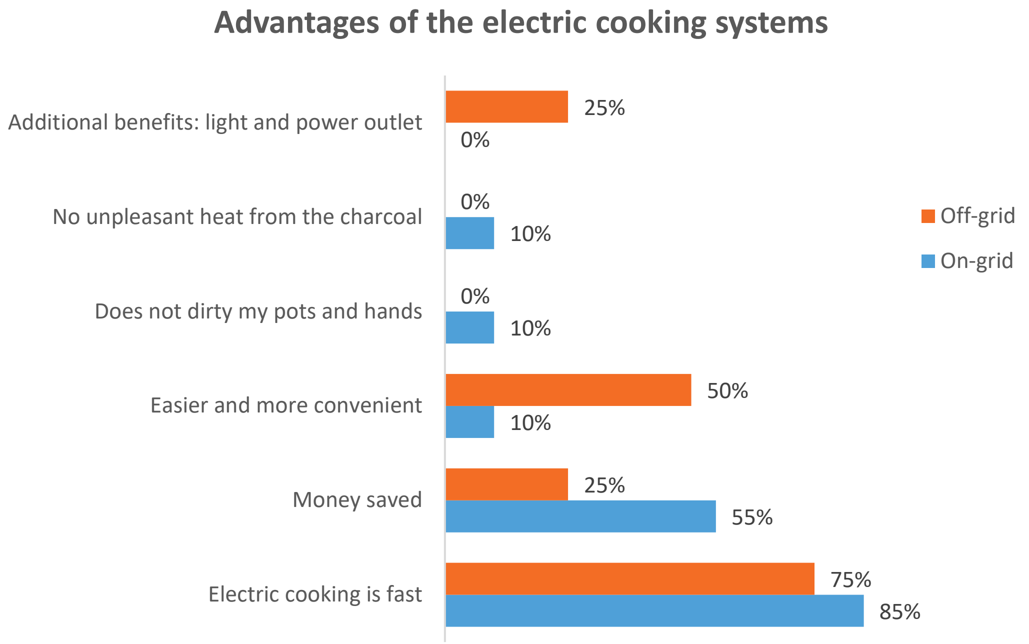


Figure 28 : The benefits of electric cooking as mentioned by the cooking participants

Forty-five percent (45%) of participants responded that they increased their cooking frequency as a result of the electric cooking devices, while 48% responded that there was no change, and 7% replied that it depended on finances available for purchasing additional food to cook (Figure 19).

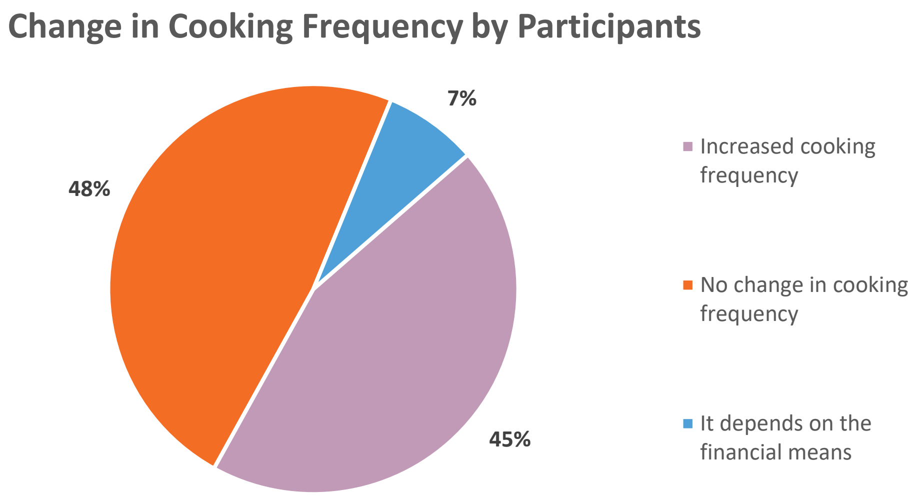


Figure 29: Change in Cooking Frequency by Participants

All participants responded that electric cooking saved them time compared to status quo cooking. 78% of participants indicated that they used that time for relaxing, 33% for household chores, 15% for focusing on business and income tasks, 7% for self-care, and 7% for family care (Figure 20).

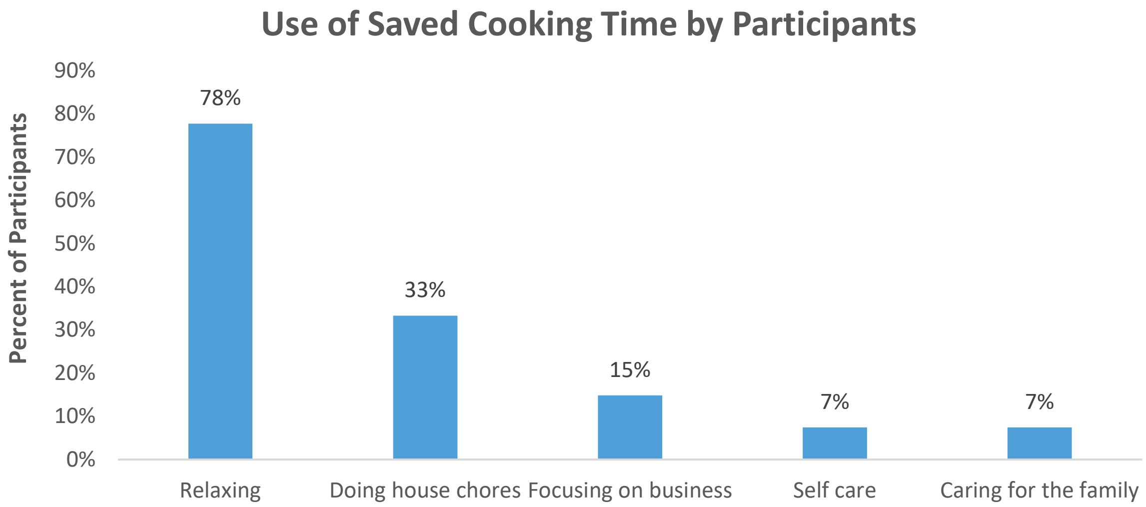


Figure 30: Use of Cooking Time by Participants

The cooking participants were asked about the number of people who are being fed on a daily basis from their kitchen. The smallest number mentioned was two people, and this is for a couple whose children are schooled in other towns, which is customary in rural Haitian families. The largest number mentioned by cooking participants was 13, and this includes not only family members but neighbours and friends as well those who regularly eat at the participant's house. The majority of participants were serving between 4 and 10 people with household cooking (Figure 21).

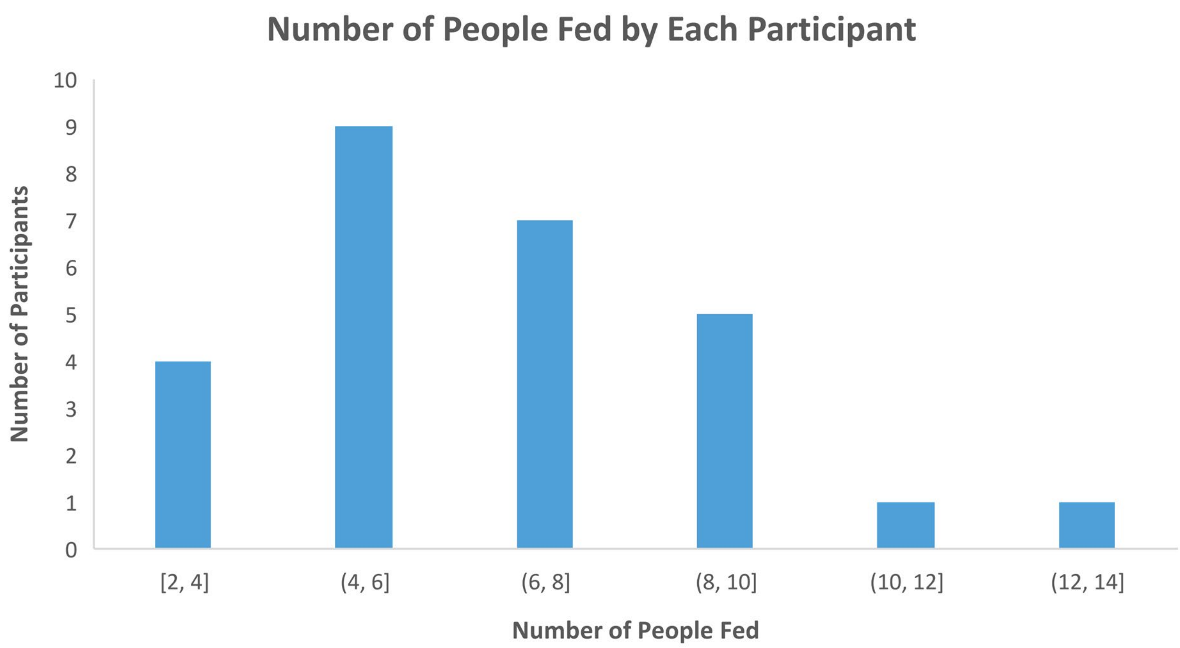


Figure 31: Number of People Fed by Each Participant

In a small town like Les Anglais, it is not uncommon to have more than 1 house in a “lakou” (yard) where the extended family or a neighbour live. Depending on the relationship among the various people, they might cook and eat together or the head of one household could cook and send food to the other houses. Figure 22 below gives an idea of the different categories of people the cooking participants prepared food for. The category with the highest frequency is “Household and family only” and it does not always refer to a nuclear family only but also includes in some cases cousins, aunts, brothers, parents that live in the same yard or under the same roof.

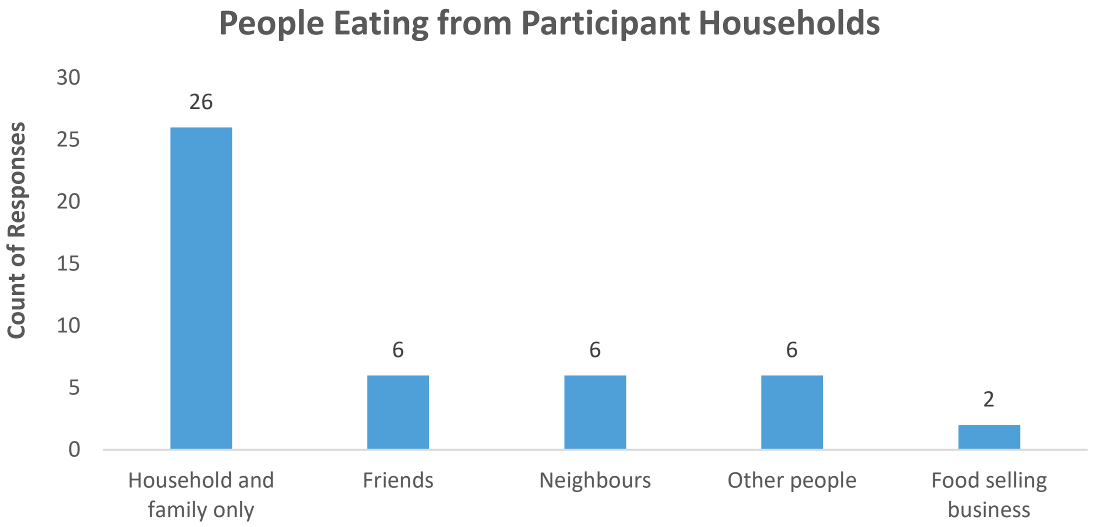


Figure 32 : Composition of people eating the meals prepared

Electric cooking participants were also asked about their charcoal expenses before the start of the project and three months into the project. For some participants, charcoal has disappeared completely from their kitchen. For others, there has been no change in consumption or no change in the amount spent on charcoal. This can be explained by a few factors:

i. The participants have a food selling business, where they sell BBQ chicken. They are now able to divert more charcoal towards their business as they remove it from their kitchen.
ii. Some participants do not purchase charcoal but produce it themselves. So, their charcoal expenditure has not been affected by the project.
iii. Some participants still purchase charcoal but instead of consuming all of it, only save some as a backup fuel and then sell the rest.

Monthly charcoal expenditures for participants before electric cooking ranged from 525 htg ($8.28 USD) – 9,300 htg ($147 USD).[3] with an overall average of 2,538 htg ($40.28 USD) and an average of 2,278 htg leaving out the highest expenditure participant. After electric cooking, expenditures ranged from 0 htg ($0 USD) to 6,200 htg ($98 USD). Most participants saw savings as a result of

[3] It should be noted that there are several participants with higher expenditures that utilize charcoal for food service businesses.

electric cooking, with 13 participants saving between 80% and 100% on monthly charcoal expenditures (Figure 23)(Figure 24).

Figure 23 highlights the change in before (blue) and after (orange) expenditures for each customer. It should be noted that participants 8, 18, and 20 all utilized charcoal significantly for selling food instead of solely self-consumption. Other high expenditure participants cooked very often or for a lot of people. Some households didn't record a before expenditure baseline (4, 8, 13, 15) and some households didn't record any expenditure values at all (6, 14, 24). Otherwise, most of the customers saw a clear decrease in expenditures.

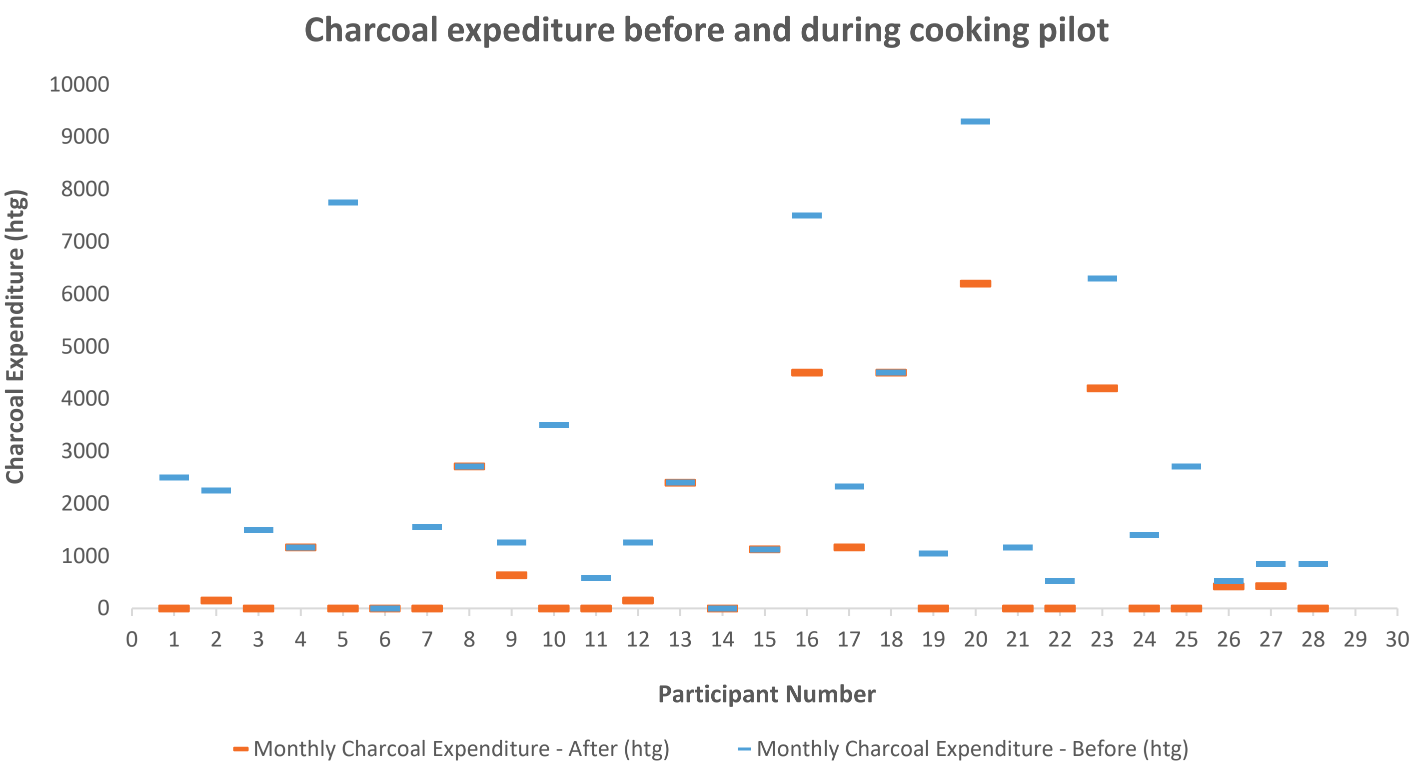


Figure 33: Average Monthly Charcoal Expenditures Before and After

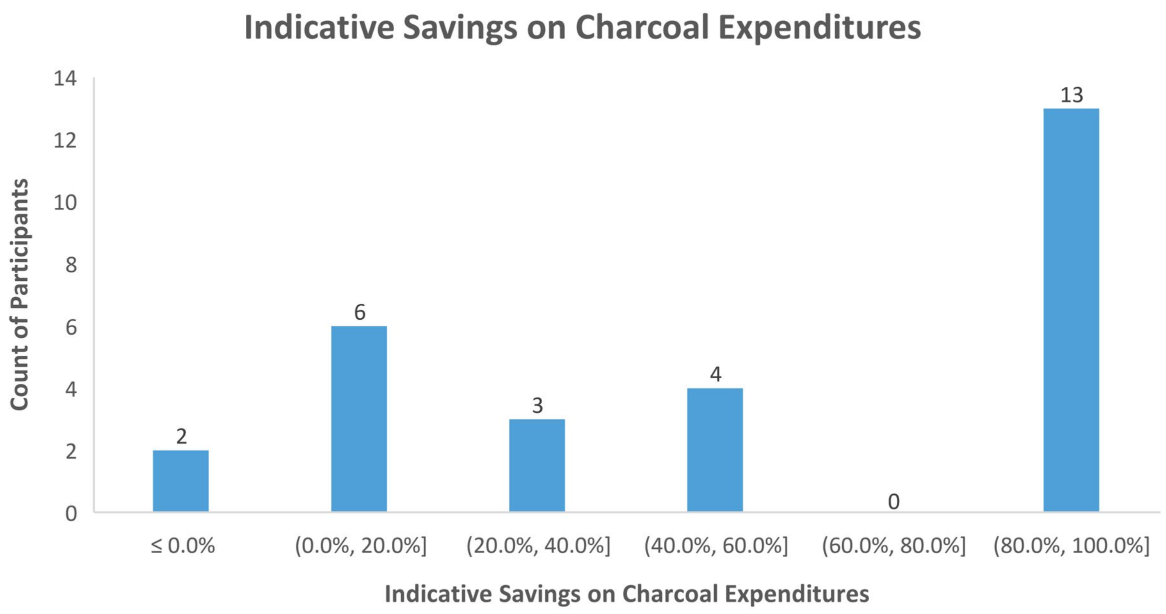


Figure 34: Indicative Savings on Charcoal Expenditures

Since most of the electric cooking project participants reported saving money on charcoal (other baseline fuels were utilized, but primarily fuel use was charcoal, so expenditures focused solely on charcoal), they were asked about how they were planning on using those savings. The most popular response was investing it in schooling either for themselves or for their kids. The second most popular response was to invest in their own business. Now that some money is available, participants can buy in greater bulk quantities for some products. One ice-cream maker mentioned how she can now produce twice the amount of ice cream as she is able to buy more ingredients. This in turn, is helping her generate extra revenue from her business.

Another interesting response was the ability to now buy more nutritive food. Some participants are not putting aside the money they are saving for future use. Instead, some mentioned that they are now able to buy better quality food like better meat cuts, more frequently. Many of those food products were not within their financial capacity, but they can now afford it (Figure 25).

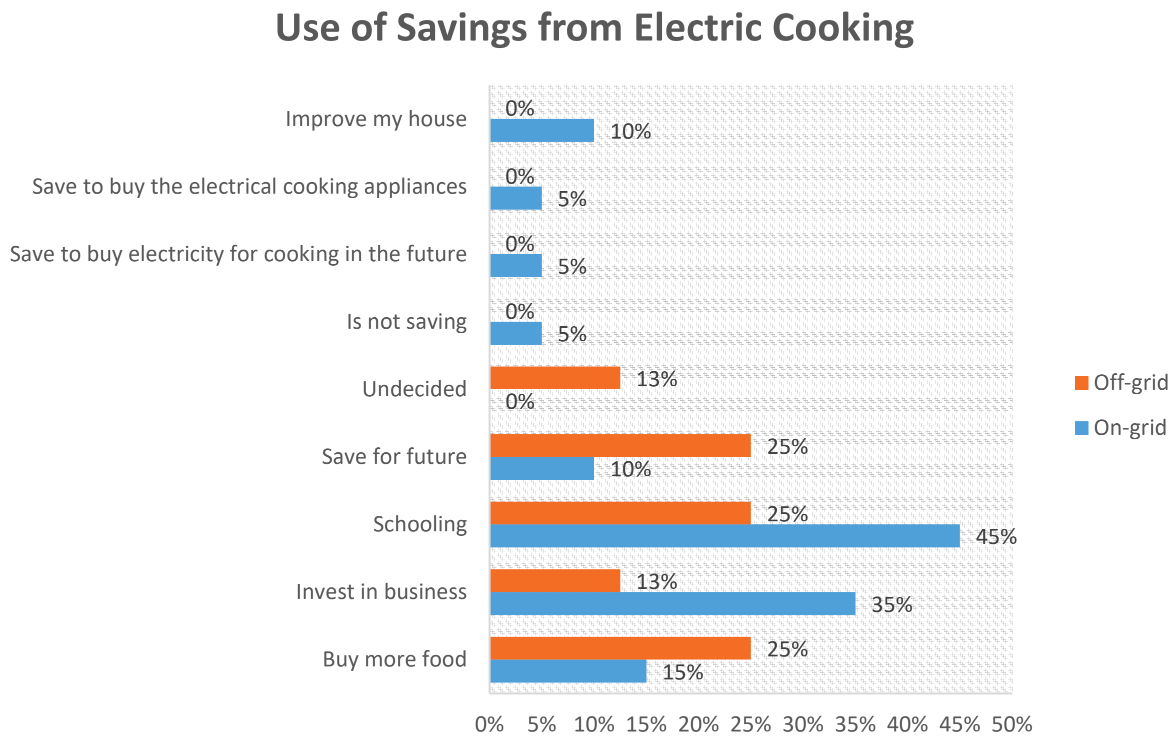


Figure 35 : Projected use of savings made during the electric cooking pilot project

Only a few challenges were mentioned by the electric cooking participants. The one that was mentioned almost as often by the microgrid and the off-grid participants was related to the size of the appliances and how that would in turn limit what they were able to cook with them. For instance, the Simpot is a 6-quart pot and is well sized for a small nuclear family of 5 to 8 family members.

However, beyond that number, it can be challenging to prepare some Haitian meals with the Simpot. One example is the rice and beans dishes (diri kole) which can be voluminous. Mashed breadfruit, called "tom tom" was also mentioned as a difficult meal to prepare with the electrical appliances. The breadfruits are normally boiled whole, and some families can boil up to 8 breadfruits at a time to feed everyone. The Simpot is too small to contain this volume and the pots available to use on the induction cooktop are also not big enough. For this meal, many participants go back to their traditional charcoal stoves and aluminium pots.

Another disadvantage communicated by some participants was that the ferromagnetic pots which were provided or available on the market in town or in the nearby towns were too thin. This would sometimes result in food being burned for some meals. For instance, rice cannot be cooked without risks of getting burned on the induction cooktop.

Another drawback of the system is how cooking can be disrupted if there is a power outage for the microgrid participants (i.e. if there is not enough sun during the day and the batteries do not get the chance to charge enough). Some of the off-grid participants for example keep a small amount of charcoal in stock and have no choice but to go back to the traditional, outdoor kitchen to prepare food on the charcoal stoves until the weather has improved sufficiently for the system to be operational (Figure 26).

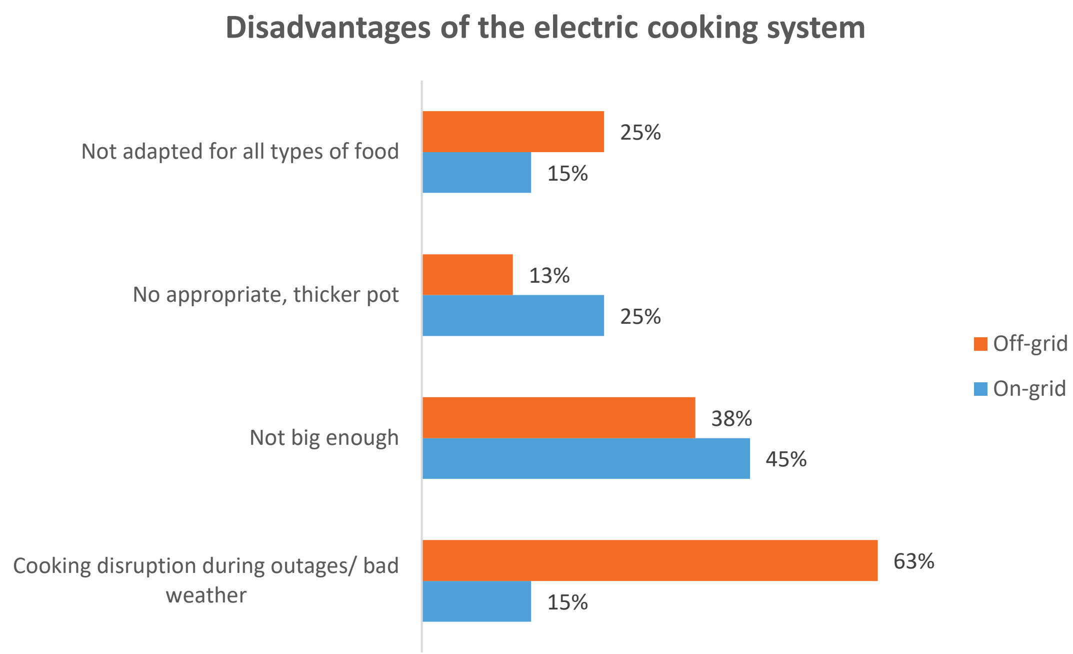


Figure 36 : Challenges of cooking with the electric cooking system

A deeper dive into the survey and specific narratives from participants can be seen in the Changing the Narrative section below. Further, participant profiles for four participants can be seen in the supporting annexes.

Tariffs and Cost

The research project offered free electricity for electric cooking to the participants in order to prioritize actionable data for planning electric cooking. Even though there was an absence of a true price signal and therefore data on demand elasticity for customers, we can still draw some insights on what effective tariffs might be for electric cooking interconnected on EarthSpark's microgrids. In general, EarthSpark offers different levels of time varying prices to its customers depending on their service level ranging from 25 htg/kWh – 60 htg/kWh. Currency fluctuation changes this range substantially, but as of December 2020 this was equivalent to about 40 – 95 cents per kWh.

By dividing customer charcoal expenditure savings by the monthly electric cooking electricity consumption, a range of indicative willingness to pay values are highlighted. Overall average indicative willingness to pay was around 30.76 htg/kWh. However, 13 of our participants reported an indicative tariff at or above existing EarthSpark tariffs and 4 customers highlighted extraordinarily high economic value for the electric cooking (>100 htg/kWh). If the four high WTP customers are removed indicative average WTP drops to 15 htg/kWh, which is still close to normal tariff range.

Some customers, however, did not report charcoal savings (or charcoal information at all) and some reported very low savings (or high electric cooking usage which distributed those savings) which resulted in very low to zero willingness to pay values. Many of those customers have charcoal consumption or use (i.e. food service enterprises) that couldn't fully be replaced by the electric cooking deployed in this project. There are of course lots of other factors to consider, but these values coupled with customer survey responses at least highlight potential pathways for certain customers to cost effectively utilize electric cooking on microgrid tariffs compared to baseline alternatives if initial capital costs for equipment can be met (discussed later).

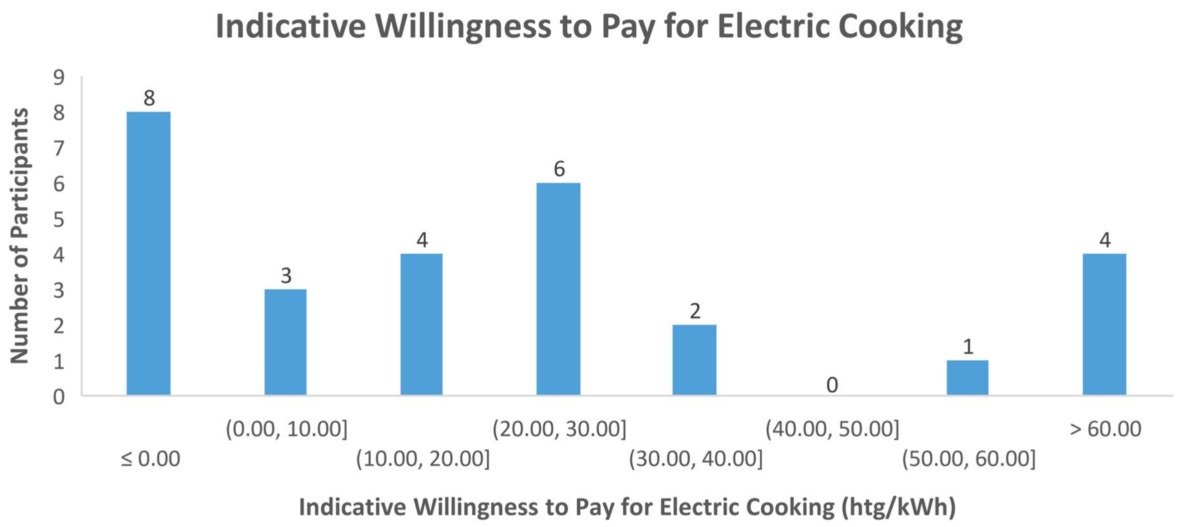


Figure 37: Indicative Willingness to Pay for Electric Cooking

Off-grid outlet

One of the notable additions for the off-grid system was the 3rd outlet (usb and AC outlet) to support basic energy access needs including lighting, small radios, and cell phone charging. Over the course of the study the off-grid participants utilized 29.6 kWh of electricity and were very excited about the opportunity (see changing the narrative section below). Daily usage averaged 0.06 kWh per customer and overall average hourly usage was 0.011 kWh, but ranged from 0.002 to 0.025 kWh across the eight customers (Figure 28).

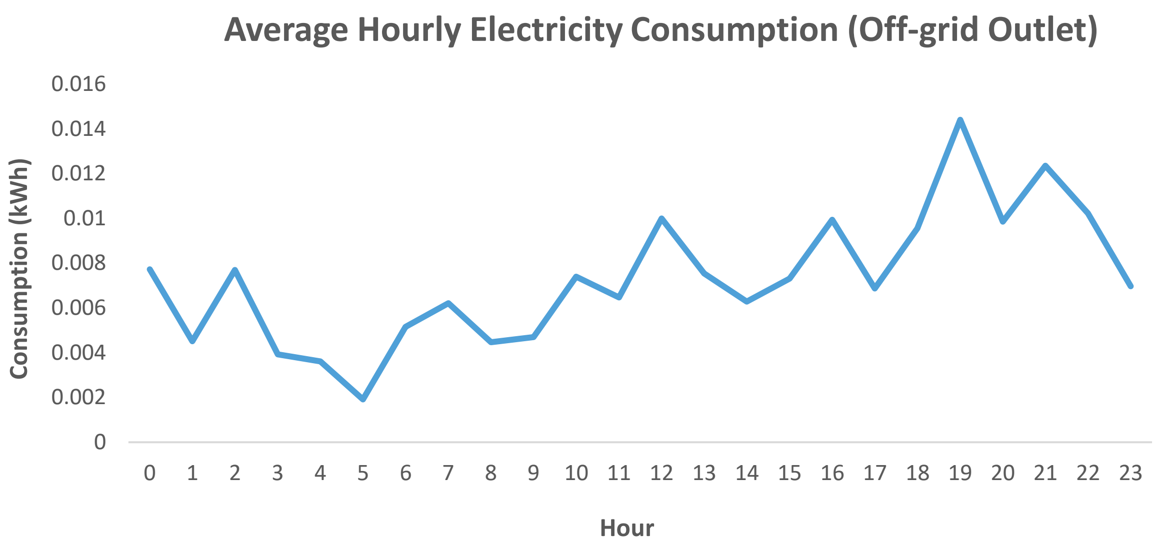


Figure 38: Average Hourly Electricity Consumption (Off-grid Outlet)

4. Key Takeaways

The biggest takeaways from the project results include:

1. Electric cooking significantly reduces the time burden of cooking, particularly for staple foods which creates significant time savings that can be used to open up opportunities for leisure, income, education, and family care.
2. Participants utilized the induction stove more frequently and more intensively than the electric pressure cookers, but both devices showed significant daily usage.
3. Electric cooking load is concentrated in the middle of the day aligning with the traditional Haitian midday meal and peak solar generation.
4. Electric cooking noticeably increased grid loads and caused an increase in generator usage for the microgrid system even contributing to overloading of the generator on certain rainy days when combined with other grid loads.
5. The electric cooking participants saw a variety of benefits from electric cooking, particularly time saved during cooking
6. For many participants the frequency of cooking in their household increased with electric cooking because of the added convenience it offered over status quo fuels.
7. Utilization of the electric cooking solutions varied, but overall participants had sustained and high interest in and engagement with electric cooking devices.
8. Financial savings on charcoal expenditures following electric cooking deployment ranged significantly customer to customer, but the project highlights indicative willingness to pay values for many customers at or above current microgrid tariffs. This demonstrates potential pathways for the financial viability for powering electric cooking with well-designed microgrids.
9. Basic energy access is a critical benefit provided by the off-grid systems because it enables lighting and cell phone charging.

All of this highlights a crucial opportunity for electric cooking to be a catalyst for socioeconomic development and to help change the narrative on clean cooking in Haiti and beyond.

5. Changing the narrative on modern energy cooking services

Appliance performance and acceptance

Key questions related to the technical performance and acceptance of electric cooking are discussed individually below:

1. ***Did you have any issues with the performance of the appliance during field trials/testing/use?***

There were several issues reported by participants that were managed throughout the pilot project. In general, the cooking appliances met expectations for fast cooking. The induction cooktop proved to be more efficient than expected, since at the lower levels it consumes less power. With that, participants were advised to stay at lower power levels to limit battery discharge during cooking for off-grid participants and to stay within the limitations of the smart meters, for the microgrid setups.

During field trials, a few ideas were brainstormed regarding the microgrid set up to assess the number of meters needed, the installation in people's kitchens, and also the materials needed to make the electric cooking most advantageous to the participants. Initially, the idea was to use two connected switches that would operate like a knife switch, such that only one cooking appliance would be operational at a time. This would have reduced the amount of materials used for the setup, whilst keeping the granularity of the data collected by the only meter that would be required. However, this setup did not meet quality and safety requirements and would have limited the cooking experience, hence the idea was abandoned in favor of the final setup illustrated in Figure 29 below.

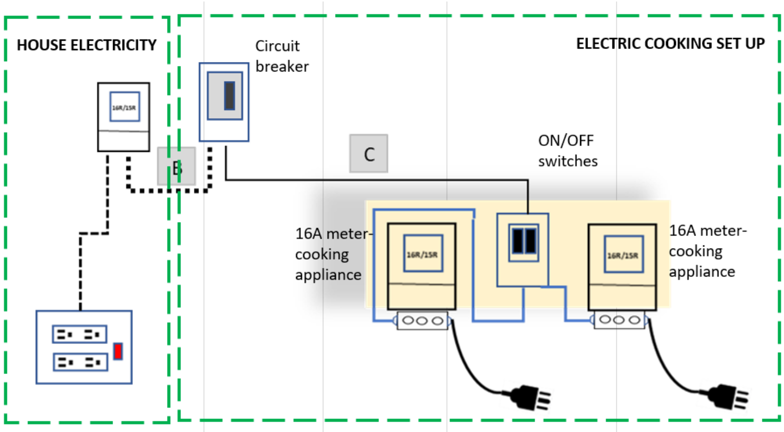


Figure 39: Electrical Setup for the Microgrid Electric Cooking Pilot

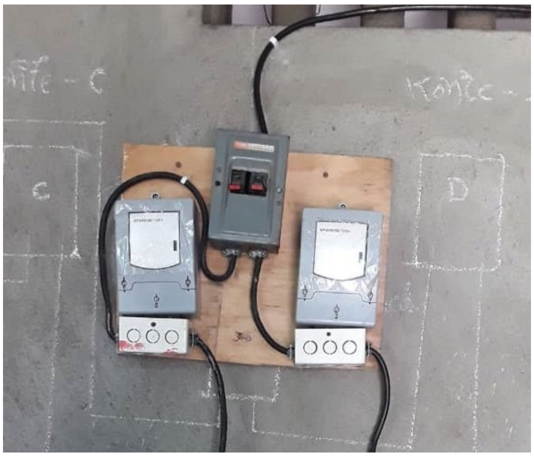


Figure 40: Microgrid electric cooking setup, with two meters and two individual switches, installed in a house

Figure 30 above shows the final electric cooking setup installed in a participant's kitchen. The setup included two smart meters, one for each appliance, and a load center with two individual switches. White chalk marks are also visible on the wall, showing the previously planned installation set up that did not include the anchoring piece of plywood.

One challenge was to make sure that no participant could tap into the meters and have free electricity for purposes other than electric cooking in their homes. This was overcome by installing a junction box underneath the appliances' meters to eliminate access to the meters' inlet and outlet electrical ports. Another challenge was to make sure that other appliances would not be plugged into the electrical cooking setup. This was achieved by cutting off the cooking appliances' prongs and replacing them by a receptacle outlet and having the prongs coming directly from the smart meters instead. Though this does not make the system 100% theft proof, tampering would most likely be noticeable Figure 31.

Figure 41: Smart meters with junction box installed underneath to eliminate access to the meter outlet ports and unauthorized connection.

For the installation of the SUNSPOT systems, there were no major challenges. One modification that had to be made was for some of the wooden boxes which were found to be incorrectly assembled when electrical installation was about to take place. Fortunately, all of them were made by a local carpenter who was able to quickly fix the mistake (Figure 32).

Figure 42: Wooden boxes for off-grid applications

For setting up the SUNSPOT, there were no difficulties as a setup video was available from which an electrical schematic was derived and drafted to facilitate the process for the team of technicians.

Figure 43: SUNSPOT assembly by EarthSpark staff

During field testing, all induction cooktops and Simpots were tested with a power source to ensure that all of them were functional. All devices turned on and turned off normally. At this stage no specific fault in certain specific functionalities of the appliances could be identified. Further, for off-grid systems, all battery voltages were measured and noted. All were above 12.6V as required. All panels' OCV were also verified and none found to be faulty. This process was facilitated by a QA/QC testing guide provided by SUNSPOT.

During field use, however, a few issues were reported by the participants and all of those were noted and compiled in a document for issue tracking and resolving and for future reference (see the supporting annexes).

A summary of a few issues is provided below:

1. During the initial deployments, one induction cooktop was declared faulty when it stopped working during operations. The product was inspected but the root cause for the issue was not fully identified. It is, however, suspected that it stopped operating due to insufficient ventilation during cooking. This was noted as a lesson learned and this information was shared to participants during training sessions as an essential practice when using the cooktop.
2. For microgrid installations, there were several instances where one upstream totalizer meter, which is special meter used to remotely turn on and off sections of a grid subnetwork, would reach its maximum current limit and enter into a "Protect" mode, temporarily cutting off all power for all customers downstream of it. This would result in a blackout in a section of the subnetwork, where many electric cooking participants would be using the cooking appliances around the same time. This totalizer meter was bypassed for the duration of the project, to allow for smooth cooking and good data collection.
3. For the Simpot (electric pressure cooker), three thermal fuses burnt out in a total of two appliances. Replacement fuses were sourced and installed. The appliances worked again after that: for one of them, it is still working up to date, and for the other Simpot, a second thermal fuse burnt and was replaced once more (Figure 34).

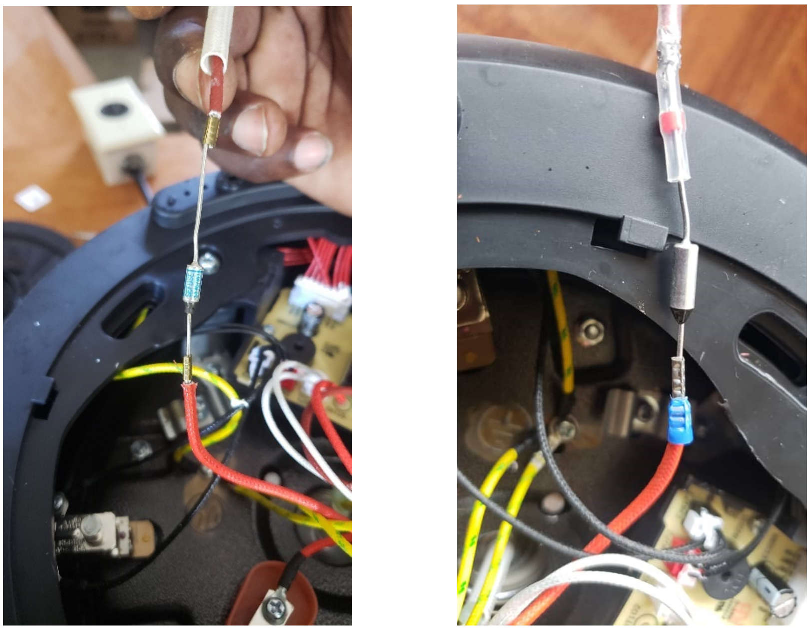


Figure 44: Burnt thermal fuses in the Simpot (left) and after replacement(right)

4. One Simpot had an issue with the lid and had the LID indication appearing on the screen. Initially the lid was swapped, but the problem persisted. The whole Simpot was eventually swapped for another unit. It is likely a manufacturer's defect.
5. For the off-grid installation, one inverter had a malfunction. It appeared to be cycling power continuously causing an inability to sustain proper cooking loads. The inverter was swapped for another unit and the faulty unit was inspected but the root cause of the problem could not be identified.

- ***If you made any modifications to an appliance did these modifications work as anticipated?***

As above, a few modifications were made on the appliances, either before deployment to the participants or in a few cases during pilot implementation.

1. The most important modifications focused on the microgrid participants' appliances. As mentioned above, the prong was swapped for a receptable outlet, so that the electric cooking appliances could not be plugged into any outlet in the house but rather only into a dedicated meter (Figure 35). This modification has been working very well, with not a single issue reported due to bad connections or shorts or no power due to the change made.

***Figure** 45: Modified Simpot and induction cooktop with their outlets.*

2. One of the induction cooktops suffered some damage caused by impact on the top glass. While the appliance was still turning on and operating normally, for safety reasons, the broken top glass was swapped with the glass from another defective cooktop that damaged due to suspected insufficient insulation. The swapping was easy, and the cooktop has been working normally since.

Figure 46: Damaged induction cooktop following impact

3. For the three thermal fuses that blew in the Simpots, the replacement for one of them lasted for about two weeks before blowing again. However, it was reported to be working normally after the swaps. The replacement fuse was not identical to the original one, but the specifications were as close as one could be sourced on the market.

2. ***Have there been any changes to cooking practices? How sustainable are these changes likely to be?***

As above, surveys were conducted with the participants in November 2020 which highlighted some changes in cooking habits:

1. <u>*Cooking frequency increased for about half of the participants.*</u>

The common cooking fuel used in rural Haiti is charcoal. In Les Anglais, it is sold on the roadside by regular vendors any day of the week, and on Wednesday, at the big market, a lot of the charcoal producers and retailers gather at a special spot to market their product. Charcoal is generally sold either by “marmit”, “tol” or “buket” for about 50HTG, 150 HTG, and 750 HTG unit price respectively.

Figure 7: The charcoal “marmit”, “tol” or “buket” and bags being sold at Les Anglais Wednesday market

Due to the cost, tediousness of preparing a charcoal fire for cooking, and the cooking time, many households prepare only one big meal per day in a big cooking pot made of aluminium, and commonly called “chodye”. With electric cooking, the inconvenience of cooking with charcoal is absent. Many meals, drinks and snacks can be concocted in less than 30 minutes, meaning the time of the day is no longer relevant variable when making the decision about whether to cook or not. However, some participants did not increase their cooking frequency due to limited financial means that did not allow them to purchase a greater quantity of food products.

It is suspected that the habit of having more frequent meals might remain after the pilot project, depending on whether the cost of electricity for cooking is affordable compared to charcoal. For the project, the money not spent on charcoal has been used to buy more food for certain participants, making it possible to consume food more frequently. There is an incentive to switch to clean grid electricity as highlighted above, particularly when compared to the price of charcoal which keeps going up on the market. For example, one bucket of charcoal used to cost 75 htg in February 2020, but it was up to 175 HTG in October 2020, which is a 133% price increase. There is an attempt to fix the price at the market to 100HTG a bucket by the local government, but it is unknown if this change will last a long time due to expected opposition from charcoal producers.

2. *Food portions per cooking session*

Increasing cooking frequency often means that portions can be reduced, as each meal can be individually prepared. Qualitative data collected from some of the cooking participants who have numerous families or are feeding many people indicate that the electric cooking appliances are not sufficiently large to cook a lot of food for more than one meal.

One exception is an off-grid participant who mentioned cooking more food and only once daily because more people have been coming to his house to eat since the cooking pilot has started. He lives in a region with a strong sense of community and feeds his parents, in-laws and neighbours, in addition to his nuclear family. He therefore makes one larger meal to feed everyone.

With the convenience of electric cooking, it is predicted that food portions prepared for individual meals will tend to shrink as there is no longer the urgency to cook everything at once. Also, electric cooking users are currently limited to the 6-quart Simpot. The same applies for food prepared with the induction cooktop, as it can’t hold more than 25 pounds on its surface.

3. *Cooking time and eating time.*

One big benefit mentioned by the project participants is the fact that they can wake up in the middle of the night and have a hot drink or porridge. The traditional Haitian kitchen with charcoal is usually in an outdoor kitchen and cooking in the middle of the night, especially if it is raining, is not the best experience. The clean electric cooking is located inside the house and “right next to the user”, making it more practical. Morning food preparation time has also shifted to later times as cooking is faster. This gives the user a longer night’s rest.

This trend is expected to continue and will vary a lot among the participants based on their individual activities. However, for microgrid customers, this will likely be dependent on the TOU (time of use) electricity tariff chosen for electric cooking. While they might still use electric cooking at different times of the day, the probability of them cooking when electricity is the cheapest is higher.

4. *Cooking preparation process.*

Participants mentioned how the steps in electric cooking had to be different from when cooking with charcoal. Electric cooking appliances heat up much faster meaning that users need to ensure their vegetables and ingredients are ready before starting to cook to avoid ruining their dish due to overcooking or burning. This is a change from cooking with charcoal which is quite slow to reach to a high temperature and would therefore allow the cook to prepare ingredients in the meantime.

This trend will most likely be followed by all participants if they want to be able to prepare their food quickly without it being burnt. As this habit is developing during the pilot study, it might become the new normal when preparing food. One option when using the induction cooktop is that electric cooking users could set it to lower levels to increase cooking duration and hence get the time to prepare their ingredients.

3. ***Is the appliance being used as part of a fuel stack? (if yes which other fuels/appliances are used for what purpose?)***

The other fuels mentioned by the participants were charcoal, propane, and wood. Table 1 below shows how widespread those fuels are among them. While there are no regular wood users among microgrid participants, some mentioned they can occasionally use wood if charcoal is not available, but it is not a common practice for them.

Table 5: Alternative fuels used among the cooking pilot participants

Question	On grid	Off grid
# of participants questioned	20	9
Regular propane users	3	1
Regular charcoal users	20	8
Regular wood users	0	4

Most participants use charcoal as the main fuel as it is locally produced and widely available. Charcoal is used mainly for everyday cooking in most rural households in Les Anglais. However, some participants mentioned the use of charcoal for ironing their clothes.

Figure 47: Charcoal being used for cooking and for the iron (left) at one of the cooking participants' residence

Figure 48: Three types of charcoal stoves that are used by the cooking participants, both on- and off-grid.

It was noted that four participants, three microgrid and one having an off-grid set up (the EarthSpark R+D application), use propane to supplement the use of charcoal as cooking fuel. Some of the propane users indicated mistrust in propane stoves due to the fear of explosion or gas leakage. Filling the propane tank for people in Les Anglais also poses a few challenges as this cannot be done locally and the propane tank will have to be transported to another town where that service is available. The closest town that can fill propane tanks is a two-hour drive away, and the closest big city, Les Cayes, requires a 3-hour drive. For those not owning a vehicle, they pay a “taptap” (pickup truck used for public transit) driver 25 HTG to transport the propane tank to a filling station to refill it. It is also possible that there is no propane in the closer town and that the taptap will not travel further. In this case, the user will have no other choice than to use charcoal, if they do not have a spare propane tank that is still filled.

Figure 49: One of the microgrid participants who has been using propane as well as charcoal before the start of the project.

Only a few participants used wood, and they are mostly off-grid or/and the participants who have a household member who is a cultivator and can easily source dry wood or branches in the mountains. Furthermore, off-grid houses are generally in less populated areas and dried branches could be more readily available for fuel.

Figure 50: Wood being used by an microgrid participant before the project launch

Kerosene stoves are also sometimes used in Les Anglais, but none of the participants used kerosene as part of their fuel stack.

The results section above gives an indication of the amount of money that was spent on charcoal before the start of the project and during the project. For some participants, there has been a complete switch to electrical cooking. This is mostly the case for microgrid participants who have higher power reliability due to the 24/7 microgrid. For those who are off-grid, bad weather can affect their ability to stop using charcoal completely. However, one off-grid participant has been able to do so; she however still uses dry wood occasionally.

4. ***Did users adapt easily to the new product/service (e.g. was there a lot of questions/help needed?)***

All participants had an initial mandatory training during which they had a chance to learn how to operate the appliances effectively and safely. Some training materials written in Haitian creole and explaining how the two appliances work along with some quick reference guides were printed and shared to all participants. Those materials were used as reference materials during the training sessions. These can be seen in the supporting annexes.

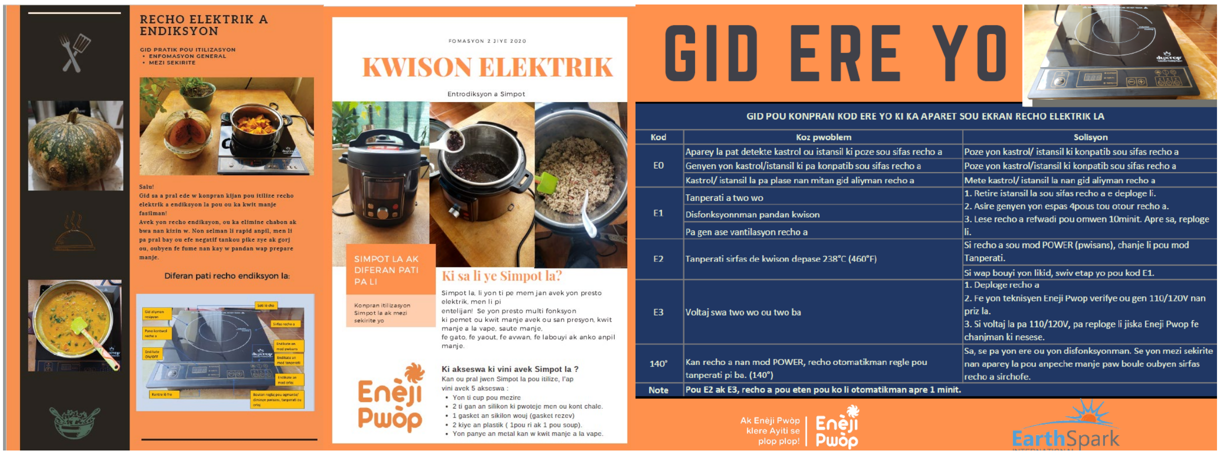


Figure 51: Some of the training materials, in Haitian creole, provided to the electric cooking project participants

There were many questions, indicating a level of understanding and interest in how the appliances work. The training sessions also included a cooking demo. Participants were invited to come forward and attempt to put the right settings on the two appliances. Each participant had the chance to try it at least one time.

Figure 52: Training sessions and cooking demo for the participants

After the deployment of the appliances, most participants called Enèji Pwòp staff during their first cooking experience to make sure they were doing the right manoeuvres. The trainers were available on call to respond to questions and make in-house checks to assist in setting the equipment correctly and providing supplementary advice.

However, not all participants are fully comfortable with the functionalities of the appliances. For the induction cooktop, which is simpler, understanding and a good level of comfort in operating it was quickly reached among the participants. For the Simpot, not all functionalities were fully explained as they might not be used in the Haitian cuisine. Cooking under pressure with manual setting and under Sauté mode, were the two modes that were explained as most versatile. Cooking participants still call the office to report they cannot use the Simpot for some reason. However, as expected, the participants who use the electric cooking appliances the most often are the one who quickly become the most comfortable and confident with them and stop calling for assistance the earliest.

5. ***Are any additional behavioural changes visible at household level – e.g. changes to household decision making dynamics, gendered roles, impacts on children/ vulnerable adults?***

The arrival of electric cooking has not had major impact on the traditional gender roles in the Haitian household. Women are still the ones who are cooking most of the time. Only one household had a man as the main cook using the electric cooking system.

As identified above, electric cooking has however significantly reduced cooking time burden which has opened up new opportunities for women, particularly for leisure. One participant who has weak health mentioned the benefits of not having to be exposed to the heat of the charcoal during cooking and that electric cooking is beneficial for her health. Another testimony of one participant was how the new cooking system was convenient for her when making a tea at night after she got sick. Finally, one off-grid participant highlighted that before with charcoal, she would try to prepare food for kids before school, but at times it would take so long that the food was not ready and her kids had to leave for school. Since the household got the SUNSPOT, there is not a single day that her kids have gone to school without eating.

In most households, kids do not usually use the electrical appliances as the adults are worried that they will damage them and make them liable to pay the fine associated with a damaged appliance. So, in most cases, kids would still be using charcoal if they were to cook. There are only a few cases where the electric cooking appliances are reported to be used by kids to make food. It should be noted that some participants' kids were welcomed to join for the training, which can be very helpful if the main cook in the house has a low level of literacy.

For the off-grid systems, the impact of the electric cooking system has been even greater. Most of those participants might have very limited source of lighting and the SUNSPOT which was deployed in their homes has been life changing.

1. For cooking, just like for the microgrid participants, off-grid pilot participants have expressed the positive change in their cooking habits, particularly savings from using less charcoal, health and safety from less exposure to the heat and smoke from the charcoal stoves, and convenience of having the system inside their house and available at any time.
2. For lighting, a couple of off-grid participants use rechargeable lights in their homes but for most of them, flashlights, solar lamps or kerosene lamps are the only source of lighting at night. The SUNSPOT system comes with a USB light and bulb which provides good lighting during cooking in the room where the system is installed. Some participants have mentioned how their kids are able to use the lighting to study at night and the usefulness of this light in the morning when getting ready for work and school. Another participant has reported how he was able to provide lighting all night for a wake at his house and this made him very proud.
3. There are a few options for phone charging for people who do not have electricity in their homes in Les Anglais: use a small panel, charging the phone at someone's house or using a phone charging station business. The SUNSPOT system has not only brought electric cooking but also clean lighting and a means to charge cell phones. For the off-grid participants, this represents another way for them to save some money, as phone charging stations can charge customers between 10 and 20 HTG to charge a cell phone, depending on the phone size. This could mean savings up to 140 HTG per week for someone who has a bigger phone and charges it daily. SUNSPOT users can also charge phones for their family members and friends in the neighbourhood.

Market Surveys

Below are specific discussions related to market potential in Haiti:

- ***How do the results from market surveys/customer interactions reflect your original assumptions about the target market for your product/service?***

The pilot was initially attempting to include as many food vendors as possible, as it seemed more economically viable for them in the long run to switch from charcoal to electricity and it would be easier for them to afford electricity for cooking if they are generating a revenue from the activity. One potential candidate, who is a popular food vendor, was interviewed before the start of the pilot project. She declined to participate after seeing pictures and knowing the sizes of the appliances as she was worried the system would not be sufficiently large for her needs (she indeed cooks a large pot of rice and vegetable stew daily). It turned out to be accurate as, from the survey responses collected during the project, one disadvantage frequently mentioned by respondents was related to the size limitation of the pots and/or appliances.

However, two other food vendors engaged in the pilot project have been able to use the electric cooking appliances to reduce their charcoal consumption. They mostly prepare street food like" fritay" (fried food) and "pate" (fried dough with filling) and cook some of their food with the electric cooking devices. Another benefit for some of them, is the ability to cook food for their family with electricity without it disturbing the cooking process for their food business, as no interruption is required, both the family meal and the food for the business can be prepared simultaneously on different fuel sources.

Another assumption made was that the arrival of electric cooking would eliminate the need to use charcoal for the participants. While this is true for a handful, many of them still use charcoal for the following reasons:

1. The cooking appliances are not sufficiently large.
2. Some food items which are very present in the Haitian cuisine like breadfruit and "mayi moulen" (polenta), need to be prepared in the big aluminium pots either due to the volume of the food or because the pots are thick enough to prevent burning the food.
3. Related to the above, the only ferromagnetic pots available in town or in the closest big city are thin and can burn some food. Those which are both ferromagnetic and thicker are either not available or not affordable for most households.

- ***What modifications would be required for your product/service to be relevant to your target market?***

Based on the weaknesses of the system as mentioned by participants during the surveys, it might be more advantageous to use larger Simpots. Some of the pressure cookers on the market can go up to 8 quart and might be preferred for larger families, rather than the 6-quart volume that was used for the cooking pilot project. Considering Haitian eating habits, rice is very present at the table and the 8-quart pressure cooker might be able to cater for a greater share of the meal's requirements for most of the households. Further, appliances like rice cookers could also be considered instead of full electric pressure cookers.

As above, the participants indicated that feeding 4-6 people is the standard, however it is also customary for Haitian households to offer food to neighbours, send food to some family members living in town, or invite a visitor to have food. Those elements add a level of variance and increase the number of food consumers and tend to support the idea that larger size pots and appliances would work better.

The ferromagnetic pots which were sourced locally and within a price range that would be affordable to a typical rural Haitian household were quite thin. While they are good for boiling food or making tea and coffee, frying food in those pots proved to be undesirable as the pot for the food would tend to burn easily. Thicker pots would have been much better and avoided the burning of food which needs to be prepared on a high heat level.

Most of the pressure cookers on the market are designed for English speaking users and the menus on the appliances are in English. Haitians speak Haitian creole but most participants can also understand French. Few people understand and read English in rural Les Anglais. The fact that the indications are in English tend to limit the understanding of the use of the Simpot and the likelihood that the users would explore other functionalities of the appliance. A pressure cooker from a French manufacturer like Cookeo from Moulinex or from Krups where there is a language setting for French, could have enhanced the user experience. Unfortunately, the price point for those two products is quite high.

Supply chains

- ***Did the supply chain have any impacts on your project (positive or negative)? Please explain in as much detail as possible.***

Along with some delays in accessing the electric pressure cookers and induction stoves themselves, importing the equipment and materials for the on-site manufacturing of the SUNSPOT systems also experienced some delays due to customs and COVID-19.

Ferromagnetic pots were supplied to participants who did not have any at home already. Local sourcing was however challenging. The pots were either sourced in the capital, Port-au-Prince (8 hours' drive away), or in Les Cayes (3 hours' drive away). In some cases, the stores did not allow the opening of boxes to verify that the pots were indeed ferromagnetic, and some of the pots came in boxes without indication of whether they work on induction cooktops. Some boxes mentioned that the pots would work on all types of stoves, but this turned out to be untrue. This resulted in the sourcing of some pots which did not work on the induction cooktop and hence represented an unnecessary expense for the project.

All of the pots sourced in Port-au-Prince and Les Cayes were thin stainless-steel pots which could not be used for cooking all meals due to the risk of burning the food. This resulted in participants going back to their aluminium pots on charcoal to be able to successfully prepare some meals like breadfruit, "tomtom" which is made from breadfruit and the Haitian polenta. Some people also like it when rice forms a crust (locally called "graten") at the bottom of the pot and this cannot be formed in the thin stainless-steel pots, and while it can form in the Simpot, the graten cannot be scraped for eating as this would damage the Simpot inner pot. Having better quality, thicker pots might have resulted in greater success in making participants turn away from charcoal usage.

The incident with the burnt fuse resulted in the cooking participant being deprived of the usage of the Simpot for many weeks until the thermal fuse was replaced. The thermal fuse had to be sourced online and from the USA, and since the supplier did not ship to Haiti, the fuse had to be sent to someone in the US who in turn shipped it to Haiti. From Port-au-Prince, it can take 1 to 2 days to be sent via public transport to the project location, in Les Anglais.

The project investigated the possibility of sourcing the induction cooktops and pressure cookers in Haiti and two stores were identified in Port-au-Prince. Unfortunately, they only had less than 10 units in stock in all the stores in the country. Quotes for importing through them turned out to be more expensive than ordering online and would have doubled the price at least. This resulted in a small delay to get the appliances in the country and to the participants.

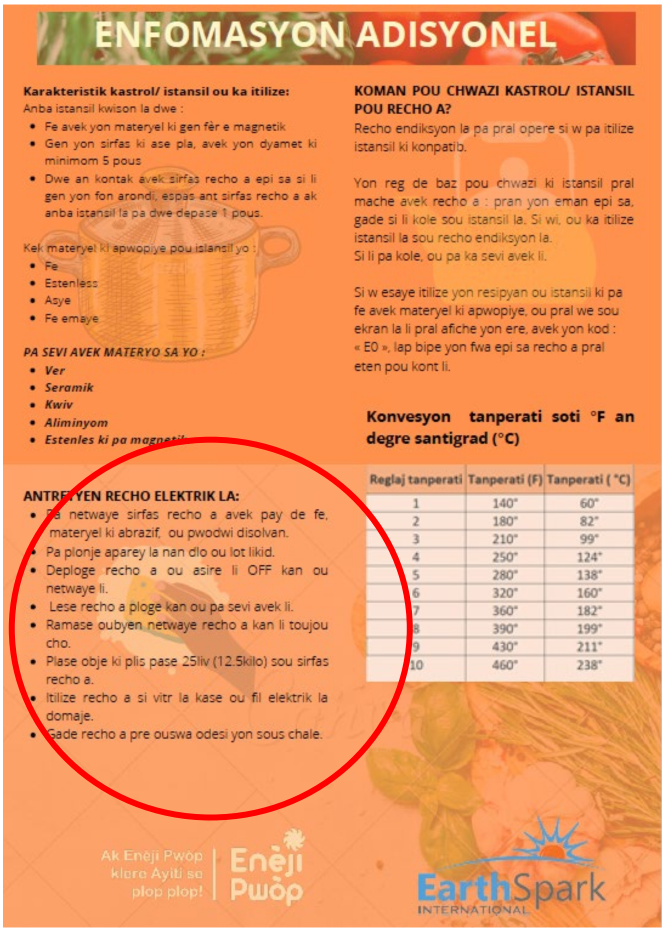
- ***Is it feasible to scale up the supply chain under the current (excluding covid-19) circumstances – if yes what would it take to achieve the scale up? If no what is currently hampering scale up (apart from Covid-19)?***

As mentioned in the Issue Log (see the supporting annexes), part of the grid would have an outage when all cooking participants in that area would cook at the same time. This would usually happen on Sundays as people take more time to cook special meals. The grid in Les Anglais is equipped with special totalizer meters which have a current rating of 60A and which allow for remote disconnecting of a section of the electrical grid during maintenance activities. Due to the high number of participants connected to that totalizer which also now supports a newly connected telecom tower, it would exceed its current limit and go into "protect mode" effectively cutting off all power for any customer downstream of it. After recurrent events, the totalizer meter was temporarily removed in order to reduce service disruptions. Should the project be scaled up, either more totalizer meters would need to be removed, or totalizer meters with higher current rating would need to be sourced. Another alternative would be to stagger the cooking times for various users to ensure they are not all connected at the same time.

Another modification to the grid in case of a project scale up would be for the generation system. The Les Anglais microgrid has a 27kW (MCR) diesel backup generator. During rainy days when the batteries were discharged and the generator had to take over, the generator overloaded a few times. This usually happens if too many electric cooking loads are connected simultaneously. Should there be a big increase in the number of electric cooking users, and the generator is in charge of powering the grid, there will be an overload and a blackout. A few solutions for that would be either increasing the solar PV + storage capacity, upgrading to a bigger generator that supports bigger demand, or using a staggering of the cooking loads to ensure that at any time, should the genset kick in, there are zero risks of overloading the system. Alternatively, the application of DSM (demand side management) during rainy days to prohibit the powering of the bigger grid loads (including or not including cooking loads, depending on operator and customer preferences) could also be implemented to ensure power reliability in the microgrid. Including cooking loads in the "deferrable demand" for the grid would mean that electric cooking users would be required to keep a backup cooking fuel source when they cannot power their electrical cooking appliances.

- ***How can the appliances be maintained? Was maintenance needed on any of the appliances/systems during the project? (if yes please add additional detail on type of maintenance needed, how it was managed etc).***

The microgrid installations required no maintenance of the electrical set up. For the SUNSPOT, monthly checks were undertaken to make sure the system was functioning normally and that there was no tampering with the components. In terms of the cooking appliances themselves, basic cleaning notes based on the manufacturers' recommendations were shared with the users during the training sessions. For the induction cooktop, the only maintenance required is wiping the glass surface with a soft damp cloth to remove grease or food spills.



ENFOMASYON ADISYONEL

Karakteristik kastrol/ istansil ou ka itilize:
Anba istansil kwison la dwe :

- Fe avek yon materyel ki gen fèr e magnetik
- Gen yon sirfas ki ase pla, avek yon dyamet ki minimom 5 pous
- Dwe an kontak avek sirfas recho a epi sa si li gen yon fon arondi, espas ant sirfas recho a ak anba istansil la pa dwe depase 1 pous.

Kek materyel ki apwopiye pou islansil yo :

- Fe
- Estenless
- Asye
- Fe emaye

PA SEVI AVEK MATERYO SA YO :

- ***Ver***
- ***Seramik***
- ***Kwiv***
- ***Aliminyom***
- ***Estenles ki pa magnetik***

KOMAN POU CHWAZI KASTROL/ ISTANSIL POU RECHO A?
Recho endiksyon la pa pral opere si w pa itilize istansil ki konpatib.

Yon reg de baz pou chwazi ki istansil pral mache avek recho a : pran yon eman epi sa, gade si li kole sou istansil la. Si wi, ou ka itilize istansil la sou recho endiksyon la.
Si li pa kole, ou pa ka sevi avek li.

Si w esaye itilize yon resipyan ou istansil ki pa fe avek materyel ki apwopiye, ou pral we sou ekran la li pral afiche yon ere, avek yon kod : « E0 », lap bipe yon fwa epi sa recho a pral eten pou kont li.

ANTRETYEN RECHO ELEKTRIK LA:

- Pa netwaye sirfas recho a avek pay de fe, materyel ki abrazif, ou pwodwi disolvan.
- Pa plonje aparey la nan dlo ou lot likid.
- Deploge recho a ou asire li OFF kan ou netwaye li.
- Lese recho a ploge kan ou pa sevi avek li.
- Ramase oubyen netwaye recho a kan li toujou cho.
- Plase obje ki plis pase 25liv (12.5kilo) sou sirfas recho a.
- Itilize recho a si vitr la kase ou fil elektrik la domaje.
- Gade recho a pre ouswa odesi yon sous chale.

Konvesyon tanperati soti °F an degre santigrad (°C)

Reglaj tanperati	Tanperati (F)	Tanperati (°C)
1	140°	60°
2	180°	82°
3	210°	99°
4	250°	124°
5	280°	138°
6	320°	160°
7	360°	182°
8	390°	199°
9	430°	211°
10	460°	238°

Ak Enèji Pwòp klere Ayiti se plop plop! Enèji Pwòp

EarthSpark INTERNATIONAL

Figure 53: Page 2 of the induction cooktop training guide with the maintenance instructions encircled in red

For the Simpot, cleaning of the lid and stainless-steel inner pot can be performed by washing with soap and water. No metal scourer was used because of the risk of abrasion. The lid inner ring also needed to be washed with soap and water. The Simpot body itself cannot be immersed in water, but a damp cloth can be used to clean it outside and where the slit where cover locks in. The cleaning of this slit is important as foodstuff can fall in it preventing the complete locking of the cover during pressure cooking.

Monitoring electricity supply and use

- ***Did load profiles of cooking match what you expected? How did the energy demand of cooking practices match energy supply?***

In many ways the load profiles matched what was expected given the experience of EarthSpark and the observed Haitian cooking practices. The project expected there to be significant demand in the middle of the day coinciding with the primary meal, with some cooking in the shoulder periods as well, particularly in the early morning (coffee, tea, spaghetti, etc.) as well as the early evening (porridge, pate, etc.). One surprising element however was the increase in frequency of cooking events even in short little spurts for tea, porridge, etc.

Additionally, it was a pleasant surprise to see how much the devices were being utilized by the participants and therefore the total amount of electricity consumed. The added electric cooking load for the microgrid coincided with the grid adding telecommunications loads as well, so as highlighted above, for already existing microgrids there is definitely a need to add additional capacity, deploy time restrictions, and/or consider strategies like demand-side management (DSM).

- ***If grid connected, what is the stability and experience of the grid (voltage drops etc)***

As discussed above voltage drops, and more importantly current spikes were an issue for this pilot study as the concentrated electric cooking loads for certain grid segments would cause the aggregation meters installed for theft detection, "Totalizers", to trip and go into protect mode. Once these totalizers were bypassed the electricity supply was more stable and reliable.

As above, the other issue for stability and reliability occurred with the backup generator particularly on rainy days when the batteries were fully discharged and caused an overload of the generator. However, with data and evidence generated from this, and other projects, microgrids and electric cooking can be designed in parallel for target communities so that the systems are more intentionally designed to support electric cooking load and that electric cooking load is helping support the financial viability and service provision of the microgrid itself. To accomplish this, results-based financing specific to supporting cooking loads may be required.

- ***Time of use – did you provide time-shifted access or limit cooking to ensure a more reliable supply? How did participants react to this change?***

The pilot project did not include any time of use restrictions or incentives through tariffs for this initial research stage. It is anticipated that restricting cooking time availability would strongly reduce the desirability of the electric cooking devices. Instead, it is more likely that EarthSpark would adopt time-varying prices for electric cooking that would offer cheap electricity during the day when there is strong solar availability and more expensive electricity at night when the grid is needing to utilize the batteries or the backup generator. The customers are already used to this concept as it is the long-standing practice for the general electricity tariffs. This would actually align quite well with Haitian cooking practices as well given the heavy focus on the midday meal when there is generally strong solar availability.

- ***Datalogging technology and analytics: what was used? (e.g. data loggers, cooking diary matched with electrical data read from appliance-level sub-meters) how effective were they for the task?***

A combination of technologies and data sources were utilized. First, all of the electric cooking devices were connected to an individual smart-meter which allowed for close monitoring and analysis of electricity consumption on a 15-minute interval. By isolating the devices on individual meters, we were able to avoid some of the challenges related to load disaggregation for data analysis. Overall, the smart meters worked well for tracking consumption patterns and provided good visibility into the overall impact of electric cooking. There were some challenges, particularly for the off-grid customers, in maintaining meter communication. Since the communications signal needed to be relayed from microgrid meters over a hill to the off-grid site, it sometimes resulted in communication gaps with the meters which caused the data stored locally to "push" to a single interval when it reconnected. This resulted in some challenges for tracking true time of use and profiles for the off-grid participants.

Further, looking to a more granular interval like 5-minute might reveal more nuanced patterns in the electric cooking, and particularly the designation of a cooking event or meal. A more aspirational approach would be working together with the appliance manufacturers and the smart metering systems to embed a radio board directly into the cooking appliances to enable direct communication over the SparkMeter mesh network to the appliances themselves both for monitoring and evaluation purposes and for direct demand response capabilities. Any DSM in the cooking process will require deep collaboration with those cooking to determine how to efficiently run programs while also avoiding ruining people’s dinners.

The project also collected cooking diaries from the participants. These provided some more challenges for the project. With complications from COVID and other factors, there wasn’t as tight of monitoring as planned which led to a lot of missing data (days and questions) from participants as well as participants recording information several days after the fact. Further, the diary questions didn’t always reveal the right data for triangulating what meals were done when and with what fuel.

All of this made it very challenging to effectively match the electricity data with the diary data. The challenges stemmed from multiple cooking events for single journal entries and vice versa, out of alignment times, lack of clarity on fuel type used, lack of consistency in time recordings, and a broader definition of cooking time for some participants. In the end, the diary data was used to understand participant recorded timing and the Haitian meals, but was not used in the analysis of the electricity consumption which represents a critical piece to address as the project continues beyond the initial MECS grant. The diary questions and the overall process are being re-evaluated based on the learning experience so far.

Finance and affordability

- ***Were your systems/products considered affordable by your target market?***

The initial capital costs of the systems are likely too expensive for most low-income families due to the underdeveloped supply chain of both the devices and the supporting accessories (i.e. ferro-magnetic pots) available in rural communities like Les Anglais. If that barrier can be overcome through something like results-based financing or pay-as-you-save type models (discussed below), there is reason to believe that (subsidized) ‘market rate’ electric cooking could be attractive to customers based on their indicated willingness to pay for electric cooking services.

- ***Is there anything that would have made them more desirable/more affordable?***

The size of the devices is a critical hurdle for desirability in communities like Les Anglais. It was a drawback noted by most of the participants and a key impediment for people even being interested in the study in the first place. Further, the pots that were compatible with the induction stove in particular were less than desirable because they would burn food. For affordability, establishing supply chains and better access to devices and advocating for a bundling of electric cooking appliances and related cookware as part of an energy access duty tax exemption would help eliminate the need to engage with customs and imports which significantly raises costs. Another track is to more formally connect electric cooking deployments with procurement for other microgrid components at the outset of a grid.

- ***Are policy/tax changes needed to make it feasible on a larger scale?***

While there are no specific policies or taxes directly hindering electric cooking specifically, the government does have an opportunity to develop a better enabling environment for electric cooking, particularly as it relates to imports/customs. Further, the government can potentially play a more catalytic role by developing and supporting specific programs for results-based financing and other mechanisms to help drive investment in electric cooking, particularly connected to microgrids and other energy access pathways starting to scale up in Haiti. As an aside, Haiti has a long way to go on forming a basic enabling environment for energy access, so addressing this foundational issue should be a priority.

- ***Was full cost recovery achieved? Could it ever be achieved by everyone?***

Full cost-recovery wasn't achieved since the electricity and devices were given to participants for free, but the project does suggest potential pathways for cost-effectiveness for certain customers if initial capital costs of the devices can be overcome. Further adoption would likely occur if ongoing cost/kwh for verifiable cooking applications were subsidized. Such a results-based financing approach is not unreasonable given the considerable health, climate, and environmental benefits of electric cooking.

The indicative willingness to pay values calculated in this project highlighted that many customers would find electric cooking tariffs set around current microgrid tariffs attractive, and some customers even highlighting very large indicative values. Obviously, these values will decrease when customers are actually faced with price signals, but for certain customers there is a viable pathway. The biggest challenge is overcoming the initial capital cost of the devices. Leveraging microgrid models to utilize blended-financing particularly for results-based financing streams for health and development outcomes might present an attractive opportunity for scaling electric cooking if the viability can be demonstrated for donors and social impact investors. Further, pay as you save models may also work if the savings margins are high enough with the rising cost of charcoal.

Stakeholder interactions

Below are a few discussion questions related to stakeholder interactions.

- ***Which stakeholders/people were important to any successes in the project? How did you engage with them? What were their roles?***

The project implementation can be broken down into different stages. Those stages and respective relevant stakeholders are indicated in Table 5 below. For a large part of the in the field work, Enèji Pwòp staff in Les Anglais (technicians and 1 grid ambassador) have been the key actors.

Table 6: Stakeholders at different phases of project implementation

#	Phase	Stakeholders
1	Participants selection and assessment	Enèji Pwòp grid ambassador and the cooking participants

2	Sourcing phase	Store owners/managers in Port-au-Prince and Les Cayes
3	Importing phase	Customs broker, customs company, customs officers
4	Manufacturing phase	Local carpenter, Enèji Pwòp technicians
5	Training sessions	Enèji Pwòp grid ambassador, the cooking participants
6	Installation and verification phase	Enèji Pwòp technicians
7	Utilisation	Cooking participants
8	Energy diaries filling and data entry	Cooking participants, grid ambassador
9	Interviews and surveys	Cooking participants
10	Market assessment	Les Anglais charcoal vendors
11	Music for videos	Suite Positif troubadour registre – a fantastic band of Les Anglais musicians who kindly rallied to the cause of supporting electric cooking

Figure 54: Carpenter working on the SUNSPOT box manufacturing

Figure 55: Cooking participants with the grid ambassador during the 1st training session

Figure 56: Les Anglais charcoal vendor explaining the market pricing

Figure 57: Cooking participant giving an interview

Figure 58; Suite Positif Troubadour Registre members performing

Figure 59: Microgrid installation by Enèji Pwòp technician during COVID-19 pandemic

Figure 60: Panel installation for a SUNSPOT off-grid by Enèji Pwòp technicians

- ***Did you meet any resistance/opposition from any stakeholders to the project and, if so, explain why? How did you respond to this opposition? What was the outcome? Any ongoing challenges?***

There was a big challenge in the importing phase related to the customs agent utilized. There was a lack of professionalism from the company which put some stress on imports. EarthSpark hired a new company based on a manufacturer's recommendation for importing and customs clearance and this resulted in massive delays and lateness penalties from Haitian Customs. It also resulted in a loss of money as some fees were never reimbursed by the agent. Another agency was contacted to take over the rest of the process and delivery.

An ongoing challenge is ensuring that electric cooking participants are diligent when it comes to filling their energy diaries. There is a lot of forgetfulness in filling the correct information leading to data gaps and inconsistencies. For some microgrid participants, some cooking meters were temporarily shut down to force the participants to come to the office with the filled diaries. This strategy was quite effective to get filled diaries, however, better strategies are required to incentivise participants to improve the accuracy of their data.

- ***Were you surprised by something someone said (positive or negative)? Please explain why you were surprised.***

Something pleasant mentioned by a few participants was how visitors from the big cities were impressed by the systems and were interested in purchasing the appliances from us if we were selling them. It was surprising to see people who came from Port-au-Prince, which is the capital and where the bigger stores and a multitude of products are available, arrive in a small rural town at almost the end of Haiti and feel envious of the facilities that are available to the electric cooking participants. It also brings a sense of satisfaction that great development and progress can take place even in the most remote of locations under the right conditions.

Scaling up electric cooking

- ***How is a transition to clean energy cooking likely to occur in your focus country?***

In Haiti, an estimated 97.3% of rural households depend primarily on solid fuels for household cooking (74.7% wood, 22.5% charcoal, 0.1% lignite) and cooking indoors (63%) and on inefficient traditional unvented and unimproved cookstoves or over open flames. Given the extreme nature of this challenge it is likely that the transition will likely need to come from a variety of parallel pathways. So far, there have been several efforts in Haiti working to expand the use of ICS and LPG, most notably USAID/Chemonics' Improved Cooking Technology Program and the Clean Cookstove Alliance's Action Plan for Haiti. The ICTP project focused on expansion of improved biomass cookstoves and LPG for urban food providers and households in the capital of Port-au-Prince. The project had mixed results with 6% of households in the program area adopting improved cookstoves, and 44% of orphanages, 12% of schools, and 22% of street food vendors adopting LPG.

The Action Plan and associated efforts have also focused on improving the production and availability of efficient cookstoves, improving the efficiency of charcoal production, and creating an enabling environment for market growth. These efforts have mirrored challenges faced by other global initiatives in that deployment and uptake of clean cooking has been slow, especially for rural households given cultural practices, initial capital cost for alternatives, availability of cookstoves, limited supply chains, and community engagement.

That reality, along with the country's parallel efforts to address energy access, highlights an opportunity for electric cooking to drive near term action on clean cooking if planned intentionally and integrated effectively into energy access programming and investing models.

Regardless, for the clean cooking transition to be successful in Haiti, it will take a coordinated effort bringing together NGOs, private businesses, the Haitian government, multi-lateral donors, and community stakeholders.

- ***Which stakeholders do you think will be important to facilitating the scale up of clean cooking and why?***

As above, it will be critical to engage a variety of stakeholders to help facilitate the massive required action to overcome the cooking challenge facing the country. The government, particularly through collaboration with multi-lateral donors and other international partners, will need to elevate clean cooking to be a priority focus for socioeconomic development. Further, these stakeholders will need to help coordinate policy and investment frameworks to help catalyze and coordinate funding and action for clean cooking, including by creating linkages to other funding/policy sectors, especially with health and the broader energy sector.

Specific dialogues also need to be opened with donors and impact investors and the broader research community to help create the right incentive framework and project/business models to more effectively support the advancement of clean cooking in Haiti. NGOs and private businesses will need to co-develop these models and then help ensure that they are tailored and deployed to effectively meet the priorities and needs of the target communities. The communities themselves are of course critical in this process and need to be meaningfully included in the design and development of solutions, business models, and particularly the development of marketing and outreach materials. Technology providers also need to be engaged to help innovate and create new products more closely tailored to the needs of developing communities, particularly for electric cooking as discussed above.

- ***What needs to be done to facilitate the scale up of clean cooking in your focus country that isn't being done at the moment?***

First, to call out the obvious problem, the energy sector in Haiti needs either an open space for innovation or clear and coherent regulation. The current regulatory environment for microgrid development is stifling progress. Beyond that fundamental issue, one of the biggest actions that is needed presently is the development of results-based financing and other mechanisms to specifically connect clean cooking to other sustainable development goals, especially as it relates to food security, energy access, poverty alleviation, and health. This deliberate connection can help to catalyze and coordinate investments and models in target communities. There are scattered efforts in the country as highlighted above, but nothing specifically for coordinating clean cooking at the community level, and nothing at all for driving investment in electric cooking in particular.

6. Social inclusion and Impacts

- *Please describe how social inclusion of the poorest, marginalised and most vulnerable groups were incorporated into the completion of this project – this includes the integration of equity, people with disabilities, remote communities, elderly, children, and lowest income households. Please describe any impacts from your project that can contribute to social inclusion.*

In deploying electric cooking solutions to households in the rural community of Les Anglais, the project is directly supporting vulnerable populations, particularly women and children and the extreme poor, by reducing health impacts from traditional fuels, reducing cooking burden, and improving overall quality of life. Traditionally, women and young girls can spend 4-6 hours per day on cooking tasks including collecting cooking fuel and prepping and cooking meals. The electric cooking solutions substantially reduced cooking times thereby increasing available time for education, income activities, and simply leisure. The devices also limited the use of charcoal for cooking which reduced potential exposure to dangerous household air pollution, especially for women and children. The project also enabled a basic level of energy access for an off-grid community which helped power basic lighting and cell phone charging. This can create key quality of life improvements and access to opportunity for extreme poor populations while reducing exposure to harmful energy alternatives like kerosene, paraffin candles, and biomass-based fuels. Participants highlighted this element as a substantial benefit from the project.

The UN recognizes the complementarity of the right to a healthy environment (including built environment and the structural inequities in living conditions), right to development, and the right to health, focusing increasingly on 'diseases of poverty' among rural populations. Household air pollution is widely recognized as a critical barrier to achieving basic human rights, particularly the right to health, right to a healthy environment, and the right to development. By expanding opportunities for electric cooking and basic energy access the project created specific pathways to improve these rights for the most vulnerable and marginalized populations by significantly reducing exposure to health hazards, improving gender equality, improving quality of life, reducing time burden, etc. Further, energy access and access to clean cooking can address the specific social/power dynamics and structural inequities from differing access to resources that affect vulnerable populations in situations of energy poverty, while also strengthening the agency of those populations to change the conditions of their vulnerability. A key resource imbalance addressed by electric cooking in this project was related to time as it significantly reduced the time burden for cooking activities, particularly for women and children.

7. Gender

- *Please provide an explanation on how you included the specific needs of women and girls in your work. Explain how women and girls were included in the design, implementation and monitoring of your activities, giving practical examples.*
- *Please include an assessment of whether any unintended or negative consequences may have risen as a result of your activities (e.g. increased potential for gender-based violence.*

The project deliberately engaged women and households in designing the electric cooking solutions through direct consultations and conversations. Notably, the project also engaged men for input and participation so as to not unintentionally reinforce gender stereotypes around cooking. Of the primary participants beyond EarthSpark and Enèji Pwòp team members, only one was male, so there is more work to be done on this front. The pressure cooker and induction stove devices selected were specifically chosen to target two critical challenges for women related to cooking, namely time burden and household air pollution, while also providing opportunity for quality of life improvement. During implementation, participants, primarily women were given direct training and support for understanding and utilizing the electric cooking devices. Further, the demonstration events and the outreach materials were also tailored to support the specific questions and recipes that are commonly used by women in Les Anglais. Ongoing support/troubleshooting was also made available to participants to help answer specific questions related to individual recipes and approaches.

As identified above, electric cooking significantly reduced the time burden of cooking which has opened up new opportunities for women, particularly for leisure. All participants responded that electric cooking saved them time compared to status quo cooking. 78% of participants responded indicating that they used that time for relaxing, 33% for household chores, 15% for focusing on business and income tasks, 7% for self-care, and 7% for family care. One participant who has weak health mentioned the benefits of not having to be exposed to the heat of the charcoal during cooking and that electric cooking is beneficial for her health. Another testimony of one participant was how the new cooking system was convenient for her when making a tea at night after she got sick.

8. Next steps

- *Please describe the next steps you will take to scale up the results of your project. Please outline any partners, funding opportunities and utilisation of results to enable this.*

EarthSpark plans to extend the electric cooking pilot beyond the lifespan of this initial MECS grant. Initially this will include a continuation of the cooking project participants and a more expanded and formal research report highlighting the benefits, challenges, and implications of deploying electric cooking solutions in a microgrid context. This research report will form the baseline of EarthSpark's future planning, research, and project development. Alongside this research report EarthSpark will be finishing its other workstreams with MECS to develop a documentary and other communications materials to support future outreach and advocacy for electric cooking with rural Haitian audiences, Haitian diaspora members and the broader international community. EarthSpark is also looking for new opportunities to scale up this pilot project to more customers and additional microgrid locations. This includes both future rounds of MECS funding as well as other partners like the Green Climate Fund. Before scaling up, EarthSpark will need to explore how the usage of electric cooking changes when existing participants have to start paying for the electricity. If they continue to use the electric appliances, then a larger pilot exploring different appliance financing models and experimenting with several different tariffs would be justified.

9. Conclusions

Overall, the project is a first-step working to prove the viability, effectiveness, and attractiveness of electric cooking technologies powered by robust, reliable solar + storage energy systems supporting critical socioeconomic development outcomes in Haiti. This will help to demonstrate key demand for the solution and create actionable evidence for how to effectively design business models and frameworks to better support future electric cooking rollouts. In doing this, the project will be demonstrating viable new revenue streams and opportunities for energy access providers which will help improve assistance, service, and offerings to other communities. This will also create pathways for donors, NGOs, private sector, and other stakeholders to meaningfully develop opportunities for the expansion of clean cooking.

An exciting body of research lies ahead. In addition to adding appliances for larger cooking applications like large families, institutions, and street vendors, exciting further research would push into load monitoring and possible appliance-level monitoring with direct appliance communications functionality. While survey responses and alternative costs have determined a starting point for willingness-to-pay, there would be enormous value in a deeply participatory tariff discovery process including optimal demand-side management and time-of-use tariff program requirements and constraints.

10. Appendix

The following supporting resources are included in the EarthSpark Final Appendices (minus data).pdf

- Agenda for participant trainings
- Participant Profiles (4x) highlighting specific experiences and recipes from individual participants
- Outreach and guidance materials for simpot, induction stove, and basic black beans recipe
- Participant Issue Log

For the excel data file, please email mecs@lboro.ac.uk noting EarthSpark Appendices Data in the Title Field

- Electricity consumption and cooking event data workbook
- Off-grid outlet electricity consumption workbook
- Survey/participant interview data workbook
- Aggregated data from participant cooking diaries (corrections made where possible on timing and meals)