Kwison Elektrik

SOLAR POWER FOR ELECTRICITY ACCESS AND ELECTRIC COOKING IN HAITI

2021

EarthSpark INTERNATIONAL

MECS Modern Energy Cooking Services

SUNSPOT™

Ak Enèji Pwòp klere Ayiti se plop plop! | Enèji Pwòp

Authors

Andy Bilich, Wendy Sanassee, Allison Archambault, Adam Eberwein, Jean Thaylord

Acknowledgments

The authors would like to thank the following individuals for their help in implementing the research study and scoping, developing, editing, and reviewing this report: Doug Danley, Madison Sturgess, Teresa Danley, Joey Dunn, Jon Leary, Jane Long, Simon Batchelor

Funding

Funding for this project generously provided by a research grant funded by Loughborough University (via the Modern Energy Cooking Services Initiative under UKAID).

Pictures

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EarthSpark International

EarthSpark International builds energy-related business models that expand opportunity for people living in hard-to-reach places. We focus first on what can work in Haiti. Where there is no incumbent infrastructure, there is an opportunity to build energy systems that use today's technologies, business models, and community participation to deliver clean, affordable, reliable electricity. This is our way of working towards climate justice and Sustainable Energy for All.

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Abbreviations

EP	Enèji Pwòp
EPC	Electric pressure cooker
ES	EarthSpark
EUR	Euros
HTG	Haitian Gourde
KW	Kilowatts
KWH	Kilowatt hours
LIDC	Low-Income Developing Country
MECS	Modern Energy Cooking Services
SIDS	Small Island Developing States
SM	SparkMeter
USD	US Dollar

EarthSpark International

EarthSpark International is a non-profit headquartered in Washington DC that builds business models to solve energy poverty. We focus on what can work in Haiti while building best practices relevant around the world. EarthSpark has been working on energy access in rural Haiti since 2009:

- 2009-12: Built network of 100 independent retailers for small-scale solar + cookstoves
- 2012: Launched Haiti's first pre-pay microgrid in, expanded to a town-sized solar smart grid for ~2000 people in 2015.
- 2015: Established microgrid landscape Haiti through national microgrid market study in partnership with Enèji Pwòp
- 2019: Secured the first ever microgrid operating license from Haiti's new energy regulator to launch a second smart solar microgrid; began pre-development for two additional grids.
- 2020: Secured funding commitment from Green Climate Fund towards microgrid expansion blended finance project in Haiti.

During its operations, EarthSpark has been constantly innovating and developing real-world solutions to on the ground problems for communities and energy access. So far, EarthSpark has incubated and spun off 3 companies:

- **Enèji Pwòp** is a Haitian microgrid operations company that currently operates two microgrids in Les Anglais and Tiburon. Learn more at https://www.enejipwop.com/
- **SparkMeter** provides microgrid operators with smart metering and billing services. SparkMeter, developed initially for EarthSpark's microgrid work in Haiti, is now the leading global supplier of smart metering services for energy access microgrid operators around the world. Learn more at https://www.sparkmeter.io/
- **Participant Power** is a microgrid development company that leverages blended financing to support new microgrid projects.

Learn more about EarthSpark's work at http://www.earthsparkinternational.org/.

Partners

SUNSPOT – SUNSPOT™ is a self-contained off-grid solar electric power system.
The SUNSPOT™ solar electric cooking system provides a clean, efficient and cost-effective alternative to wood or charcoal. Solar electric cooking is made possible by three recent trends – the dramatic fall in the price of solar panels for utility projects, the availability of low cost,

highly efficient induction cookstoves and the introduction of Pay-As-You-Go financing in rural communities. Learn more at www.sunspotpv.com.

Modern Electric Cooking Services (MECS) – Modern Energy Cooking Services (MECS) is a five-year programme funded by UK Aid (DFID) in partnership with Loughborough University. The intended outcome is a market-ready range of innovations (technology and business models) which lead to improved choice of affordable and reliable modern energy cooking services for consumers. We will seek to have the MECS principles adopted in the SDG 7.1 global tracking framework and hope that participating countries will incorporate modern energy cooking services in energy policies and planning. Learn more at mecs.org.uk.

Executive Summary

Around the world, people are realizing that fire-based cooking is neither good for the cooker nor for the climate. Over 2.8 billion people are still relying on charcoal, biomass or kerosene to cook. Traditional cooking fuels are often expensive, bad for people's health, and bad for the environment. The impacts are particularly outsized for women in rural communities.

Global "clean cooking" efforts have focused on improved cookstoves, biomass briquettes, and expansion of LPG. However, clean cooking has lagged significantly compared to the need, and the solutions have often not fully solved the problems. Recent initiatives focusing on electric cooking are a welcome shift. For too long access to electricity and access to improved cooking technology have been siloed. Combining the two issues has the potential to more effectively meet people's basic needs while boosting the business model for solar-powered electricity systems in remote communities.

This study explores the potential of electric cooking in rural 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. Overall, the pilot project has showcased the value of electric cooking for both local communities and microgrid operators. Key findings indicate that electric cooking in this context is a:

- **Catalyst for improved quality of life for communities** – Participants' primary observation was the time savings and convenience of electric cooking compared to traditional fuels. Indicative willingness to pay values for most participants met or exceeded existing microgrid tariffs which highlights the opportunity for electric cooking to support improved livelihoods for vulnerable households. The electric cooking deployments also significantly reduce the risk of household air pollution.
- **Critical pathway for improved service for microgrid operators** – Electric cooking requires significantly more energy than what most "energy access" microgrids have been designed to deliver. This is both a challenge and an enormous opportunity for microgrid developers. The significant new revenue stream may be an incentive to build more robust infrastructure which, in turn, delivers additional benefits to the community and operator. Electric cooking also reduces GHG emissions from baseline fuels (a key metric for microgrid regulators and investors) and further allows for greater utilization of installed solar as cooking profiles in Haiti align with solar production.
- **Scaling-up electric cooking** – Results-based financing and other smart incentives could specifically connect clean cooking to other sustainable development goals, especially food security, energy access, poverty alleviation, and health. This deliberate connection

could help to catalyze and coordinate investments and service delivery to target communities.

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 hope is that 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.

Introduction

Introduction

From steaming fluffy rice with black bean sauce to fried plantains and plenty of tropical fruit to vibrant vegetable, meat, and fish stews, the intoxicating aromas of Haiti's cooking provide a conduit to its culture. In Haiti, food brings families and communities together.

While Haiti's cuisine is both nourishing and flavourful, the reliance on charcoal and other woodfuels presents serious risks to household health and opportunity for its communities, particularly women and young children. By empowering communities with electric clean cooking powered by reliable electricity from EarthSpark's existing solar microgrids operations in Haiti, there is enormous potential to curb the negative health, socioeconomic, and environmental impacts of status quo cooking fuels while preserving the rich culinary tradition that underpins Haitian society.

Study Overview

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. The study is part of a broad research grant funded by Loughborough University (via the Modern Energy Cooking Services Initiative under UKAID) and implemented by EarthSpark International.

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, 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.

Key research questions for the study include, but are not limited to:

- What is the baseline situation for traditional cooking in rural Haiti?
- Can electric cooking devices support Haitian cooking both in terms of physical capability, but also for meeting the expectations and preferences of local communities?
- How can electric cooking devices be deployed effectively in a microgrid context to support community cooking needs without compromising other microgrid electricity service?
- How can electric cooking enable time and cost savings and reduction of harmful indoor air pollution for households, particularly women?
- What tariff design and other financing mechanisms are needed to support affordability and uptake of electric cooking solutions?
- What actions need to be taken to support an enabling environment for clean electric cooking in Haiti and beyond?

Report Organization

The report is organized into the following sections:

Section 1: Background – Background information and context on energy access and access to clean cooking fuels, impacts of traditional cooking fuels, and traditional approaches to clean cooking for developing communities with an emphasis on Haiti.

Section 2: Electric Cooking – An overview of electric cooking research in developing communities, particularly highlighting key challenges to overcome and applications for microgrid contexts.

Section 3: Methodology and Data – Study methodology, technology selection, participant selection, and data sources/analysis approach for the electric cooking study.

Section 4: Results and Analysis – Results and analysis including consumer preferences, compatibility of Haitian meals with electric cooking, electric cooking consumption profiles, cost considerations, and impact on microgrid operations

Section 5: Discussion – Implications of the research for broader electric cooking in Haiti and beyond including a discussion of community impacts, impacts on microgrid models and operators, social inclusion, finances and affordability, development of an enabling environment for electric clean cooking, and key future research steps.

Section 6: Challenges and Lessons Learned – A discussion of key challenges during the study and important lessons learned that can be leveraged in future research.

Section 7: Conclusion – Discussion of the overall impact of the study and the critical next steps.

Section 8: Annexes – Supporting information including references, participant surveys and energy diaries, etc.

Background

Energy Access and Access to Clean Cooking

An estimated 789 million people worldwide lacked access to electricity in 2018 (IRENA, 2020). In Haiti, only 30% of the population (5-10% in rural areas) has access to electricity (World Bank Scaling Renewable Energy Program, 2015). While progress has been seen for electricity access with the population gaining access outpacing population growth, access to clean fuels and technologies for cooking remains a critical obstacle to achieving the United Nations Sustainable Development Goal 7 (SDG7) which aims to, ensure universal access to affordable, reliable and modern energy services by 2030 (International Energy Agency, 2019).

In 2018, over 2.8 billion people lived without access to clean cooking fuels and technologies, relying instead on woodfuels, charcoal, kerosene, and other solid biomass fuels as their primary cooking fuel. The most recent projections from the International Energy Agency (IEA) suggests that the global community will fall far short of the 2030 universal access target with over 2.3 billion people still without access to clean cooking by 2030 and 1.8 billion in 2040 (International Energy Agency, 2019).

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[1]) and the vast majority

[1] In rural areas with large charcoal production operations, there is a lot higher proportion of charcoal used for cooking.

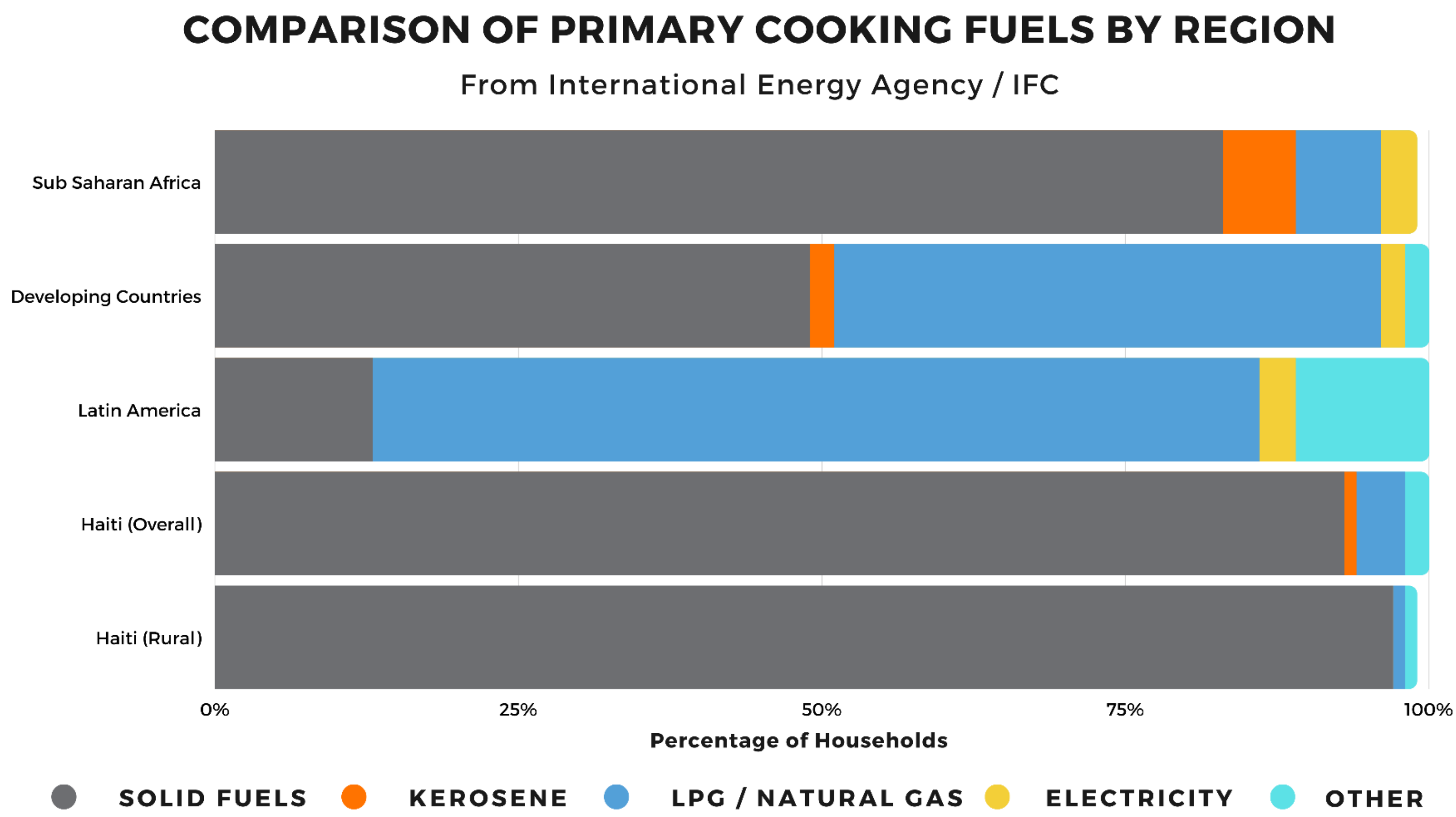


Figure 1: Comparison of Primary Cooking Fuels by Region

of cooking is done indoors (63%) and on inefficient traditional unvented and unimproved cookstoves or over open flames (Institut Haïtien de l'Enfance and IFC, 2018) (Figure 1).

Traditional Cooking Impacts

Combustion of traditional cooking fuels like biomass and kerosene in inefficient cookstoves or over open flames results in high levels of household air pollution (HAP) and exposure to health-damaging pollutants, especially for women and young children (World Health Organization, 2014) (Clean Cooking Alliance, 2017).

This life-long exposure, including through critical periods of maternity and child development, can have serious consequences for health (World Health Organization, 2014). The World Health Organization estimates that almost 3.8 million people die each year from illnesses like pneumonia, stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer that are attributable to HAP from the use of kerosene and biomass fuels for cooking (World Health Organization, 2018). In Haiti, the World Health Organization estimates that there were over 11,000 deaths attributable or partially attributable to HAP in 2016 including over 2,000 children under 5 (World Health Organization, 2016).

In addition to the elevated HAP risks, traditional cooking also creates significant socioeconomic challenges, particularly for women in rural communities. On average women can spend 4-6 hours per day on collecting and preparing fuel for cooking and for cooking activities themselves. This can have significant impacts on health, education, income opportunities, and simply leisure time for women which serves to sustain and exacerbate gender inequality in developing communities (Practical Action Consulting, 2019). Further, the lost economic potential from unpaid work hours collecting fuel for women amounts to

Figure 2: Impacts of Traditional Cooking

an estimated $12 trillion annually (McKinsey Global Institute, 2015). Haitian women for example spend twice as much time on domestic tasks as men and can spend up to five hours per day collecting firewood, collecting water, and cooking (Global Alliance for Clean Cookstoves, 2017).

Socioeconomic impacts are also seen from fuel expenditures which can represent a significant portion of household income and limit available income for other necessary expenditures like education and food (World Bank and, 2014) (Practical Action Consulting, 2019). In 2015, with a traditional stove and traditional wood charcoal, the average household in Haiti spent an estimated 58-67 htg/day on fuel (Global Alliance for Clean Cookstoves, 2017) and approximately 10% of their annual income on fuel (Clean Cooking Alliance, 2017). This is compounded by the use of inefficient stoves. Additional evidence from EarthSpark's microgrid planning surveys highlights that in more remote rural areas in Southern Haiti nearly 100% of households utilize wood or charcoal for cooking and that some households can spend upwards of 1000 htg every week for cooking fuels.

Haitian woman with a traditional stove

In addition to the human health, gender, and socioeconomic impacts, utilizing wood, charcoal, and other solid fuels can contribute to other externalities including forest degradation, biodiversity loss, soil degradation and climate change (SEI and HIVOS, 2020). In fact, cooking and heating fuels like wood, agriculture waste, and charcoal are estimated to contribute almost 25% of global black carbon emissions (Bond, et al., 2013) and non-renewable woodfuels contribute an estimated 1.9-2.3% of greenhouse gas emissions annually.

Haiti still has over 75% of its primary energy supply from biomass and woodfuels (International Energy Agency, 2018) and does experience environmental degradation from charcoal and woodfuel production, particularly in certain local communities. In Haiti these impacts may be less pronounced than previously estimated. A recent report on the charcoal industry in Haiti highlights that Haiti's tree cover is significantly higher than previously estimated and while there are localized impacts from charcoal production, the decentralization of charcoal production in Haiti has led to forest recovery in traditional production areas. Further, there are indications from production trends that indicates high utilization of renewable biomass for charcoal production in Haiti (World Bank, 2018) (Figure 2). However, there is still localized environmental degradation in many areas.

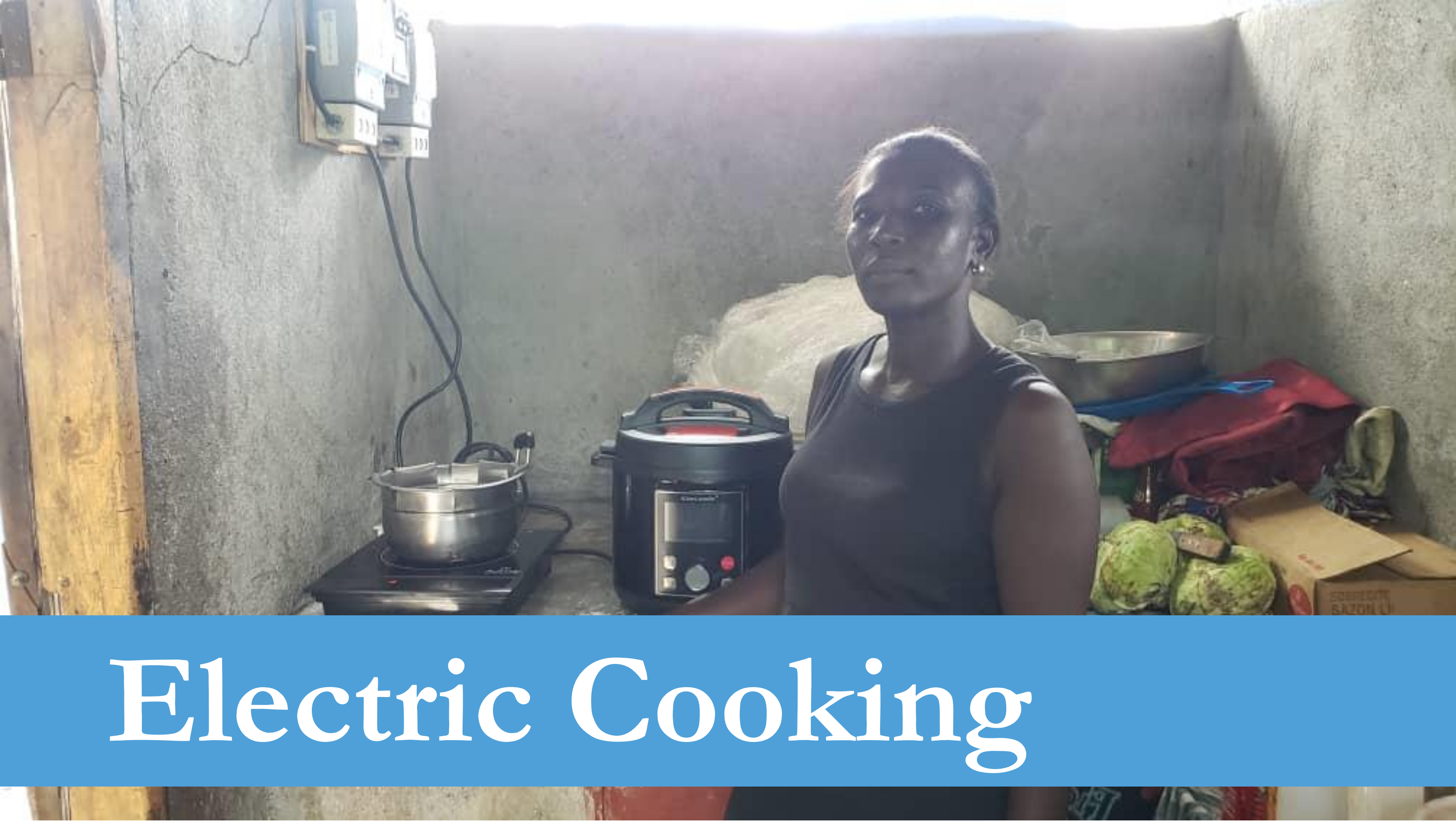
Historical Approaches to Clean Cooking

Globally efforts towards the expansion of clean cooking alternatives have focused on improved cookstoves, biomass briquettes, and expansion of LPG. However, clean cooking has lagged significantly compared to needed action to meet SDG7. As above, the IEA's 2019 update for SDG Outlook estimates that the current pathway for access to clean fuels for cooking will leave over 2.3 billion people without access in 2030 and over 1.8 billion in 2040 (International Energy Agency, 2019). Further, while definitely an improvement in emissions over the status quo fuels, LPG and ICS stoves including kerosene all utilize fossil fuels which can still cause localized health impacts while also contributing greenhouse gas emissions which drive global climate change.

Haitian woman cooking over traditional stove

In Haiti there have been several efforts 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 (USAID/Chemonics, 2015).

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 (Global Alliance for Clean Cookstoves, 2017). 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.



Electric Cooking

Electric Cooking Research

A number of recent initiatives have now been focusing on electric cooking as a key competitor and opportunity for clean cooking in developing communities. The updated Beyond Fire Report on electric cooking from Hivos and the World Future Council highlighted that due to significant decreases in both batteries and PV modules (76% and 82%, respectively since 2010) as well as expanding demonstrations for customer preference and functionality, electric cooking is rapidly becoming a viable solution for clean cooking deployment, particularly in mini-grid systems. The study specifically found that electric slow cookers and pressure cookers can enable household cooking costs between EUR 15 and 21/month for SHS (17.65 – 24.71 USD) and between EUR 3.56 – 9.53/month for mini-grids (4.19 – 11.21 USD) indicating that electric cooking is well within the range of cost-competitiveness of other cooking alternatives. Compared to the original report, the updated study also highlighted the key importance of appliance efficiency for electric pressure cookers in driving unit economics for electric cooking (SEI and HIVOS, 2020) (Couture & Jacobs, Beyond Fire: How to Achieve Electric Cooking, 2019) (Couture & Jacobs, 2016).

In the 2020 report “Cooking with Electricity: A Cost Perspective”, the Energy Sector Management Assistance Program (ESMAP) explored five case studies for a range of electric cooking solutions in different contexts (urban, national grid in Kenya; urban, national grid in Zambia; rural micro-hydro mini-grid in Myanmar; rural, solar hybrid mini-grid in Tanzania; and rural, off-grid SHS in Kenya). Overall, the report highlighted that eCooking on national grids

Haitian woman with "SparkStove" system

or mini-/micro-hydropower is already cost-effective for many people today and that by 2025, the costs of cooking with AC appliances connected to solar hybrid mini-grids ($8–$25/month) and with DC appliances powered by solar home systems ($11–$24/month) become competitive (ESMAP, 2020).

One of the largest research efforts for electric clean cooking is the Modern Electric Cooking Services (MECS) Programme which has developed a long series of electric cooking research working to build a strong evidence base of deployment ready technologies and markets for clean cooking and support a shift in business-as-usual thinking for clean cooking (Batchelor S. , Brown, Scott, & Leary, 2019). The research started with the "eCook" and "PV Cook" concepts which basically couple SHS and/or battery chargers with electric cooking devices (initially electric hot plates) for applications in developing communities (Brown & Leary, 2015) (Brown, Leary, Davies, Batchelor, & Scott, 2017).

A 2018 multi-criteria decision analysis for eCook/PV Cook explored a wide variety of factors expected to affect the uptake and potential impact of eCook. These factors included infrastructure (i.e. how easy it is to obtain components in country and in communities; energy access rates, etc.), culture (i.e. what do people cook and how), human (i.e. availability of local expertise, energy policy, empowerment of women), physical (i.e. climate conditions, deforestation, etc.), and economics (i.e. financing options, cost of alternatives/status quo). The analysis highlighted that there are significant sizeable markets (millions of potential users) where the costs of electric cooking applications are expected to be highly competitive against existing commercialised polluting fuels. Specifically, in countries with charcoal prices above 1.35USD/kg, kerosene prices below 4.34USD/l or LPG prices below 6.07USD/kg, in 2020 it will be cheaper to use PV-eCook than these fuels under all scenarios. Countries in between these ranges will be cheaper under some scenarios and more expensive under others, suggesting that some markets are likely to emerge within each country. Haiti was one country where the eCook concept was seen to be quite viable (Batchelor S. , et al., 2018).

MECS has followed up on this initial research with focused country level research on electric cooking particularly electric pressure cookers in a number of different applications and countries.

A first study of urban applications of electric cooking in Kenya highlighted that in urban contexts with relatively high traditional fuel prices and moderate electricity prices, both direct AC and battery-supported eCooking can already offer considerable cost savings and will become more competitive as polluting fuel prices continue to increase over time. Another off-grid study in Kenya highlighted that charcoal prices already make solar electric cooking cost effective and that the penetration of SHS and PAYG solar in communities will enable solar cooking to be cost comparable to investing in LPG. In Zambia, MECS modelling has shown that electricity is already by far the cheapest option and LPG is not competitive at all. Battery-supported cooking is already the cheapest way to mitigate issues with load-shedding and blackouts in more urban environments. A Tanzania case study highlights the effectiveness of electric cooking supporting small cooking enterprises despite high mini-grid tariffs for electricity (Leach, Leary, Scott, & Batchelor, 2019).

In a study of electric cooking design in Cambodia, a significant majority of participants highlighted a preference to adopt electric cookstoves mostly due to taste. The study also highlighted a strong desire to control their energy consumption patterns and understand the unit costs for electric cooking (initial perception is that electricity is more expensive). To explore this, the study utilized smart meters to support expanded customer awareness building and behavioural shifts and found that smart metering, and particularly focused energy literacy for customers to see/understand the electricity consumption and cost patterns associated with various common cooking exercises was a strong supporting factor for adoption of electric cooking alternatives (MECS, 2020).

A summary of the results from electric pressure cooker field studies in Kenya, Tanzania, and Zambia highlights that electric pressure cookers are highly desirable and that over 90% of the cultural cooking menus can be cooked effectively on electric pressure cookers. Despite this and substantial energy savings over traditional hotplates and other devices, electric pressure cookers were only chosen 50% of the time by participants which highlights significant opportunity for training and awareness building for end users (Batchelor S. , Brown, Scott, & Leary, 2019).

Other MECS research has also included load modelling for electric cooking devices, technical assessments of specific cooking devices, political economy of electric cooking, as well as the development of multiple electric pressure cooker recipe books for different foods and geographies.

Outside of the MECS initiative, a research study assessing the desirability of electric pressure cookers in off-grid households in Kenya specifically found that electric pressure cookers are generally desirable as they are perceived as time-saving and easy to use in comparison with biomass cooking. The study estimated that if electric cooking was below roughly $14.10 per month in costs, users would make the switch from firewood (Access to Energy Institute, 2019).

Electric Cooking and Microgrids

A key point from the early research on electric cooking is that a utility business model is seen as the most attractive for poor households, particularly if combined with mobile enabled payment mechanisms because it can overcome some of the financial barriers and risks from the new electric cooking technologies (Brown & Leary, 2015) (Brown, Leary, Davies, Batchelor, & Scott, 2017). The recent ESMAP report further supports this by concluding "the uptake of eCooking will depend substantially on the willingness of the private sector— in particular solar companies, mini-grid operators and utilities—to adopt the technology as part of the suite of services it offers its customers."

Given the challenges in many rural areas for expansion of centralized utility models, microgrids, particularly represent a key opportunity for energy access and electric cooking as they can leverage critical economies of scale and utility business models to support electric cooking investment for customers and the cooking load can in turn help provide additional revenue streams for microgrid financial viability. This notion is further supported by the estimation that mini-grids will be the cheapest option for electricity access for 490 million of the 1.2 billion to be electrified by 2030 (Sustainable Energy For All, 2020).

Haitian woman with electric cookers

In fact, there have been a number of studies and projects already incorporating electric cooking load into microgrid operations (in addition to the MECS studies previously mentioned). A few key studies are discussed below:

Accelerating uptake of electric cooking on AC microgrids through business and delivery model innovations (MECS, 2020)

The study found that customers appreciated cooking with the electric pressure cookers and that the cookers had a positive impact

Participant with "SparkStove" system

on customer quality of life (decreased cooking time, decreased health impacts from smoke) with minimal impacts on cooking costs. Electricity consumption data from household electricity meters showed that customer electricity consumption on average increased by 2.6 kWh per month (~20% increase) demonstrating an active demand for electric cooking. The project also highlighted the importance of in-person hands-on training for electric cooking for customers as well as financial assistance (the study leveraged a loan facility) to support households overcoming the initial cost of the pressure cookers.

Unlocking electric cooking on Nepali micro-hydropower mini-grids (Clements, et al., 2020)

A 2020 study introduced electric cooking for 10 households in a micro-hydro mini grid in Nepal and found that the transition to electric cooking reduced firewood collection times as well as cooking times for participants and that participants enjoyed cooking on the stoves due to elimination of indoor air pollution. Participants generally cooked two meals per day on average consuming 0.25 kWh/day and 0.14 kWh/meal. The study also highlighted high initial capital costs for electric cooking technologies as well as the reliability of electric supply as key potential barriers to electric cooking in microgrid settings.

Enabling combined access to electricity and clean cooking with PV microgrids: new evidences from a high-resolution model of cooking loads (Lombardi, Riva, Sacchi, & Colombo, 2019)

A 2019 study in Tanzania conducted an assessment of the techno-economic potential of a fully-renewable solar micro-grid for electricity load and electric cooking in community and household applications. The study highlighted cost-competitiveness for electric cooking particularly for community service applications. Specifically, the study found a range of Levelised Cost for Cooking a Meal (LCCM) for electric cooking ranging between 0.16 and 0.70 USD/kWh (depending on assumptions for device penetration and fuel stacking). which was comparable to all other cooking options for the area. Not only does the analysis highlight that highly-efficient electric cooking can be cost-competitive with all other cooking options, but also that the profitability of electric cooking is much higher when a cost-optimised modern energy system configuration is utilized.

Tecno-economic assessment of an off-grid PV-powered community kitchen for developing regions (Dufo-Lopez, Zubi, & Fracastoro, 2012)

An assessment of off-grid PV+battery mini-grid systems coupled with low demand cooking appliances (rice cookers) for communities in India, Indonesia, Bangladesh, Pakistan, and Nigeria found the levelised energy cost for electric cooking in a microgrid setting to be around 0.03€ per meal or less and the life cycle emissions of the system (manufacturing, transport and decommissioning) to be around 7 gCO2 per meal.

Power Generation Planning of Galapagos' Microgrid Considering Electric Vehicles and Induction Stoves (Clairand, Arriaga, Canizares, & Alvarez-Bel, 2019)

An analysis of integrating electric cooking load from induction stoves under Ecuador's National Efficient Cooking Program into the planned expansion of island microgrids in the Galapagos highlighted that the economic impacts of electric cooking load depended on the penetration of devices and their utilization as well as the varied predictability of those cooking loads. The study found electricity demand for electric cooking to range between 0.3-0.6 kWh, 1-2 kWh, 0.8-1.6 kWh (breakfast, lunch, and dinner respectively). The study ultimately supported integrating electric cooking into future microgrid development and expansion.

Challenges for Electric Cooking

Some critical challenges that were highlighted by a number of the studies (Scott, Jones, & Batchelor, 2020), (Brown, Leary, Davies, Batchelor, & Scott, 2017), (MECS, 2020), (MECS, 2020) (Batchelor, Khan, Scott, & Leary, 2017) (MECS, 2020) include:

Financial Barriers: Given the applications for poor communities, the most critical barrier has been the cost of the electric cooking systems both in terms of the upfront capital, but also the time to actually procure electric cooking components. Further in many cases there was a perception that the price of electricity was higher (even where electricity is cheaper) and in other cases the value of the time spent gathering fuel in the baseline situation isn't always factored into household decision-making or perception of value.

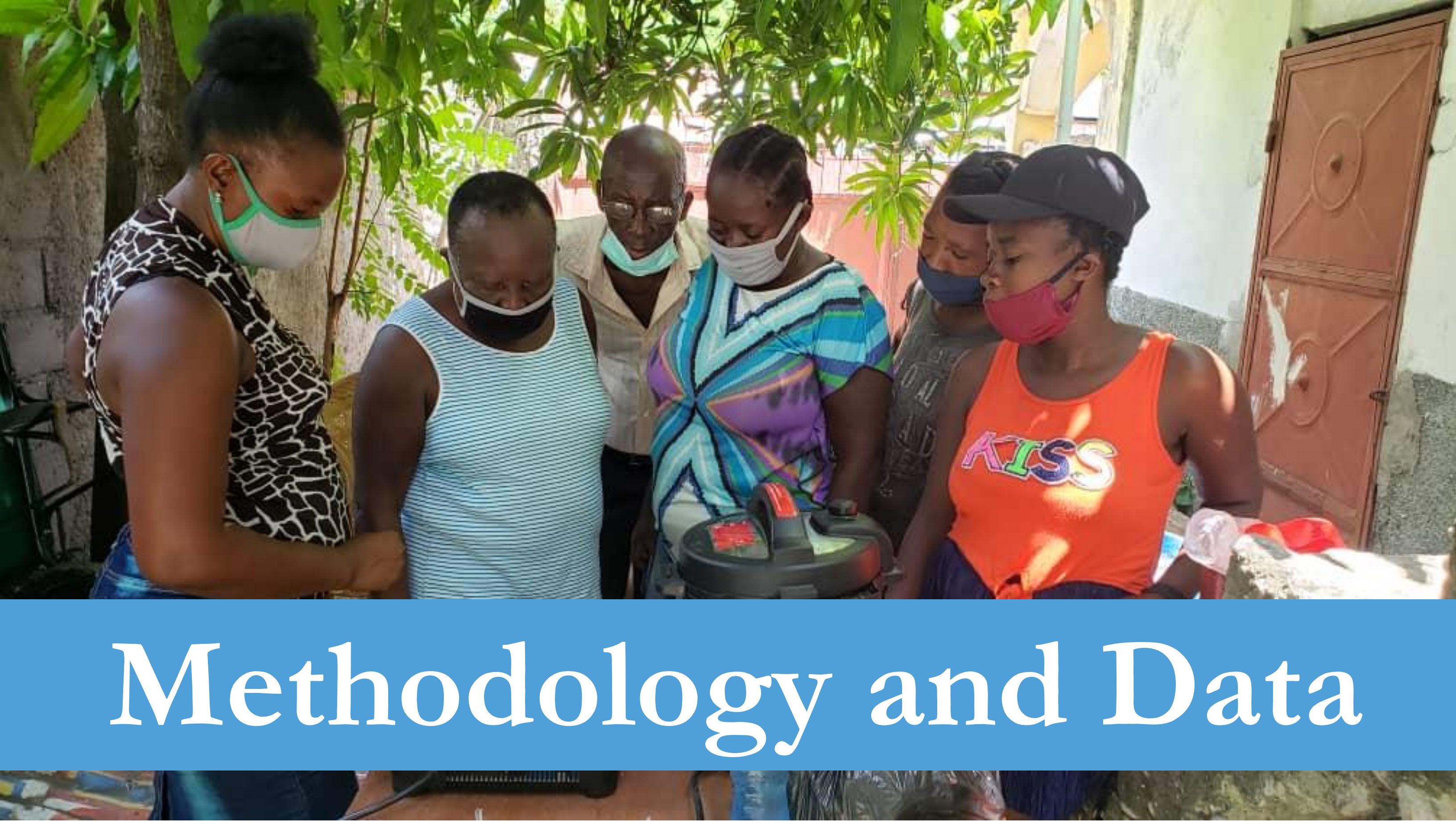
Awareness: Awareness of electric cooking technologies and their potential applications and benefits is very limited for end-users, but also even for development partners, government staff, and local leaders. This a significant barrier for commercialization of electric cooking technologies.

Availability of Technology: The bottlenecks for electric cooking equipment (and supporting spare parts) often lie in the supply chain and the availability of technology in country and particularly in community for rural areas.

Infrastructure/Electricity Availability: There is significant uncertainty for end-users on the availability/sufficiency of electricity supply for cooking. For many, mini-grids and national electricity grids have significant load-shedding and unpredictable cuts to electricity supply which can interrupt cooking on electric systems. There is also a challenge related to weak local electricity infrastructure (particularly for electricity connections and wiring);

Quality and Type of Technology Available: The size of many electric cooking appliances available are too small for the cooking needs of large families. Further there tends to be varied quality levels for electric pressure cookers and other devices available to end-users. Overall, the research has demonstrated that the right program design, support, and awareness building can overcome these challenges and that on the whole electric cooking is an increasingly viable and attractive option for modern clean cooking in developing communities.

Overall, the research has demonstrated that the right program design, support, and awareness building can overcome these challenges and that on the whole electric cooking is an increasingly viable and attractive option for modern clean cooking in developing communities.



Methodology and Data

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 (SUNSPOT™ solar electric cooking system) in 8 off-grid households.

The study was conducted by EarthSpark International, a non-profit based in Washington DC that builds business models to solve energy poverty, in partnership with Enèji Pwòp, an EarthSpark International spinoff that is a microgrid operations company currently operating two microgrids in rural Haiti. The study was conducted in the rural community of Les Anglais in Southwestern Haiti which is the site of EarthSpark and Enèji Pwòp's first microgrid in Haiti. The microgrid itself is a 100kW solar PV hybrid microgrid serving about 2000 people.

Participants

In total 20 on-grid 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. All households were encouraged to participate through direct engagement from Enèji Pwòp staff. Unfortunately, some of this selection was complicated by COVID-19.

For on-grid participants, the first requirement was that participants needed to be existing Enèji Pwòp customers. 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 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 on-grid 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.

Haitian family with their new electric cooking installation

Further, with COVID initially access to customers houses was limited initially and technicians could affect their own installs.

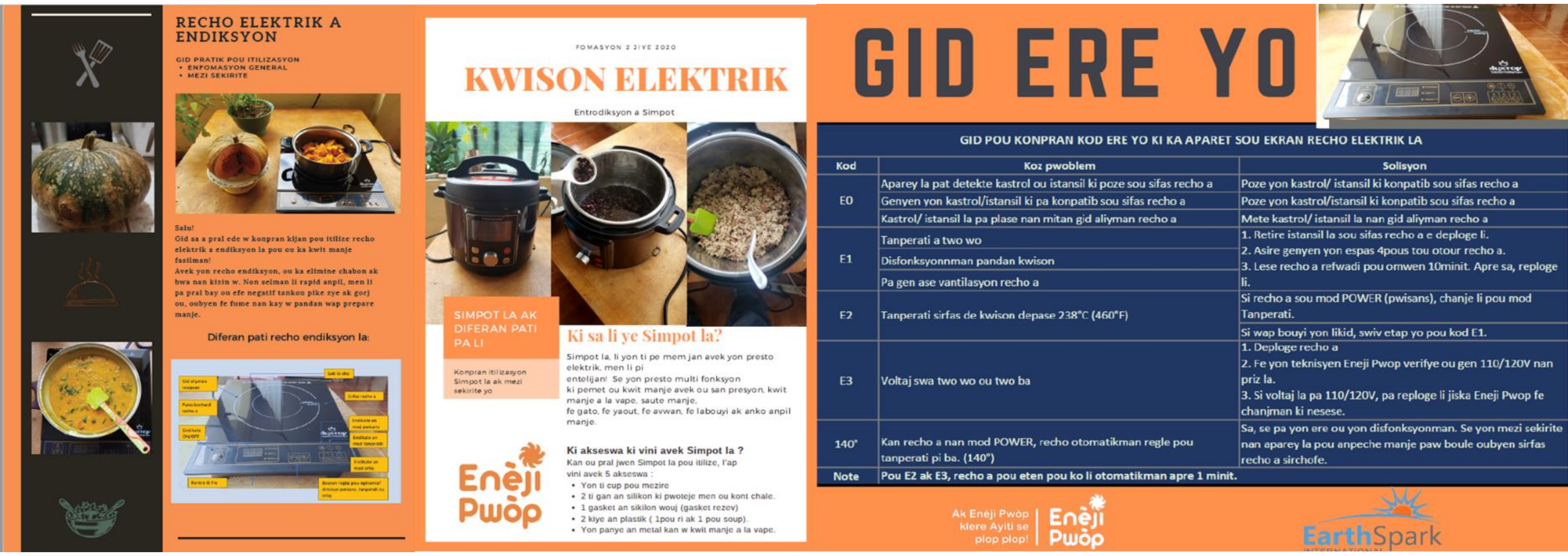
For off-grid households, Enèji Pwòp selected households in a specific neighbourhood more isolated from the rest of the town to simulate households that are not likely to be connected by the microgrid. This neighbourhood also needed to be easily accessible by truck given the installation requirements for the solar home 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.

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 demonstration events focused on cooking specific dishes using the pressure cookers and/or induction stoves. 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

Training event for electric cooking technologies



Participant Guidance Materials

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).

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 Sparkstove 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 (on-grid): The SparkStove system consists of the two different electric cooking devices and three different smart

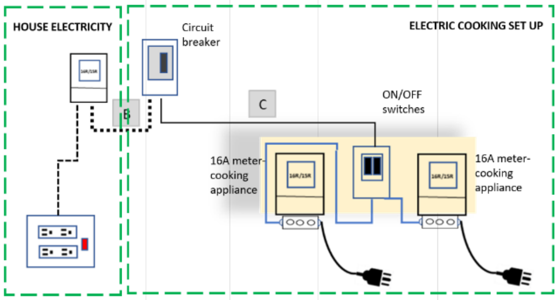


Figure 3: Electrical Setup for "SparkStove" system

meters. The induction stove and the electric pressure cooker were both connected to a 16A smart meter with circuit protection via a circuit breaker which in turn was connected to a breaker box and then to a 60A smart meter for the overall household (Figure 3).

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. Further, the setup allowed the cooking meters to remain active even if the customers' main electricity meter ran out of credit.

Installation of devices followed best practices, in the context of rural Haiti at the time of installation. Any instance necessitating alternative methods were described to the customer during training, to allow for ensured safe operation of the system. Future installations will work to return to normal installation practices.

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 in 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.

Data Sources

The study leveraged a few different tools and technologies to collect and analyse 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.

- **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.
- **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 SHS. 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 analyse the data.

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[2]). 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. The sections below detail the following results from the study:

- Baseline cooking fuels
- Customer Profiles and Menu
- Electric Cooking Consumption by Customer
- Electric Cooking Events
- Impact on Microgrid Loads and Service
- Charcoal Costs and Indicative Willingness to Pay

Baseline Cooking Fuels

The most 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

[2] 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.

Charcoal production and distribution in Les Anglais

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 "sac" for about 50HTG, 150 HTG, and 750 HTG unit price respectively. 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".

Baseline Charcoal Stoves – "Chodye"

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.

It was noted that four participants, three microgrid and one having an off-grid set up (including 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.

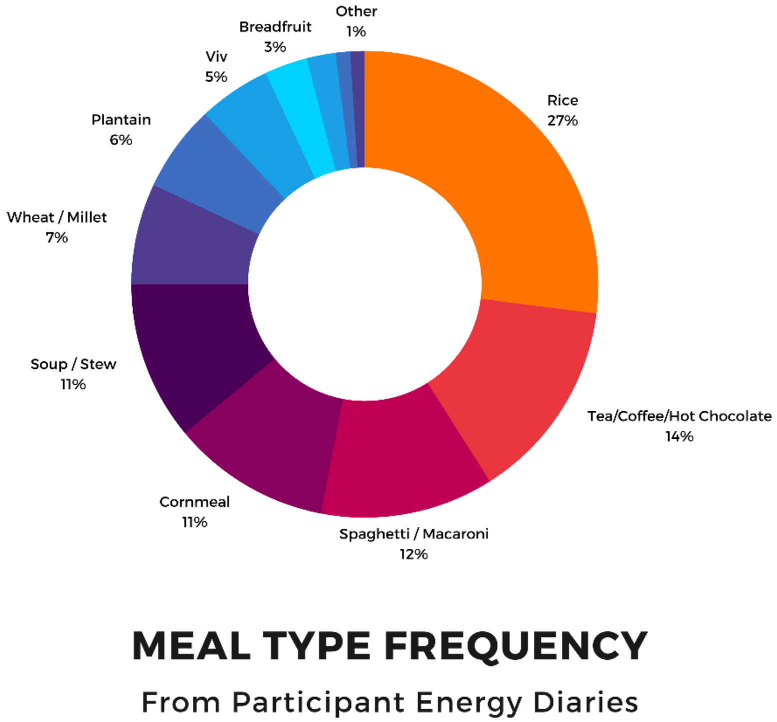
Participant and Menu Profiles

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. However, the fact that it was mostly women participating in the electric cooking project also indicates that they are the ones being the most impacted.

Haitian Rice and Bean Sauce

Survey results indicate that most of the cooks in the households are between 36 and 55 years old (16 of 28 participants), followed by 18–35-year-olds (7 of 28), and people 55+ years old (4 of 28). 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.

The 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



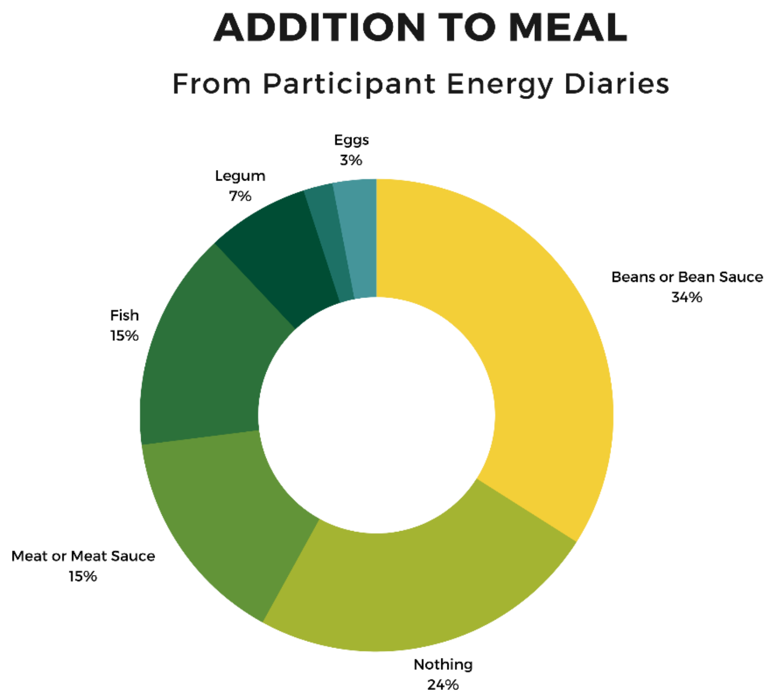


Figure 4: Base Meal Type and Addition to Meal Frequencies

largest number mentioned by cooking participants was thirteen, 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 four and ten people with household cooking.

In a small town like Les Anglais, it is not uncommon to have more than 1 household in a 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. Most of the time households were cooking only for their household and immediate family, but on occasion friends, neighbours, and others also ate the meals prepared. Two participants even highlighted that they also supported a small enterprise selling prepared food.

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 information.

The participants made a variety of traditional Haitian meals over the course of the baseline and electric cooking study period. These meals mostly consisted 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. Mostly food was boiled or fried and rice was the most common item prepared followed by tea/coffee/hot chocolate and spaghetti/macaroni) (Figure 4). Beans were the most common addition followed by fish or meat. Other additions included vegetables, legum (braised vegetables with sauce and coconut), eggs, etc. (Figure 4).

Electric Cooking and Customer Consumption

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/bouillon (51%), wheat/millet (41%), spaghetti/macaroni (39%), rice (32%). Comparisons of participant recorded cooking/prep times can be seen in Figure 5 below. Many of the dishes still have time intensive prep work, but the cooking time savings significantly cut overall meal preparation times (Figure 5).

As above, there were some 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" as well as hourly, daily, and monthly averages as discussed below (see the supporting annexes for raw data). A cooking event was defined as any time the pressure cooker or induction stove meters were recording power draw greater than 100W on average. Continuous 15-minute intervals represent the same "cooking event". 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) (Figure 6). 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

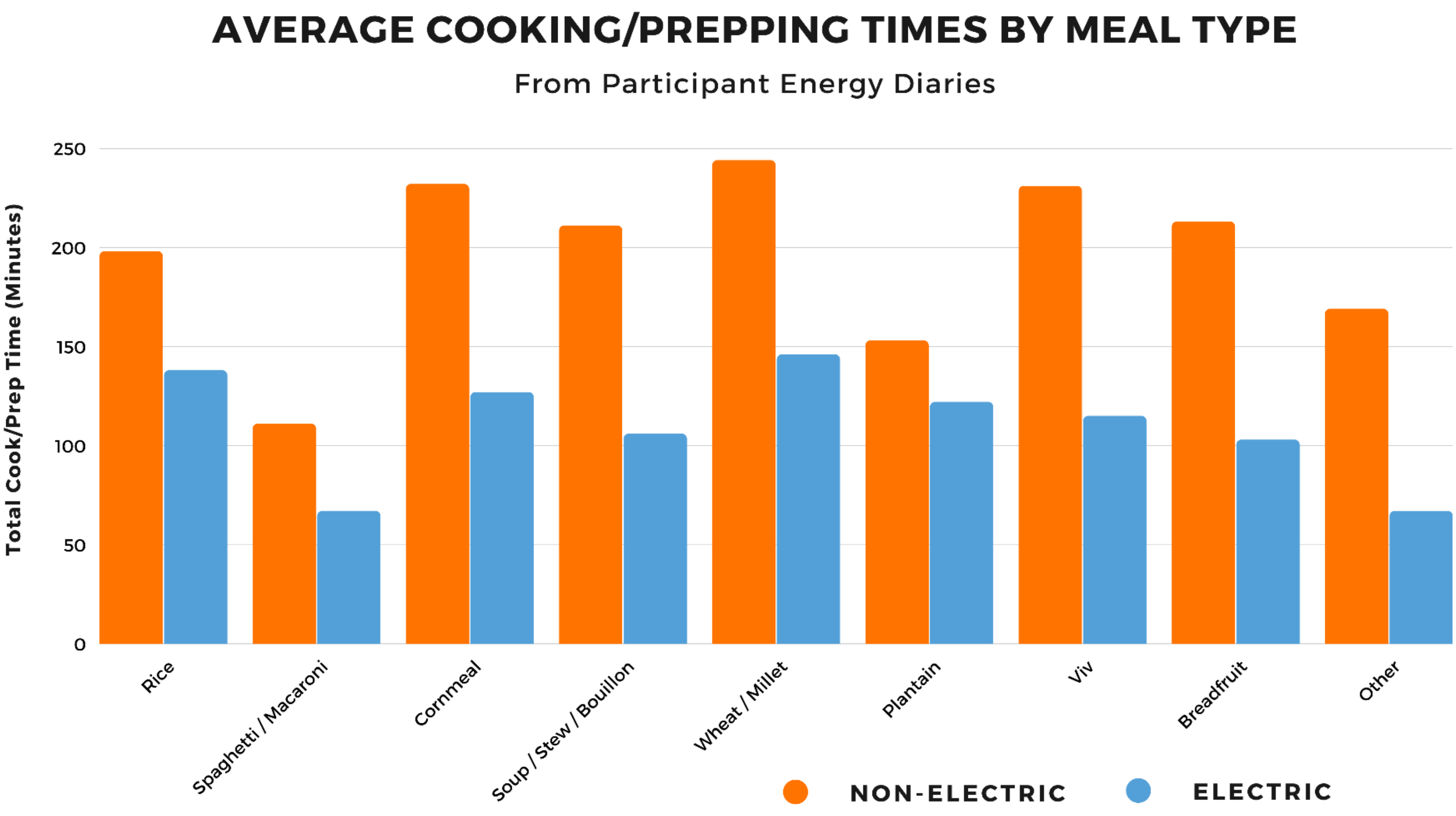


Figure 5: Average Cooking/Prepping Times by Meal Type

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, but as above given the profiles of the participants it is expected that they will be somewhat similar.

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. In total there were only 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. Other metrics as well showed significant ranges across

Figure 6: Electric Cooking Events by Device

ELECTRIC COOKING EVENTS BY DEVICE

From Participant Smart Meter Data

METRIC	PRESSURE COOKER	INDUCTION STOVE	BOTH
Total Cooking Events	1,372	2,282	166
Total Cooking Time (Hours)	1,135	2,271	307
Average Cooking Event Time (Minutes)	50.00	60.23	111.73
Total Electricity (kWh)	1,127	2,583	269
Average Cooking Event Electricity (kWh)	0.83	1.14	1.63

customers. With the exception of the less than interested participant, most households showed meaningful and sustained utilization of electric cooking devices (Figure 7).

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 8).

Figure 7: Summary of Individual Participant Electric Cooking

PARTICIPANT ELECTRIC COOKING SUMMARY

From Participant Smart Meter Data

METRIC	AVG AVERAGE	MED MEDIAN	RNG RANGE
Observed Days	80	79	42 - 132
% of Days with Electric Cooking	79%	84%	24% - 99%
Average Count of Daily Electric Cooking Events	1.53	1.40	0.09 - 3.41
Average Cooking Event Time (Hours)	1.52	1.38	0.02 - 5.07
Average Cooking Event Electricity (kWh)	1.72	1.31	0.31 - 4.91

It should be noted that Figure 8 is only SparkStove participants. Unfortunately, with instability in meter communications for off-grid meters (due mostly to intermittent coverage and relay distance), intervals are only recorded intermittently with single intervals accounting for the consumption in other periods. Although the energy consumed was logged and eventually transmitted, 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. However, from participant surveys and observations it is expected that the on-grid consumption profiles are generally representative of the off-grid consumption profiles as well.

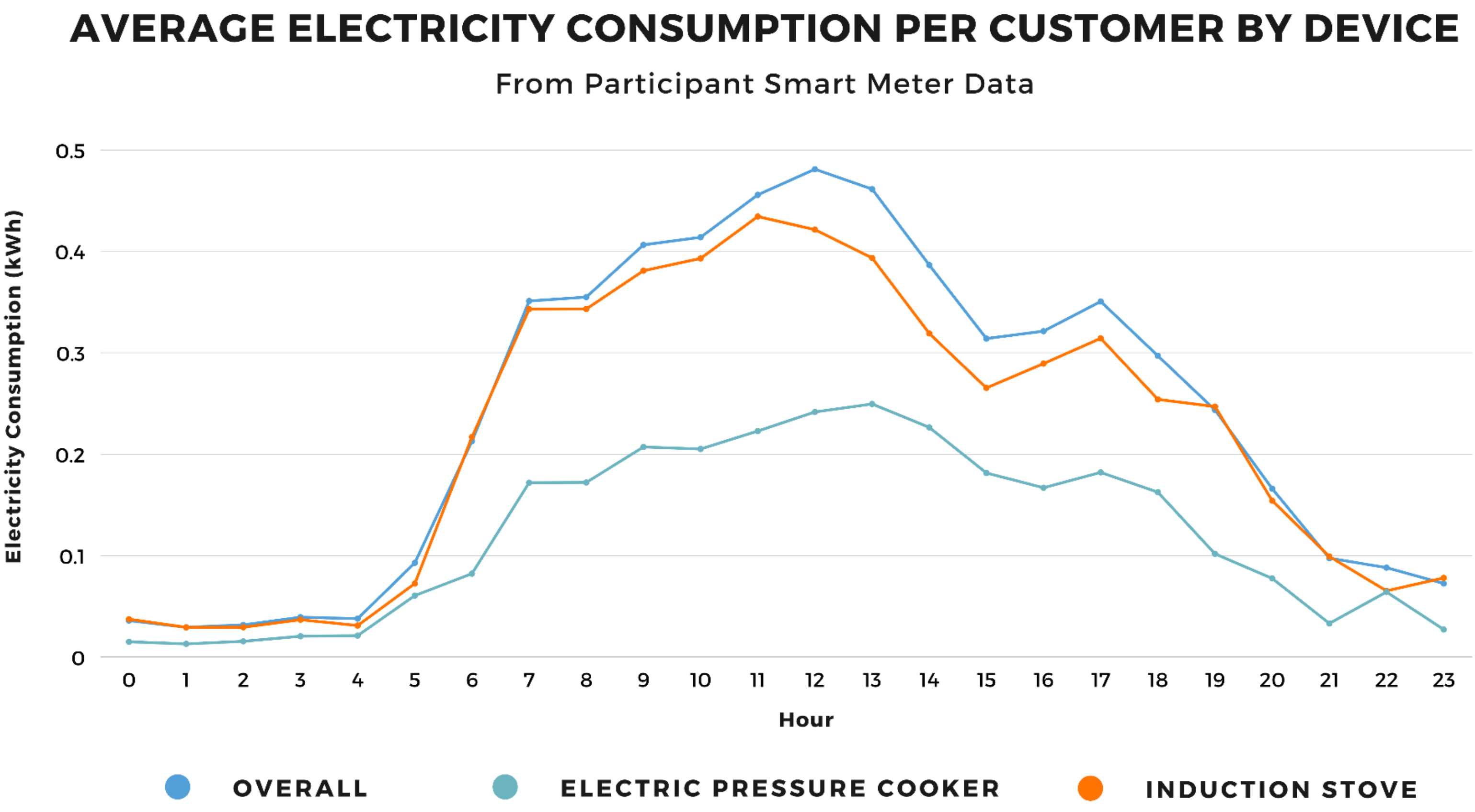


Figure 8: Average Electricity Consumption per Customer by Device

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.

Microgrid Operations and Power Quality

Overall, from July 1, 2020 to November 10, 2020, 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 (Figure 9).

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

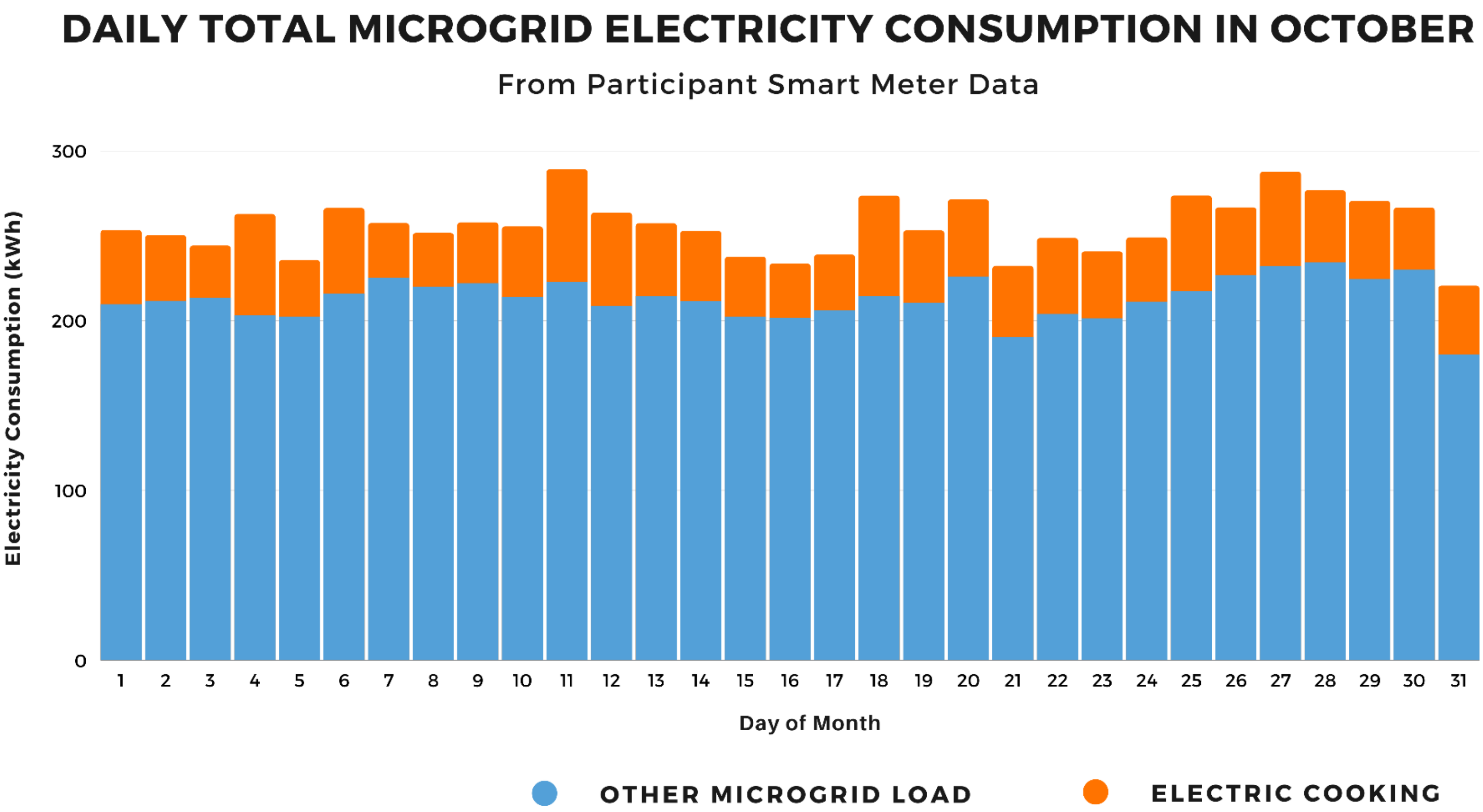


Figure 9: Daily Total Microgrid Electricity Consumption in October

averaged 38.0 kWh and daily pressure cooker use averaged 15.9 kWh.

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.

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% (Figure 10).

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

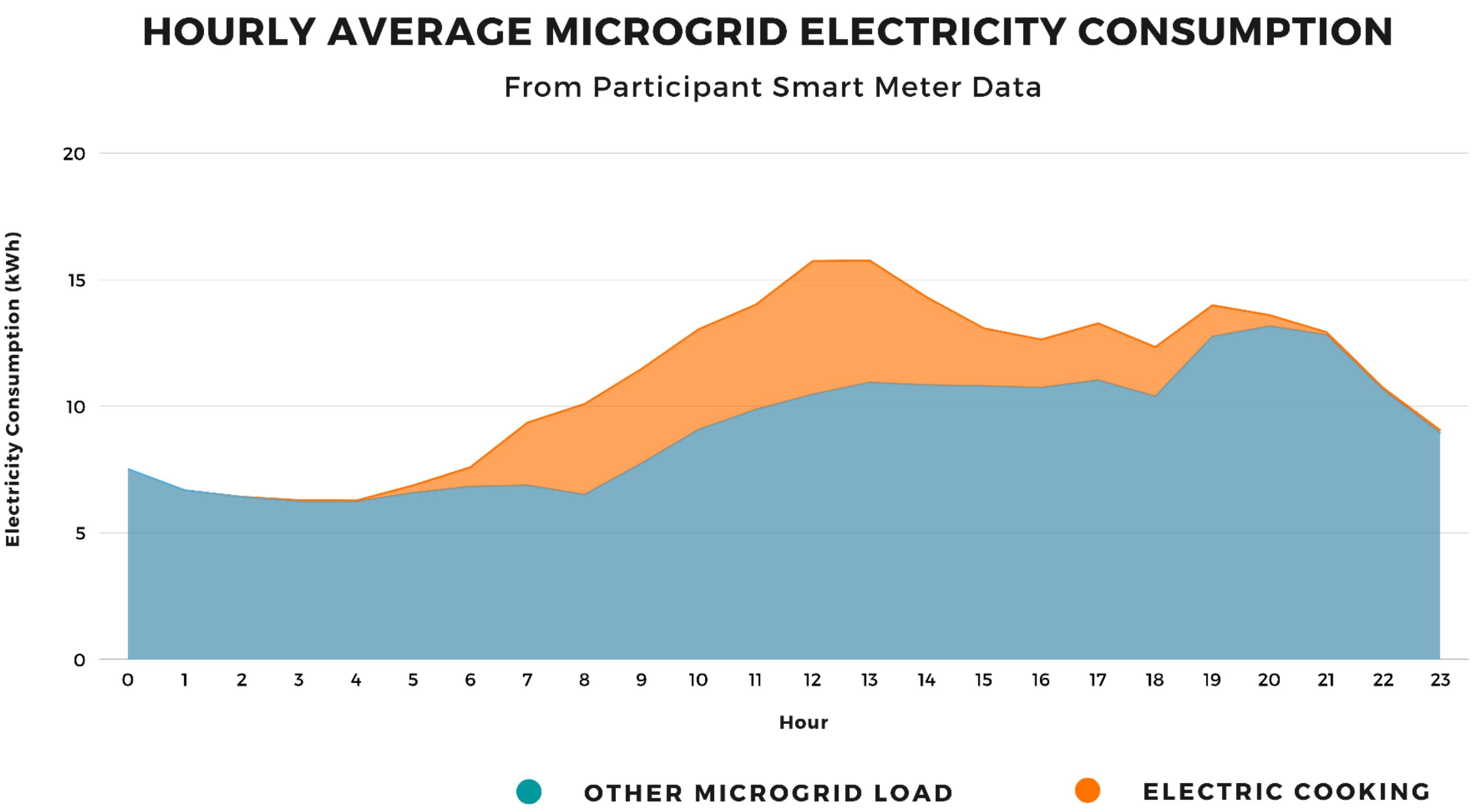


Figure 10: Hourly Average Microgrid Electricity Consumption

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).

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.

Customer Surveys

For the most part, the electric cooking participants responded extremely positively to the electric cooking technology. 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.

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. 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 was 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.

relaxing, 33% for household chores, 15% for focusing on business and income tasks, 7% for self-care, and 7% for family care.

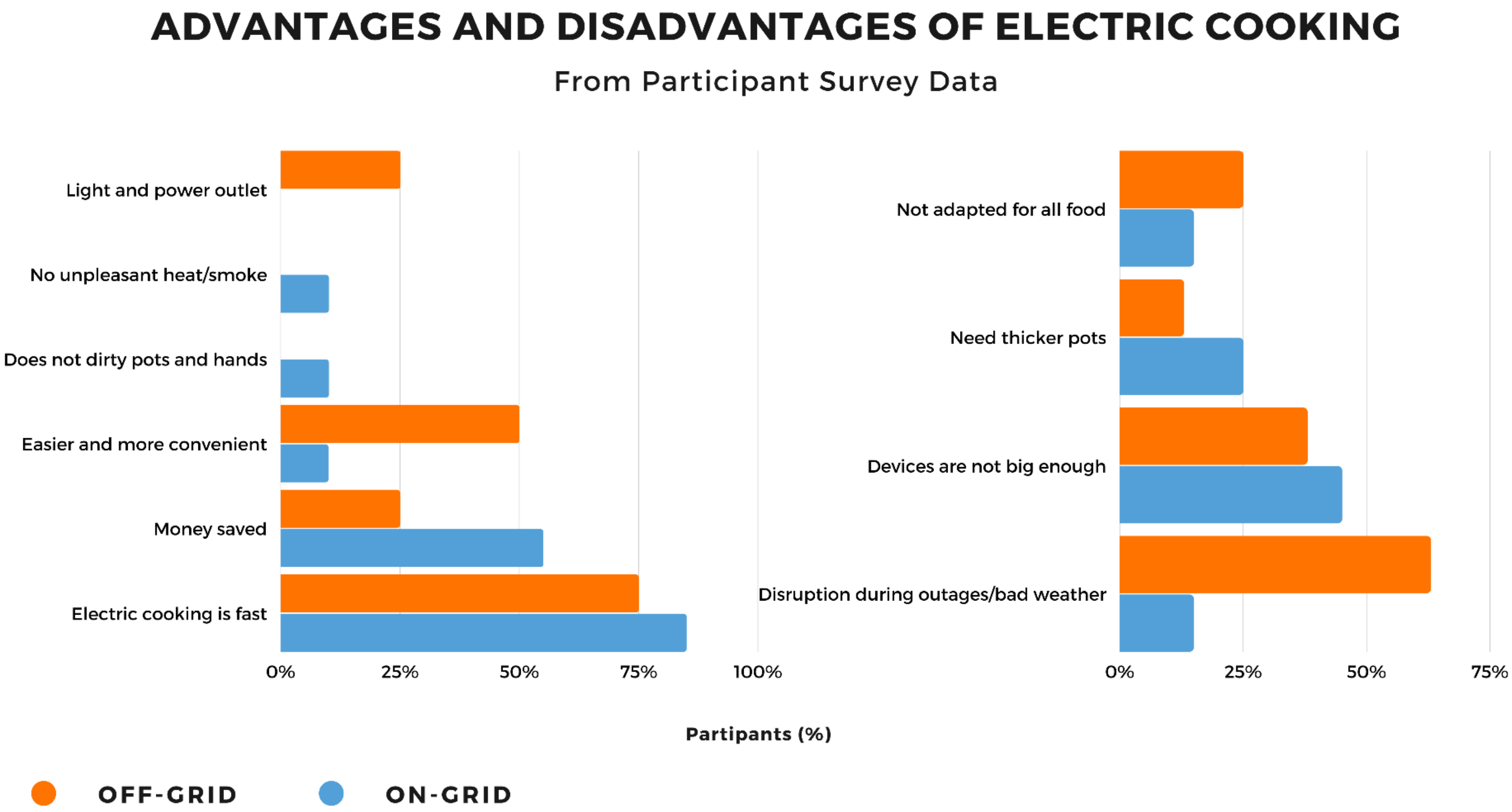


Figure 11: Advantages and Disadvantages of Electric Cooking

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.

All participants responded that electric cooking saved them time compared to status quo cooking. 78% of participants indicated that they used that time for

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 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 in the market in town or in the nearby towns were too thin. This would sometimes result in food being burned for some meals. 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.

The key advantages, benefits, and challenges of electric cooking systems as highlighted by the on- and off-grid participants can be seen in Figure 11.

Charcoal Costs and Indicative Willingness to Pay

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:

1. Some 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.
2. Some participants do not purchase charcoal but produce it themselves. So, their charcoal expenditure has not been affected by the project.
3. Some participants still purchase charcoal but instead of consuming all of it, only save some as a backup fuel and then sell the rest.

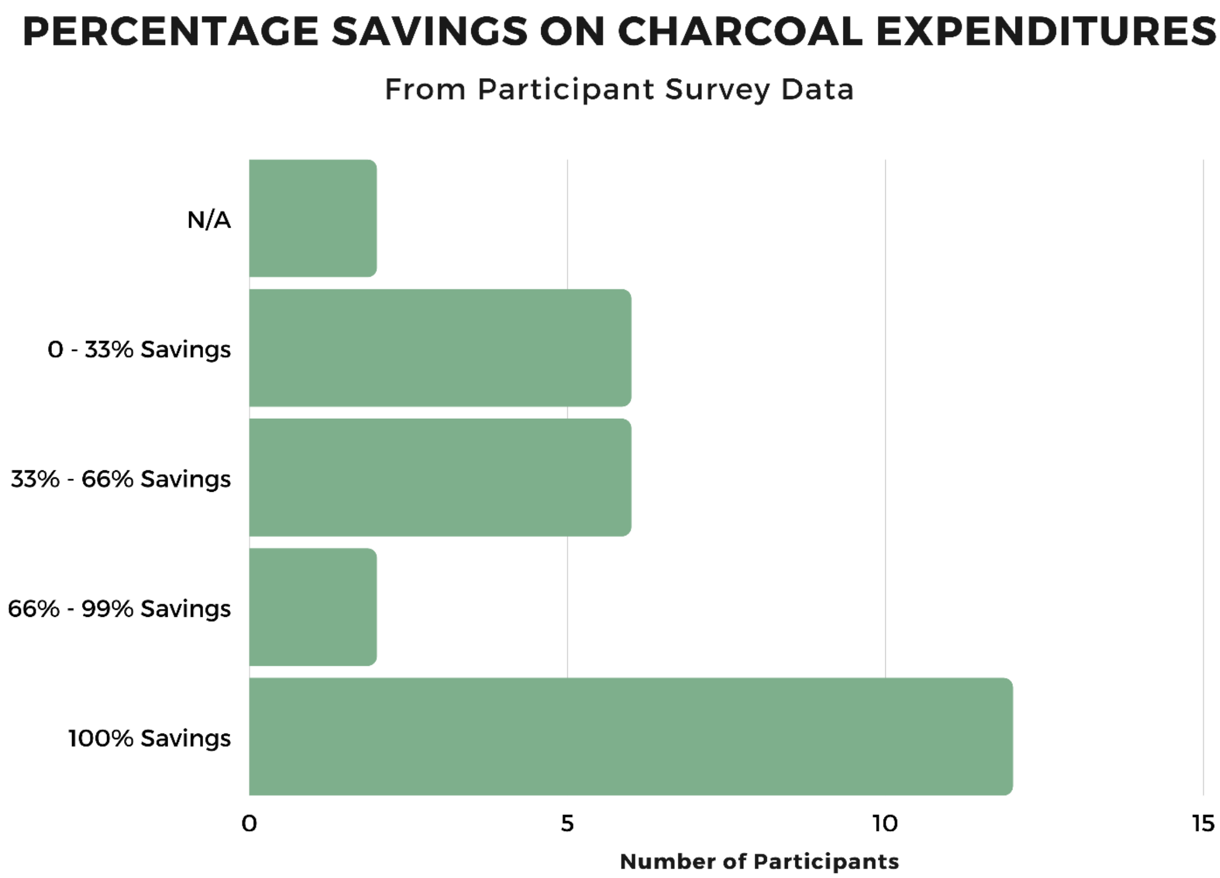


Figure 12: Percentage Savings on Charcoal Expenditures

Monthly charcoal expenditures for participants before electric cooking ranged from 525 htg ($8.28 USD) – 9,300 htg ($147 USD) 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 electric cooking, with 13 participants saving between 80% and 100% on monthly charcoal expenditures. Figure 12 highlights the savings on charcoal expenditures for each customer. It should be noted that some participants 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 and some households didn't record any expenditure values at all. Otherwise, most of the customers saw a clear decrease in 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 (45% of on-grid customers and 25% of off-grid customers) was investing it in schooling either for themselves or for their kids (Figure 13). The second most popular response was to invest in their own business (35% of on-grid, 13% of off-grid). 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. Some participants are not putting aside the money for future use. Instead, some participants 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

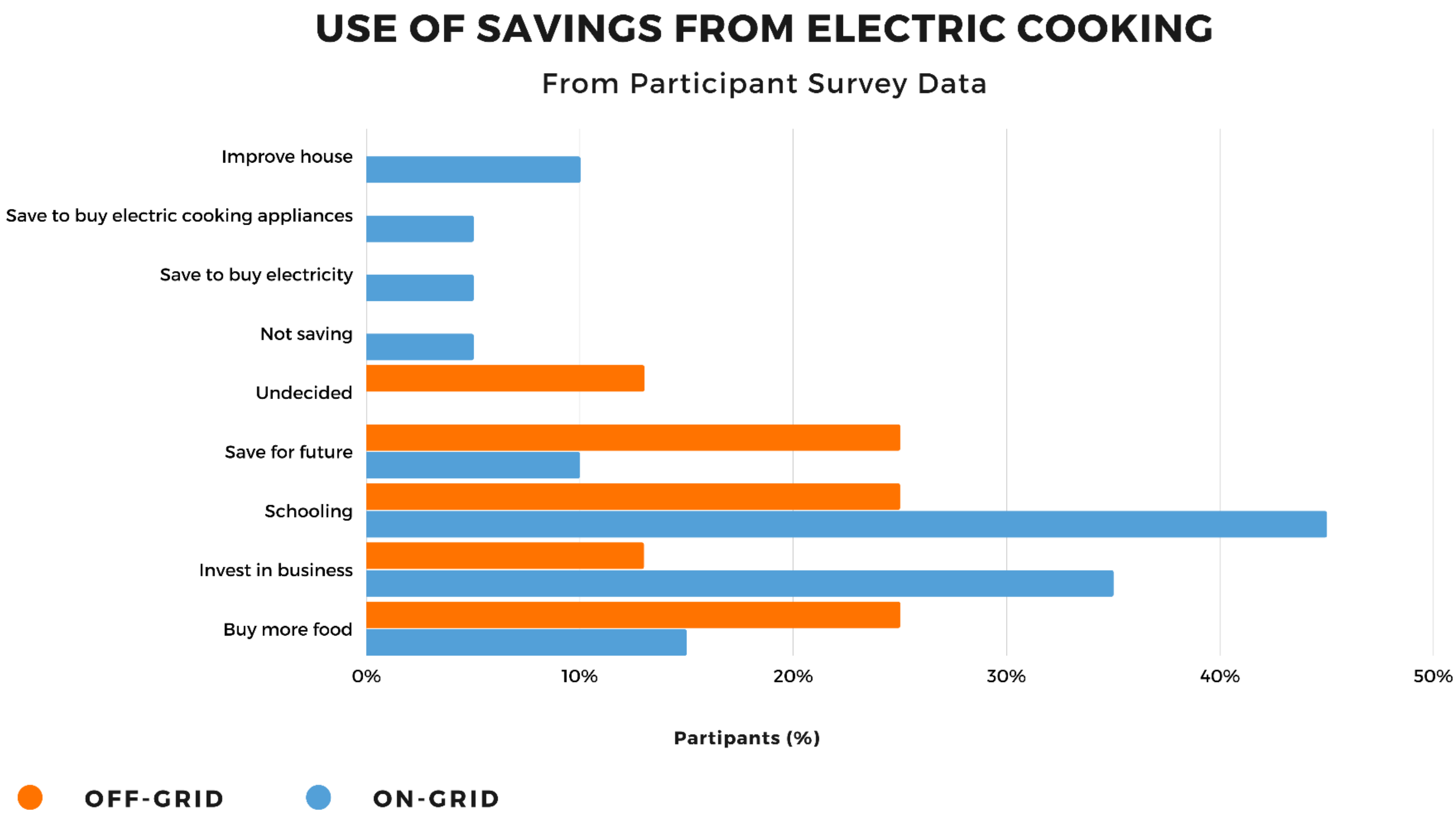


Figure 13: Use of Savings from Electric Cooking

financial capacity, but they can now afford it.

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 (WTP) was around 30.76 htg/kWh. However, 13 of the 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 still indicates an indicative willingness to pay that could be

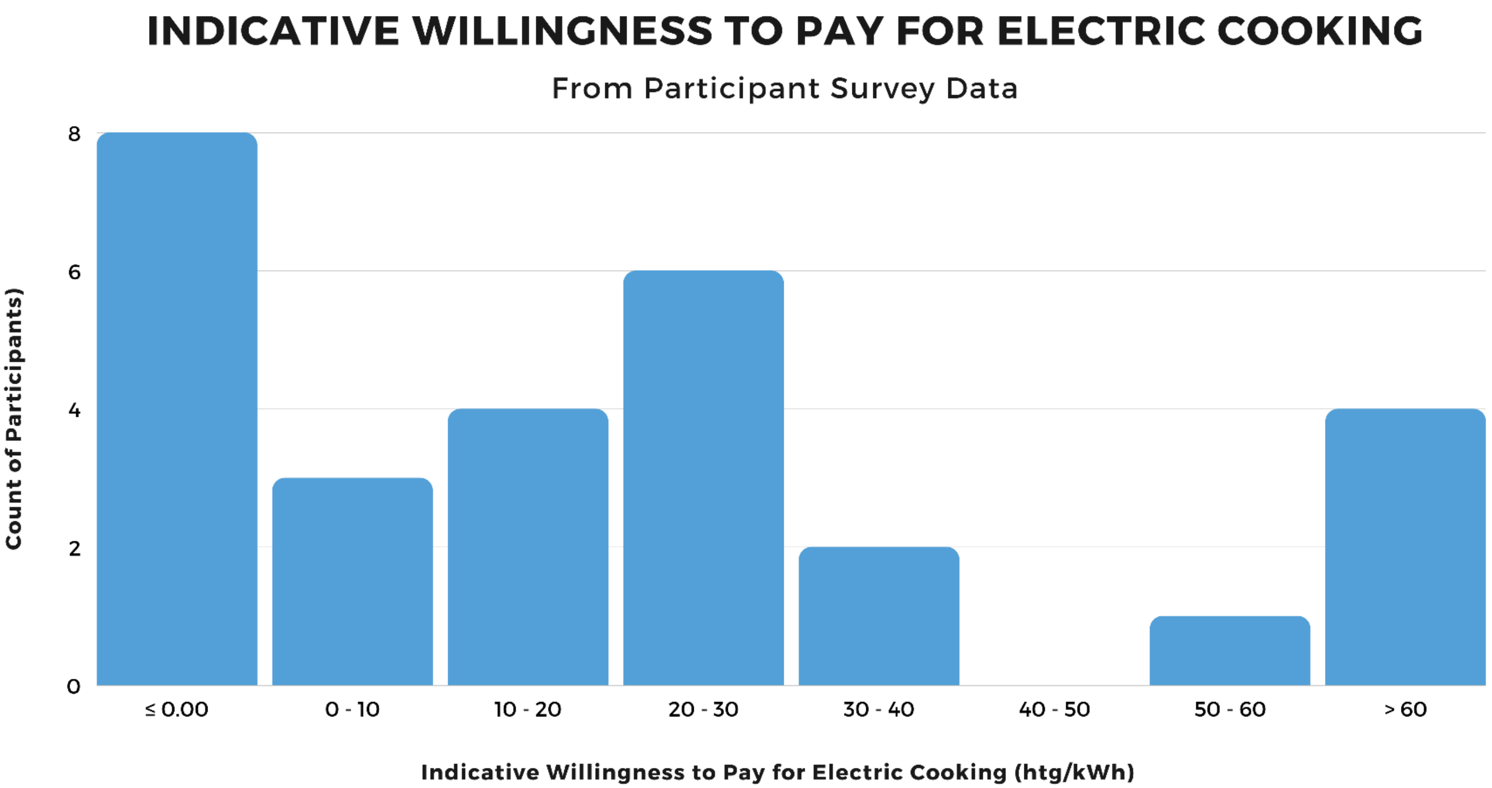


Figure 14: Indicative Willingness to Pay for Electric Cooking

approached with specific incentives, results-based financing, or improved service (i.e. bigger devices as discussed below), particularly if low engagement and low usage customers are removed from future electric cooking deployments (Figure 14).

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).

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.

Discussion

Overall, the pilot project has showcased the value of electric cooking for both local communities and microgrid operators while also laying the foundation for further research and outlining key needs for scaling up electric cooking in Haiti and beyond.

Community Impacts - Catalyst for Improved Quality of Life

Overwhelmingly, the electric cooking pilot demonstrated the life-changing potential of electric cooking for communities.

The biggest impact noted by participants has been the time savings and convenience of electric cooking compared to traditional fuels. For this pilot electric cooking reduced the time burden of cooking 32-53% for staple foods in Haiti resulting in extra time for leisure, income, education, and family.

The electric cooking solutions also improved the convenience of cooking. For example, a few participants highlighted the fact that they can now wake up in the middle of the night and easily have a hot drink or porridge as a key benefit of the electric cooking devices. Traditionally, charcoal is utilized in an outdoor/separate kitchen area 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. One participant in particular noted specifically how the new cooking system was convenient for her when making a tea at night after she got sick.

Further morning food preparation time has been improved allowing both for more efficient cooking and a longer night's rest. One off-grid participant specifically shared

PARTICIPANT SPOTLIGHT: AGATTE

BIO

Agatte, 64, born and raised in the town of Les Anglais is an accomplished school teacher. She is one of the on-grid participants and has been one of the earliest customers of the electrical grid in Les Anglais. Agatte is categoric: electric cooking represents a big upgrade in the Haitian kitchen.

- Moving away from charcoal allows for more time to herself to relax and watch tv. It is also very good for her purse, especially since the price of the charcoal bucket keeps going up year after year.
- The cleanliness of the system is a noted improvement compared to the smoke of her outdoor kitchen
- Agatte, who was recently sick, highlighted how waking up in the middle of the night to make a hot tea to comfort her now felt like a completely different process. What would have taken her at least 30 - 45 minutes with charcoal now takes her only 10 minutes. This traditional soothing tea made her feel well, so she could carry on with her activities normally the next day.

PROJECT SUMMARY

Charcoal expenditure before project:	600-750 HTG/Month
Number of people fed from meals:	Between 5 - 9
Greatest benefit from electric cooking:	It is very quick and I do not have to spend money on charcoal
Impact on finances and/or lifetyle with the project:	I have more time to myself to relax and watch television.
Weaknesses of electric cooking:	The availability of good cooking pots that work with the induction cooktop is one of the biggest drawbacks of electric cooking. For cooking, Haitian households generally use sand-casted aluminium pots, known as "chodye" that hold a very generous amount of food.

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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.

It was also mentioned a few different times during participant interviews that 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.

Electric cooking in this pilot also reduced fuel costs compared to baseline charcoal. This of course was a function of the free electricity provided during the pilot research, but even with this indicative willingness to pay values for most participants were at or above existing microgrid tariffs which highlights a critical opportunity for electric cooking to support improved livelihoods for vulnerable households, particularly if the cost of charcoal continues to rise in rural areas. For example, one bucket of charcoal use to cost 75 htg in February 2020, but it was up to 175 HTG in October 2020, which is a 133% price

DIRI KOLE AK SOS PWA

Serves 8

by Agatte

BLACK BEAN SAUCE (SOS PWA)

Ingredients:

- 660ml black beans
- 1 leek
- Half of a capsicum
- Some "gro thym" leaves
- 6 cloves
- 2 pinches of salt
- 3 cloves of garlic
- 1 Tsp olilve oil
- 1 Tbs of butter
- 1 Tsp of ghee

Step 1: Wash the beans and sort them to remove unwanted materials.

Step 2: Bring to boil in the Simpot with water, cloves, garlic, leek and half of the oil. Boil under pressure and sealed for 30-35 minutes.

Step 3: Quick release and open the Simpot after boiling and transfer the contents to another pot.

Step 4: Separate the cooked beans from the cooking water, but retain the latter for later.

Step 5: Using a mortar and pestle, crush 3/4 of the cooked beans until you obtain a paste.

Step 6: Put the Simpot on Saute mode and add some oil, salt, the capsicum and the ghee. Cook and turn for 2 minutes.

Step 7: Add the black bean paste, and the boiling water and the rest of the uncrushed black beans. Cook until the sauce thickens.

Step 8: Add some leaves of "gro thym" and stir into the sauce for a few minutes.

Step 9: When the sauce reaches the desired consistency, turn the Simpot off.

WHITE RICE

Ingredients:
- 880ml of white rice
- Water
- 1/2 of a leek
- Salt
- 1 Tsp of vegetable oil

Step 1: Boil some water in a pot on the induction cooktop, at level 2.

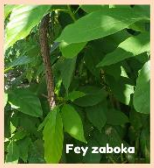
Step 2: Add the leek, salt and the oil in the water.

Step 3: When the water has boiled, add the rice and let it cook until soft and ready.

Note: add enough water to cover the uncooked rice by 1inch.

TRADITIONAL HAITIAN TEA

Ingredients: Fey jirof (cloves leaves), atiyayo (ocimum campechianum), fey zaboka (avocado leaves), fey poban sech (bloggoe banana dry leaves), fey pwa congo (congo beans leaves), po lay (garlic peel), fey gwo ten (Hyptis suaveolens (L.) Poit.), salt, baking soda.



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.

Finally, the electric cooking deployments also significantly reduce the risk of household air pollution. Though not quantified specifically (discussed below in future research), several participants highlighted the health and convenience benefits of removing smoke and heat impacts from their cooking tasks.

For the off-grid systems, the impact of the electric cooking system has been even greater because it has also provided critical baseline energy access for lighting and phone charging. For lighting, a couple of off-grid participants previously used 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.

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 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 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.

Impacts for Microgrid Models and Operators – Critical Pathway for Improved Service

Overall, electric cooking was a surprising success from the operator point of view as well. Electric cooking can leverage existing capacity and logistics support to enhance the value proposition of integrated electrification to customers and add an additional revenue stream for microgrid operators. Electric cooking also reduces GHG emissions from baseline fuels (a key metric for microgrid regulators and investors) and further allows for greater utilization of installed solar capacity and reduced curtailment as, at least in Haiti, electric cooking loads tend to be highest in the middle of the day when the solar resource is strongest.

In many ways the load profiles matched what was expected given the experience of EarthSpark and the observed Haitian cooking practices. The project illustrated significant electric cooking 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.

Electric cooking requires significantly more energy than what most "energy access" microgrids have been designed to deliver. This is both a challenge and an enormous opportunity for microgrid developers. The significant new revenue stream may be an incentive to build more robust infrastructure which, in turn, delivers additional benefits to the community and operator.

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 reduce the desirability of the electric cooking devices for some participants, but generally many participants were still interested in electric cooking even once the timing window was shortened to not include the evening hours once the sun set following the initial pilot project window.

Time restrictions are one pathway that can be considered, but it is more likely that EarthSpark could 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 that EarthSpark provides. 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.

As hinted above, 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 highlighted 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. 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. ferromagnetic pots) available in rural

PARTICIPANT SPOTLIGHT: MANITE

BIO

Manite is a courageous 53 year old woman, born and raised in Les Anglais, in the south of Haiti. She has four grown up kids who live, work or study in other towns. Everyday, she cooks food for herself and 4 other family members: her husband, her mother and her 2 nieces. Manite used to be a food and juice maker and vendor. That was until about 1 year ago when she stopped doing so following a doctor's recommendation: one day, while pushing her wheelbarrow full of juice and food over to her selling spot, she injured herself. Now, she is getting by with small jobs, like the retailing of food products such as plantains, yam and pwa congo (congo beans).

At times, when the opportunity arises, she sells "1 bal, 2 bal tenis, ou 1 bal pepe" (1 or 2 lots of tennis shoes or secondhand clothes). She however wants to restart selling food as it is more profitable. Even if she doesn't get many customers in 1 day, the unsold food can still be eaten by her family. Manite, who was only 10 years old when she learned to cook from her mother and her aunt, still remembers the first meals she made: "diri peyi, pwa nwa, ak pwa congo!" (the local rice, black beans and congo beans!)

PROJECT SUMMARY

Charcoal expenditure before project:	About 1,125 HTG/ month
Number of people fed from meals:	5 most often, 13 at most when my kids come to visit.
Greatest benefit from electric cooking:	Cooking is much faster and comfortable and I do not have to buy charcoal.
Impact on finances and/or lifetyle with the project:	I can invest more time taking care of my house, cleaning, washing, etc. I can also relax a bit more.
Noticeable changes in cooking habits:	I cook more frequently now, as the time of the day matters little. Even if it is in the middle of the night, I can easily prepare someting to eat.

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communities like Les Anglais. If that barrier can be overcome through something like results-based financing or pay-as-you-save type models, 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. 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 where the appliance capital costs are paid off initially using customers' charcoal savings may also work if the savings margins are high enough with the rising cost of charcoal.

Even at low tariff levels around 20 – 25 htg/kWh (below current tariffs) electric cooking presents a new value stream for microgrid operators and further allows for utilization of excess solar that would otherwise be wasted. This allows for increased flexibility in the sizing of microgrid systems. Based on the findings from this initial project EarthSpark is already considering 10% of customers with electric cooking in the planning for the next round of microgrids in Haiti.

Social Inclusion and Gender Impacts

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.

More generally, energy access and access to clean cooking can also 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.

As highlighted above, 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. Specifically, 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.

Further, 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.

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.

Scaling-up Electric Cooking

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. While there are no specific

DIRI KOLE AK LEGIM

by manite

Serves 8

RICE & BEANS (DIRI AK PWA)

Ingredients:

- 2.5 ti marmit (1.5L) of rice
- 1 glass (220ml) of black beans
- 1 Maggi cube
- 2 teaspoons of salt
- Oil
- Epis (made with 3-4 cloves of garlic , 2 leeks, 3 cloves)

Step 1. Boil the black beans in a pot of water at level 5 on the induction cooktop for 30 minutes.
Step 2. Remove from cooktop, and using a strainer, separate the beans from the cooking water. Set aside both the strained beans and the water.
Step 3. In the Simpot on Saute mode, fry some "epis" and then add the beans and maggi cube. Stir a few times.
Step 4. Now add the cooking water and some more water and let it boil. To accelerate the boiling process, cover the Simpot without locking the lid.
Step 5. While the water is boiling, clean the rice to remove foreign materials and wash a few times until the washing water is clear.
Step 6. When water has boiled in the Simpot, add the washed rice and 2 tsp of salt. Stir.
Step 7. Turn off the Simpot and turn back on to set for 13 minutes on Pressure mode.
Step 8. After 13 minutes, let the pressure in the Simpot fall by natural release.

VEGETABLE STEW (LEGIM)

Ingredients:

- 2 Maggi cube
- 1 Tsp of salt
- 6 eggplants,
- 3 mirlitons
- 1 watercress
- 3 green papayas (peeled, crushed and boiled),
- 1 cabbage
- 1 handful of greens liane panye.
- Tomato paste
- 1 Tbs of oil
- Epis (made with 3-4 cloves of garlic, 2 leeks, 3 cloves)

Step 1. Cut the vegetables in small pieces except for the cabbage and watercress.

Step 2. Boil the cut vegetables on the induction cooktop at level 5.

Step 3. When the vegetables are boiled, remove from flame, mash them and then add the cabbage and watercress, cut in thin pieces.

Step 4. In another pot, add the oil and fry the "epis" mixture in it, using the induction cooktop at level 3. Then stir in the tomato paste and add some water to make a sauce. Add 2 tsp of salt.

Step 5. Now add the vegetables to the utensil and then add 2 maggi cubes. Sitr and cook for 1 minute.

PARTICIPANT SPOTLIGHT: JEANNE

BIO

If someone in Les Anglais tells you that they bought BBQ chicken for dinner, there is a 1 in 2 chance that it was prepared by Jeanne. Her mother, originally from Anse d'Hainault in Grand'Anse department, came to Les Anglais at a young age, and is the one who taught Jeanne her first tricks in the kitchen when she was 10. From preparing "mayi moulen" (Haitian polenta) as a child, Jeanne has made cooking and selling food one of her principal business activities and her tasty BBQ accompanied by "bannann peze" (twice fried pressed plantains slices) , rigatoncini pasta, and "pikliz" (pickled cabbage) is well known in town. On nights when there is no chicken, you may be able to taste her traditional "ragù" with goat meat, and sip a Prestige at La Releve bar next door.

Jeanne's case is a bit different from other cooking pilot project participants. Being a food vendor who makes chicken, she does not have any other choice but to keep using charcoal for her business due to the large volume of food she prepares on a daily basis. However, with electric cooking, she does not have to stop preparing food for her business to cook for her family as both can be done simultaneously, hence saving her a lot of time. Jeanne also sells food products (like flour, biscuits, vegetable oil, etc.) at the big market on Wednesdays and it's possible that some customers knock at her door for purchases on other days of the week. This additional income helps to pay schooling for her son and has been even more important lately, with the revaluation of the Haitian gourde and a decrease in the price of imported foodstuff. This has led to more people eating at home instead of buying BBQ.

PROJECT SUMMARY

Charcoal expenditure before project:	2715 HTG/ month, including for BBQ business
Number of people fed from meals:	Minimum 5 if only family, but can go up to 12
Greatest benefit from electric cooking:	It is so much faster than charcoal
Impact on finances and/or lifetyle with the project:	With the extra time I have, I can focus more on my business.
Noticeable changes in cooking habits:	I cannot cook more often as cost of living is too high.
Weaknesses of electric cooking:	The "bom" (pot) that she has available to use is too thin. Whenever she uses the induction stove to prepare food, the food can burn. If another thicker pot was available, that would have been much better.

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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.

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. Further existing 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,

VYAN POULE

Serves 8

by Jeanne

Bean sauce (Sos pwa)

Ingredients:

- 1.5 gode (660ml) black beans
- 2 Tsp of salt
- Epis paste made by crushing together 1 leek, 2 cloves of garlic, 15 cloves

Step 1: With the induction stove on level 3, boil a pot of water.

Step 2: Meanwhile, sort, and rinse the black beans.

Step 3: Add the beans to the boiled water and let it cook until ready.

Step 4: When the beans are ready, remove about half of the cooked beans and mash them using a pestle.

Step 5: Add the "epis" paste to the pot, salt and stir in the mashed beans.

Step 6: Let the sauce thicken. Once it reaches the desired consistency, the bean sauce is ready to be eaten.

White Rice (Diri blan)

Ingredients:

- 5gode (2.2L) of white rice
- 1 leek
- 2 pinches of salt
- 1 Tbs of vegetable oil
- Water

Step 1: Turn on the Simpot on Saute mode and let it warm up.

Step 2: Add the oil, the leek and salt and stir. Then add the water.

Step 3: Place the Simpot lid to accelerate the boiling process.

Step 4: In the meantime, wash the rice several times until the water is clear.

Step 5: Once water has boiled, add the rice to it.

Step 6: Put the Simpot on Pressure mode and cook the rice for 13 minutes. Let the prsssure drop by natural release and the rice is ready.

Chicken with Sauce (Sos vyan poule)

Ingredients:

- 1 Tbs of oil
- 1 Tbs of tomato paste
- 1 Maggi cube
- 3 potatoes, peeled and diced
- 2 carrots, peeled ad diced
- 1 onion, sliced
- 3 pieces of previously cooked chicken

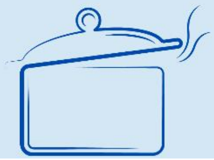
Step 1: Fry the tomato paste in the oil, in a pot on the induction cooktop at Level 5.

Step 2: Add the potatoes, carrots and some water. Let the vgetables boil.

Step 3: Once they have boiled, add the Maggi.

Step 4: Lower the induction level to 3, add the chicken and let it cook with the rest of the ingredients for 5 - 10 minutes.

Step 5: Turn off the induction cooktop and sprinkle the onion over the top.



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.

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.

Future Research

This pilot project opens up an exciting body of research to explore to amplify and accelerate the deployment of electric cooking solutions to support community clean cooking both in Haiti and beyond. Potential research areas include, but are not limited to:

- **Electric cooking for larger users –** The current pilot focused on electric cooking solutions to support single household cooking needs, but in local communities there is a demonstrated need to expand future research efforts to include appliances and models for larger cooking applications like institutions, churches, street vendors, etc. This not only expands the benefits of electric cooking, but also creates key community support and buy-in for electric cooking.

- **Improved grid integration of electric cooking** – Electric cooking devices can be better integrated into microgrid operations by for example designing products with more specific controls for direct communication with appliances and appliance level monitoring/controlling of electric consumption across customers, load disaggregation, and/or optimizing the placement of electric cooking customers on the distribution grid.
- **Pricing and financing for electric cooking** – The initial pilot prioritized research outcomes and gave electricity to participants for free, but it will be critical for microgrid planning to explore effective tariff designs and price/incentive signals like time variant pricing for end users to both support demand for electric cooking as well as operational needs for microgrid operators. 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. Further, as highlighted above, a critical challenge is overcoming that initial capital barrier, so exploring pathways like results-based financing for health outcomes and/or pay-as-you-save type models will be important for further validating the electric cooking model for solar microgrids.
- **Quantification of health and HAP benefits** – One of the key potential benefits from electric cooking is the reduction in household air pollution and associated health impacts from baseline cooking fuels. The present project addressed this qualitatively with participants responding that a key benefit of the electric cooking was a reduction in the inconvenience of smoke and heat from charcoal. It will be important to more deliberately quantify the reduction in HAP by deploying specific air quality monitoring and analyse the impacts on end outcomes like respiratory health.

EarthSpark is actively working to find partners and pathways to address these exciting opportunities as part of its continuing work on electric cooking.

Lessons Learned

Throughout the project implementation there were a number of challenges faced as well as key lessons learned that are important to highlight in order to inform future electric cooking efforts in Haiti and beyond. These have been broken down into the following categories discussed individually in more detail below:

- Design, Performance, and Technical Issues
- Electric Cooking Equipment
- User Acceptance and Uptake
- Data Analysis and Collection

Design, Performance and Technical Issues

Since the pilot project was giving participants free electricity for electric cooking, one challenge faced was to make sure that no participant could tap into the meters and have free electricity for purposes other than electric cooking. This was overcome by installing junction boxes to eliminate access the electricity meters' inlet and outlet electrical ports. Further, the actual electrical prongs from the cooking devices themselves were adjusted so that they were hardwired to the smart meters instead to prevent other appliances from being plugged into the electric cooking setup.

During the initial deployments, one induction cooktop was found faulty but after inspection 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.

PARTICIPANT SPOTLIGHT: ROSANNE

BIO

45 year old Rosanne was born in Digue, Les Anglais, but moved to Port- au-Prince when she was 15. Unfortunatley, after the big earthquake in 2010 in the capital, Rosanne who was then 35 and already a mother of 3, moved back to "Lezangle" with her family. Within a couple of years, she found employment at Eneji Pwop as a workshop supervisor for efficient charcoal cookstoves. She is now the micro-grid ambassador for Eneji Pwop in town and one of the most senior employees.

Rosanne has 4 kids now, and only Fofo, the youngest, who is 9, still lives with her and attends school in Les Anglais. Being the first beneficiary of the appliances for the project, she now cannot imagine her life without clean cooking! Even Fofo has learnt to use the electrical appliances, and agrees that it is very simple to use!

"Depi mwen sevi avek kwison elektrik, mwen pa konen pri chabon, paske mwen pa fonksyone ave'l anko. Epi sa, mwen pa nan foubi anko paske chodye yo pa kon vinn nwa e sal mam jan ak le mwen sevi ak chabon".

PROJECT SUMMARY

Charcoal expenditure before project:	525 HTG/Month
Number of people fed from meals:	6 people (2 neighbors)
Greatest benefit from electric cooking:	Meals get cooked so quickly and I do not have to use a scourer to clean my pots as they don't get as dirty and black as when I cook with charcoal
Impact on finances and/or lifetyle with the project:	Now I am saving the money I would have spent buying charcoal. I also have more time for other activities like developing my small business and taking care of myself.
Noticeable changes in cooking habits:	I cook more often and even at night, as the system is so convenient.
Weaknesses of electric cooking:	I do not really see any major disadvantages but if I have to mention something, it would be if there is a blackout while I am cooking I would be forced to buy charcoal, even if it is at night. If I cannot find a charcoal vendor, then I won't be able to cook.

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Enèji Pwòp

There were additional issues with needing to replace thermal fuses for a few electric pressure cookers and the top glass for one of the induction stoves highlighting the importance of sourcing replacement parts and having them on hand locally to support electric cooking deployments.

For microgrid installations, there were several instances where one upstream totalizer meter, which is a special meter used to remotely turn on and off sections of a grid subnetwork, would reach its maximum power 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.

This highlights several critical lessons for electric cooking and microgrid planning. First for current grids electric cooking needs to be deployed very strategically to ensure minimal impacts to other electricity service. By extension, future microgrids need to specifically incorporate electric cooking loads at the start to ensure optimal deployment and design of the distribution and generation systems - EarthSpark has already integrated 10% of future grid customers as electric cooking into its grid planning efforts. Further, this experience suggests strong research potential for engaging smart meter and electric cooking suppliers to better optimize technology solutions for microgrid integration of electric cooking.

Electric Cooking Equipment

Based on the participant surveys, it is clear that larger pressure cookers need to be sourced to fully match user needs and preferences. Some of the pressure cookers on the market can go up to 8, 10, 12, and even 20 quarts and might be preferred for larger families, rather than the standard 6-quart volume that was used for the cooking pilot project. Considering Haitian eating habits and particularly the common practice of sharing food between neighbours and friends outside the home, larger pressure cookers might be able to support a greater share of the meal's requirements for most households. Further, appliances like rice cookers could also be considered instead of full electric pressure cookers. Sourcing larger pots adds to cost considerations, but is seemingly well worth the effort if it allows for more effective electric cooking participation from participants.

Further, 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. The fact that the indications are in English tend to limit the understanding and use of the pressure cookers, particularly for

DIRI KOLE AVEK PWASON SOS WOUJ

by Rosanne

Serves 8

Rice and beans (Diri ak Pwa):

Ingredients:

- 220ml black beans
- 1 Tbs vegetable oil
- 1 capsicum
- 1.32L white rice
- 1 Maggi cube
- Water
- "Epis" mixture (made of leek, and garlic)

Step 1: In the Simpot, under Pressure mode, cook the black beans for about 30min.

Step 2: Using a strainer, separate the beans from the cooking water. Set both aside for later use.

Step 3: Under Sauté mode in the Simpot, fry the "epis" in the oil, and add the capsicum.

Step 4: Stir in the beans and then the Maggi.

Step 5: Add the cooking water, and let it boil.

Step 6: In the meantime wash the rice until the washing water is clear.

Step 7: Once the water has boiled in the Simpot, add the rice and stir the contents of the pot. Set the Simpot to 15 minutes under Pressure mode. If you like it when the rice makes a "gratin" (crispy rice that forms at the bottom of the pot), set the time to 20 minutes.

Fish in a red sauce (Pwason avek sos wouj):

Ingredients:

- 6 small fish (pwason woz)
- Sour oranges for cleaning the fish
- 3 cloves of garlic
- 1 leek
- 1 chili
- 3 Tbs of tomato paste
- 1 Tbs of oil
- 2 Maggi cubes

Step 1: Wash, remove scales and clean the fish. Wash with the sour oranges.

Step 2: Using a mortar and pestle, crush the garlic, leek and Maggi cube.

Step 3: Leave the fish to marinate in that mixture for a little.

Step 4: Using the induction cooktop at level 3, fry the tomato paste in the oil.

Step 5: Add some water to prepare some sauce, and increase the induction cooktop level to 4.

Step 6: Add 1 Maggi cube and the fish to the sauce.

Step 7: Simmer for 10 minutes. The fish and sauce is ready.

the more advanced settings or cooking modes. 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.

For the induction stoves, one of the biggest challenges was the lack of proper cookware. Ferromagnetic pots were sourced for participants that didn't already have them either 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 and delay for the project.

Further, the initial ferromagnetic pots that were sourced locally in Haiti and within a price range that would be affordable to a typical rural Haitian household were unfortunately quite thin. While they were 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. Having better quality, thicker pots might have resulted in greater success in enabling electric cooking usage for participants.

The project also 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.

User Acceptance and Uptake

Cooking is very entrenched in cultural and social norms making behavioural change difficult if not impossible to catalyze and sustain without deliberate community engagement. For this project, all participants had an initial mandatory training during which they had a chance to learn how to operate the appliances effectively and safely. Further, Enèji Pwòp staff conducted several additional demonstration events to exhibit the electric cooking devices for the community. Participants were also given training materials and basic recipe guides written in Haitian creole that explained how the two appliances and some basic tips and tricks for cooking Haitian staples. All of these trainings were conducted by a combination of the Enèji Pwòp grid ambassador for Les Anglais and the Enèji Pwòp technicians.

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.

All of these elements were critical for building community comfort with and acceptance of electric cooking. Having the technicians and ambassador participate in the study alongside the other households further created trust and internal advocacy for clean cooking which helped to improve participation throughout the study.

As discussed above, some of the biggest barriers to customer acceptance and utilization of electric cooking were related to the equipment itself – either not being able to cook the way they would normally (i.e. too thin of pots for the induction stove, not being able to cook the amount needed (i.e. too small of pressure cookers), or not being able to use electric cooking because of outages on the microgrid or not enough capacity with the off-grid solution.

Participants also 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 prepped 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 high temperatures and allows for prep work to be done alongside.

Data Analysis and Collection

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, the project was able to avoid some 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 (meters were rated as 100-meter line of site for reliable communication), 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.

An additional consideration for future efforts is looking to a more granular 5-minute interval which 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 to the appliances themselves.

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. Beyond clearer monitoring and evaluation, more specific diary training should be employed along with adjusted diary templates to garner more specific responses from participants.

Conclusion

Conclusion

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 hope is that 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 is 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.

Exciting work is on the horizon and EarthSpark looks forward to building on this research foundation and elevating electric cooking as a key tenet of integrated electrification.

Annexes

Annex: References

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