Cooking with Electricity in Myanmar: Barriers and Opportunities

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Executive Summary

In Myanmar, reliance on biomass for cooking remains high. The World Bank has reported that over 73% of people in Myanmar rely on biomass for household cooking needs (Koo et al, 2019). The use of biomass for cooking has been associated with adverse effects on health and the environment. According to the World Health Organisation (WHO), nearly 4 million people die prematurely each year from illnesses attributable to household air pollution (WHO, 2020). The Modern Energy Cooking Services (MECS) programme aims to support households transitioning to modern energy cooking services and technologies. MECS is carrying out research activities in partnership with Gamos and Hivos Southeast Asia to find out how compatible electric cooking appliances are with domestic cooking practices in Myanmar.

This report presents findings from Controlled Cooking Tests (CCTs) conducted in Yangon. These tests are part of a research process that MECS has developed that we refer to here as 'The Kitchen Lab'. The Kitchen Lab involves selecting representative dishes from Myanmar cuisine, cooking them on different fuels and devices, and comparing their performance. Data was produced on energy consumption, cooking duration, taste, and user experience. This process was also supported by producing household 'Meal Diaries'. For this activity, participants recorded the details of meals they prepared at home throughout the week. This helped to identify a variety of dishes and cooking preferences. The report also draws from focus group discussions that were held online due to restrictions implemented due to Covid-19. The CCTs concentrated on eight cooking categories: Short-boiled, long-boiled, medium-boiled, short-fried, deep-fried, rice, and tea with boiling water. The Dishes were cooked using a Liquid Petroleum Gas (LPG) stove, fuelwood, a charcoal stove, an Electric Hotplate, a Rice Cooker, an EPC, a Red Pan, an Induction Stove, an Infrared Stove, a Slow Cooker, an Electric Kettle, and a Thermo-Pot.

Findings show that Myanmar is highly compatible with energy-efficient modern technologies. It was cheaper to cook Myanmar dishes on a range of electrical appliances than it was on firewood, charcoal and LPG stoves.

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1 Introduction

The environmental and health problems associated with using biomass and open fires for cooking directly affect millions of people, whilst illnesses that can be attributed to household pollution disproportionately affect women and children. Recent data has shown that in Myanmar, 62 percent of child deaths from acute lower respiratory infections can be attributed to indoor air pollution (Rana et al, 2019).

The World Bank's Energy Access Report has shown that in Myanmar households, over 73% cook with biomass (Koo et al, 2019). The data shows that 46.9% of households use a three-stone stove as their primary cooking solution, mostly on firewood (46.3%). That clean fuel stoves makeup 23.6%, and that improved cookstoves are used by 16.5% of households. The report reveals a significant difference between households in urban and rural areas regarding cooking patterns. In urban areas, electricity is the most popular energy source for cooking (56.5%), followed by charcoal (22.5%) with 77.4% of rural households relying on firewood.

A recent report published by the MECS programme (Price et al, 2021) shows that 43.9% of households without an electricity connection are too isolated to gain access, suggesting the necessity for further electrification and the adoption of LPG as a transition fuel. The same report states 27.2% remain unconnected due to upfront costs associated with transitioning.

With a wide range of electric cooking appliances available in Myanmar, the burden of cooking can be made simpler, quicker, healthier, easier, and perhaps even more enjoyable than it would be cooking with firewood, charcoal, and traditional pots and pans. Energy efficient cooking devices can save families a significant amount of time each day by reducing the cooking time (as well as the time spent collecting fuel or preparing and monitoring the stove). Data from the World Bank's Energy Access report reference above suggests that electric cooking can save approximately 100 minutes per day in fuel collection, 10 minutes in fuel preparation, and a further 30 minutes in cooking time, compared to the use of firewood. (Koo et al, 2019)

Transitioning from solid biomass to cleaner energy sources such as electricity can reduce toxic levels of black carbon in households. As women and children are disproportionately affected by household air pollution measures that reduce these emissions promote health equity. Women are also responsible for cooking in the vast majority of households across Myanmar. The health benefits and added convenience of clean cooking helps to address an important aspect of gender inequality. Cooking and fuel collection can both be laborious, and these activities often amount to unpaid labour. Electric cooking may also positively impact children and especially girls, who may be asked to carry out these activities.

1.1 Objectives and methodology

This study was carried out as part of the Modern Energy Cooking Services (MECS) programme to assess the viability of eCooking in Myanmar. The study aimed to understand the relevant cultural cooking patterns and preferences of households in this context. The Controlled Cooking Tests (CCT) were carried out from October 2020 to January 2021 in Yangon. The CCT was designed to assess the performance of a range of electrical appliances and traditional cooking methods in a controlled setting. The Kitchen Lab approach that MECS has developed is a research methodology that enabled MECS to assess the compatibility of Myanmar cooking with modern energy efficient electric cooking. These tests were undertaken in home settings to ensure that the kitchen environment was representative of Myanmar households. This process aims to identify culturally appropriate opportunities for transitioning to eCooking.

The tests conducted in Yangon were designed to assess: How much energy is used to prepare selected meals using LPG, Charcoal, wood, and electricity? How much does preparing the meal cost on each fuel type on average? What was the average cooking duration on each device? Were the dishes as tasty? How well did the device respond to preparing the dish in terms of taste? How convenient was the cooking experience on each device? Focus Group Discussions were held to determine the dominant cooking processes in Myanmar cooking. A representative dish was selected from each cooking category that would pose different cooking challenges for the devices. This study settled on 8 cooking categories: Short-boiled, long-boiled, medium-boiled, short-fried, deep-fried, rice, and tea with boiling water. Testing was carried out on 3 fire cooking fuels: LPG, Fuelwood, and Charcoal, and 9 electrical appliances: Hot Plate, Rice Cooker, EPC, Red Pan, Induction Stove, Infra-red Stove, Slow Cooker, Electric Kettle, Thermo-pot.

1.2 Cooking Fuel Landscape in Myanmar

The primary fuels for cooking in Myanmar are firewood, charcoal, electricity and LPG. Despite tariff increases and the introduction of a progressive tiered tariff system in June 2019, electricity prices remain the lowest in the Southeast Asia region (Oxford Business Group, 2021). The cost of electricity for households starts at MMK35 ($0.023) per kilowatt hour (kWh), and rises to MMK125 ($0.081) per kilowatt hour. This makes electric cooking inexpensive for the vast majority of families in Myanmar and, regardless of the cooking appliance used, electric cooking is much cheaper on a per-meal basis than cooking methods that use other fuels such as LPG and charcoal.

A MECS programme report shows that a household cooking exclusively with electricity spends MMK 8,000 per month on average on their entire electricity bill (Price et al, 2021). In contrast, the cost of cooking exclusively with either purchased wood or charcoal is approximately MMK 13,600 and MMK 10,300 respectively, without taking into account the cost of electricity for lighting and other non-cooking activities. Households cooking exclusively with LPG only spend MMK 7,100 on their cooking fuel.

Myanmar is electrifying at a rapid rate. Only 34% of households were electrified in 2016, but this had increased to 50% by 2019 (Price et al 2021). Beyond the national grid, parts of Myanmar have benefited from cross-border electricity provisions (with Thailand in the East and India in the West) as well as from a rapidly growing decentralised renewables sector. In these contexts, where the cost of electricity is much higher, energy efficient cooking appliances can have a dramatic effect on reducing energy consumption and the cost of clean cooking. While some communities still have access to free firewood to meet their cooking needs, the quality of the wood can vary (e.g. wet/dry) and the availability is likely to reduce over time. Therefore, affordable and reliable clean cooking solutions are required throughout the country.

The costs of biomass cooking are not just financial and environmental. Energy efficient cooking devices can save families a significant amount of time each day by reducing the cooking time (as well as the time spent collecting fuel or preparing the stove). The vast majority of cooks in Myanmar are women, and therefore a reduction in cooking time has the potential to contribute to gender equity by freeing up women's time.

The MECS Myanmar; Cooking Transitions report shows that cooking with electricity can save approximately 100 minutes per day in fuel collection, 10 minutes in fuel preparation, and a further 30 minutes in cooking time, compared to the use of firewood. (Price et al, 2021). The most popular appliances are rice cookers, electric frying pans and kettles. Households in Myanmar have proven that electric appliances are suitable for cooking the wide diversity of dishes that are cooked and eaten throughout the country. Beyond the national grid, parts of Myanmar have benefited from cross-border electricity provisions (with Thailand in the East and India in the West) as well as from a rapidly growing decentralised renewables sector.

In Myanmar 13.9% have no access to electricity, 38.6% have grid access. The 48% with off grid access use Solar lantern or SLS (19.4%) (Solar home system (11.4%), Rechargeable batteries (9.2%), Local Mini Grid Connection (7.9%), Electric Generator (0.1%) (Koo et al, 2021)

Mini Grid Connections - A special dynamic of Myanmar's energy space is the communities that have successfully developed thousands of isolated mini grids over the last few decades. Many of these systems have been developed by local communities in partnerships with local social entrepreneurs. The mini grids are now also being developed by foreign developers subsidised by the World Bank National Electrification Programme. In both of these types of mini grids there is potential for electric cooking, and also to increase the financial viability of the mini grids themselves. eCook systems can offer decentralised energy storage that can strengthen weak grids without needing to rely on the centralised system..

Solar Home Systems - It is feasible to utilise solar PV as a source for eCooking. Pioneers in Myanmar have succeeded in running electrical cooking devices on low power systems. Pilots such as 'e-waste to e-cook' are seeking to make eCooking more reliable in areas where energy supplies are more constrained by using energy storage.

2 Food culture and dietary patterns in Myanmar

Cook's profile

Name: Ma Ja Nu
Location: Myitkyina, Kachin State
Context: Peri-urban
Primary fuel mix: Electricity & Charcoal
Grid connection: Regional Grid

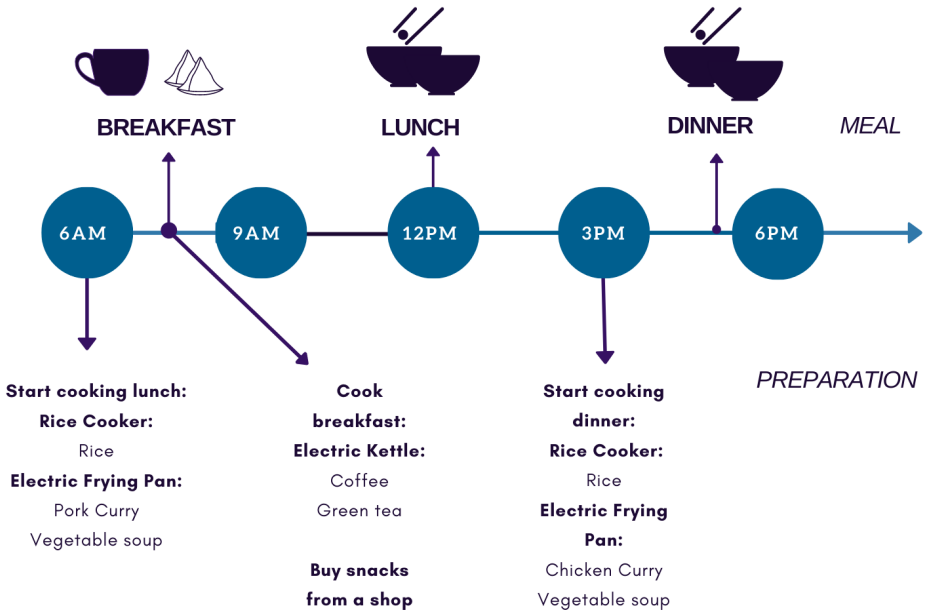


Fig.1 Ma Ja Nu's typical daily cooking timeline (authors' own)

Ma Ja Nu has been cooking in Myitkyina since the 1970s. She transitioned from a biomass fuel stack to primarily using electricity for cooking when it became more widely available to her in 2011. Transitioning helped to alleviate time spent cooking and reduce the amount of smoke being released in the kitchen.

"It is cheaper to use electricity, we save around 7000 kyats per month compared with using charcoal only."

"When we cook with firewood and charcoal, and especially for rice, you have to be near the rice pot and watch. It makes the kitchen dirty, especially the ceiling and the walls... but with electricity there is no dirt and the kitchen stays clean"

"There are issues with the electricity supply as there is sometimes a shortage especially in summer when the river dries up there isn't enough water for the hydro power plant."

Cuisine

Myanmar's varied terrain includes mountainous regions in the the North and West of the country, dry flat plains in the centre, and a large delta region in the lowlands where the Ayayerwaddy river enters the sea. The delta receives a substantial amount of rainfall and is home to major rice production areas and fishing communities. The marine and freshwater fisheries serviced by the long coastline, lakes and river systems are an important component of the economy. The proximity of certain produce to particular areas, and Myanmar's rich cultural diversity has influenced the country's cuisine. There are not many vegetarians in Myanmar, and people enjoy eating a range of meats such as pork, chicken, mutton. (Aye, 2019) The food is characterised by a wide range of curries, noodles, soups and salads.

Rice: The main staple of Myanmar cuisine is rice which comes in variations that differ in terms of texture and aroma. Rice production accounts for 43% of agricultural production, enabled by the country's climate (FAOSTAT, 2021). Though rice is commonly eaten plain, variations include fried rice, myanmar-style biryani, and glutinous "sticky" rice. Rice is the main staple throughout the country with variations that differ in terms of texture and aroma.

Curries: Curries make up a significant portion of Myanmar cuisine and come in very different styles. Burmese curries tend to be made with a lot of oil whereas Kachin curries are often prepared without any oil.

Noodles: Noodles are used in a variety of dishes like soups and salads; they are usually boiled, but can also be fried.

Soups: A diverse range of soups are consumed across Myanmar, either as a main dish or side dish. One of the most popular is Mohinga, a fish based noodle soup.

Salads: Salads are often consumed as snacks, or side dishes. Lapet thoke is a salad typically made from fermented tea leaves, yellow split peas, toasted sesame seeds, peanuts, dried shrimp and chilli.

Tea: Myanmar has a distinctive tea culture. It is often drunk socially in one of Myanmar's inimitable tea shops or at home. Two of the most popular types of tea in Myanmar are green tea, and a milky tea made with condensed milk.

Fig.2 A red electric frying pan and rice cooker can meet the majority of cooking needs for a typical household in Myanmar

2.2 Cooking popular dishes from Myanmar: techniques and processes

Many popular dishes in Myanmar can be prepared through either boiling, frying, simmering, deep frying, roasting or by a combination of these techniques. Boiling is a popular cooking technique in Myanmar that consists of adding water to food and bringing the pot to a boiling point. Dishes that require boiling include rice and mohinga. Stir frying is another popular technique in Myanmar where partially submerged food is heated quickly in hot oil. Dishes that require this method include sauteed vegetables, and fried rice. A synthesis of stir frying followed by boiling or simmering is representative of cooking a wide range of dishes including fried noodles, bean soup and chicken batchelor soup.

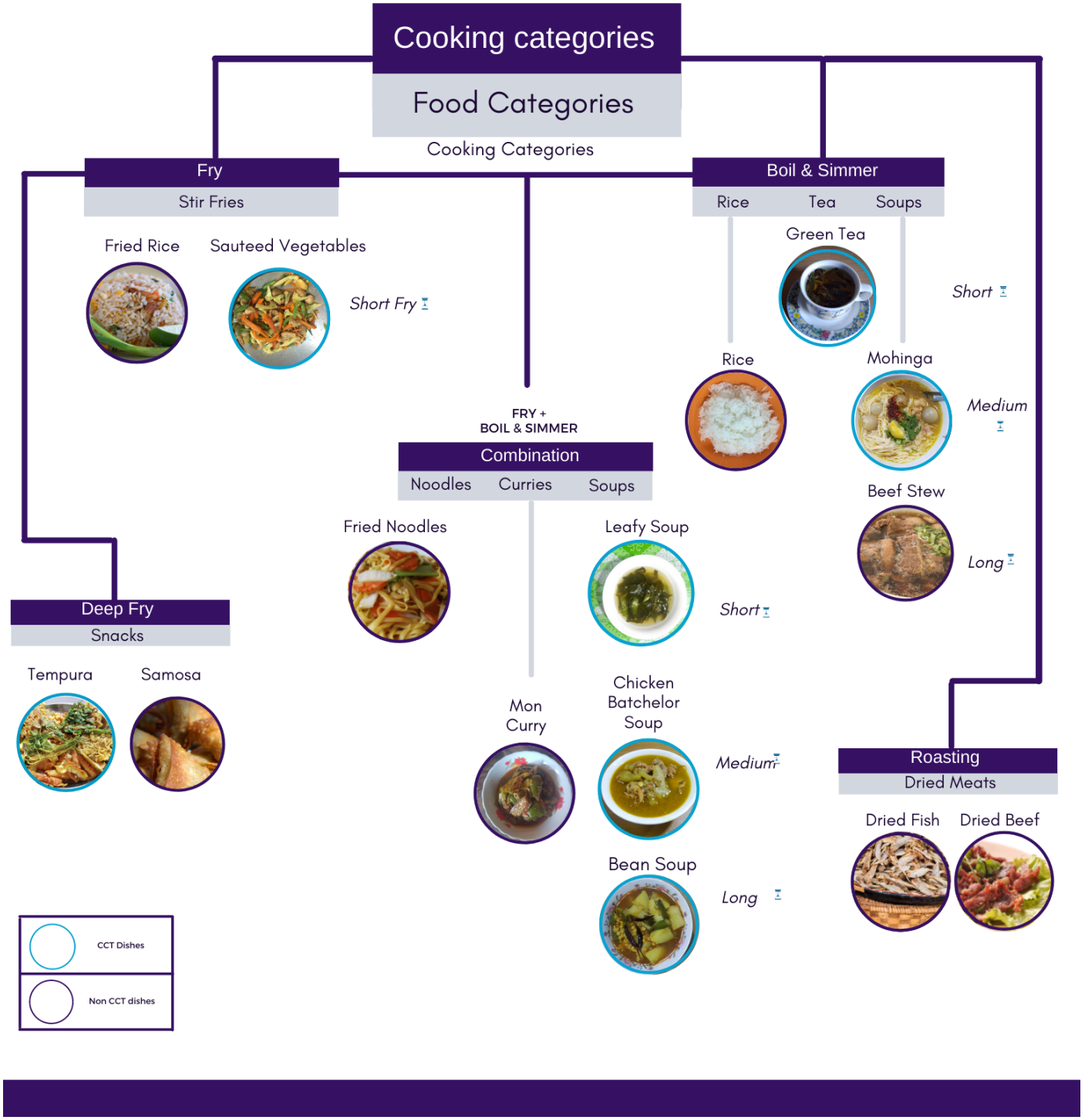


Fig.3 - Food typologies, developed for Myanmar by the MECS programme (authors' own)

3 Baseline fuels and LPG

Firewood

Firewood remains a very popular fuel choice in Myanmar. The Myanmar Living Conditions Survey showed that 60% of people use firewood as their primary fuel source in 2017 (Central Statistical Organization (CSO), UNDP and WB, 2020). This indicates a shift away from households relying on firewood for cooking compared with data collected from the National census in 2014 (Myanmar census 2014, MIMU). Deforestation is a huge concern in Myanmar. 1.3 million acres of forest was lost nationally between 2010 and 2015, equating to 8.5% of the country's trees. (UNFAO, 2015)

Charcoal

The Myanmar Living Conditions survey referenced above showed that 9.4% of the population used charcoal as their primary fuel source. The national census estimated that Charcoal cooking households consume 572,000 metric tons of charcoal annually (Myanmar census 2014, MIMU). Despite the country's regulations that place restrictions on charcoal exports Myanmar is one of the worlds largest charcoal exporters. A recent report by Forest Trends on charcoal production in Myanmar has shown how the industry has links to criminality, and mass deforestation. The report highlights how the charcoal industry concentrated in Tanintharyi is contributing to mangrove deforestation and coastal damage and how illicit activity within the industry also means that producers often evade important environmental regulations (Woods, 2020). Cooks in Yangon adopting electricity and gas for cooking have already slowed the rate of deforestation of the mangroves in the Ayeyerwaddy delta.

LPG

The same Myanmar Living Conditions survey has shown that as of 2017, LPG use for cooking remains low at only 1.4%. Such a low rate has led to talks of a potential boom in the country's LPG market. Though Myanmar has been producing natural gas since the 1990s, the majority of Myanmar's natural gas is off-shore and unsuitable for LPG production. There is a perception that using LPG is dangerous and is more expensive than using other fuels.

Table 1 Baseline and LPG stoves used in the CCT

Appliance / device	Specifications
	**LPG stove** o Make: Namilix o Model: PL1926PS o a steel frying pan and different sized steel pots were used on the stove

	**Charcoal stove** o Amay Lat Yar o a steel frying pan and different sized steel pots were used on the stove
	**Firewood Stove** o A steel frying pan and different sized steel pots were used on the stove

4 Cooking with electricity: the kitchen lab CCT

4.1 Dishes

The CCTs carried out in Yangon aimed to measure the relative rate of fuel consumed by different cooking devices as they are used in the normal household environment. The tests were done with the help of everyday cooks cooking the different dishes as they would normally cook them at home. The team tested a range of typical dishes (most common) using a range of cooking fuels and cooking devices, as shown below. In the subsequent pages, the report outlines and discusses the CCT findings.

Dishes cooked: As noted earlier, the testing focused on three categories of dishes, according to the cooking techniques involved:

- **Frying**
  - Tempura: Typically deep-fried, a tempura paste is prepared and used to coat vegetables, prawns, and fish. Tempura is popular across Myanmar and eaten as breakfast, snacks, or as a side dish to a main meal
  - Sauteed Vegetables: this side dish uses seasonal and local vegetables, such as carrots, baby corn, snow peas, mushrooms, cauliflower, tomatoes and onions, and these are fried with seasoning added (soy sauce, oyster sauce, garlic, seasoning powder)

- **Boiling/Simmering**
  - Mohinga: This traditional dish, often cooked at religious ceremonies and large gatherings as well as at home, consists of a ready-made mohinga paste, rice noodles, onions, and a range of seasonings. In some rural areas, a paste is made from scratch
  - Rice: rice is the main staple in Myanmar.

- Green Tea: consumed by all ethnic groups in Myanmar, using dried tea leaves (traditionally sun-dried or roasted)

- **A combination of boiling and frying**
  - Bean Soup: Eaten in most regions in Myanmar, this dish is cooked in different ways depending on a household's cultural background and living standard. Garbanzo beans (chickpeas) are soaked in water then boiled, and vegetables and spices are added to the dish.
  - Chicken Batchelor Soup: Eaten by urban and rural households across Myanmar, chicken is marinated and fried with vegetables (usually gourd), and then simmered with additional seasonings added.
  - Leafy Soup: This curry accompaniment involves toasting roselle leaves and then simmering the leaves with water, onions, okra (ladies' fingers) and seasonings.

The dishes were selected based on focus group discussions with local partners.

4.2 Appliances

The following table details the main electrical appliances used in the tests:

Table 2 - Electrical appliances used in the CCT

Appliance / device	Specifications
	**Electric hot plate** o Make: SOGO o Model: 001 o 1500W o a steel frying pan and different sized steel pots were used on the stove
	**Electric Pressure Cooker** o Make: Midea o Model: MY-SS5062 o 900W o 5 litre aluminium/teflon pot

Electric Frying Pan

- Make: OTTO
- Model: SEP-1801
- aluminium pot

Rice Cooker

- Make: Midea
- Model: MB-YJ5010
- 650W
- 5 litre aluminum/teflon pot

Induction Stove

- Make: Midea
- Model: C16-SKY1613
- 1600W
- a steel frying pan and different sized steel pots were used on the stove

Infrared Stove

- Make: Kangaroo
- Model: KG378i
- 2000W
- a steel frying pan and different sized steel pots were used on the stove

Slow Cooker

- Make: You Shan Mo Chu
- 235W
- 4.5 litre clay pot

	**Plugin energy meter** o UK Plug Power Meter AC 230V~250V 13A Max o Operating voltage: 230V AC o Frequency display: 50Hz o Wide voltage range: 230V - 250V Operating current: max 10A

Figure 4 Cooking appliances and devices used

Table 3 Appliances for Green Tea used in the CCT, alongside the baseline stoves and other electrical appliances

Appliance / device	Specifications
	**Electric Kettle Pot** o Make: Nakita o Model: NK-188 o 1850-2200W o 1.8 litres
	**Thermopot** o Make: Panasonic o Model: NC-TYS32 o 670W o 3.2 litres

4.3 Calculations

Table 4 Assumptions for data calculation

Assumptions	Unit	Source
1 Unit of electricity (MMK)	125	(highest tariff rate - 201+ kWh/month)
1 litre of gas (MMK)	2273	Market price, 2020 (Yangon)
1 kg of charcoal (MMK)	612	Market price, 2020 (Yangon)

Energy content of firewood (MJ/kg)	16	
Energy content of charcoal (MJ/kg)	31	
LPG default energy content (MJ/kg)	46.1	
MJ conversion to kWh	0.2778	
kWh conversion to MJ	3.6	

The section below presents the findings of the kitchen lab test across devices for the different types of dishes cooked. These results represent the averages of three rounds of testing. Two cooks participated at each round and cooked each meal three times on each device. Results at each round were compared with results from previous rounds to ensure consistency and identify and remove anomalies.

4.4 Results Overview

Figures 4 and 5 below provide a comparative analysis of the energy consumption and cooking time for the 8 dishes included in the CCTs. Excluded from the list of appliances are a) the slow cooker, due to the different nature of the cooking process involved, b) the hotplate, which appears to have been faulty and skewed many of the test results, and c) the electric kettle and thermopot, which were only tested for green tea. It should be noted that the kettle and thermopot required the lowest amount of energy to produce green tea, and the kettle took the shortest time (second shortest - induction stove; joint third shortest - thermopot and the electric pressure cooker).

	Energy Consumption (kWh and kWh equivalents)								
	Boil/Simmer				Fry		Combination		
	Green Tea	Mohinga	Rice (Yaykhan)	Rice (strained)	Tempura	Sauteed Vegetables	Bean Soup	Chicken Bechalor Soup	Leafy Soup
Electric Frying Pan	0.115	0.425	0.391	0.402	0.684	0.212	0.776	0.543	0.234
EPC	0.124	0.405	0.258	0.471	0.570	0.217	0.512	0.468	0.230
Induction Stove	0.108	0.380	0.385	0.439	0.568	0.205	0.941	0.469	0.229
Rice Cooker	0.163	0.357	0.224	0.550	0.634	0.159	0.687	0.402	0.235
Infrared Stove	0.181	0.472	0.356	0.515	0.923	0.315	0.987	0.622	0.366
LPG	1.193	0.639	0.639	0.767	1.278	0.341	1.832	1.065	0.319
Charcoal	1.625	2.250	2.417	2.417	3.792	3.834	5.250	4.709	1.445
Firewood	1.089	3.145	2.903	3.629	5.481	2.311	3.734	5.200	2.534

Fig.4 Comparing the energy consumption of different fuels/appliances for a given dish

The conditional formatting of these tables are individual to each column, providing a visual representation of stove/appliance performance for each dish - from best performing (dark green) to worst performing (dark red). Figure 4 shows that every electrical appliance consumed significantly less energy than the charcoal and firewood stoves. The LPG stove consumed a comparable amount of energy than the infrared stove for some dishes, most notably sauteed vegetables and leafy soup. However, the infrared stove was the worst performing electrical appliance for all dishes except rice (see below for more detail on rice cooking methods and appliance performance).

The best performing appliances across all of the dishes were the rice cooker, electric pressure cooker, and induction stove, and all three of these appliances perform well across the three categories of boiling/simmering, frying, and a combination.

	Cooking Time (mins)								
	Boil/Simmer				Fry		Combination		
	Green Tea	Mohinga	Rice (Yaykhan)	Rice (strained)	Tempura	Sauteed Vegetables	Bean Soup	Chicken Bechalor Soup	Leafy Soup
Electric Frying Pan	6	24	34	34	49	12	48	31	13
EPC	9	32	26	54	99	17	88	46	18
Induction Stove	5	19	26	26	37	11	44	27	12
Rice Cooker	17	36	20	70	91	17	70	38	26
Infrared Stove	10	27	41	38	56	20	59	36	21
LPG	8	22	23	29	35	9	51	38	12
Charcoal	17	32	42	49	74	26	74	37	20
Firewood	20	44	29	35	57	10	57	40	18

Fig.5 Comparing the cooking time for a given dish

Across almost every dish, the stoves/appliances that complete the cooking process in the shortest time are: the induction stove, the LPG stove, and the electric frying pan. The notable exception is rice (yaykhan), which reflects the fact that the rice cooker is tailor-made for this very process. Perhaps surprisingly, the EPC proves to be time consuming in comparison to the other stoves and appliances. The heat transfer from stove to pot is less intense in the EPC and rice cooker, in comparison to the other stoves, and this seems to impact the cooking time of both fried and boiled/simmered dishes. Also, having to add ingredients at different stages of the cooking process means that the lids for these two appliances are not always in use, further reducing the benefits of these two energy-efficient appliances. It is also worth bearing in mind that pressurisation was not required or even possible for the vast majority of these dishes. For recipes using unsoaked beans, tough meats or animal bones (pork ribs, goat and pork feet), the EPC is likely to be much more advantageous both in terms of cooking time and energy consumption.

Figures 6 and 7 below show the average ratings (/10) these appliances and stoves received with respect to each of the dishes. It is clear that tempura is not as easy or enjoyable to prepare/cook across all stoves and appliances, compared to other dishes (see below for more details). The straining method of cooking rice appears to be least well suited to the electric pressure cooker and rice cooker, compared to other appliances and stoves. Firewood was very unpopular across all dishes and for a variety of reasons. Wet and cold conditions meant the cooking time was longer, and the participants did not like the smoke and ash from the fire, which also happened to dirty the pots and make them difficult to clean.

	Cook's Scores (/10)							
	Boil/Simmer			Fry		Combination		
	Mohinga	Rice (Yaykhan)	Rice (strained)	Tempura	Sauteed Vegetables	Bean Soup	Chicken Bechalor Soup	Leafy Soup
Electric Frying Pan	9.0	8.0	7.5	7.7	8.7	9.0	9.0	9.0
EPC	9.3	10.0	6.0	5.5	8.3	10.0	9.0	9.0
Induction Stove	9.0	8.0	7.5	7.0	9.0	8.7	8.7	8.0
Rice Cooker	8.7	10.0	7.0	5.3	7.3	9.0	9.0	8.0
Infrared Stove	9.0	8.0	8.5	9.3	10.0	9.0	9.7	9.0
LPG	9.7	9.0	8.0	9.0	9.7	8.0	9.7	9.3
Charcoal	7.7	5.0	7.5	7.0	7.0	7.3	8.5	7.7
Firewood	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

Fig.6 The average rating given by the cook for the appliance, for a given dish

	Tasting Scores (/10)							
	Boil/Simmer			Fry		Combination		
	Mohinga	Rice (Yaykhan)	Rice (strained)	Tempura	Sauteed Vegetables	Bean Soup	Chicken Bechalor Soup	Leafy Soup
Electric Frying Pan	9.7	10.0	9.0	8.7	9.7	9.0	9.0	10.0
EPC	9.3	9.0	8.5	5.5	9.0	9.7	9.3	9.3
Induction Stove	10.0	9.0	8.5	7.0	9.0	8.7	9.0	8.0
Rice Cooker	9.7	8.0	10.0	6.0	9.0	10.0	10.0	10.0
Infrared Stove	8.7	10.0	9.0	9.0	10.0	10.0	9.3	9.7
LPG	10.0	8.0	9.2	8.0	9.3	9.7	10.0	9.7
Charcoal	9.3	9.0	9.4	9.0	9.3	10.0	10.0	9.3
Firewood	5.0	5.0	5.0	5.0	5.0	8.3	5.0	5.0

Fig.7 The average rating given by the tasters for the appliance, for a given dish

From a tasting perspective, and with the exception of tempura and firewood, all stoves and appliances shown in Figure 7 were able to cook the dishes successfully. As one might expect, the electric frying pan and the infrared stove made the tastiest fried foods, relative to other stoves and appliances. The taste of dishes cooked on charcoal was rated highly, but no more so than the taste deriving from foods cooked with different modern energy stoves and appliances. It appears as though firewood was capable of producing good dishes but only when the logs were dry and able to burn sufficiently well. Wet firewood meant that the fried dishes did not crisp, and a range of dishes discoloured during the cooking process.

4.5 Fried Foods

4.5.1 Tempura

Tempura is the only selected dish that requires deep frying. To do this successfully, a large quantity of oil needs to be heated to a high temperature, and this temperature needs to be sustained as much as possible during the cooking time. Therefore, in the absence of specialist equipment, it is difficult to prepare tempura to the highest of standards.

Nevertheless, this presents an interesting challenge for the purposes of the CCTs. Can tempura be cooked more successfully using the more generalised modern cooking stoves/appliances, in comparison to charcoal?

Fig.8 The cooked selection of tempura

Figure 9 below splits the cooking time between a) the time taken to heat the oil and b) the time to cook multiple tempura food (tofu, gourd sticks, potato chips, corn seeds, onions, and pennywort bundles). The cooks explicitly

stated that the induction stove and LPG stove were preferable cooking options, because they provided a high heat and the temperature could be controlled. An electric frying pan is not far behind these two stoves, while an infrared stove and charcoal stove cook tempura in roughly the same amount of time. An EPC and rice cooker are the worst performing appliances, which is to be expected given that the benefits of these appliances are not matched to deep frying. This shows that a different frying option is important for Myanmar cuisine, and that a range of other modern cooking appliances do a better job than charcoal.

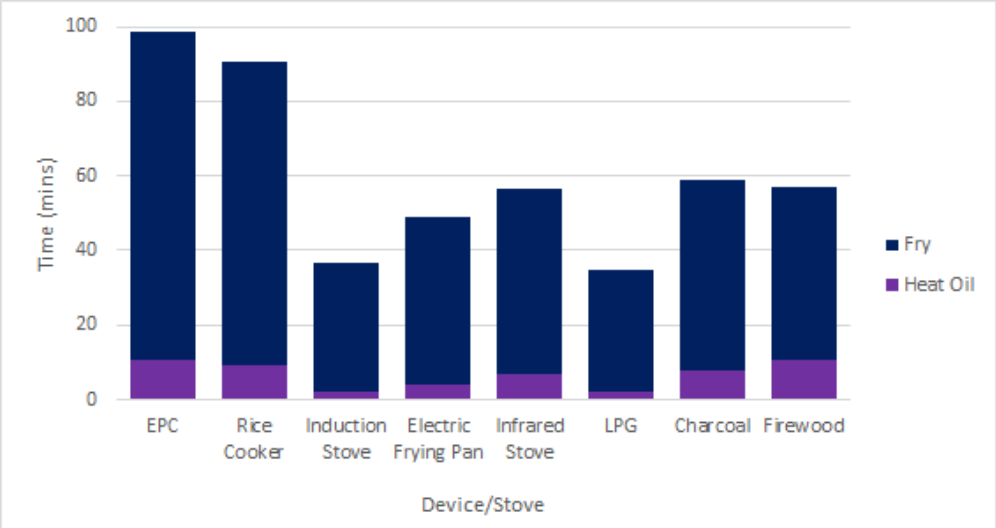


Fig.9 Cooking times for batch frying a range of tempura battered foods

The shorter the cooking time, the more suitable the appliance is for deep frying. To some extent this is also reflected in the scores that both the cook and the person tasting the food gives each of the appliances/stoves. Figure 10 below shows that the EPC and rice cooker made the least satisfying tempura. The LPG stove performed the best for both the cook and the taster. The biggest disparity between the two perspectives was found in the use of the charcoal stove, which produced tasty food, but at the expense of the cook's enjoyment and convenience.

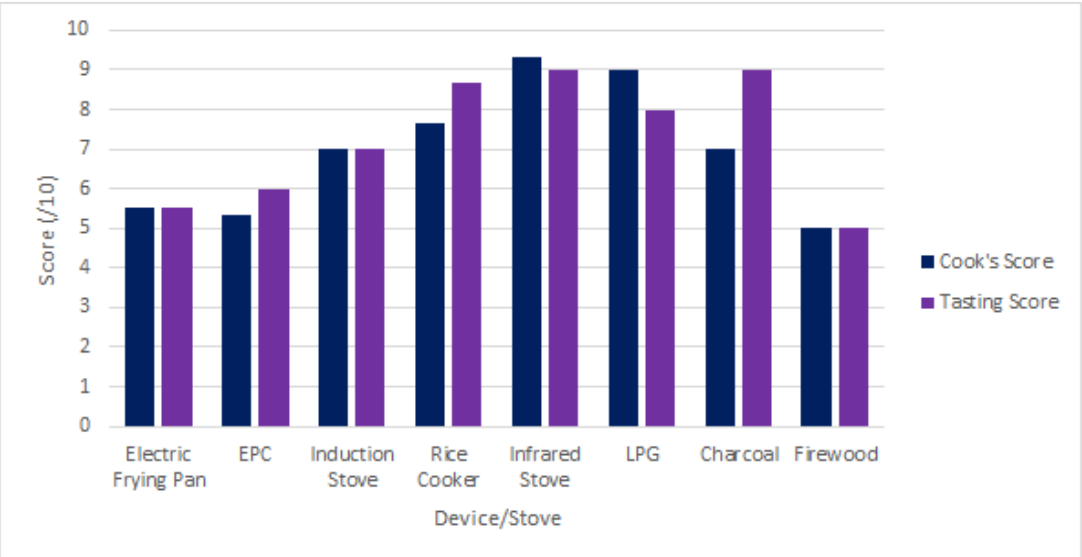


Fig.10 Average scores (/10) given to the cooking/tasting of tempura

Table 5 below provides a comparison of the energy consumption and estimated cost of cooking tempura, according to different stoves and appliances. In terms of energy consumption, all electrical devices proved to be more efficient than both LPG and charcoal, and the induction stove and EPC were the most efficient of the five, consuming less than

6 times the energy used in the charcoal stove. The table provides two different cost contexts; the middle column uses the highest grid tariff and LPG and charcoal prices in Yangon as at the end of 2020, while the final column uses estimates relating to the costs of LPG and charcoal in Shan State, and the cost of electricity on a typical rural hydro mini-grid in Shan State.

Despite choosing the highest marginal rate of grid electricity, cooking tempura with electricity tends to be at least half as expensive as LPG, and 3 to 4 times cheaper than charcoal. In a regional mini-grid context, cooking tempura is cheapest using charcoal, and the induction stove and EPC are the next cheapest.

	Energy Consumption (kWh)	Energy Cost - Grid (Yangon) (MMK)	Energy Cost - Mini-Grid (Shan State) (MMK)
Electric Frying Pan	0.68	85	146
EPC	0.57	71	121
Induction Stove	0.57	71	121
Rice Cooker	0.63	79	135
Infrared Stove	0.92	115	197
LPG	1.11	197	144
Charcoal	3.79	279	90

Table 5 Average energy consumption and energy costs when cooking tempura

Overall winners - Tempura:
LPG stove
Induction stove
Electric frying pan

4.5.2 Sauteed Vegetables

Analysing the same metrics for sauteed vegetables gives us insight into how the different stoves and appliances perform during a traditional frying process.

The performance of the appliances differ from the perspectives of cooking time (Fig 12), taste and cooking experience (Fig 13). The cooking times are shortest using the LPG stove, induction stove, and electric frying pan. Perhaps surprisingly, the cooking time on the infrared stove is longer than all other electrical devices including the rice cooker and electric pressure cooker. Cooking the vegetables on the charcoal stove takes almost three times longer than on LPG.

Figure 11 Sauteed vegetables

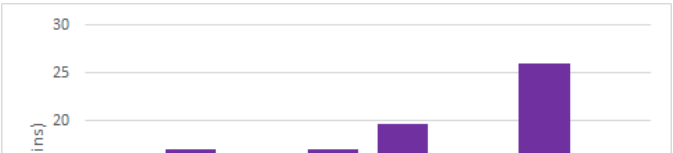
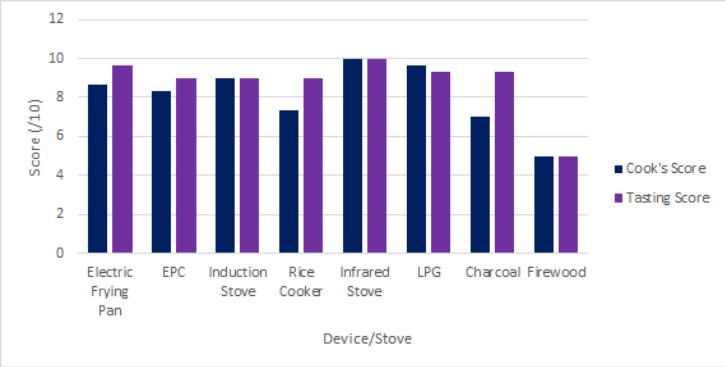


Fig.12 Time taken to cook sauteed vegetables (mins); Fig.13 Rating the cooking/taste of sauteed vegetables



All of the appliances and stoves listed here make good tasting sauteed vegetables, with very little difference between them. The cooks least liked cooking using the charcoal and firewood stoves and the rice cooker. Using biomass was a challenge for many reasons, including:

- took time to start the fire
- sparks from the fire, hitting the person cooking
- very high temperatures that cannot be controlled
- uncomfortable heat and smoke
- hands got dirty during the process.

The problems of using the rice cooker were less severe, and revolved around the time it takes to heat oil and the difficulty controlling the heat.

Similar to the results for tempura, the charcoal stove consumes much more energy than modern equivalents (see Table 6 below). For this dish, LPG is almost as energy efficient as the electrical appliances, of which the rice cooker is the most efficient. When this is converted into the cost of cooking, LPG prepares the dish at double the cost of most of the electrical appliances, in the Yangon context. In the Shan State mini-grid context, cooking with electricity appears to be cheaper than both LPG and charcoal.

	Energy Consumption (kWh)	Energy Cost - Grid (Yangon) (MMK)	Energy Cost - Mini-Grid (Shan State) (MMK)
Electric Frying Pan	0.21	26	45
EPC	0.22	27	46
Induction Stove	0.21	26	44
Rice Cooker	0.16	20	34
Infrared Stove	0.32	39	67
LPG	0.34	61	72
Charcoal	3.83	282	80

Table 6 Average energy consumption and energy costs when cooking sauteed vegetables

Overall winners - Sauteed Vegetables:

LPG stove

Induction stove

Electric frying pan

4.6 Boiled/Simmered Foods

4.6.1 Mohinga

Fig.14 Mohinga

In the case of mohinga, a dish at the centre of Myanmar cuisine, we have been able to analyse the performance of electrical devices for the two stages of the cooking process: boiling, followed by simmering. Given that mohinga paste is widely available in Myanmar, the recipe followed in the controlled cooking tests is a simpler version that uses a pre-made paste, rather than making the paste from scratch.

Figure 15 below shows energy consumed during these two cooking phases for each electrical device. This graph shows that the induction stove (0.147 kWh) and electric frying pan (0.157 kWh) were the most energy-efficient during the initial boiling phase. As one might expect, the most energy-efficient appliances during the simmering phase were the rice cooker and the EPC (both 0.223 kWh). However, it is also clear that the differences were marginal across all five devices and for both stages of the cooking process.

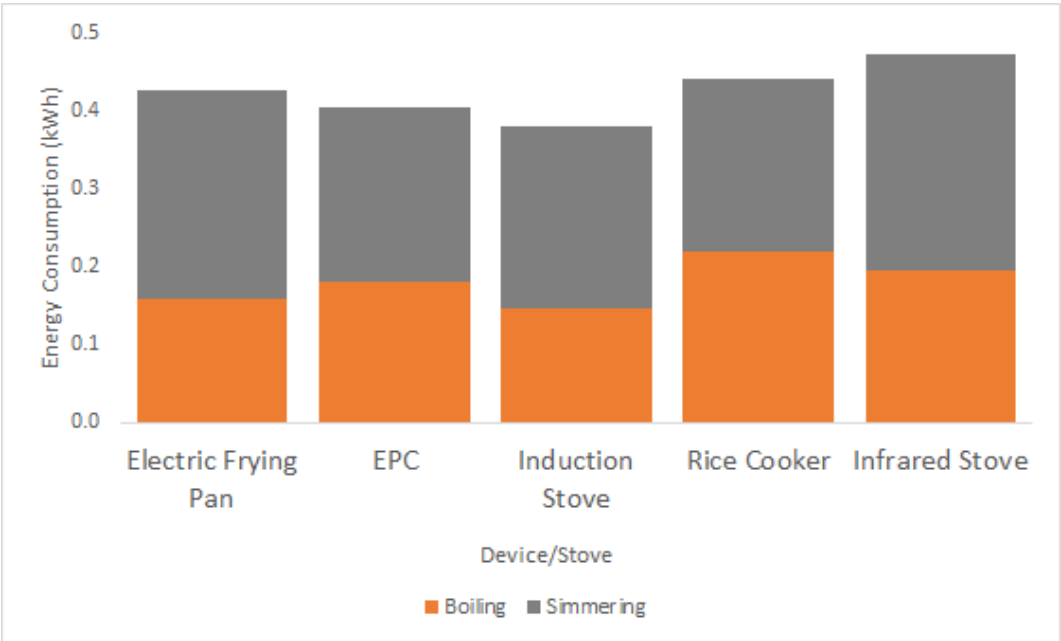


Fig.15 Energy consumption when cooking mohinga (kWh)

There were more significant differences across the devices in terms of cooking time. Figure 16 below shows the induction stove was quickest across both stages of the cooking process. The EPC and rice cooker take longer to reach a high temperature, resulting in longer boiling times than other electrical devices.

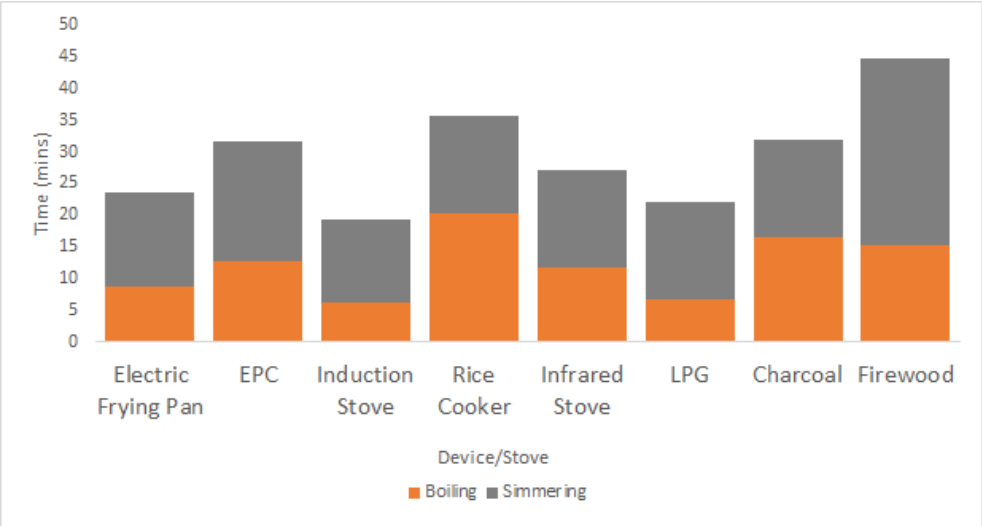


Fig.16 Time taken to cook mohinga (mins)

Overall, cooking mohinga on a charcoal stove took a long time (comparable to the EPC and rice cooker) while LPG took the second shortest time. Cooking with firewood was by far the most time consuming. While it was easy to record the cooking time of each stage, it was not possible to measure the charcoal, wood and gas used for different stages of the process. The gas was set to the highest power for the boiling stage, resulting in a short boiling time, but a medium heat was used for simmering. While we cannot provide numerical data about these two stages, comments about the cooking experience prove extremely insightful:

Using the gas stove:

- "Easy to operate, can cook quickly. Only 7 minutes waiting time for 1.5 litres of boiling water"
- "good to use, fast, clean, able to control the heat"

Towards the end of the boiling phase, water would spill out around the lid, forcing the cooks to open the lid and risk too much water evaporation. However, the cooks were pleased to be able to immediately turn down the heat when required.

Using the charcoal stove:

- "when fire was strong, we cannot control the heat. Water evaporated a lot so that we need to add water again and again. Need to take care for spilling over when boiling"
- "took time to be ready, needed more work to keep burning (blowing wind with hand fan)"
- "frequently covered the lid because the heat was not very high"

In one of the three tests, the heat from the charcoal stove was too strong, and in the other two tests it was too weak. This shows much more variability during both phases than we would ever see from modern energy cooking devices, and it results in a lower overall score. Even with a strong fire, the cooking time on charcoal was quite long, as the cook's needed to keep adding water.

The scores for each of the cooking devices are shown below. Cooking on charcoal is the clearest outlier, while the taste of food cooked using the infrared stove was not up to the standard of the food cooked on other devices. However, this also seems due to variability - in the first test too much water evaporated and the soup was too thick. In the second test, the soup was too thin. In the third test, the taste of the food was rated 10/10.

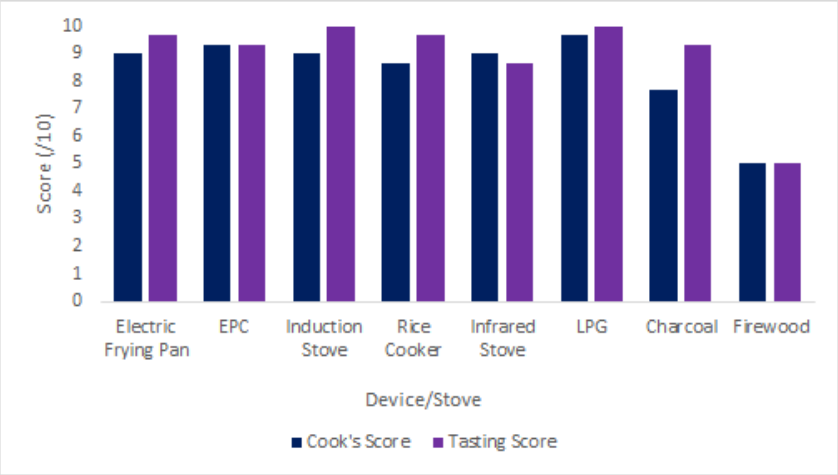


Fig.17 Rating the cooking and taste of mohinga

Overall Winners - Mohinga:
Induction stove
LPG stove
Electric frying pan

4.6.2 Rice

The cooking tests included two different methods of cooking rice. The first method (YayKhan) involved adding a limited amount of water that would be fully absorbed by the rice at the end of the cooking process, while the second method involved boiling rice in a greater volume of water, and throwing the excess water away once the rice is cooked, at which point the rice is returned to the pot/device for a short steam. The first method ('YayKhan') was carried out once, and the second method ('Straining Method') twice. The results of these two methods are detailed below:

	YayKhan (Absorption) Method				Straining Method			
	Energy (kWh)	Time (mins)	Cook's Score (/10)	Taster's Score (/10)	Energy (kWh)	Time (mins)	Cook's Score (/10)	Taster's Score (/10)
Electric Frying Pan	0.39	34	8.0	10.0	0.40	34	7.5	9.0
EPC	0.26	26	10.0	9.0	0.47	54	6.0	8.5
Induction Stove	0.39	26	8.0	9.0	0.44	26	7.5	8.5
Rice Cooker	0.22	20	10.0	8.0	0.55	70	7.0	10.0
Infrafred Stove	0.36	41	8.0	10.0	0.51	38	8.5	9.0
LPG	0.64	23	9.0	8.0	0.77	29	8.0	8.0
Charcoal	2.42	42	5.0	9.0	2.42	49	7.5	10.0
Firewood	2.90	29	5.0	5.0	3.63	35	5.0	5.0

Fig.18 Comparing methods of cooking rice: steaming (one test) and draining (average of two tests)

The green highlights show the two best performing devices/stoves for energy consumption, time, and the satisfaction of the cook and the person tasting the food.

If we focus on the YayKhan method, we see that the rice cooker is the most efficient and the quickest device for cooking rice, and receives a cook's rating of 10/10. The EPC received the same rating, and is the second most efficient in terms of energy consumption. For the Straining Method, where a larger quantity of water needs to be brought up to boil, the best performing devices were the electric frying pan, induction stove, and LPG stove.

In almost all cases, the YayKhan method was a more efficient, quicker, and more satisfactory way of cooking rice. We must also recognise that the first method requires a smaller volume of water, which is an additional benefit.

Households that cook with electricity in Myanmar tend to use a rice cooker alongside a stove designed from other dishes (e.g. the electric frying pan). It is therefore no surprise nor a concern that the electric frying pan, the infrared stove, and induction stove did not perform as well for the YayKhan method. LPG seemed to be a satisfactory (although less efficient) option, whereas rice on a charcoal stove took much longer and used large amounts of energy.

Overall Winners - Rice (YayKhan):
Rice Cooker
Electric Pressure Cooker
LPG Stove/Induction Stove

Overall Winners - Rice (Straining):
Induction Stove
Electric Frying Pan
LPG Stove

4.7 Dishes with frying and simmering components

Three soup dishes were included in the controlled cooking tests, and these dishes have slightly different cooking methods. As the preparation of these soups require both frying (/toasting) and simmering/boiling, we are able to analyse how each of the devices fared during these two very different cooking methods, and which devices were the most efficient and convenient for the overall dish.

4.7.1 Bean Soup

Bean soup is perhaps the most complicated dish included in the cooking tests. Chickpeas are usually soaked in water for approximately five hours, and are then boiled until soft. Onion, garlic, ginger, and dry ingredients are then fried, before the chickpeas, the chickpea water, vegetables, tamarind paste and seasoning are added, and the soup is left to simmer.

This process has been followed for every device, and the cooking process begins when the chickpeas have been soaked and they are ready to be boiled.

However, one of the benefits of the EPC is that it could dramatically reduce the overall cooking time, if we include the five hour soaking time at the beginning. While soaking may not be thought of as 'cooking', it still requires a member of the household to be available five hours before the rest of the cooking takes place. Under pressurisation, it is possible that the dried chickpeas could be prepared in a short space of time, providing more convenience to the household.

Fig. 19 Ingredients for bean soup

Figure 20 below compares the energy consumption (kWh) of the electrical appliances for each stage of the cooking process, showing overall that the EPC was the most energy efficient, followed by the rice cooker and electric frying pan. In the case of the EPC and rice cooker, we can see

clearly that simmering food requires very little energy, particularly compared to the other devices listed.

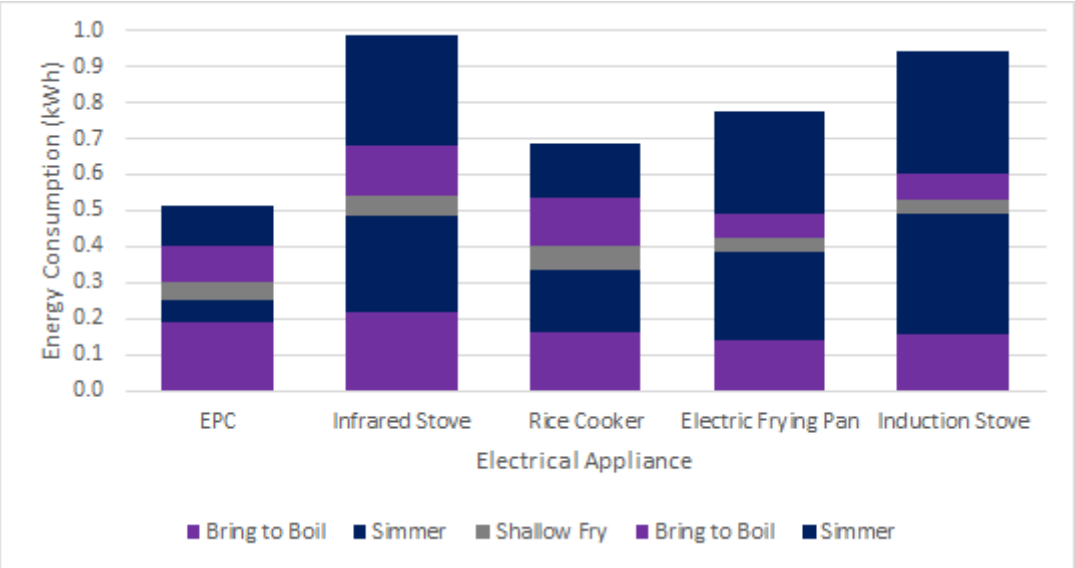


Fig.20 Energy consumed for different stages of the Bean Soup cooking process (kWh)

It was not possible to estimate the energy consumption for each stage of the cooking process when cooked on charcoal. Overall, cooking bean soup on charcoal required over five times the energy consumption of the least efficient electrical appliances (infrared stove, induction stove), and cooking on LPG required twice the energy of these same appliances.

The cooking time for each stage of the cooking process was recorded for charcoal and LPG tests as well as for the electrical appliances. Figure 21 below shows that the electrical appliances requiring the least amount of energy to cook the dish (EPC, rice cooker) take the longest time to cook overall. In the case of the EPC, the very long simmering process is due to the fact that 'Bean Mode' was chosen, which lasts approximately forty minutes. This function is better suited to legumes that have not been pre-soaked, and given that all other devices needed between 13-17 minutes to complete the first simmering process, we can confidently estimate that an EPC could be used in a similar manner to this. If the EPC simmering time reduces from 44 minutes to 17 minutes, the cooking time is the same as the infrared stove, and quicker than for the rice cooker and for charcoal.

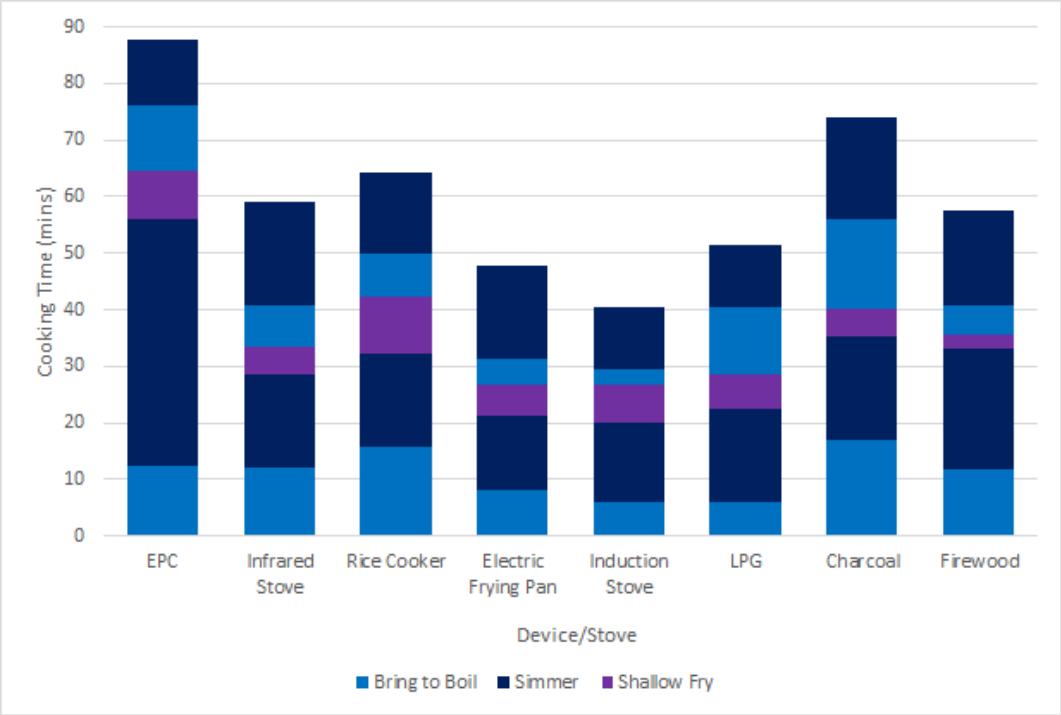


Fig.21 Cooking time for different stages of the bean soup cooking process (mins)

The induction stove and electric frying pan proved particularly efficient (in terms of time) in completing both boiling stages - particularly after the frying stage. As with other dishes included in the tests, the induction stove out performs the infrared stove both in terms of energy consumption and cooking time.

From the cook's perspective, all electrical appliances listed here received an average score of at least 8.7 out of 10. The EPC was the preferred option, scoring full marks across all three tests. A wide range of reasons were given for this scoring: 'easy to use and clean', 'no need to worry about spillover and [burning]', 'all the veggies and beans are well cooked', 'texture of all veggies are looking good'.

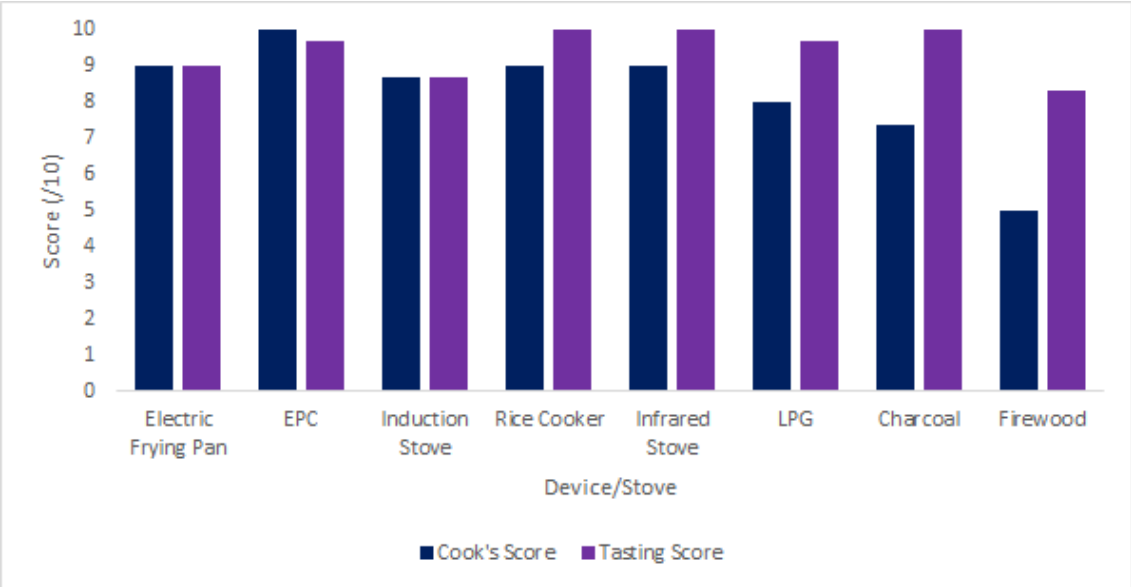


Fig.22 Rating the cooking and taste of bean soup

The lower score for the induction stove (8.7) was due to the delay in temperature change. It took too long to reduce in temperature during the frying stage, and this rushed the cook and increased the risk of burning. The team also had a similar problem using LPG; although the temperature is more easily controlled, the high heat coupled with a thin pot meant that it required more effort to ensure the food did not burn.

The taste of the dish was very good for all of the devices, including charcoal and firewood. The induction stove received the lowest score, and this was largely due to the radishes and beans not always being cooked through enough. This suggests a longer cooking time may have been required.

Overall Winners - Bean Soup:
Electric Pressure Cooker
Electric Frying Pan
Rice Cooker

4.7.2 Chicken Batchelor Soup

The process for preparing chicken batchelor soup begins with a homemade paste that is then used as a marinade for the chicken. Later, all of the ingredients are fried for a short period of time, and with a little water. More water is added and the soup is brought up to the boil. The soup finishes with a simmer, ending when the chicken can easily be cut with a spoon.

Fig.23 Chicken batchelor soup

Figures 24 and 25 below show the energy consumption and cooking time for batchelor soup. It could be argued that the results from the infrared stove are an outlier, with a disproportionately high energy consumption and cooking time for the initial frying stage. However, this looks to be partially explained by a different cook preparing the dish for rounds 2 and 3, preferring to fry for longer, and simmer for a shorter period of time. The results from round 1 of the infrared stove appear very similar to the average results of the induction stove.

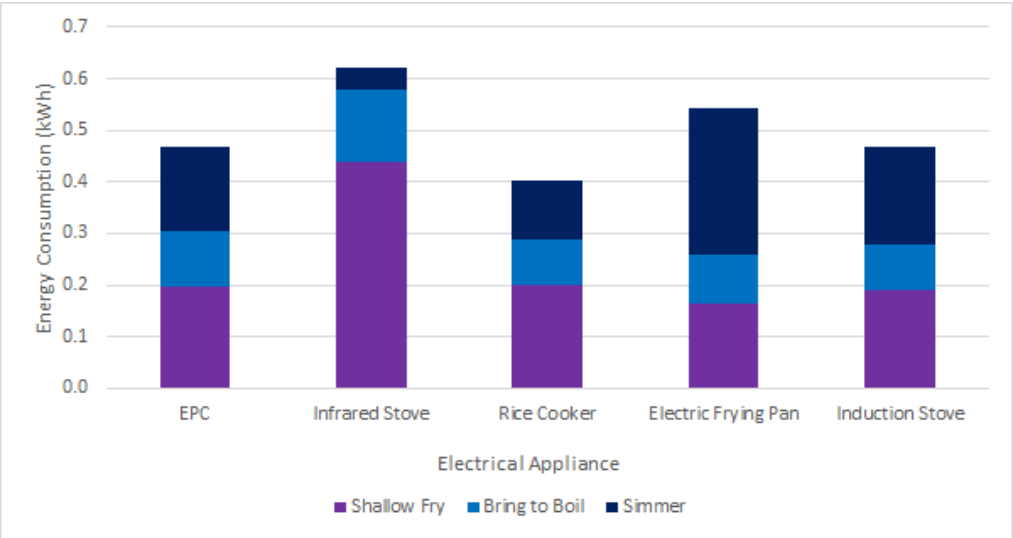


Fig.24 Energy consumed for different stages of the chicken batchelor soup cooking process (kWh)

A similar pattern emerges for this dish, in comparison to bean soup. The EPC and rice cooker are the most efficient appliances from an energy point of view, whereas the electric frying pan and induction stove (and arguably the infrared stove) take the shortest amount of time. Most of the energy efficiency savings take place at the simmering stage, although the EPC and rice cooker are efficient throughout.

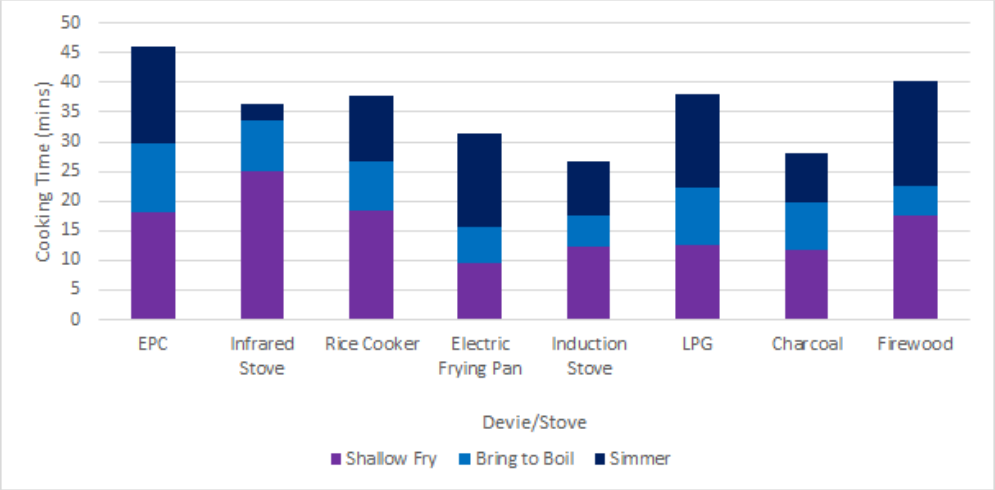


Fig.25 Cooking time for different stages of the chicken batchelor soup cooking process (mins)

We are unable to report the energy consumption of the charcoal stove, due to a weighing error. The LPG stove used double the energy of the electrical appliances, and in terms of financial cost was three times more expensive.

Perhaps surprisingly, the charcoal stove cooks the dish in a relatively short time. However, charcoal receives the second lowest rating from the perspective of the cook, with firewood cooking performing the worst of all devices and stoves by some distance (Figure 26).

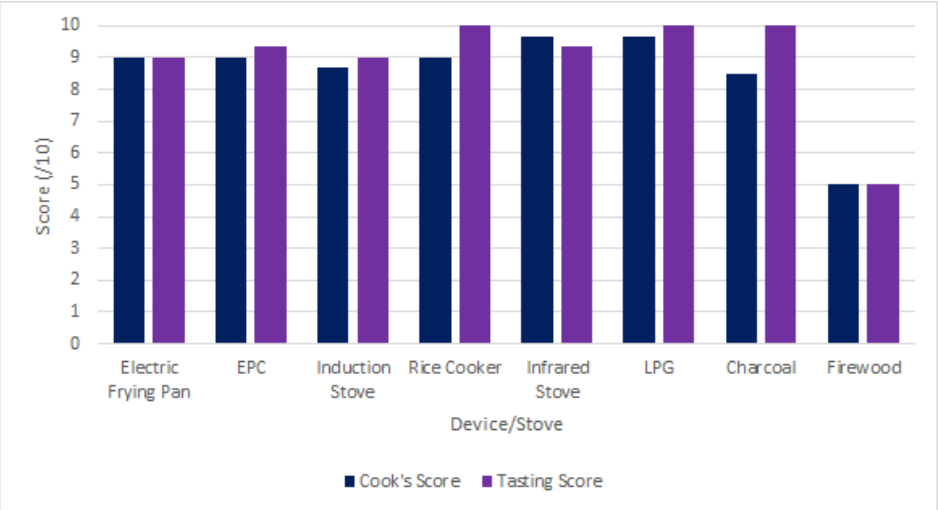


Fig.26 Rating the cooking and taste of chicken batchelor soup

The reasons for this low score have also been expressed in relation to other dishes: the charcoal and firewood stoves make for dirtier cooking conditions, and the cook is exposed to a lot of heat. In the first charcoa test, the cook was struck by a spark from the coals.

Again, all other devices are viewed favourably, and the lowest average score from the cook's perspective is in relation to the induction stove (8.7). While the tasters enjoyed the food cooked on charcoal (a perfect score of 10/10 across all three rounds), it was no better than the soup cooked in the rice cooker or using the LPG stove.

Overall Winners - Chicken Batchelor Soup:
Rice Cooker
Electric Pressure Cooker
Infrared/Induction Stove

4.7.3 Leafy Soup

The final dish included in this analysis is leafy soup. The cooking methods are similar to the methods used for chicken batchelor soup, but instead of frying the ingredients in a little water, the dish begins by *'toasting'* (or dry frying) the roselle leaves, without water or oil, until the leaves become soft and dark. This is the quickest of the three soups to cook - usually between 10 and 20 minutes.

Fig.27 Leafy soup

Due perhaps to the short cooking time, four of the five electrical appliances consume roughly the same amount of energy, just over 0.2 kWh. The infrared stove is the outligher, requiring 50% more energy, and almost all of this is for the initial toasting/dry frying stage. However, this is due to a change in cook for rounds 2 and 3, who preferred to fry the leaves for more than twice the time of the cook in round 1. This was the case for the infrared stove rounds of chicken batchelor soup, detailed above. These differences are included in the analysis in order to account for different cooking techniques, although it is recognised that this makes comparisons between appliances more difficult. In terms of the round 1 results for the infrared stove, the energy consumption was still higher than all other electrical devices, but only by about 20% as opposed to 50%.

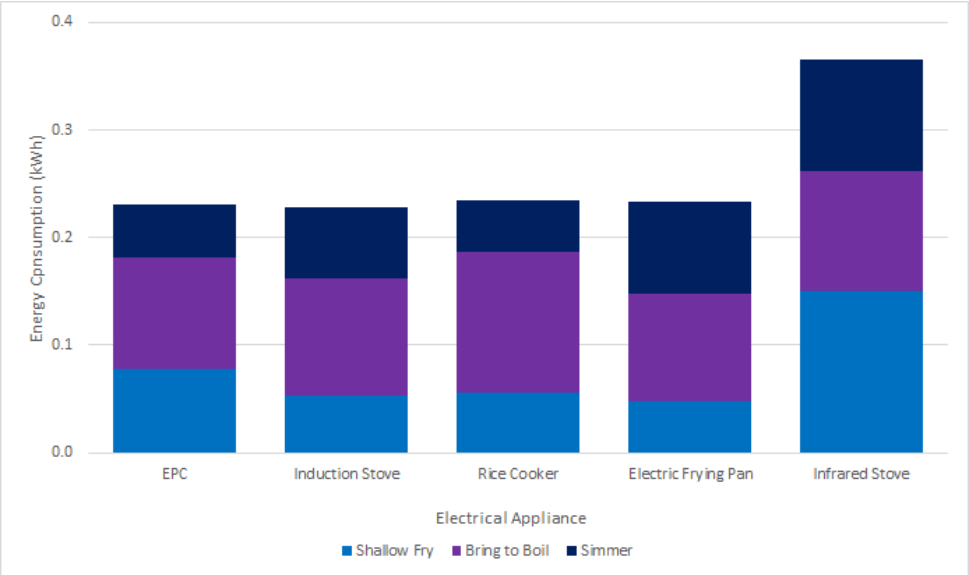


Fig.28 Energy consumed for different stages of the leafy soup cooking process (kWh)

In terms of cooking time, the electric frying pan, induction stove and LPG stove were the quickest - at just over 10 minutes. The EPC and rice cooker took longer to toast/dry fry the leaves, and then longer to reach boiling point. Round 1 of the infrared stove took 15 minutes - in between these two sets of appliances. The cooking time on charcoal and firewood is similar to the time using an EPC, both in terms of the overall time taken and the time of each of the three cooking stages.

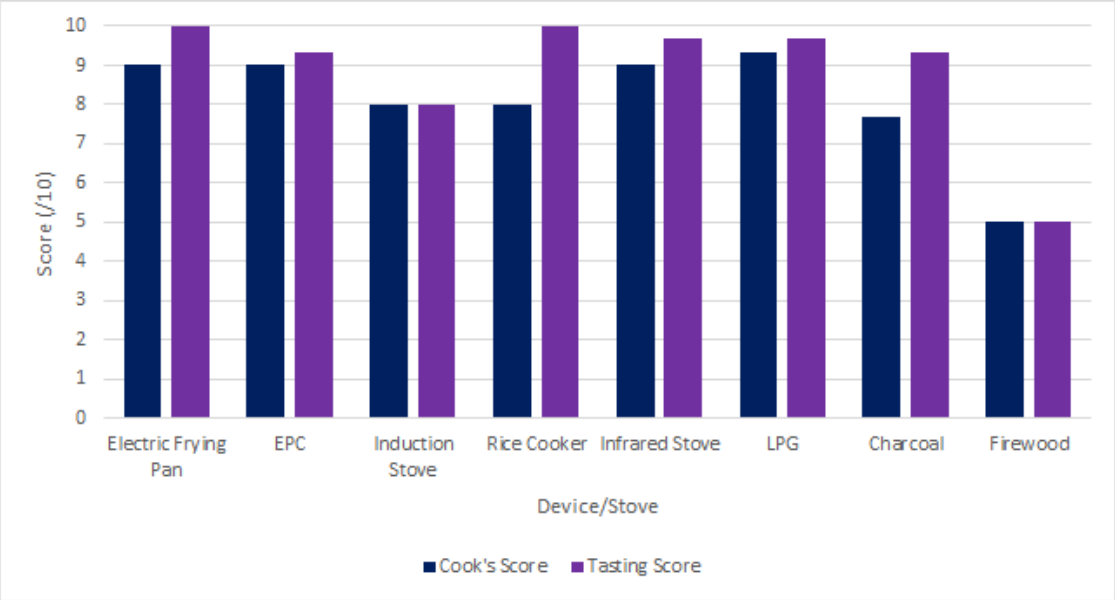


Fig.29 Cooking time for different stages of the leafy soup cooking process (mins)

Finally, we turn to the perspectives of the cooks and the tasters. The cooking experience was lower for the induction stove, rice cooker, and charcoal stove. In the case of the induction stove, the challenge was that it takes time for the temperature to reduce, which meant the leaves were more likely to burn, and later the liquid was more likely to spill over. The low score from the taster is due to the fact that the leaves tasted burnt in round 1. The rice cooker was not a favourable option because it took too long to fry and boil. There was also an issue related to the fact that the rice cooker being used was three years old, and the control switch needed pushing frequently. The problems with the charcoal stove are the same as with other dishes: dirty conditions and variable temperature. Apart from the induction stove, the rest of the appliances scored above 9/10 on average, from a tasting perspective.

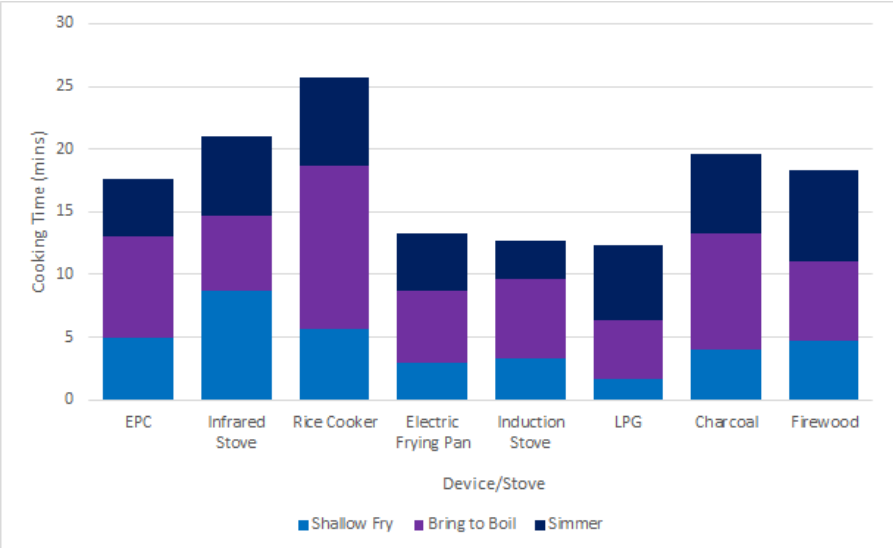


Fig.30 Rating the cooking and taste of leafy soup

Overall Winners - Leafy Soup:
Electric Frying Pan
LPG Stove

For these dishes that required a combination of cooking methods, the electric pressure cooker appears to be a consistent 'winner' in comparison to alternative devices. The electric frying pan also performs well across all three dishes. Overall, the differences in performance across all of the modern energy devices included in this analysis are marginal.

5 Comparing the CCTs with the 2017 Cooking Diaries

These controlled cooking tests, carried out in 2020, are part of an evolving research methodology that began with a cooking diaries study in 2017, as part of an Innovate UK project (132724). Before a second round of cooking diaries are conducted in Myanmar, which is due to take place in 2021, these CCTs provide an opportunity to collect more detailed data about the performance of different cooking devices, in relation to popular dishes in Myanmar cuisine.

Very few direct comparisons can be made between the 2020 CCTs and the 2017 diaries. In 2017 the study involved a far more organic process, whereby participant households were asked to incorporate electrical cooking appliances into their routine cooking practices, which included a wide range of dishes cooked according to different recipes and styles/methods. The data could therefore only be analysed by food type, e.g. soups, vegetable dishes, curries, as opposed to specific dishes, but even within these typologies the cooking times and energy consumption varied considerably. Energy consumption was also calculated per person, and this was not the case in the CCTs. Finally, the 2017 study also included reheated foods, which require far shorter cooking time and energy consumption ("9 out of 10 curries cooked on the induction stove were reheated", Leary et al, 2019).

The controlled nature of the tests in 2020 include a standardised recipe for each dish, time and energy recordings (where possible) for each stage of the cooking process, and the same dish being cooked on multiple devices. Together, these interventions allow us to directly compare the cooking devices, in terms of energy consumption, cooking time, and the cost of cooking the dish.

It is possible to make relative comparisons across the two research projects. In Figure 31 below, we can see that like-for-like dishes are cooked using less energy on an induction stove, in comparison to the infrared stove and the electric frying pan (although the frying pan was the most energy efficient for curries). This tallies with the overall results of the 2020 CCTs, as does the fact that the rice cooker is (as expected) much more energy efficient than an induction stove when it comes to cooking rice.

	Induction Stove	Infrared Stove	Electric Frying Pan	Rice Cooker	Charcoal Stove	Wood Stove
Soups	0.3	0.48	0.56			
Curries	0.4	0.53	0.15			
Other (meat/fish/tofu)	0.59	0.75				
Vegetables	0.12	0.3	0.32			
Rice	0.55			0.21	2.09	1.41

Figure 31 Mean energy consumption for common dish typologies (Mj/per person)
(Taken from Tables 28 and 43 in Leary et al, 2019).

In terms of cooking times, the LPG stove was found to be far quicker at cooking typical Myanmar dishes compared to electrical appliances, wood and charcoal. This may partly reflect the argument that 'quick-cook' dishes are more likely to be cooked using LPG - which is more expensive than electricity - compared to dishes with a longer cooking time. Eggs tended to take 10 minutes, for instance, whereas rice and curries tended to take at least 30 minutes. When we turn attention to the CCTs, we find that the LPG stove was among the most efficient stoves in terms of cooking time, although the cooking time was often comparable with a range of electrical appliances, most often the induction stove and electric frying pan. Both the CCTs and 2017 diaries show that electric cooking takes less time than charcoal cooking, and the 2017 study confirms it is also quicker than cooking with wood. Figure XX below presents this data in graphical form, according to dish typologies.

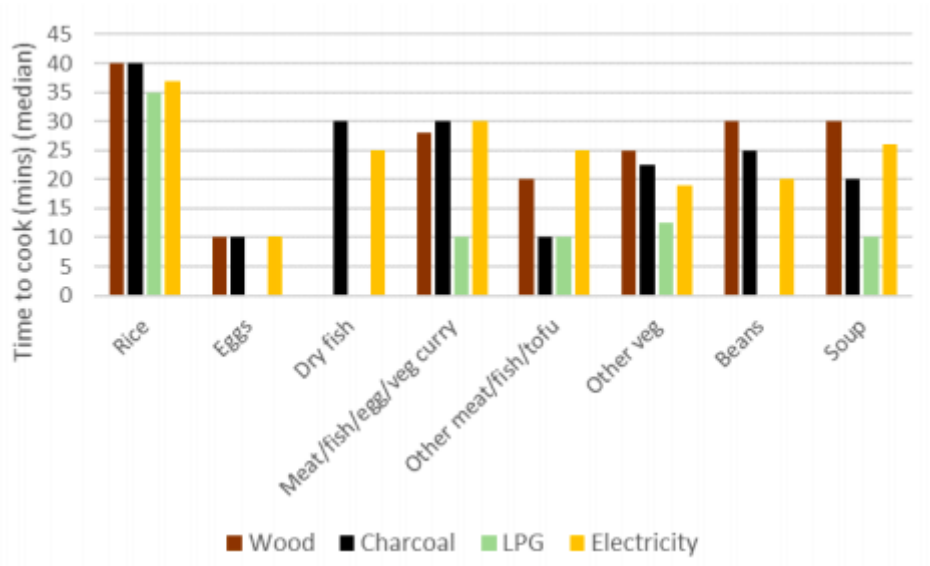


Figure 32 Median cooking time for common dish typologies (mins) (Figure 18 in Leary et al, 2019).

While a comparison between the two studies is limited in the ground it can cover and in validating results, this shows that we are gaining increasing levels of detail and insight into the potential suitability of different modern energy cooking appliances in the Myanmar context.

6 Conclusion

Clean cooking technology for households in low- and middle-income countries like Myanmar offer enormous promise to advance at least five of the UN Sustainable Development Goals (SDGs): Good health and well-being (SDG 3); gender equality (SDG 5); affordable and clean energy (SDG7); climate action (SDG 13); and life and land (SDG 15). Cleaner and modern fuels and energy sources, such as LPG and electricity, have potential impacts on social and environmental factors, including limiting rates of deforestation, improving health, reducing the costs of cooking, time savings, and cleaner kitchens and cooking vessels. Despite the fact that electricity is widely used for cooking in grid-connected areas of Myanmar, empirical evidence of the impact of modern cooking technologies remains limited.

Our findings show that a wide range of electric cooking appliances are well suited to the Myanmar context, providing affordable and convenient cooking options that are liked by both the cook and those sampling the dishes that have been prepared. The electric pressure cooker, rice cooker, induction stove, and electric frying pan all prove to be reliable and satisfying performers in almost every test conducted, which include a wide range of dish typologies and different cooking methods, namely frying, boiling, and simmering.

At present, households that cook with electricity in Myanmar tend to use a rice cooker and an electric frying pan. These products tend to be affordable and widely available. One of the main research questions that the CCTs hoped to answer was: would the benefits of the electric pressure cooker be transferable to the Myanmar context? The EPC proved to be among the top performing appliances for four of the dishes highlighted above: all three soups (which used a combination of frying and boiling/simmering methods) and rice (steaming). Without the need for pressurisation, the EPC did not perform as well as the LPG stove, induction stove, and electric frying pan, when it came to preparing Mohinga (boiling/simmering) or any of the fried dishes. However, these differences were often very marginal, and the CCTs demonstrate that the EPC is capable of preparing fried dishes to a high standard, and is both convenient and cost-effective. If pressurisation is not going to be necessary for much of Myanmar cuisine, and if EPCs are going to be more expensive to purchase than other appliances, it may be useful to adapt the marketing strategy accordingly. An 'all-in-one' cooking device may be more attractive to consumers than a device focusing on pressurisation, and particularly by those who assume that frying is not possible in an EPC.

Given that a range of electrical appliances worked well for a variety of dishes, it is to be expected that the future of home cooking Myanmar will be similar to the existing practice of having both a rice cooker and a device for frying, whether it be an electric frying pan, induction stove, infrared stove, EPC or LPG stove. Although LPG is currently a more expensive option for cooking when compared to electricity, an LPG stove proves to cook a wide range of Myanmar dishes to a high standard and in a short space of time. It is both more affordable, efficient, and cleaner than using charcoal. If LPG distribution networks develop in Myanmar and it becomes more cost-competitive as a cooking fuel, then the LPG stove will be of enormous benefit to households in Myanmar, who would be able to practice clean cooking irrespective of issues with the electricity supply.

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1.

2. Annex 1: Kitchen Lab CCT results

		Boil	Steam	Sauté	Simmer	Fuel /device	Time on stove (hh:mm)	Energy used (kWh)	Energy Used (MJ)	Energy Used (kg)	Cost / dish (UGX)
Staple foods	Matooke		✔			Charcoal	1:37	4.10	14.88	0.48	476
						LPG	1:25	2.59	9.22	0.2	1921
						Hot plate	1:27	1.06	3.82		799
						EPC	0:54	0.34	1.22		257
Stews	Beans (soaked)	✔		✔	✔	Charcoal	2:27	5.36	19.22	0.62	622
						LPG	2:00	4.64	16.60	0.36	3444
						Hot plate	2:25	1.73	6.23		1298
						EPC	1:11	0.50	1.80		376
	Meat	✔		✔	✔	Charcoal	1:27	3.59	13.02	0.42	417
						LPG	0:59	2.03	7.38	0.16	1504
						Hot plate	1:49	1.3	4.68		978
						EPC	0:47	0.56	2.02		418
Vegetables	Sukumawiki		✔		✔	Charcoal	0:20	0.85	3.07	0.099	99
						LPG	0:09	0.34	1.20	0.026	249
						Hot plate	0:15	0.21	0.76		155
						EPC	0:14	0.29	1.04		215