# Comparing energy consumption and costs – from cooking across the MECS programme

*(Version 2.1)*

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**Authors: Nigel Scott, Prof. Matt Leach**

*Working paper for comment*

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# Executive Summary

Electricity can play a role as a clean cooking fuel in efforts to reduce the use of biomass and to reduce greenhouse emissions. The paper draws on data generated from studies in multiple countries to address the widespread concern that electricity is too expensive for cooking.

By aggregating energy data and fuel prices found in the study countries (drawn from Africa and developing Asia), the cost of cooking typical meals with an electric pressure cooker (EPC) are shown to be approximately one third the cost of using LPG, and less than 20% of the cost of cooking with charcoal. The EPC is an example of the new generation of efficient electric cooking appliances that use much less energy than traditional appliances such as hotplates. Other modern electric cooking devices can be grouped according to their energy performance: modern hobs (induction, infrared) use 10% less energy than a hotplate, automated devices can save 25%, and EPCs can save 50%. The paper describes features of cooking under pressure, which leads us to conclude that it is not meaningful to compare efficiency figures with other cooking appliances since EPCs require less 'useful' energy (according to the standard definitions of that), to cook typical meals.

The range of energy used is much less when cooking dishes in an EPC, because energy losses are reduced. The sealed lid means no steam escapes during cooking, and the insulated pot means heat losses are minimal. Therefore, the duration of cooking time has much less impact on total energy consumption than for conventional cooking appliances.

Different cooking styles found in African and Asian countries result in different amounts of energy needed - African dishes used approximately half as much energy again as Asian dishes. There are certain dishes that use a lot of energy, such as bean stews and matoke, both part of an African menu.

While an 'efficiency' for each device is an attractive concept, it relies on having a clear definition of the useful energy that is provided: for the water boiling test this is about change in temperature and then change in state of the water, which is physically easy to define and measure/calculate, but is not appropriate for comparisons between some devices. A better definition of the 'useful' energy to use in an efficiency test is not obvious. Specific energy use, and the energy ratios that come from comparing those for different fuel and stove types, may be a more realistic means of assessing relative performance.

The paper presents a series of energy ratios, which show that cooking with charcoal uses 15 times as much energy as an EPC, seven times as much energy as a modern hob, and six times as much as a standard hotplate. Cooking with LPG uses four times the energy used by an EPC and approximately two and a half times the energy used by a modern hob.

# Contents

# 1 Introduction

The need for action to reduce consumption of woody biomass is enshrined in the Sustainable Development Goals. SDG15 calls for sustainable management of forests and a reversal of land degradation, and commitments to reductions in greenhouse gas emissions are one of the targets for SDG13[1]. Accordingly, countries around the world now recognise the need to reduce dependence on biomass fuels for cooking, and many governments are taking action. In some instances, policies specifically target the adoption of clean cooking fuels and technologies as alternatives to biomass; for example the Third National Development Plan for Uganda includes a target to increase the share of clean energy used for cooking from 15% to 50% over a five year period (National Planning Authority, 2020). Other countries may focus only on reducing biomass consumption; for example, support for efficient biomass cookstoves is identified as a measure to 'Promote efficient and sustainable exploitation of biomass for household utilization' in Zambia (National Energy Policy 2019, 2019). Current efforts are failing to reduce the number of people cooking with biomass, as population growth in sub-Saharan Africa outstrips slow progress in the proportion of people using clean cooking fuels (IEA, 2019). Electricity has been identified as a clean cooking fuel that has the potential for positive impact on multiple of the Sustainable Development Goals, and can play a role in new strategies to accelerate the adoption of clean cooking fuels (Batchelor et al., 2019).

However, when the Modern Energy Cooking Services (MECS) programme[2] we first started exploring the possibility of cooking with electricity, the immediate reaction was 'it's too expensive to cook with electricity'. Since then we've conducted consumer studies and undertaken cooking trials in a number of countries, which have tried to unpick this myth. Perhaps the most authoritative study is the 'Cooking with electricity; a cost perspective' paper, which uses five case studies to compare not only fuel costs but also the cost of cooking appliances, and uses a discounted cash flow analysis to compare levelized costs of cooking with different technologies.

Policy makers are rightly concerned to understand the relative costs of cooking with clean fuels, but there is also a growing interest in the energy used by modern cooking fuels and devices, and how that compares to the energy used by traditional cooking fuels and devices. This interest is driven by the need to characterise the greenhouse gas emission impacts of transitions in cooking within national plans for decarbonisation (and hence their nationally determined contributions (NDCs)) and also for calculations that are required to claim carbon credits and other impact benefits.

In this paper we take a look at data that has been generated by the MECS programme on both energy consumption and costs of cooking associated with a range of fuels and devices. To date, this data has been presented in reports on individual, country specific studies. Although cooking with an EPC often turns out to be cheapest, we have not been able to discount the possibility that this is due to some country specific factor. Therefore, we are currently engaged in an ongoing activity to pool together as much field data as possible from previous MECS studies to create a more robust (larger) dataset and to explore what we can learn about the relative costs of cooking using different fuels. This paper needs to be updated as and when additional data from ongoing field work become available. This version of the paper builds on the first version by including energy data from additional electric cooking devices. This additional data has been sourced mostly from controlled cooking tests in Myanmar and Bangladesh; at this point there remains scant data on these devices from African countries.

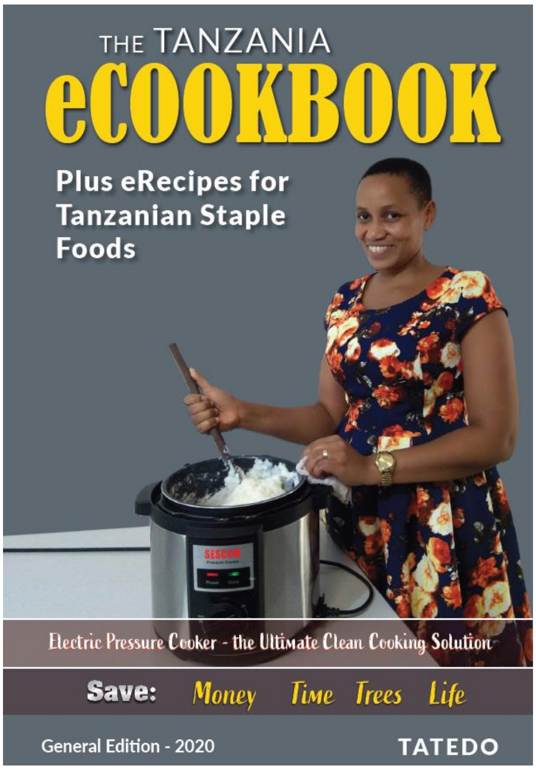
[1] https://sdgs.un.org/goals (accessed 13th April 2022).
[2] https://mecs.org.uk/ (accessed 13th April 2022).

# 2 Background

The collated dataset contains over 300 data points for foods cooked using a range of electrical appliances, and over 130 data points of foods cooking using traditional fuels (wood, charcoal and LPG). Most studies have generated data from households with different numbers of people, and some of the controlled cooking studies have used different portion sizes (e.g., meal for 4 or 6). Therefore, the analysis here is based on specific energy consumption figures measured in terms of MJ/person/event.

Distinguishing between meals and dishes cooked can be a bit tricky. We refer to cooking or heating 'events' rather than meals because in most studies, a heating event can cover either a meal (breakfast, lunch, dinner) or another heating purpose, such as heating water for bathing. A single heating event record could cover multiple purposes, e.g., food could be prepared for both breakfast and lunch (two purposes). Then a single heating event, for a single purpose such as preparing a dinner, could include several dishes and/or heating water as part of that meal. Of the 300 electric cooking data points, 82% involve cooking only a single dish, as do 59% of the data points for traditional fuels.

Data has been gathered from the following types of studies across a range of countries (see Table 1);




- **Cooking Diaries** – a small number of cooks (e.g., 20) are typically asked to cook as normal for a couple of weeks (baseline phase) and then to swap to using electric cooking appliances to cook as much of their menu as possible during a transition phase. During the study, cooks record all the dishes cooked, and measure the energy used (a more detailed description can be found in the Cooking Diaries 3.0 Protocols document).
- The Electric Cooking Outreach (ECO) **Challenge Fund** – one of the challenge fund themes was to investigate whether efficient electric cooking appliances fitted the cooking culture and electricity supply context of a given country. Many of the projects commissioned included some kind of cooking diaries exercise. However, only one project in Nepal generated data on individual dishes.
- **Kitchen lab tests** – these take a mixed-methods approach, combining Controlled Cooking Tests (CCTs) with qualitative data that takes account of the cooking experience as well as the quality of the dish from an eating perspective. A small number of typical dishes are cooked by the same cook but using different fuels and appliances. Tests are repeated multiple times for each dish.
- **Cookbooks** – present data on the energy and cost of cooking a small number of dishes using different fuels. Sometimes data from the kitchen lab tests is used and sometimes data is generated by the cooks who contribute recipes for the cookbook.

*Table 1 Sources of data on cooking energy (and costs)*

| | Cooking Diaries | ECO Project | Kitchen Lab | Cookbook |
|---|---|---|---|---|
| Africa | | | | |
| Kenya | ✓ | | | ✓ |
| Tanzania | ✓ | | | ✓ |
| Uganda | ✓ | | ✓ | |
| Zambia | ✓ | | ✓ | |
| Asia | | | | |
| Bangladesh | | | ✓ | |
| Cambodia | ✓ | | | |
| India | | | | ✓ |
| Myanmar | ✓ | | | ✓ |
| Nepal | | ✓ | | ✓ |

# 3 Energy efficient electric appliances

When cooking a single dish with electricity, an EPC was most commonly used to cook the dish. A mix of electric devices tended to be recorded in the Cooking Diaries studies. Data from additional electric devices, such as hotplates, induction and infrared hobs was also available from laboratory tests (see Table 2).

REAM in Myanmar carried out the most extensive tests (largest number of records) and was the only country to compare most of the different devices (see Table 3):

- Myanmar – only country to test frying pan and Slow cooker
- Bangladesh – only country to tests a 'curry cooker', which appears to be a multi cooker (Figure 1).
- Nepal – compared EPC with induction and infrared
- Uganda and Zambia compared EPC with hotplate


*Figure 1 Curry cooker appears to be name given to multi-cooker[3]*

[3] https://mecs.org.uk/wp-content/uploads/2021/03/Cooking-Diary-and-Appliance-Testing-Bangladesh.pdf

*Table 2 Different electric cooking devices tested (single dishes only) (Number of records)*

| | Source | | | | Total |
|---|---|---|---|---|---|
| | CD | Cookbook | ECO | Lab | |
| EPC | 17 | 16 | 5 | 55 | 93 |
| Mix | 40 | 0 | 0 | 0 | 40 |
| Hotplate | 0 | 0 | 0 | 27 | 27 |
| Induction | 0 | 0 | 0 | 23 | 23 |
| Infrared | 0 | 0 | 0 | 21 | 21 |
| Rice cooker | 0 | 0 | 0 | 16 | 16 |
| Curry cooker | 0 | 0 | 0 | 9 | 9 |
| Frying pan | 0 | 0 | 0 | 8 | 8 |
| Slow cooker | 0 | 0 | 0 | 6 | 6 |
| Kettle | 0 | 0 | 0 | 1 | 1 |
| Thermopot | 0 | 0 | 0 | 1 | 1 |
| Total | 57 | 16 | 5 | 167 | 245 |

*Table 3 Devices tested in each country (single dishes) (number of records)*

| | Bangladesh | India | Kenya | Myanmar | Nepal | Tanzania | Uganda | Zambia | Total |
|---|---|---|---|---|---|---|---|---|---|
| Frying pan | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 8 |
| EPC | 7 | 27 | 10 | 8 | 8 | 9 | 19 | 5 | 93 |
| Hotplate | 10 | 0 | 0 | 7 | 0 | 0 | 5 | 5 | 27 |
| Induction | 10 | 2 | 0 | 8 | 3 | 0 | 0 | 0 | 23 |
| Infrared | 10 | 0 | 0 | 8 | 3 | 0 | 0 | 0 | 21 |
| Kettle | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Rice cooker | 8 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 16 |
| Slow cooker | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 6 |
| Thermopot | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Curry cooker | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| Total | 54 | 29 | 10 | 55 | 14 | 9 | 24 | 10 | 205 |

Figure 2[4] illustrates how EPCs are much more economical than hotplates, with median consumption values of 0.050 and 0.103 kWh/person/event respectively (0.18 and 0.37 MJ/person/event). The outlier in the EPC data is chicken biryani cooked in Kenya and the outlier in the hotplate data is an energy intensive Zambian bean stew. Although these are referred to as outliers, they are energy intensive dishes that are commonly cooked, so they have been included in the analysis.

[4] In these box and whisker charts, the 1st, 2nd (median) and 3rd quartiles are represented by the 3 lines of the box; the mean is represented by the cross; the whiskers represent maximum and minimum values not categorised as outliers (values greater than the 3rd quartile + 1.5 times the interquartile range (IQR), or less than the 1st quartile - 1.5 times the IQR).

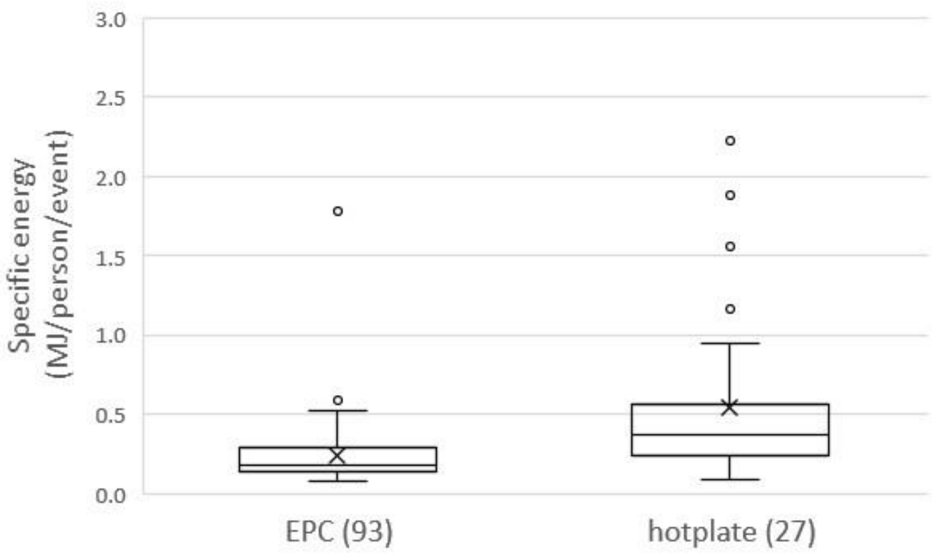



*Figure 2 Specific energy consumption - electric appliances (single dishes only)*[5]

The cooking diaries studies are a good way of generating 'real world' data, in which ordinary cooks prepare everyday food in their home environment. The down side is that you can't control how they cook, what recipes they use, and they are free to use devices inappropriately (e.g. cooking for too long, not controlling the power level, leaving the lid off). It can be argued that comparing results from controlled cooking tests is more reliable. However, the results in Figure 3 show very similar results; the median consumption for dishes cooked in an EPC is marginally higher at 0.052 kWh/person/event. There is no change in the value for hotplates because no data on the unique use of hotplates was generated from the Cooking Diaries studies.

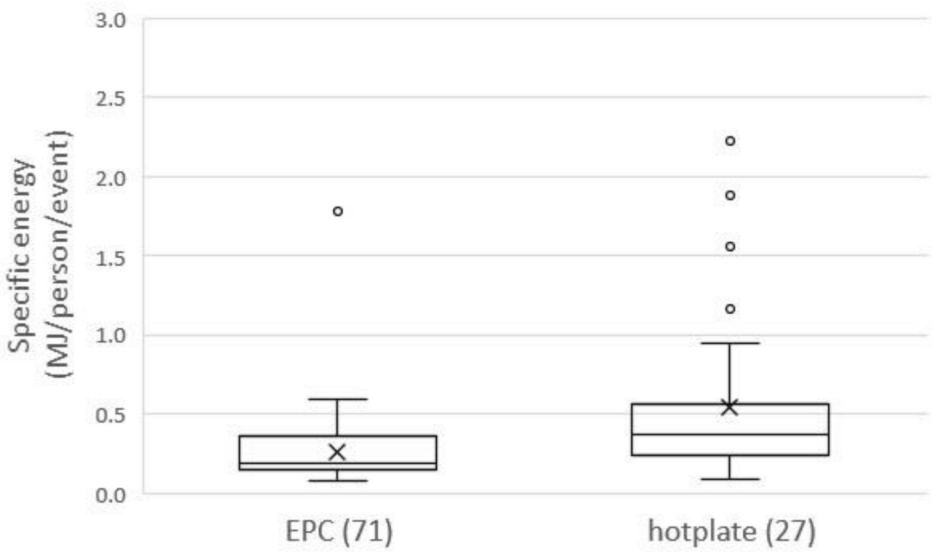



*Figure 3 Specific energy consumption from controlled tests - electric appliances (single dishes only)*

[5] This chart includes data generated from both cooking diaries and controlled tests.

It is clear from both Figure 2 and Figure 3 that the range of energy used is much less when cooking dishes in an EPC. When cooked on a hotplate in a laboratory test, a Zambian bean stew used 0.82 kWh/person/event (3.0 MJ/person/event), which pulls up the mean value. The Kitchen Laboratory Test report does point out that cooking 500g of beans can usually feed a family for two meals, so it is perhaps unfair to include the consumption figures in this analysis, but they have been included for the purposes of comparison. Figure 3 includes a number of bean stews tested on hotplates in Uganda and Zambia, all of which tended to use relatively high amounts of electricity. While the mix of foods cooked in EPCs will be different to the precise mix of foods cooked using hotplates, it does include similar stews, yet the interquartile range is much tighter. This is a consequence of the way an EPC works. Most of the energy consumed is used in bringing the contents up to pressure. Once at pressure, automated control adds small amounts of energy to make up for heat lost during the cooking period. These losses are minimised because of the shortened cooking period, and the insulating effect of the air gap between the pot and the external casing. Therefore, differences in the period of cooking at pressure make relatively little difference to the total energy consumption.

# 4 Regional differences

Given differences in diet and cooking style between Africa and Asia, we might expect to see regional differences in energy consumption. And indeed, it can be seen in Figure 4 that African dishes use more energy for both categories of electric cooking devices. The median figures are also presented in Table 4. The most reliable comparison is between African and Asian use of EPCs, as these sub-sets have the greatest number of data points: African dishes used half as much energy again as Asian dishes – 0.078 and 0.045 kWh/person/event respectively (medians). Note that the mean values for each of the three African categories in Figure 4 are influenced by a single energy intensive dish in each category – Kenyan chicken biryani (EPC) and matoke (mix), and Zambian bean stew (hotplate).

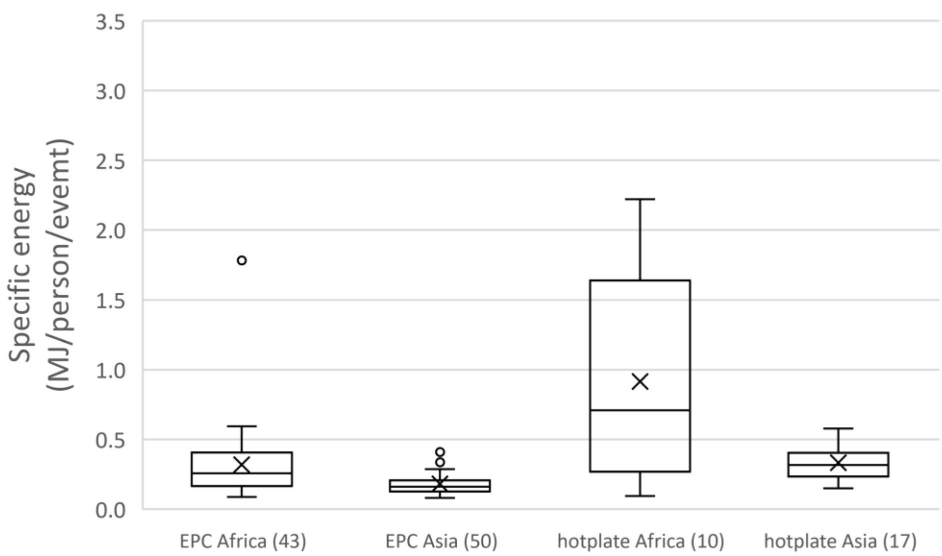



*Figure 4 Specific energy consumption - electric appliances by continent (single dishes only)*

Figures in Table 4 indicate that cooking African dishes on a hotplate uses approximately twice the energy needed to cook Asian dishes. Note that the ratio is less when using an EPC – it drops to 1.6. Again, this reflects the reduction in variation in energy consumption when using an EPC, described above.

*Table 4 Specific energy consumption - electric appliances by continent (single dishes only)*

| | N | Median | |
|---|---|---|---|
| | | MJ/person/event | kWh/person/event |
| Africa | | | |
| EPC | 43 | 0.258 | 0.072 |
| Hotplate | 10 | 0.709 | 0.197 |
| Asia | | | |
| EPC | 50 | 0.162 | 0.045 |
| Hotplate | 17 | 0.318 | 0.088 |

# 5 Comparing efficiencies of electric cooking devices

## 5.1 The physics of cooking

So how does the efficiency of an electric pressure cooker compare with a simple hotplate? This is a question that is often asked, which is not surprising because most assessments of energy savings from improved stoves are based on comparing thermal conversion efficiencies of improved and traditional stoves.

A recent study using a cheap single spiral coil hotplate concluded that it would boil water at an efficiency of approximately 50% (Wollele, 2020). Even if we assume a more conservative efficiency of 60% for a more advanced hotplate, a conservation of useful energy approach based on the energy ratios achieved across Asian dishes prepared indicates that the efficiency of the EPC would be 120% (and 160% based on the energy ratios for African dishes). This is clearly nonsense.

This exercise illustrates the impact of cooking in a different way. EPCs are a good example, but there are others, such as microwaves. If cooking is done in a pot with a lid (at atmospheric pressure), then a given dish will require a fixed amount of energy to cook, irrespective of how that energy is sourced – the 'useful' energy transferred into the pot and its contents remains constant. By contrast, when food is cooked at pressure in an EPC, it requires less energy input to the pot and its contents to cook.

A pressure cooker is effectively an insulated pan and lid, in which the rate of steam escape is minimised / controlled. If steam is not allowed to escape, then the pressure inside the pan increases. The change from a liquid phase to a gaseous phase occurs when the vapor pressure of the liquid is equal to the ambient pressure exerted on the liquid. So as pressure increases in the pan, water molecules in the fluids in the pan need additional heat to gain the speed necessary to evaporate, i.e., the temperature of the pan's contents continues to increase until the water has sufficient energy to evaporate at a boiling point that is higher than 100°C. An electric pressure cooker might operate at around 1 atmosphere (100kPa) pressure above ambient, which leads to a boiling point of around 112°C. Sensors detect when operating pressure has been reached and then switch off (or modulate down) the heat input, maintaining the contents just at the boiling point. A key feature is that when the lid is sealed and the release vale is closed, steam generation is negligible.

Cooking involves raising the temperature of food until chemical reactions take place; those reactions usually happen faster at higher temperatures, and the higher temperatures also allows the heat to penetrate throughout the food more quickly. So the higher pressure in an EPC means the food cooks at a higher temperature and therefore more quickly.

Compared with conventional cooking, additional heat is needed to raise the pan and its contents to the higher temperature. Additionally, once at the operating pressure (and hence at the elevated boiling point), the heat loss from the device will be higher than if it were operating at 100°C, as loss is proportional to temperature difference. However, the rate of heat loss is reduced much more than this by the low thermal transmittance (U-value) of the appliance construction, due to the insulation around the pan. Furthermore, if the food cooks, for example, in half the time, then the heat loss itself is further reduced, as losses are sustained over a shorter time.

The water boiling test[6] is commonly used as a means of assessing the thermal conversion efficiency of cooking appliances. This measures the energy required to bring a pan of water to the boil and then to simmer it for 45 minutes. The efficiency is calculated by comparing the measured energy use with the 'useful' energy needed to raise the pan and water to boiling point (calculated from the physics of its mass and density) plus the energy needed to evaporate the water that is lost during the test (calculated from the physics of that evaporation). This methodology is **particularly inappropriate to reflect the performance of a pressurised cooking device** because EPC cooking times are shorter than for unpressurised devices, yet the WBT specifies a standard simmering duration (45 minutes); this long test results in an unfairly high electricity use for the EPC, artificially reducing the measured efficiency. Furthermore, the WBT protocol includes the latent energy of water evaporated as part of the stove 'output' but an EPC has very low water evaporation, so this also suggests that the WBT does not reflect the operation of an EPC.

So asking about the efficiency of an EPC, if using standard efficiency measurements, is the wrong question. We should be asking about the specific energy required to cook a specified dish (or meal) when using different fuels and devices.

## 5.2 Comparing a range of electric cooking devices

Specific energy consumption figures have been calculated for all single dishes cooked in a range of electric devices. Average figures in Table 5 show that EPCs use least energy, by some margin. However, the figures in Table 5 may be misleading because there is no consistency in the foods cooked in the different devices. For example, Indian curries have frequently been cooked in an EPC, but not in other devices.

*Table 5 Specific energy consumption to cook single dishes in different devices (MJ/person/event)*

| DEVICE CATEGORY | Mean | Median | N | Std. Deviation |
|---|---|---|---|---|
| EPC | .2458 | .1800 | 93 | .20322 |
| Hotplate | .5484 | .3720 | 27 | .63606 |
| Induction | .3113 | .2760 | 23 | .18285 |
| Infrared | .3386 | .2633 | 21 | .16115 |
| Rice cooker | .2710 | .2708 | 16 | .12021 |
| Curry cooker | .2420 | .2580 | 9 | .08161 |
| Frying pan | .3041 | .2938 | 8 | .16848 |
| Slow cooker | .6641 | .5803 | 6 | .23586 |

[6] CCA have published a WBT protocol: https://cleancooking.org/binary-data/DOCUMENT/file/000/000/399-1.pdf (accessed 13th April 2022).

More meaningful results can be achieved by selecting a subset of only those dishes that were cooked in several devices (Table 6). The specific energy consumption figures (Table 7) still show that EPCs use least energy, and that the slow cooker uses most energy.

*Table 6 Dishes cooked in different devices (dishes commonly cooked in multiple devices) (number of records)*

| | Frying pan | EPC | Hotplate | Induction | Infrared | Kettle | Rice cooker | Slow cooker | Thermopot | Curry cooker | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bean Soup | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 7 |
| Beef curry | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 6 |
| Chicken Bechalor Soup | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 7 |
| Chicken curry | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 6 |
| Chickpea dal | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 6 |
| Dal | 0 | 2 | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 1 | 9 |
| Fish curry | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 6 |
| Green tea | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 9 |
| Leafy Soup | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 7 |
| Mixed vegetables | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 6 |
| Mohinga | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 7 |
| Noodles | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 5 |
| Rice | 1 | 3 | 2 | 3 | 3 | 0 | 2 | 1 | 0 | 0 | 15 |
| Sauteed Vegetables | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 6 |
| Tempura | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 5 |
| Total | 8 | 17 | 15 | 18 | 18 | 1 | 16 | 6 | 1 | 7 | 107 |

*Table 7 Specific energy consumption to cook dishes commonly cooked across multiple devices (MJ/person/event)*

| DEVICE CATEGORY | Mean | Median | N | Std. Deviation |
|---|---|---|---|---|
| Induction | .3083 | .3076 | 18 | .15138 |
| Infrared | .3619 | .3420 | 18 | .16186 |
| EPC | .2017 | .1680 | 17 | .08893 |
| Rice cooker | .2710 | .2708 | 16 | .12021 |
| Hotplate | .3519 | .3720 | 15 | .12097 |
| Frying pan | .3041 | .2938 | 8 | .16848 |
| Curry cooker | .2709 | .2640 | 7 | .06712 |
| Slow cooker | .6641 | .5803 | 6 | .23586 |
| Kettle | .0598 | .0598 | 1 | . |
| Thermopot | .0502 | .0502 | 1 | . |
| Total | .3134 | .2880 | 107 | .17040 |

A two step cluster analysis identifies the following clusters:

1. Inefficient devices – hotplate and slow cooker
2. Insulated and automated devices: frying pan, rice cooker, multi cooker (curry cooker).
3. Modern hobs: induction and infrared
4. Pressurised cooking: EPC

Although the number of valid data points is relatively low, the slow cooker appears to be as inefficient as a hotplate. This is probably because it loses energy for an extended period of time, so although it benefits from insulation and automation, it has a low overall cooking efficiency.

This classification of devices (Table 8) shows that, compared with hotplates:

- Modern hobs save approximately 10%
- Automated devices save approximately 25%
- EPCs save approximately 50%

*Table 8 Energy consumption relative to hotplate (based on median values)*

| Device | Energy used expressed as proportion of energy used by Hotplate (%) |
|---|---|
| Modern hobs | |
| Induction | 83% |
| Infrared | 92% |
| Insulated and automated devices | |
| Rice cooker | 77% |
| Frying pan | 83% |
| Curry cooker | 75% |
| Pressurised device | |
| EPC | 48% |

# 6 Traditional Fuels and energy ratios

When looking at traditional fuels, Figure 5 confirms that when cooking with both charcoal and LPG, African dishes use more energy. Note that the y-axis scale in Figure 5 is an order of magnitude greater than the scale in Figure 4.

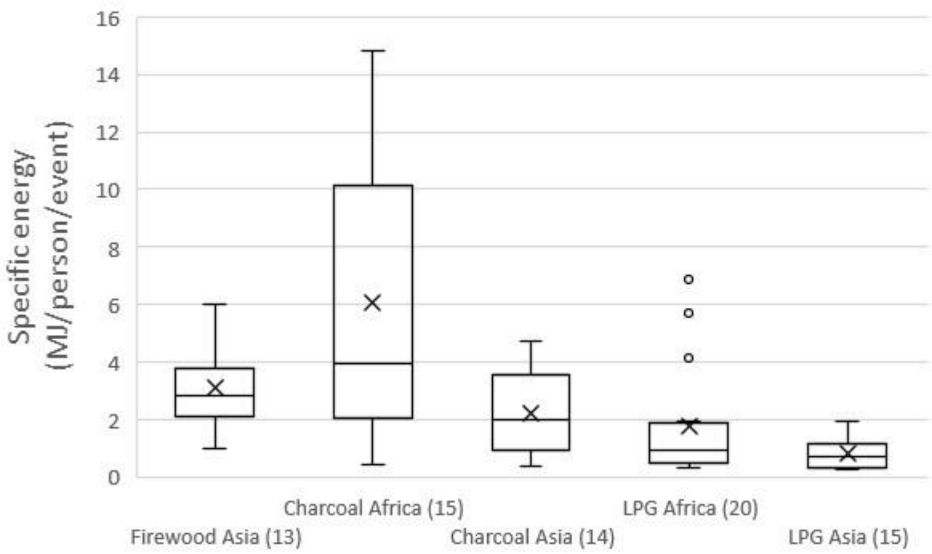



*Figure 5 Specific energy consumption – traditional fuels by continent (single dishes only)*

The energy used to cook using 'traditional' fuels can be compared with the energy used when cooking with a number of electric devices (EPCs, hotplates, induction and infrared hobs; see Table 9). These **energy ratios show that cooking with charcoal uses 15 times the energy used by an EPC** and approximately six times the energy used by a hotplate; cooking with LPG uses four times the energy used by an EPC.

*Table 9 Energy ratios - traditional fuels / electric devices (single dishes)*

| | Africa | | | Asia | | |
|---|---|---|---|---|---|---|
| | Firewood | Charcoal | LPG | Firewood | Charcoal | LPG |
| Energy consumption, median (MJ/person/event) | | | | | | |
| Traditional | | 3.92 | 0.96 | 2.83 | 2.02 | 0.69 |
| *Electric devices* | | | | | | |
| EPC | 0.258 | | | 0.162 | | |
| Hotplate | 0.709 | | | 0.318 | | |
| Induction | | | | 0.276 | | |
| Infrared | | | | 0.263 | | |
| Energy ratios (Traditional energy/eCook energy) | | | | | | |
| EPC | | 15 | 3.7 | 17 | 12 | 4.2 |
| Hotplate | | 5.5 | 1.3 | 8.9 | 6.4 | 2.2 |
| Induction | | | | 10 | 7.3 | 2.5 |
| Infrared | | | | 11 | 7.7 | 2.6 |

# 7 Costs of cooking

But what about relative costs of cooking? Ascertaining the cost of cooking with traditional fuels is notoriously difficult because everybody pays a different price, depending on location, season, what quantities they buy fuel in etc. For example, a case study from rural communities in Tanzania estimated that some people paid twice the price for charcoal if they bought it in small measures (Inston & Scott, 2022); a detailed study of charcoal prices in Zambia shows a similar trend[7]. Therefore, for the purposes of this study, data from cooking diaries studies, using multiple participants, has been omitted. Instead, only data from controlled tests has been included – that is from kitchen laboratory and cookbooks studies. Each study used fuel prices prevailing in the study country at the time of the study (see Table 11).

Figure 6 indicates that across all dishes captured, the **costs are lowest when cooking with an EPC**. Median values presented in Table 10 show that, overall, the cost of cooking with an EPC is approximately one third the cost of using LPG, and less than 20% of the cost of using charcoal. These cost figures are based on the fuel prices given in Table 11. Note the large range in electricity prices, from the lifeline tariff in Zambia to the near full cost recovery tariff charged in Uganda, so the distribution of costs presented in the figure reflect a range of fuel prices and electricity tariffs as well as variation in the amount of energy used.

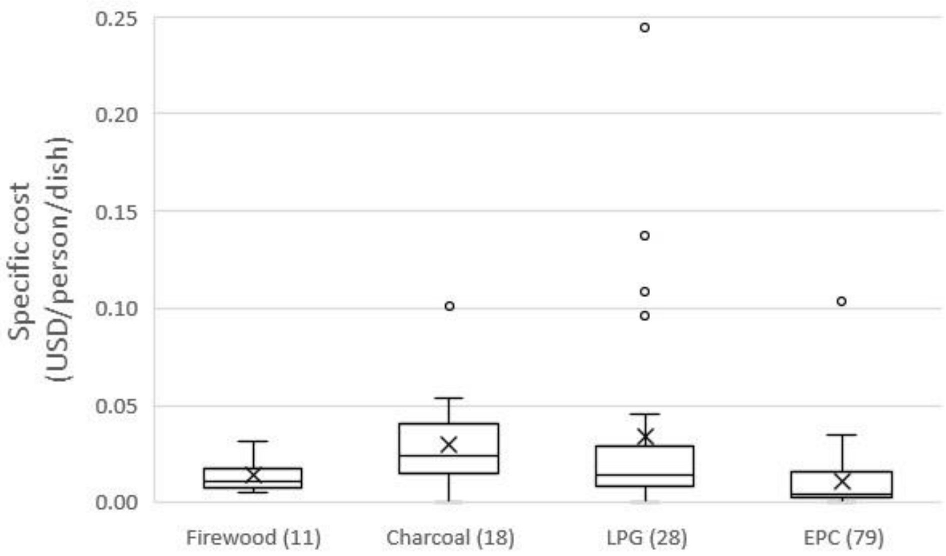



*Figure 6 Per capita cost of cooking using different fuels (controlled tests, single dishes only)*

*Table 10 Per capita costs of cooking with different fuels - medians (controlled tests, single dishes only)*

| Fuel | N | Per capita cost (USD/person/dish) |
|---|---|---|
| EPC | 79 | 0.0043 |
| Firewood | 11 | 0.0108 |
| LPG | 28 | 0.0144 |
| Charcoal | 18 | 0.0238 |

[7] https://mecs.org.uk/wp-content/uploads/2022/11/Zambia-Rising-Fuel-Prices-1.pdf

*Table 11 Fuel prices used in the studies*

| Country | Electricity tariff (USD/kWh) | Firewood price (USD/kg) | Charcoal price (USD/kg) | LPG price (USD/kg) |
|---|---|---|---|---|
| Zambia | 0.033 | - | 0.294 | 1.047 |
| India | 0.067 | | | |
| Bangladesh | 0.067 | - | - | 0.969 |
| Myanmar | 0.069 | 0.083 | 0.340 | 1.263 |
| Nepal | 0.083 | 0.053 | - | 0.857/0.924 |
| Tanzania | 0.152 | | | |
| Kenya | 0.209 | | | |
| Uganda | 0.215 | - | 0.286 | 2.714 |

Figure 7 illustrates the wide range in tariffs applied in the country studies, from 0.03 USD/kWh for the lifeline tariff in Zambia to 0.21 USD/kWh charged in Uganda (see Table 11). The trend line shows that, as a rule of thumb, the costs of cooking a single dish is approximately 0.1 times the tariff rate. This is effectively another way of representing the average energy consumption for cooking a single dish. The gradient of the trend line also represents specific energy per dish (kWh/person/dish). Note that costs for some countries tend to be below the trend line (e.g., Nepal), and costs for other countries tend to be above the trendline (e.g., Kenya). This illustrates how this rule of thumb takes no account of country specific cuisine. For example, the median consumption value of dishes cooked using EPCs across a range of African countries is 0.072 kWh/person/event (Table 4), yet dishes cooked in Kenya, for example, give a mean consumption of 0.15 kWh/person/dish.

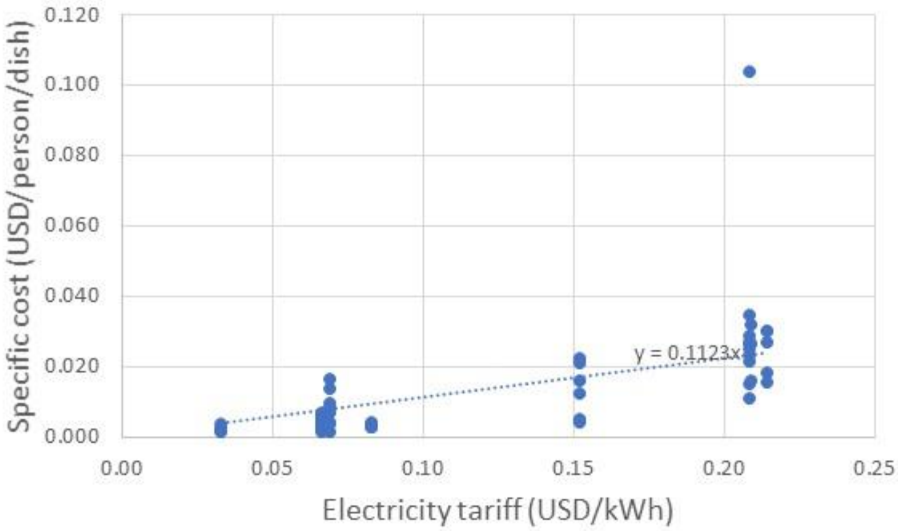



*Figure 7 Cost of cooking with EPC at different electricity tariffs (single dishes only)*

# 8 Conclusions

The costs of dishes cooked in kitchen lab and cookbook studies show that it is cheaper to cook with an EPC than any of the traditional fuels (firewood, charcoal, or LPG). Based on aggregated data from multiple countries and the range of fuel prices found in the study countries, the cost of cooking with an EPC is approximately one third the cost of using LPG, and less than 20% of the cost of using charcoal.

The new generation of efficient electric cooking appliances, such as EPCs, use much less energy than traditional electric appliances such as hotplates. The analysis suggests three categories of modern electric cooking devices. When compared with resistive element hotplates, modern hobs (induction and infrared) can save 10%, automated devices such as rice cookers can save approximately 25%, and EPCs can save approximately 50%.

When cooking under pressure, EPCs require less 'useful' energy to cook (according to the standard definitions of that), so it is not meaningful to compare efficiency figures with other cooking appliances. Neither is it appropriate to use current standard tests to assess the relative efficiency of EPCs. While an 'efficiency' for each device is an attractive concept, it relies on having a clear definition of the useful energy that is provided: for the water boiling test this is about change in temperature and then change in state of the water, which is physically easy to define and measure/calculate, but is not appropriate for comparisons between some devices. However, a better definition of the useful energy to use in an efficiency test is not obvious. Specific energy use, and the energy ratios that come from comparing those for different fuel and stove types may be a more realistic means of assessing relative performance.

These energy ratios show that cooking with charcoal uses approximately 15 times as much energy as an EPC, approximately seven times the energy of a modern hob (based on data from Asian countries only), and approximately six times the energy used by a hotplate. Based on fuel prices prevailing at the time of these studies, the cost of cooking with an EPC is approximately one third the cost of using LPG, and less than 20% of the cost of using charcoal.

The range of energy used is much less when cooking dishes in an EPC, because energy losses are reduced. The sealed lid means no steam escapes during cooking, and the insulated pot means heat losses are minimal. Therefore, the duration of cooking time has much less impact on total energy consumption that for conventional cooking appliances.

Different cooking styles found in African and Asian countries result in different amounts of energy needed - African dishes used approximately half as much energy again as Asian dishes. There are certain dishes that use a lot of energy, such as bean stews and matoke, both part of an African menu.

Energy planners, policy makers, and utilities tend to think in terms of daily or even seasonal demand, so further analysis is needed to relate the individual dish level data presented in this paper to daily demand. Again, this can be done using the cooking diaries studies, which generated data on the number of dishes prepared as part of a given meal, and the number of meals prepared in a day.

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