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Review

Losing the Energy to Cook: An Exploration of Modern Food Systems and Energy Consumption in Domestic Kitchens

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Abstract: The Modern Energy Cooking Services (MECS) programme has generated data on the amount of energy required to cook meals using different fuels and cooking devices. Fuel stacking is commonplace, especially among households with access to modern fuels. Experience shows that people tend to use modern fuels for quick tasks, such as preparing a cup of tea, but prefer to use biomass fuels for foods that take longer to cook. Therefore, changes in the choice of foods in the household menu have the potential to affect the transition to modern fuels. This paper discusses the potential of innovative and emerging aspects of food systems in low-income countries to impact on households. It starts by looking at the processing of indigenous crops to create convenient and nutritious food products. This leads to an overview of the rapid growth of the food processing industry and future opportunities. Consuming food that has been prepared outside of the home is also a common and rapidly growing practice, which is likely to be driven (and disrupted) by technological innovation. Cooking energy considerations depend largely on fuel stacking behaviours, and the paper argues that modern food systems have the potential to reduce energy consumption in the kitchen, and to play a role in displacing traditional biomass fuels with modern fuels.

Keywords: energy displacement; food systems; processed foods; eating out

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1. Introduction

In their description of the background to the Modern Energy Cooking Services (MECS) programme, Batchelor et al. [1] outline new strategies to address the challenges of cooking with biomass. The approach centres on taking a holistic view of integrating biomass cooking with agendas of access to modern energy, and climate change. This approach capitalises on substantial gains made over recent years in improving access to electricity by focusing on cooking with electricity (eCooking). However, the programme has also considered if there is potential to reduce harmful emissions within the domestic kitchen by considering foods that may be partly cooked (or even fully cooked when brought in) as well as processed foods. The original idea was sparked by a packet of precooked beans found in a supermarket in Kenya. This was an example of a precooked food that reduced cooking energy demand at the household level. The paper considers the energy implications not only of different foods, but also of different eating practices, notably various forms of eating out.

The way people in low income countries eat is changing. This is mainly due to demographic changes, dominated by rapid urbanisation. It is estimated that there will be 2.5 billion more people living in cities by 2050, and 90% of this growth will take place across Asia and Africa [2]. Price [3] gives an overview of the linkages between a range of factors associated with urbanisation, poverty, eating habits, and cooking fuels. For example, urbanisation puts existing energy resources and supply chains under pressure as demand for charcoal escalates. Busy urban lifestyles mean that people need to find ways of

preparing meals quickly. Economic development means that a growing middle class have increased disposable income coupled with aspirations to clean, modern living conditions.

Changes in consumer habits, population growth, urbanization, markets and technology (including digitization) are all recognised as determinants of evolving food systems [4]. By way of a definition: "food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products" (ibid.). These components are presented along with examples of energy inputs in Figure 1. This paper is concerned with consumption at the household level, with a focus on food processing and eating out, which itself is a mix of consumption behaviours and distribution markets (highlighted in the figure). A conceptual framework linking aspects of modern food systems to domestic energy consumption was created to guide the literature review presented in the landscaping study. The paper, entitled "Landscaping Study—Modern Foods", was published by the authors and colleagues as a working paper in 2020 [5]. This paper describes some of the literature relating to the processing, distribution, and consumption behaviours. This paper describes opportunities arising primarily in urban contexts and draws from the original working paper.

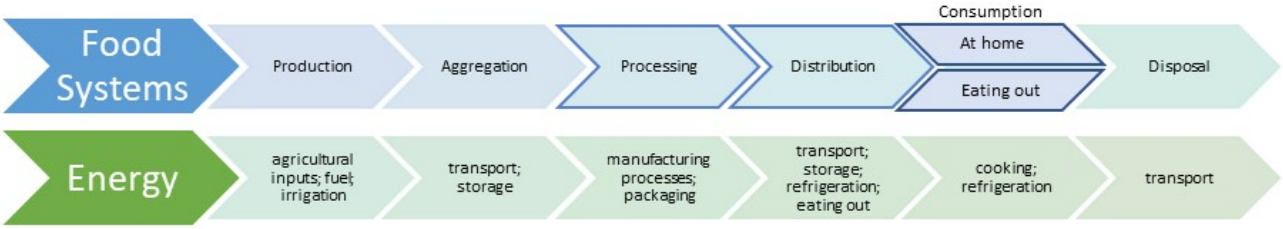

Figure 1. Interaction between food systems and energy (examples).

Urban migration may be voluntary (economic migration), or involuntary (internal displacement). Either way, migrants find themselves uprooted from their traditional foods and ways of cooking, and having to adapt to different cooking facilities, different fuels, different markets and different foods. Urbanisation presents an opportunity for people to change their eating patterns and cooking practices, which can yield multiple benefits, in terms of health, time, and quality of life. It also presents potential nutritional threats to health such as obesity, and hyper-processed foods with poor nutritional content.

2. Foods Requiring Less Energy to Cook

2.1. Cooking Fuel Costs

The cost of energy used to cook food depends on multiple factors, the most obvious of which are the type of fuel used, the type of cooking device, and the type of food cooked; additional factors include cooking techniques used, and the skill of the person(s) responsible for cooking. Costs can be reduced dramatically using modern, efficient devices, such as rice cookers and electric pressure cookers. ESMAP's "Cooking with Electricity" report [6] provides a good description of the features that can be found in these devices, such as controllability, insulation, and pressurisation. Instead of focusing on the technology, this section looks at how different foods cooked influence the cost of cooking.

Some foods take more time, energy, and money to cook than others. TaTEDO measured how much energy was used to cook several everyday Tanzanian dishes in an electric pressure cooker [7]. The results in Figure 2 show a large variation, with pilau with meat/chicken using seven times the energy used to cook spinach. The authors highlight the impact of cooking techniques on energy consumption. For example, pilau involves high temperature frying with the lid off, which is why it takes so much more energy. They also point out that the cost of cooking depends not only on the prevailing electricity tariffs, but also the tariff structure. TANESCO offer a lifeline tariff of 100 TSH/kWh for the first 75 kWh consumed each month; units in excess of this are charged at 350 TSH/kWh (2020). Given that low-income households are estimated to have a non-cooking load (e.g., lights,

TV, fridge) of 1 kWh/day [8], they could easily add EPC cooking loads. Thus, the sum of both cooking and non-cooking loads could be met by lifeline units.

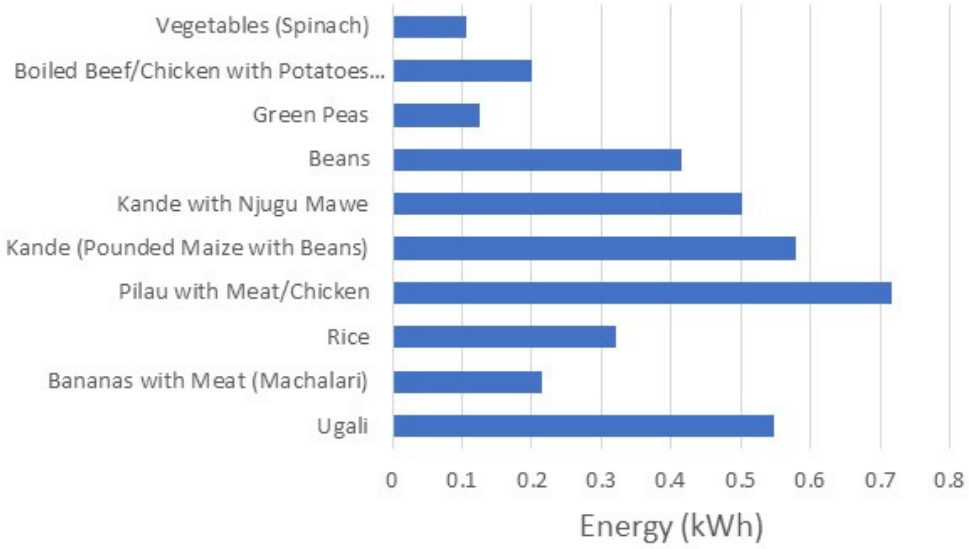

Figure 2. Energy consumptions for cooking common foods in an electric pressure cooker (Tanzania). Authors' own: based on Sawe and Aloyce [6].

Rather than comparing different meals, a similar exercise undertaken in Kenya compared the cost of cooking similar foods—specifically, beans [9]. The seven types of beans in Figure 3 are ranked according to the market price of the beans (cheapest at the bottom). However, when the cost of cooking each type of beans is included, the ranking changes, and the wairimu beans turn out cheapest. The figures given are for cooking 0.5 kg of unsoaked beans on an electric hotplate without a lid on the pan. The chart shows an overall trend that the beans that are most expensive to buy tend to be the cheapest to cook. However, the authors point out that any of these beans could be cooked in an electric pressure cooker for less than 10 Kenya shillings (KSH), in which case the market price of the beans becomes the dominant factor in the total cost of cooking.

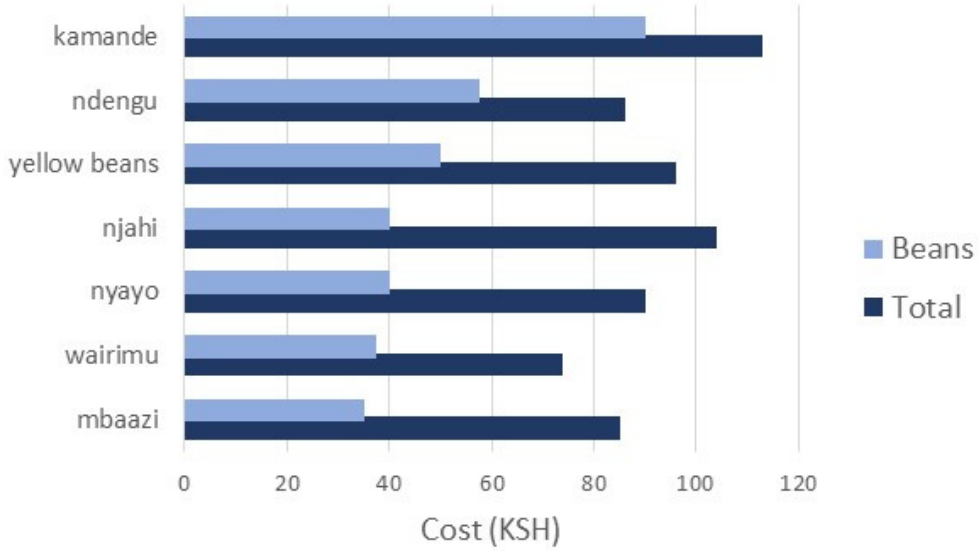

Figure 3. Cost of beans (0.5 kg) and cooking energy (hotplate, Kenya). Authors' own: based on Leary and Todd [9].

2.2. Beans

Beans are an important part of diets in low and middle income countries. They are a good and cheap source of protein, and are widely consumed; for example, 98% of Ugandan households report frequent consumption [10], and they are the primary source of protein for 90% of Rwandan households [11].

In low and middle income countries, people usually buy dried beans, whereas cooked and canned beans are commonly found in northern countries [12]. Notwithstanding differences in cooking time and energy between different types of beans presented in Figure 3, beans typically take 2 to 3 h to cook [10,11,13]. There are ways in which this cooking time (and energy consumption) can be reduced. The MECS "Kenya eCookbook" [9] describes some energy savings tips:

- Soaking dried foods can reduce boiling times by half;
- Use a lid to stop steam escaping, but this only works if the heat can be controlled;
- Think small—cut ingredients into small pieces, and smaller beans cooker quicker;
- Use leftover hot or warm water (e.g., when making tea) wherever possible;
- Use efficient appliances such as electric pressure cookers and rice cookers.

Soaking beans is perhaps the most effective of these, but there is little evidence that this is practiced, nor the reasons why not. Aseete et al. [10] states that beans are typically cooked in dried form in Uganda. In Uganda, limited cooking fuel availability has increased the price of fuel to the point where dry bean consumption is neither convenient nor affordable [13,14]. The IDCR responded to this challenging set of circumstances through their precooked beans project in Kenya and Uganda [14]. The project identified 12 varieties of beans that suited industrial processing techniques, and used them to create a range of products including packaged beans, bean flour, and a ready-to-eat snack. The packaged precooked beans require 10–15 min to cook in the home [11,13,14]. This reduces cooking times by 1.5 to 3 h, which results in a fuel saving of over 80% for consumers as well as water savings [13]. As explained by Aseete et al. [10]:

> *"The cooking time for the precooked bean is about 10–15 min which lowers the fuel and water quantities required for cooking. Shorter cooking time also means that the time spent in the kitchen cooking reduces—increasing convenience for persons who cook the beans."* (page 3)

Markets for packaged beans will increase with urbanisation. While rural households in Uganda meet 74% of their bean consumption with their own produce, the figure of 10% among urban consumers is much lower [10]. This illustrates urban consumers' greater reliance on foods purchased from markets. Expanded markets for beans provides an opportunity for introducing innovative products, such as precooked beans.

2.3. Smart Foods

A number of innovative foods are vying for attention as food systems are evolving. Sorghums, millets and some legumes are examples of foods currently being promoted as 'Smart Foods' (https://www.smartfood.org/, accessed on 25 May 2021). Value chains of the 'big three' cereals of maize, wheat and rice have received heavy investment, which is reflected in increasing global production and consumption figures, while supplies of millet and sorghum have remained stable [5]. The strapline for the Smart Food campaign by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) reads "Good for you, good for the planet, good for the farmer", reflecting the contribution that these indigenous crops can make to nutrition, the environment, and local economies.

The campaign has yet to highlight the potential cost and time benefits associated with lower cooking times. While millet is quick to cook (15–20 min), sorghums can take up to an hour. However, manufacturers are responding to growing demand for easy to cook, convenient foods, and a huge range of processed food products based on these crops are available globally. The millet-finder website (https://www.smartfood.org/millet-finder/ accessed on 25 May 2021) illustrates the diversity of processed food products available,

such as flours, pastas, breakfast cereals, snacks, and drinks. A millet pasta, for example, takes only 5 min of boiling.

The pigeon pea is another example of a nutrient rich indigenous crop that that is largely overlooked by consumers. For example, only 35% of pigeon pea production in Tanzania is consumed in country, and only 10% in Malawi [15]. This is another food that uses less cooking energy than the more commonly cooked dried beans. Tanzanian chefs trained in cooking pigeon peas felt they cooked faster and used less fuel when compared to some types of beans [16].

2.4. Challenges to Widespread Adoption of Processed Convenient Food Products

Literature on precooked beans and smart foods highlight some common issues that constrain demand and impeding markets.

2.4.1. High Prices

A study of processed beans products in Kenya found that the retail price of canned and chilled/frozen beans was approximately 2.5 times the price of sorted and packed beans [17], and this will be higher than the price of loose beans typically bought at local markets. Ugen et al. [13] also found that the retail price of canned beans imported to Uganda was three times higher than the price of unprocessed dried beans.

Indigenous smart foods, such as millets and sorghums, can also be more expensive than dominant grains. For example, when little millet, pearl millet and finger millet were trialled at a school in India, where rice-based school meals were commonplace, the associated meal costs were found to be 50%, 37% and 21% higher than the rice-based meal, respectively [18]. Respondents to a study on precooked beans in schools in Rwanda identified high prices as a deterrent to the adoption of precooked beans [11]. Interestingly, this was ranked as the third constraint, behind lack of availability, but top of the list was lack of information on precooked beans.

2.4.2. Lack of Information and Knowledge on How to Cook

Among schools in Rwanda that did not adopt pre-cooked beans, a lack of sufficient information about the food stuff was identified as the primary constraint (ibid). Respondents said that they needed to know about both advantages and disadvantages of the product in order to make an informed purchasing decision. It has already been pointed out that the value chains for these foods have not enjoyed the level of investment put into maize, wheat and rice. Information dissemination and awareness raising is one of the functions, and indeed benefits, of this kind of investment.

Given that the majority of consumers for processed bean products (in Kenya) are individuals with limited access to information on specific products, it is important that retailers use various information channels to reach out to targeted consumers [17]. Although neither a producer nor a retailer, ICRISAT are investing in a range of initiatives aimed at addressing awareness and knowledge gaps, such as reality TV shows, competitions, village level demonstrations, etc.

Consumers tend to focus purchasing decisions on price, as they lack an understanding of the wider benefits of these convenient food products. Even though the upfront cost of pre-cooked beans is three times greater than dried beans, the real cost difference is lower due to the savings in fuel, water and time. As fuel prices rise, this saving will become increasingly important [10]. Although millets are more costly than rice, if the cheaper rice meal was supplemented with additional ingredients to achieve the same nutritional benefit as the millet-based meal, it is estimated that the costs would be similar [18].

Perhaps more fundamentally, the nutrition transition towards maize, rice and wheat means that some cooks have forgotten how to cook using traditional grains. Studies in Myanmar, Tanzania and India have all outlined a gap in the knowledge of how to cook millets and sorghums domestically [16,18].

Studies report negative perceptions associated with these processed food products, most of which are based on inaccurate or incomplete knowledge. Ten percent of respondents from Rwandan schools that did not adopt precooked beans expressed a perception that precooked beans had a low nutritional value. In Tanzania, negative perceptions of finger millet were present in school students and stakeholders alike [16]. In Uganda, a similar sentiment was echoed with the idea that finger millet was a 'poor man's crop' [19].

2.4.3. Poor Availability of Crop

These foods products are commonly retailed through supermarkets, which presents some difficulties for small scale local food processors. Supermarkets use fixed price contracts, so processors were unable to change the price of their product to reflect seasonal price fluctuations arising as a consequence of raw material availability [19]. Larger processors may have institutional arrangements with feedstock suppliers, but even then, they do not have the financial capacity to buy large scale purchases on credit [19]. The IDRC project experienced difficulties with the quality of locally grown beans and had to resort to imported beans [13]. Importing brings its own set of problems. For example, processing companies in East Africa would be keen to import from Tanzania, but finger millet was subject to an export ban [19]. Poor trading relations impact the flow of products both ways. Tanzanian processers were also constrained in the volume of products that could be imported from Kenya [19].

Institutions, such as schools, prisons, and the military, present an attractive market for food processing companies, as marketing costs are lower and supply chains can be shorter. However, poor availability of precooked beans was identified as a barrier by institutional canteens in Rwanda [11], and a study in Tanzania found there was limited availability of the large quantities required by schools [16].

3. Food Processing

3.1. Background to the Food Processing Industry

In the post-independence era, food processing industries in low-income countries were largely partially or wholly state-owned processors. In the liberalisation era toward the end of the 20th century, the state-owned sector was largely divested into private enterprises. This paved the way for acquisitions and mergers as multinational foreign direct investment (FDI) affected the processing sector [20]. Multinational companies realised that investing overseas could be profitable. In 2000, US investment into overseas food processing industries yielded sales that were five times higher than the sale of US exports of processed foods [21], justifying further investment. The sector deserves increasing attention, given that demand for processed food items in low income countries is projected to grow an average of 7% to 8% per year over the next 30 years [22].

Looking at the performance of packaged foods markets in selected countries over the last 15 years, Figure 4 breaks packaged foods down into food categories. This confirms that markets have been growing at an average of approximately 10% a year. It also highlights high levels of growth in rice, pasta and noodles across the given countries. It is important to note that these figures do not reflect the absolute magnitude of the market sectors.

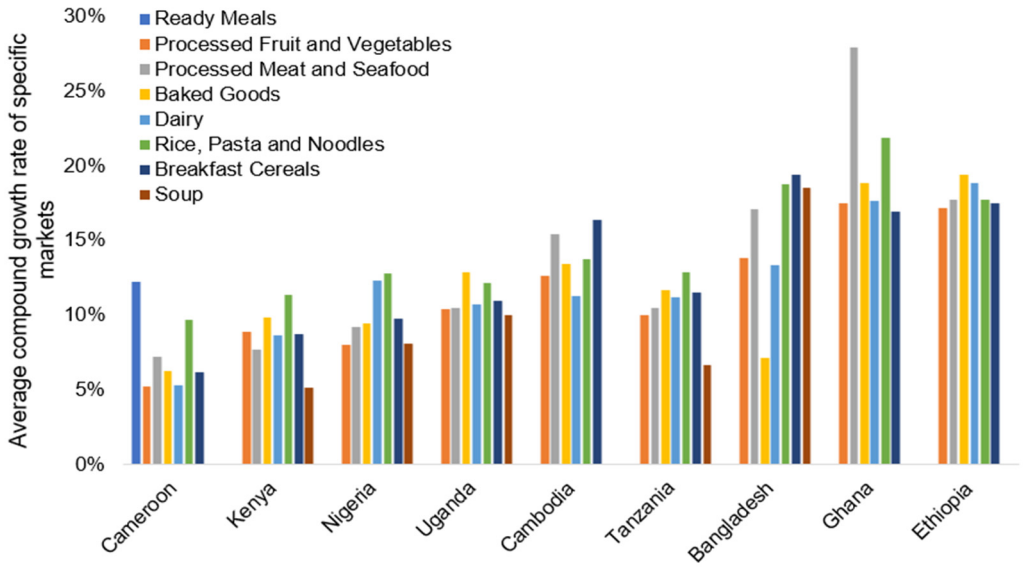

Figure 4. Average annual growth rate of packaged foods of interest (2005–2020)—MECS countries. Authors' own based on EuroMonitor Passport Data (2005–2020).

3.2. Opportunities for the Food Processing Sector

Food preserving processes (e.g., drying, freezing, salting, smoking) invest energy in the food to reduce the chances of it being wasted. Packaging, and its inherent energy, is a further feature of food processing that also contributes to preservation (e.g., hermetic cans, retort pouches). Food processing has important implications for food systems. With less post-harvest loss, less food needs to be produced, so less energy is required at the production stages. However, processing, manufacturing and packaging processes all require energy inputs. There is, therefore, a need for a systems approach to assess the overall energy balance between use of processed and traditional foods.

Processing can mitigate harvest time spikes in food availability, reducing loss and increasing profits for farmers. Note that not all processes require expenditure on energy. For example, solar drying can be achieved completely or partially passively [23,24] with the added benefit of significantly reducing the weight of the processed foodstuff, which can reduce transportation energy demand.

The process of pre-cooking beans, for example, entails cooking dried beans at high pressure and temperature. Processing foods in modern, energy efficient factories and using electricity for heating processes enables future developments to decarbonise the process by supplying electricity from renewable sources.

In low-income countries, changing diets mean that traditional processing techniques such as salting, drying and pickling are in decline. Instead, consumers prefer fresh foods that require cold storage and fast transport chains [25], which in turn require reliable energy supplies and infrastructure, and consume more energy.

Consumer demand in low income countries for processed foods is driven by several factors including, but not limited to; urbanisation, prevalence of supermarkets, rising fuel prices and higher populations [14,17]. Without sufficient food processing capacity, many low income countries rely on imports to fulfil the growing demand for processed foods. For example, Figure 5 shows that increasing demand for unprocessed (primary) foods in Ghana can be met by local production (imports remain modest and stable). In contrast, the more rapidly growing demand for processed foods can only be met by imports.

Fostering a local food processing industry offers the potential to reduce food waste, to reduce the embodied energy due to the energy inputs associated with travel and distribution losses in imported food products, and to contribute to national economic growth and wider development outcomes. For example, Rinchi [26] highlights the role of female entrepreneurs in emerging food processing industries, such as Alaska Tanzania Industries

and Java Foods of Zambia, both of which manufacture products using local foods at affordable prices. Moving into the food sector offers women an opportunity to contribute to household income, strengthening their agency in household decisions.

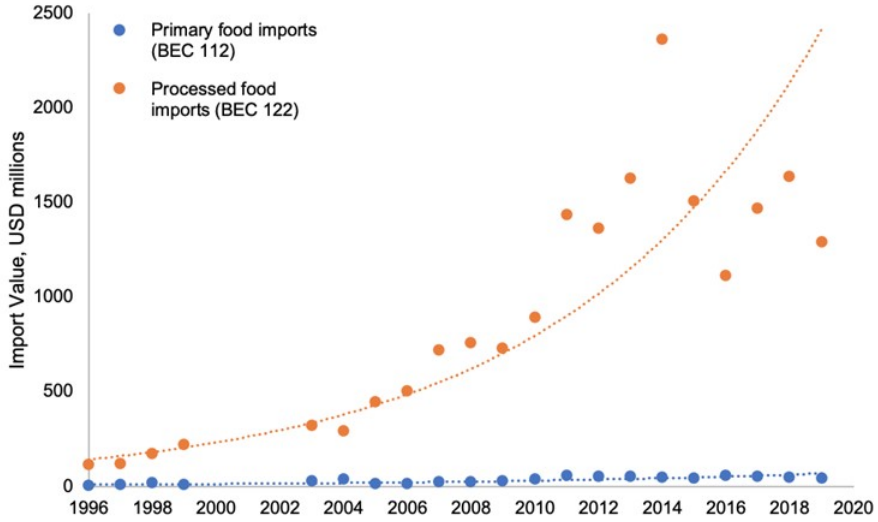

Figure 5. Example of growth in demand for imported processed food (Ghana). Authors' own (based on Comtrade data from: https://comtrade.un.org/data/, accessed on 6 August 2020).

4. Eating Out

4.1. Different Ways of Eating Out

Eating out has been identified as one food consumption behaviour that has the potential to reduce harmful emissions in the household on the assumption that food purchased would otherwise have been cooked in the home. However, studies in this area have struggled with definitions. Some studies define eating out by location, if food is eaten outside of the home. Others are more concerned with where the food is prepared, so if a family get a takeaway and eat it at home then that would be included in this definition. Given that cooking energy is inherently linked to the place of preparation, the latter approach fits well with MECS interests. A more comprehensive discussion of definitions found in the literature is included in the original working paper [5].

Market intelligence companies such as Statista and Euromonitor break data down into foodservice industry classification that are based on both venues and types of food:

1. Street stalls/kiosks—Sometimes mobile, limited product offering, takeaway, low prices;
2. Cafés/bars—Focus on drinking rather than food;
3. Self-service cafeterias—No or limited service, food is self-served or collected at counters;
4. Limited-service restaurants (LSR)—Takeaways, fast foods, cloud kitchens (in Statista, the term 'quick service restaurants' appears to be synonymous with the limited-service restaurants defined by Euromonitor);
5. Full-service restaurants (FSR)—Sit-down venues, table service.

However, food vending is a largely informal arrangement seen across many parts of the Global South and is an integral part of the food culture in society, providing to vendors an income and degree of financial independence, while providing affordable hot meals to consumers in urban areas who either have no time to cook, or lack the facilities or a place to cook [27]. Therefore, food establishments across the Global South may not fit particularly well with these industry classifications, which has implications for data collection and regulation.

Street food. Ready-to-eat foods and beverages prepared and/or sold by vendors and hawkers mostly in the street [28]. Chakravarty and Canet [29] proposed three categories, and Steyn et al. [30] add a fourth:

- prepared at home and brought to a stall for sale;
- prepared and sold at the stall;
- prepared in a small scale 'cottage type' factory and sold at the stall [29];
- food processed and packaged by industrial factories, e.g., crisps, biscuits and soft drinks [30].

Fast food. In terms of type of food, a distinction is made between 'foreign fast foods' such as burgers and hotdogs and indigenous or local fast foods. There can be a good deal of overlap between traditional fast foods and street foods, so any definition needs to consider venue as well. One study identified fast foods as being sold from formal buildings or malls [31], although in other countries they can be sold in the street or through makeshift structures [32].

Restaurants. These range from the small, informal establishments catering to low-income populations, to formal restaurant chains and high-end dining and defy rigorous classification. Most definitions centre around both kitchen facilities and sit-down dining facilities, although these can be temporary, and can often be in the informal sector.

Online delivery. Mobile phone apps that enable consumers to order food via third party delivery services is a disruptive innovation which is changing the foodservice industry. Delivery service providers can partner with food preparation businesses and list them on the app. The app provides the link between the consumer and the food provider, and the delivery company then delivers the food from the provider to the customer, taking a percentage of the food value.

Cloud kitchens. Variously known as 'cloud', 'ghost', or 'virtual kitchens', and 'virtual restaurants, these are kitchen spaces where foods are made specifically for delivery, and where establishments have no front-of-house in terms of dining space for customers [33]. The term 'virtual kitchen' usually refers to the physical space where the food in prepared, while a 'virtual restaurant' refers to the brands of food that are prepared in that space. Businesses can produce food marketed under several different brands (or restaurants). For example, the physical restaurant Top Round Roast Beef also prepares food for three virtual restaurants (Red Ribbon Fried Chicken, TR Burgers and Wings, and Ice Cream Custard) [34].

4.2. Growth in the Industry

Statista estimate the 'unorganised' street food industry in India to be growing at a rate of 6% a year, where 'unorganized' refers to 'individuals or families selling ready to eat food through vendors, 'dhabas', food carts, street stall and more' (a dhaba is a restaurant found on the side of major roads in India, commonly frequented by truck drivers). Figure 6 illustrates the dominance of street foods in the sector and indicates an even higher annual growth rate. In contrast, it is cafes and restaurants that have the highest market share in Nigeria, with Figure 7 indicating that these are growing at similar rates to street foods in India.

Eating out is a mostly urban phenomenon. A study in Tanzania found that households in rural areas spent 8% of their food expenditure on eating outside of the home, a figure that rose to 14% among urban areas, and peaked at nearly one third among households in the capital [35]. Current trends towards increased urbanisation indicate that eating out markets are likely to continue growing rapidly.

4.3. Contribution to Diet

A literature review of the contribution of street foods to the diets of people in mostly African developing countries found that the energy content of these foods accounted for 13–50% of the intake for adults, and 13–14% for children [30]. A study in southeast Asia estimated that street foods accounted for more than 40% of the diet in urban areas [36]. These figures relate to street foods and are higher than those reported by a study from Tanzania, which found that eating outside of the home accounted for 10% of the energy intake of urban residents [37]. Note that this is not necessarily contradictory, because

street foods can be consumed within the home and may even be used as part of home prepared meals.

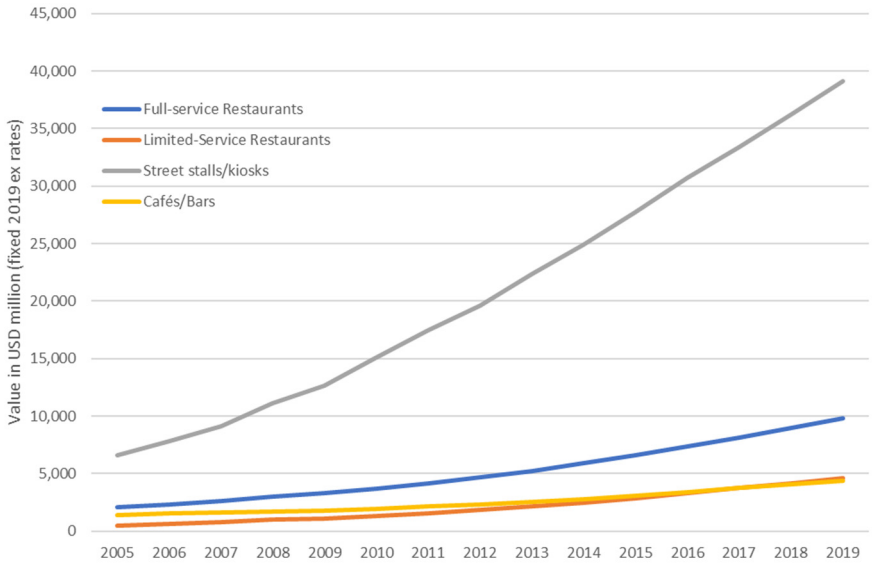

Figure 6. Growth in value of the Food service industry—India.

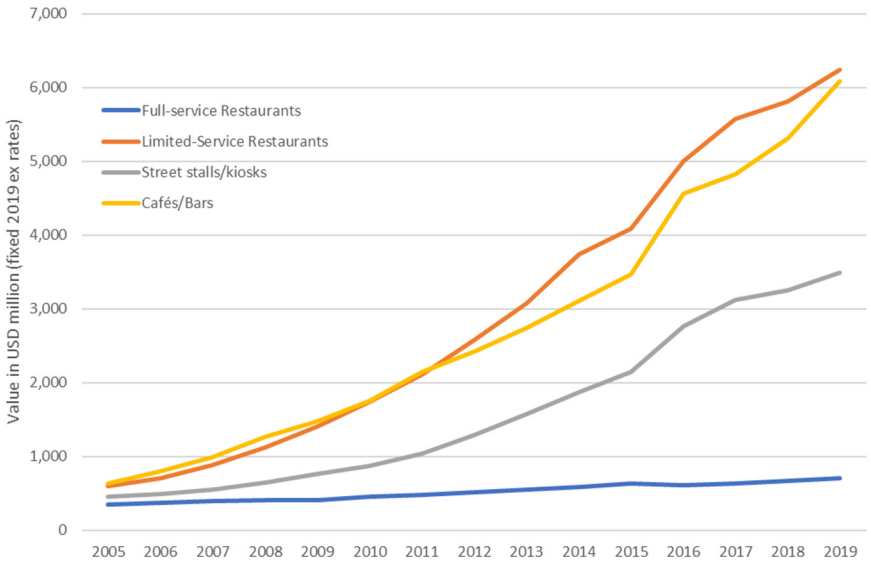

Figure 7. Growth in value of the Food service industry—Nigeria.

While processed foods, and fast foods in particular, are generally associated with poor nutritional content in the Global North, this is not necessarily the case in the South. Studies from Vietnam and Kenya showed that eating out was associated with better nutritional content and, in Vietnam, better dietary diversity [38]. Neither was eating out associated with higher energy intakes in a study of low-income consumers in Nairobi [38].

4.4. Looking to the Future—Technology

> *"A hundred and fifty years ago, most people made their own clothes. I'm fairly convinced that 20 years from now, we will mostly not make our own food."* ~Bob van Dijk, CEO of investor Naspers [39].

Mobile technology is good at connecting people. This has been put to good use in the foodservice sector in a range of apps that connect customers to food providers via delivery

companies. This section considers the online food delivery sector, which has the potential to open up new consumer segments to food providers. A growth in this sector is in turn linked to the displacement of energy consumption for cooking in the household. It then goes on to describe opportunities for opening up the market to innovative food providers, connecting them to consumers.

Globally, the food (meals) delivery business is growing rapidly. Online food delivery revenue is forecast to be 150 billon USD in 2021, and to grow at an average of 6.4% to 2024 (https://www.statista.com/outlook/dmo/eservices/online-food-delivery/worldwide accessed on 27 July 2020). There are two parts to the sector—restaurant to consumer, and platform to consumer, which are determined by who handles the delivery process rather than the ordering platform. Up to 2019, the restaurant-to-consumer sector was dominant, but the platform-to-consumer sector is forecast to rise to 53% in 2021. Note that middle income countries (such as India, Brazil) already represent some of the largest markets globally (Table 1). Not only is food delivery a mainly urban phenomenon, but it is also mostly used by younger consumers—the majority are in the 25–35 years age bracket—another feature that fits well with the demographic of low income countries. The market is characterised by tough competition amongst small start-up companies and big international providers such as Jumia Food and Dominos. Although online food delivery services are not yet widely used (see low penetration figures in Table 1), the sector is expected to grow rapidly, e.g., the market in Nigeria tripled between 2017 and 2020 [5]. As long ago as 2018, a newspaper article described how restaurants in Nairobi were downsizing their seating areas as part of a move towards delivery services [40].

Table 1. Revenue of the online food delivery market and user penetration—top 5 countries worldwide and MECS focus countries. (Ordered by decreasing revenue; from Statista).

Country Grouping	Country	Revenue 2020 (Millions USD)	User Penetration %
Countries in the world with largest revenue forecasts for 2020	China	51,514	28.4
	United States	26,527	33.8
	India	10,196	14.8
	United Kingdom	5988	36.55
	Brazil	3300	18.8
MECS focus countries *	Nigeria	465.3	4.4
	Bangladesh	96.4	3.3
	Kenya	31.1	2.5
	Myanmar	21.1	2.9
	Cambodia	16.3	3.5
	Ethiopia	12.5	1
	Cameroon	11.7	1.7
	Ghana	11.6	2
	Tanzania	9.2	1.4
	Uganda	6.1	1.2
	Zambia	3.7	1.2
	Nepal	3.1	1.1
	Rwanda	2.5	0.9
	Malawi	1.1	0.5
	Gambia (the)	0.2	0.7

* It should be noted that for all MECS focus countries, the data from Statista is not based on in-depth market analysis, but on an 'algorithm-based calculation'. This is because Statista concentrates on the major global players and all MECS countries are very small markets in comparison.

There is a low barrier to entry to creating a virtual restaurant using a cloud kitchen space. They have low overheads, require only low capital expenditure, and marketing is done via mobile apps. Furthermore, they can be quick to change style and branding, or to adapt to changing trends [41]. Although there is a nascent could kitchen sector in South Africa, there is little evidence of enterprises in other sub-Saharan African countries. Nevertheless, the ability to prepare food in small and existing kitchens and a low cost barrier to entry are a good fit with a thriving informal sector, which, coupled with a dynamic tech sector and a growing appetite amongst the young for prepared food, suggest that there is huge potential for this sector.

Any transition to eating out simply represents a shifting of cooking energy away from the household to a commercial provider. This does not necessarily mean a reduction in overall energy consumption, although cooking in bulk and using efficient appliances means that there is likely to be some reduction. The consequences of displacing the locus of energy consumption is an area for further investigation.

4.5. COVID-19 Implications on 'Eating Out'

The implications of the COVID-19 pandemic relate not only to food security. A KRC Uganda [27] report from May 2020 spoke of the impact that lockdown had on food vending in Fort Portal, Uganda, where "food vending is a lifeline for over 28,000 people daily, mostly low-income earners who buy their meals prepared by food vendors because they find it affordable, easily accessible and available" [27]. Whilst food vendors previously operated well until after midnight prior to the pandemic, lockdowns have almost completely shut them down.

With the outbreak of COVID-19 and subsequent lockdowns and curfews, once bustling streets have suddenly turned quiet. Those unable to sell had to watch their goods rot, whilst others have violated lockdown regulations to trade illicitly although they have fewer customers. Thus, most vendors have been forced to dig into their savings and use their limited capital to tide them by over the lockdown periods. In Uganda specifically, food vending is a largely gendered economic activity [27] with around 80% of the street vendors in Fort Portal, for example, being single mothers and the remaining 20% classified as youth. Additionally, many of the vendors are not local to Fort Portal, but are migrant workers in the town. Migrants and women are often food vendors elsewhere in Africa, too. Thus, the burden of shutdowns largely falls on the shoulders of female-headed households with little support in the community. This has resulted in a change in both eating patterns and change in business practice. The study observed that the food vendors would combine breakfast and lunch (usually porridge), but still eat an evening meal, thus reducing their daily intake. Furthermore, vendors felt compelled to alter their approach to business by moving from selling cooked food to fresh (i.e., raw) foods. This move is not as simple as it seems as "these are new businesses and the vendors were still learning how they work. Food vendors who had changed business said that they were making losses but had no choice but to try and find means of getting food for their households and children" or to work on farms as casual labourers [27]. Additionally, lockdowns have seen the emergence of new food actors within the informal food sector in the town: for example, the space once occupied by food vendors has now made way for milk vendors, as a directive from the government stated that milk production and sale was to be considered an essential service. These changes have implications on the diet and cooking behaviours of customers in the community.

5. Fuel and Energy Considerations

Research into sorghums and millets typically focuses on issues relating to nutrition and market acceptability, with little or no reference to the potential impact on household cooking energy. Although studies on precooked beans acknowledge the impact on household cooking energy, they have tended to focus on technical, nutritional and marketing issues. There remains a need for detailed research into the energy requirements of processed foods

such as precooked beans and processed grain products, and to demonstrate the impact on energy used for cooking in the household.

The literature on eating out does not make any association between this behaviour and potential impact on household cooking energy. A Foreign, Commonwealth and Development Office (FCDO) funded study from 2003 claims to be the first to explore the energy needs of street food vendors [42]. A later review by Matinga et al. [43] still found there to be little literature on energy, although they took a gendered view of street vendors on the basis that women dominate the informal food sector. There is an emerging body of literature on solar power for street vendors, although much of this focuses on lighting rather than cooking energy. One exception is a study of street food vendors in Mwanza, Tanzania [44]. This not only documented what fuels were preferred for cooking different foods, but also found that fuel accounted for approximately one third of costs. Costs depended on the type of foods cooked and was highest for meat and chips, and lowest for dagaa (small fish). He also found that rice and ugali were the most commonly sold foods.

Both precooked foods and eating out simply transfer the energy burden of cooking outside of the home to a commercial provider. However, processing factories have the potential to use clean fuels in heating processes. Centralised cooking facilities offer the potential for energy savings as a result of cooking in bulk and using efficient appliances. They are also more likely to be able to transition to cooking using modern fuels if the price is right.

A common feature of household cooking practice is that people like to reserve modern cooking fuels for quick cooking foods, preferring to use biomass fuels for more energy intensive dishes. They can also manage cooking practices to minimise cooking energy consumption, e.g., cooking beans for several meals in a single cooking event. A study in Ecuador found that fuelwood (commonly collected, so low cost) was preferred for cooking energy intensive dishes such as beans and grains, or when cooking for large numbers of people [45]. It also highlights that induction stoves offer high power cooking, which was useful for preparing hot drinks. Another study into LPG use in rural India found that it is mostly used in combination with other fuels [46]. Among the 40% of LPG users who used it as a secondary cooking fuel, it was mostly used to prepare tea and snacks. It is well suited to this task because heat is controllable, and it heats up quickly.

There are multiple reasons that lie behind cooking fuel stacking behaviour, as described and illustrated by Ochieng et al. [47]:

- **Time**. Using multiple stoves enables food to be cooked simultaneously, which is quicker than using a single stove and cooking multiple dishes sequentially. Three stone fires offer flexibility in terms of temperature control and number of dishes. They acknowledge that time pressure is more acute for some households, and can vary at times, e.g., less need for stacking during school holidays.
- **Technical performance of stove**. It is not possible to carry out tasks requiring a large pot on a small stove, e.g., cooking for large numbers of people, cooking in bulk, heating water for bathing.
- **Type of housing**. In households with an internal kitchen, cooks preferred not to use wood or kerosene because of the smoke and smell. In rural locations, wood could be used for cooking outside.
- **Fuel availability**. This was primarily a concern with LPG. Two issues were mentioned—unreliable availability of gas, and no warning of when a cylinder will run out. It is inconvenient when the gas runs out in the middle of cooking. Problems can also be encountered with other fuels such as unreliable electricity supplies and blockages in charcoal supply chains, for example.
- **Fuel cost**. It can take several days for people to gather enough money to pay for an LPG cylinder refill.

Note that although they explored taste preferences, there was a wide variance in opinions. They also note the importance of attitudinal values associated with different fuels, in particular a desire to minimise use of modern fuels (LPG). For example, even though LPG was cheaper than charcoal, users would prefer to cook energy intensive dishes using charcoal because they did not want to deplete the gas. This is an interesting example of rational behaviour based on a balanced judgement of cost and availability factors. The relative importance of factors will depend on the context in specific locations.

Stacking of modern cooking fuels is an important factor in realising potential health benefits. Johnson and Chiang [48] modelled the effect of using clean stoves (Tier 4) to substitute different amounts of the daily cooking load in a household. They found the only way WHO air quality guidelines could be met was by completely displacing a three stone fire with a Tier 4 stove. In a study based on household air pollution measurements, the Clean Cooking Alliance (CCA) [49] found that personal exposure levels among cooks who stacked clean fuels with biomass fuels were not significantly lower than exposure levels among cooks exclusively using traditional fuels.

So what options are available to enable people to make a complete transition to modern cooking fuels? Studies referred to highlight the importance of supply side-initiatives (e.g., strengthening electricity distribution networks and LPG supply chains), policies to subsidise fuel costs, pay-as-you-go solutions driven by the private sector, developing multi-burner stoves, and so on. This paper has highlighted the implications for household cooking energy consumption of convenient food products and eating out. It can be argued that these food-based approaches can play a part in transitions to clean cooking fuels. Both convenient food products (like precooked beans) and purchasing food from external kitchens (eating out) can alleviate the need to cook energy intensive foods within the household. Given that these foods are commonly linked to continued use of biomass among households with access to modern cooking fuels, they have the potential to play a role in eliminating fuel stacking with biomass.

6. Conclusions

Both eating out and consumption of processed foods are expected to continue growing rapidly, as they are linked to congoing demographic trends. The most influential factors are increased urbanisation, associated migration, and economic development, but there are others such as type of dwelling and household size.

Innovative food products that take less energy to cook can clearly have an impact on the amount of cooking energy used in the household kitchen, as can increasing the consumption of food prepared outside of the home. They may also be able to play a part in transitioning to clean cooking fuels by reducing the cooking burden of energy intensive foods, which people commonly prefer to cook on traditional stoves.

Consideration of the energy implications of innovative processed foods highlights recommendations for further research:

- Understanding the energy consumption of various categories of cooked food vendors, e.g., street foods, fast foods;
- Measurement of energy consumption of modern food products and assessing energy balances (e.g., comparing dried and pre-cooked beans);
- Energy auditing of food-processing industries.

Consideration of processed foods and future developments likely in the foodservice industry highlight policy recommendations:

- Stimulating local food processing industries can simultaneously reduce imports (and transport energy and foreign exchange) and contribute to the local economy. Challenges to be addressed centre around technology, value chains (e.g., crop producers), and business operations, such as regulations and cash flow;
- Introducing virtual businesses into the informal food sector may require food safety regulation; people can make safety judgements for themselves when choosing a foodservice provider with a physical presence, but they cannot when it's virtual;

- Policy makers may need to consider the nutritional consequences of expanding access to processed and prepared foods. Obesity has added to health burdens; for example, The World Health Organisation (WHO) estimate that 23% of African men and 39% of women are obese [50]. Furthermore, this trend is commonly linked to the role of supermarkets in modern food systems.

In evolving food systems, modern food industries will feature more eating out, which will require additional energy for transport and delivery. Modern food systems will also feature more processed foods and more fresh foods, which will also mean higher energy consumptions. However, debates need to take into consideration reductions in cooking loads at the household kitchen level. This is not just a consideration of energy, as it also impacts positively on the health of women and children especially (but not exclusively), liberates time, and improves quality of life.

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