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Power to the Cooks!

New Clean Cooking Opportunities for Sustainable Development in Sub-Saharan Africa

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Key Takeaways

- 2.6 billion people globally and 1 billion in Sub-Saharan Africa (SSA) cook using biomass fuel. The detrimental effects on the environment and public health, as well as the time and money lost are considerable. If nothing new is done, this situation will worsen further in SSA.

- The rapidly decreasing costs of solar power and batteries, coupled with efficient devices such as electric pressure cookers, alongside new business models, now offer an immense potential to achieve universal access to clean cooking.

- Efficient electric cooking can be off or on grid, with or without batteries. It does not have to fulfill all cooking needs; fuel stacking is already common in many kitchens and should remain so. E-cooking can be cheaper than using biomass fuels but high upfront costs must be broken down into manageable repayments.

- Governments, intergovernmental organizations (IGOs) and nongovernmental organizations (NGOs) often implement parallel strategies to increase access to electricity and to clean cooking. Integrated e-cooking strategies should be developed and implemented to help achieve these sustainable development goals jointly by 2030.

Biomass Fuel under Fire

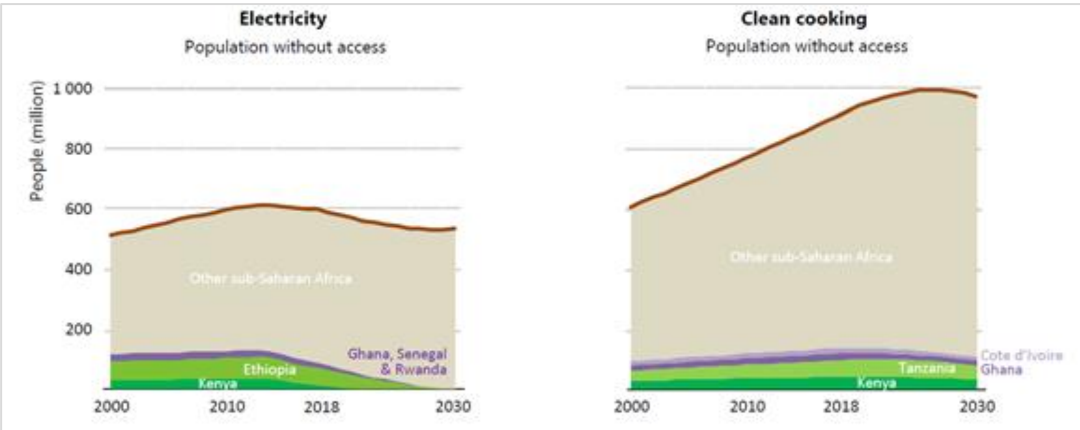
Almost 1 billion people in Sub-Saharan Africa (SSA) – and 2.6 billion globally – rely on biomass fuel (fuelwood, charcoal or dung), or kerosene and coal for cooking. The smoke from these cooking fuels kills: 2.5 to 4 million premature deaths annually (more than Malaria, HIV and tuberculosis), of which at least 500,000 are in SSA. It also leads to acute respiratory illness, cataracts, heart disease and cancer. Women and children are the most exposed. Much of the biomass is not grown sustainably and contributes to deforestation. Charcoal procurement is costly for most families in urban and peri-urban areas, collecting fuelwood and dung, lighting and tending fires in rural areas involve extensive daily drudgery, notably for women and girls, resulting in missed educational and economic opportunities.

Decades of deployment of "improved cookstoves" (ICSs) have brought relatively little change. They are usually not efficient enough to significantly reduce the consumption of biomass, and not clean enough to reduce in-door air pollution. Fossil fuels fare somewhat better in efficiency, but kerosene is not clean, and LPG is often costly: the distribution of liquefied petroleum gas (LPG) is heavily subsidized in some countries (such as Morocco or Indonesia), causing real burdens on public finances.

Decades of deployment of "improved cookstoves" have brought relatively little change

According to the Stated Policy Scenario of the International Energy Agency (IEA), progress is expected in some countries such as Ethiopia and Nigeria. Yet, in other SSA countries, population growth will outpace the number of people gaining access to clean cooking. If nothing changes, SSA's population with no access to clean cooking will increase by 2030, before returning to current levels or so by 2040.[1]

Figure 1: Recent Evolution and Short-Term Projection of SSA Populations without Access to Electricity and Without Access to Clean Cooking



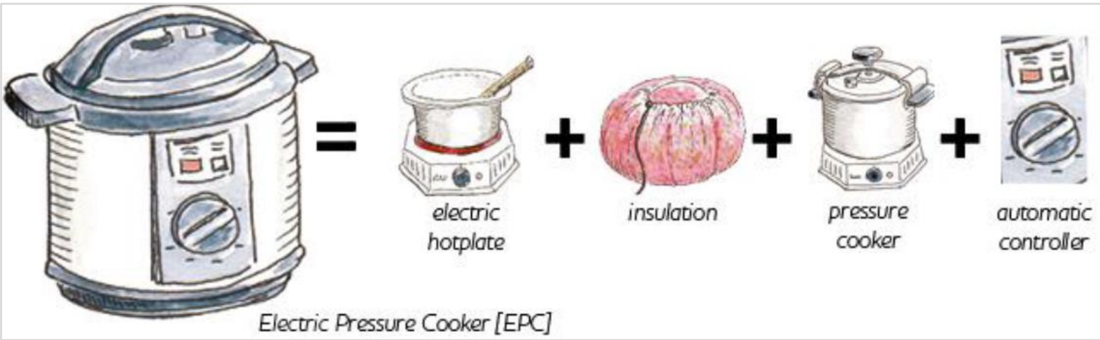
Source: IEA, 2019, Africa Energy Outlook 2019.

1. IEA, *Africa Energy Outlook 2019*, WEO Special Report, IEA Publishing, Paris.

This situation is obviously unacceptable and requires a rapid transition from biomass fuels to cleaner and sustainable fuels. Improved stoves and LPG can contribute to this, but there is growing evidence that only a massive roll-out of clean electric cooking appliances, together with the massive deployment of solar photovoltaic (PV) power can achieve universal access to both electricity and clean cooking in SSA by 2030, thus fulfilling Goal 7 of the United Nations' Sustainable Development Agenda for 2030, namely access to affordable, reliable, sustainable and modern energy for all.

Cooking Efficiency Is a Complex Matter

Both lab and in-field studies show that electric cooking is more energy efficient than combustion cooking.[2] How much more is a complex issue, and energy efficiency is only one of the factors that leads to in-door pollution. It is clear, however, that, besides three-stone outdoor fires, traditional biomass stoves are the least efficient sources of cooking heat, followed by improved biomass stoves for wood, charcoal or pellets, then kerosene stoves, and lastly LPG stoves. All electric devices are better than the best "fuel combustion" stoves. Better heat transfers between these various sources of heat and the pot explain these findings. Induction hotplates are slightly better than resistive ones, as they stay cool while creating heat in the pot by inducing resistive current closer to the food being cooked. However, electric pressure cookers (EPC) are better than all of the above.



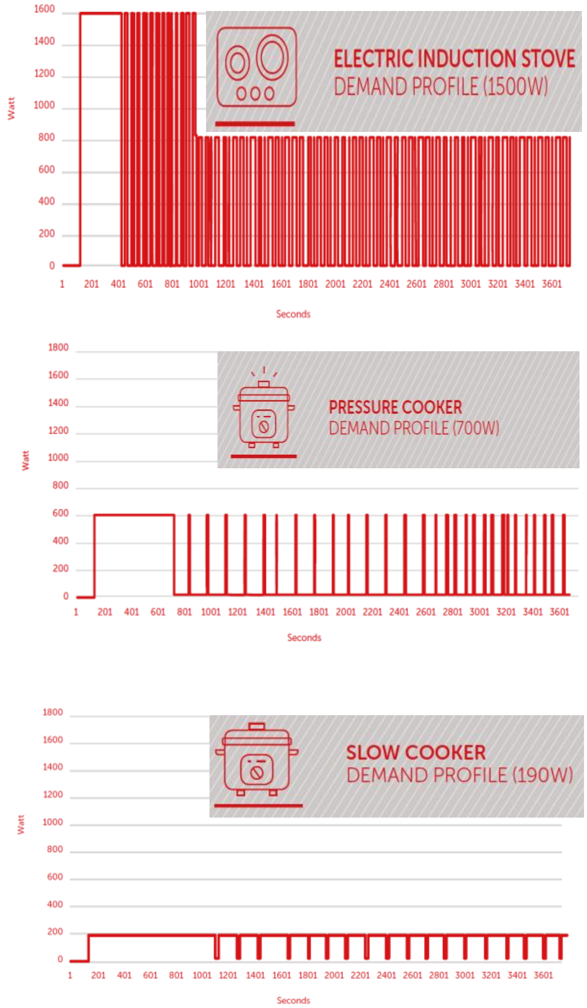
EPCs combine induction, insulation, pressure and precise energy control. This combination, complementing the merits of pressure cookers, fireless cookers (or "Norwegian marmites") and electronically controlled induction, radically modifies how cooking operates and reduces the cooking times significantly, depending on the meal in question.

Cooking results from bringing food to a given temperature for a given time: "it's the temperature that cooks, not the heat". The higher the temperature, the shorter the cooking time. More specifically, pressure allows increasing the temperature level in a pot from 100°C

2. References and detailed discussions can be found in J. Leary, M. Leach, S. Batchelor, N. Scott and E. Brown, "Battery-Supported E-Cooking: A Transformative Opportunity for 2.6 Billion People Who Still Cook with Biomass", *Energy Policy*, 159: 112619, 2021.

to 120°C. The insulation and all-in-one disposal (the heat is generated inside the insulated pot) reduces heat losses, keeping warmth and pressure with little additional inputs.

Figure 2: Electricity Consumption Profiles of Different Cooking Appliances



Source: T. Couture and D. Jacobs, Beyond Fire*, 2020.*

The graphs on the right provide a visual comparison between the demand profiles of an electric induction stove, an uninsulated unpressurized "slow cooker" (or "rice cooker"), and an EPC. As can be seen, the electric capacity required to run an EPC is more than that of a slow cooker, but less than a hotplate. More importantly, an EPC uses full power to bring food up to pressure, but then only draws power occasionally to maintain pressure and temperature. Thanks to the insulation, the retained heat continues to cook the food, with no additional energy input.

However, EPCs are not capable of cooking all meals. Cooking pancakes, chips, sausages, chapati, eggs or even pasta are either impossible or not convenient to cook with EPCs. But these are particularly good at cooking long-boiled dishes, which they do in half the time of a hotplate or induction stove.[3] And use only a fraction – from a tenth to a third - of the energy that would be needed in using fuelwood or charcoal.

These long-boiled dishes and "heavy foods" like beans and cereals are the largest energy consumers in African kitchens as they require one to two-hour cooking times. Many other dish types, such as meat/fish/veg stews, soups, roasts, etc. are possible. EPCs can pressurize while cooking but do not need to. Frying (browning) can be done, but deep frying requires an additional piece of equipment.

Of course, electric cooking also involves other appliances, such as kettles, often the first to enter a kitchen, slow cookers, microwave ovens, grills, ovens, steam ovens, etc.

In a major effort to acquire a deeper understanding of cooking as a cultural habit, scientists at the University of Loughborough have developed a methodology to establish "cooking diaries" (within the framework of their Modern Energy Cooking Services (MECS) program supported by UK Aid). In each of four countries, three African (Kenya, Zambia

3. J. Leary and S. Batchelor, *Why Understanding Real Cooks Is Fundamental to Going Beyond Fire*, Modern Energy Cooking Service (MECS), July 1, 2019, available at: https://mecs.org.uk.

and Tanzania) and one Asian (Myanmar), about twenty households from urban and peri-urban parts of the major economic centers were asked to keep detailed cooking diaries for six weeks, recording exactly what they cooked, when and how. For the first two weeks, they cooked as usual with their own fuels and stoves. For the other four weeks, they transitioned to cooking with electricity with different appliances. Fuels quantities were measured precisely, including electricity. As a result, MECS established that in real kitchens, across all meal types, with an 'appliance stack' of efficient and inefficient electric cooking appliances, cooking with electricity uses approximately one tenth of the energy of cooking with charcoal, and half as much energy as LPG. Across a range of dishes, EPCs use under half the energy of electric hotplates.

Cost-Effective and Reliable Electric Cooking

Globally, "only" 900 million people have no access to electricity, while 2.6. billion have no access to clean cooking. However, two thirds of the former live in SSA, where even more have no access to clean cooking. Why do they not cook with electricity then?

Affordability, or the perception of affordability, and lack of cash are significant barriers to the uptake of electric cooking, but the poor reliability of electric grid maybe even more important. Blackouts and brownouts are frequent, and the power quality lines and/or connection capacity are often too low. The poor quality of in-door electric wiring may also be too weak to support the power required by electric hotplates and burn outs may occur. Even people having acquired an electric cooking appliance do not use it to its full potential, fearing running up huge monthly electricity bills. Also, supply chains for energy-efficient electric cooking appliances are often week in SSA.

Grid operators and policymakers are often reluctant to push for e-cooking as they fear preparing dinners will add loads at peak hours and further destabilize already-fragile power systems. Therefore batteries, although the most expensive part of a full e-Cook system, appeared to be key to the MECS vision. However, the introduction of EPCs may modify the picture somewhat: could the role devoted to batteries be played, to some extent, by the EPCs themselves?

The excellent insulation of EPCs can keep dishes warm for hours – a dinner can be cooked in the middle of the afternoon, during energy surplus or load valleys, even in the absence of the cook, thanks to automatic programing. This would help ride through brownouts. The power demand of EPCs is less than that of electric hotplates, reducing the risks to in-door electric wires. If needed, cooling dishes can be warmed up again with another device and another fuel, at an energy cost that is far lower than that initially used to cook them. Fuel stacking ensures cooking is always feasible, and smart users can easily manage to ensure that "heavy foods" require long cooking times are cooked when solar energy is available.

Still, batteries overcome these issues more easily. When used on-grid, however, batteries always increase the cost of e-cooking. Mini grids usually have built-in storage in the form of centralized battery banks, and the versatility of demand allows keeping their size reasonable.

In standalone solar systems, a small battery capacity may still be part of an economic optimum as it allows reducing the size of solar panels – and the amount of electricity dissipated. A standard EPC requires a power capacity of 500 watts (W) to 1 kilowatt (kW), but in the presence of a battery a significantly smaller capacity PV module could be sufficient to accumulate the daily energy required. Simpler cooking devices – not yet commercially available – may use diode chains as heating elements. Solar PV arrays installed for cooking needs can also serve as comprehensive solar home systems (lights, radio, mobile phone charging, etc.).

This suite of new technologies offers a cooking service at a cost comparable with LPG or kerosene

The large diversity of situations with respect to access to electricity, its quality and costs, may require an equally large diversity of solutions. PV modules in rural, off-grid areas, but also at the fringes of the grid or inside cities can be coupled with batteries. While alternative-current (AC) e-cooking appliances are fine on stable grids, the insertion of a battery would lead to preferring direct-current (DC) appliances, such as those used for camper vans. These could also be plugged into solar modules, with or without batteries, thus saving the need for inverters.

In the last few years, researchers in the MECS program have studied two alternative stacking scenarios: a fully electric solution combining a hotplate and an EPC, and a clean fuel stack of EPC cooking for about half the daily menu, with LPG stove cooking the rest.

Battery-supported systems should comprise a battery of 0.34 to 0.98 kWh for 50% fuel stacking with an EPC, but 1.0 to 3.0 kWh for cases with 100% battery-e-cooking. For solar-battery-e-cooking systems, a 100 to 240 W PV array would be enough in the first case, a 300 to 700 W array in the second.

According to the economic analysis performed by MECS researchers, with upfront costs of all equipment discounted over a financing horizon of five years, this suite of new technologies offers a cooking service at a cost comparable – or soon to be – with LPG or kerosene, and is often lower than charcoal and sometimes comparable with firewood, unless its cost is nil and collecting time is not accounted for.

The Electricity System Dimension

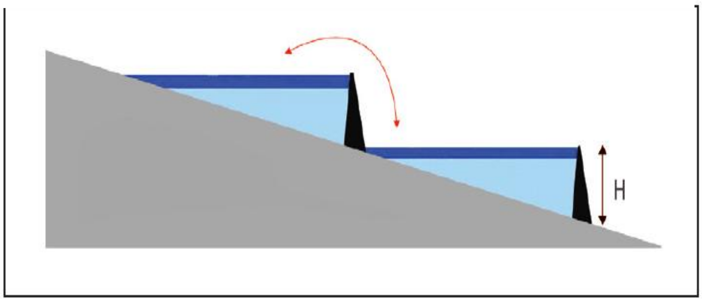
Case studies with grid electricity (in Kenya and Zambia), mini-grid (in Tanzania) and solar home systems (in Kenya) show that AC e-cooking on national grids or mini-hydropower, where the power is sufficiently stable, is already cost-effective today.[4] Battery-supported

4. ESMAP and MECS, *Cooking with Electricity – A Cost Perspective*, IBRD/The World Bank, Washington D.C., 2020.

DC e-cooking and solar-hybrid mini-grids is estimated to be cost-effective in 2025, although clean fuel stacks with LPG can make all of these technologies cost-effective today.

The generation potential from PV is not limited in SSA and is developing fast, mostly in distributed forms, mini grids (MW size), micro grids (100s kW size) and standalone systems. These may be inside cities to compensate for the weaknesses of the grid, as well as in peri-urban and rural areas to offer initial access to electricity.[5] Other renewable sources also show significant potential, such as geothermal power in Kenya.

Figure 3: Twin Dams to Convert Existing Dams into PSH Plants



The variability of solar energy is an issue in SSA, especially where it is not complemented by wind power. However, innovative options for pumped-storage hydropower such as "twin dams" have been proposed in the African context, where most standard hydropower reservoirs are several kilometers long. As Figure 3 shows, twin dams would result from the building of one additional dam, upstream an existing dam, turning one long reservoir into two compact reservoirs, with an associated pumping-turbining power house. Besides natural inflows, water would be pumped from the lower reservoir to the upper one at time of excess PV production, and then turbined when the sun sets. Twin dams on a daily cycle would be able to store many times more electricity than is produced from the natural water flows.[6] While climate change itself puts traditional hydropower at increased risks of unmanaged output variability (see IEA 2019, *op. cit.*), its partial reorientation as large electricity storage of cheap solar electricity seems to be a very sensible proposition in the SSA context.

Batteries are thus not the sole storage solution: large-scale centralized storage would allow significant cost savings, which would likely overcome the costs of extending and strengthening electric grids. This may not be possible everywhere in SSA but certainly in areas with high population densities, notably in cities and their peripheries. Such a development would not be at odds with the deployment of distributed solar capacities in these areas, including with significant self-consumption rates. On the contrary, it would help make the best of it.

5. H. Le Picard and M. Toulemont, "Booming Decentralized Solar Power in Africa's Cities: Satellite Imagery and Deep Learning Provide Cutting-Edge Data on Electrification", *Briefings de l'Ifri*, January 18, 2022, available at: www.ifri.org.
6. A. Nombré, M. Kaboré, F. Lempérière and F. Millogo, "Prospects for African Hydropower in 2050", *Hydropower & Dams*, Vol. 26, No. 2, 2019.

Business Models Facilitated by New Technologies

Transitioning to universal access to clean cooking by 2030 would cost about $150 billion a year, of which $100 billion would need to come directly from household contributions for stoves and fuels.[7] Recently, the MECS program teamed with Energy 4 Impact to develop a *Financing Clean Cooking* series of publications to facilitate the transition to clean cooking through financing and investment.

In one of their first reports, they note that most clean cooking appliances are currently sold for cash, but most poor households cannot afford their upfront costs.[8] Consumer credit is critical for them. However, new payment models are emerging.

With layaway savings, customers reserve their appliance and pay for them progressively, typically over one to six months. With third-party financing, micro-lending platforms step into the sale with a subsidized interest rate. Asset financing is quite similar, although interest rates are likely to be higher.

With pay-as-you-go (PAYGO) models, payments are made by customers on a daily, weekly or monthly basis, often using mobile money. The cooking kit can be remotely enabled or disabled if a customer tops up or falls behind on her payments. Most leading clean cooking companies have developed PAYGO solutions for EPCs, LPG cooking kits, induction hotplates, biomass gasifiers, and solar-biomass hybrid energy systems, either directly for end users or through intermediaries.

In East Africa, PAYGO services based on mobile money have developed significantly for solar lighting, but also water, grid electricity, LPG and other services. Today, the near ubiquity of mobile phone coverage opens up PAYGO to even the remotest parts of SSA. Western Africa has been unfortunately much slower in the development of these services.

Energy-as-a-service is simply a PAYGO business model in which end-users do not need to make any upfront capital investments. Utility-led financing, sometimes on the balance sheet of the utility, more often with third-party financier (itself an asset financier or a clean cooking distributor) is a powerful tool for e-cooking on grid. Repayments are collected through the utility bills.

Financing issues can also be addressed at the level of local manufacturers and last-mile distributors. For example, results-based financing (RBF) programs have been experimented in several African countries, thanks to grants provided by industrialized country governments and agencies. Although difficult in nascent markets and often

7. Energy Sector Management Assistance Program (ESMAP), The State of Access to Modern Energy Cooking Services, World Bank, September 24, 2020, available at: www.worldbank.org.
8. MECS and Energy 4 Impact, *Clean Cooking: Financing Appliances for End Users,* July 2021, available at: https://mecs.org.uk.

disrupted by the Covid-19 pandemic, they have shown promising results and useful lessons for future scale-up.[9]

A Tale of Two Countries

Recent in-depth country studies on Kenya and Zambia highlight the different contexts for e-cooking in African countries.[10]

Most Kenyans still rely on firewood (65%), charcoal (10%) or kerosene (6%) for cooking, causing indoor air pollution and forest degradation, while affecting women and girls disproportionately. Heavily promoted in the past, improved cookstoves have often been abandoned after initial acceptance. At the same time, in just 5 years, electrification has jumped from 29% to over 73%, with extension and densification of grids. Hydropower and geothermal are the main sources of electricity, and installed capacity largely surpasses peak demand. Plus, Kenya hosts the world's leading mini-grid and off-grid solar industries.

Electricity is only beginning to enter the fuel stack in a few Kenyan households with kettles, microwaves, rice cookers and other appliances. However, the aspirational fuel is LPG, used by 1 out of 4 Kenyan households as their primary cooking fuel. The reintroduction of VAT on LPG in July 2021, and the strong fuel cost increase since then, may have broken the growth dynamics of LPG use, as refilling a cylinder of cooking gas now costs 50% more than last June. By contrast, the price of electricity will be reduced by 15% at end January 2022. Hence the context looks good for e-cooking, which appears to be the best way to prevent Kenyans "going down the fuel ladder": i.e., giving up LPG and returning to kerosene, charcoal or fuelwood.

> The greatest barrier seems to be the disconnect between the clean cooking and electrification policies

Mechanisms to mitigate the high up-front costs of EPCs would be the same as those already in place to mitigate the high up-front costs of LPG cylinders and stoves. International finance could be provided for the deployment of e-cooking in Kenya in multiple ways, from development assistance to climate finance, as e-cooking contributes to greenhouse gas mitigation in reducing the use of fossil fuels, deforestation and black carbon emissions from cooking with biomass.

The greatest barrier, in this favorable context, seems thus to be the disconnect between the clean cooking and electrification policies of the Kenyan administration.

9. MECS and Energy 4 Impact, *Clean Cooking: Results-Based Financing as a Potential Scale-up Tool for the Sector,* October 2021, available at: https://mecs.org.uk.

10. J. Atela *et al., Techno-Policy Spaces for E-Cooking in Kenya*, MECS, November 2021, available at: https://mecs.org.uk; N. Scott and L. Archer, *Basic Use of Electricity for Cooking (Zambia)*, MECS, November 2021, available at: https://mecs.org.uk.

The situation in Zambia contrasts strongly with that of Kenya. 16% of cooking energy was electricity already in 2015, with 34% households in urban areas using it as primary cooking fuel, thanks to relatively high connection rates in cities and low (mostly hydropower) electricity costs. For the others, however, charcoal is the primary cooking fuel.

Yet, low rainfalls in 2015 and 2016 led to load shedding. As a result, the government adopted a policy to… shift from e-cooking to LPG stoves as a "demand-side management" measure, blaming inefficient cooking devices for high demand at peak hours when most households are cooking dinner. The target set in a 2019 document from the Ministry of Energy was to reduce the proportion of urban households e-cooking from 35% to 20% while increasing the use of LPG to 40%. Hence the clean cooking policy was essentially based on improved biomass stoves, while the increase of renewable electricity generation was targeted at the same time. This was more than a simple "policy disconnect"!

Indeed, the percentage of electricity in cooking went down from 16% in 2015 to 9% in 2019, while LPG hardly rose to 0.2%. Meanwhile, firewood-use was slightly reduced from 50.7% to 48.1%, but charcoal-use increased from 32.9% to 42.4%. This shift can largely be attributed to the ongoing urbanization of Zambia. A more recent official document where these numbers are presented also mentions a 2021 target of 25% electricity in cooking energy – possibly hinting that views may be evolving on the matter.[11]

Policy Considerations

In May 2013, noting the rapid decrease in the costs of batteries and PV panels over the last 18 months, Simon Batchelor was the first to suggest that the time for solar electric cooking for Africa had come.[12] Nine years later, and thanks to the work done since, a significant body of evidence indicates the time has indeed come.

Policy makers in African countries have a major role to play

While business models are proving that the high up-front cost barrier can be addressed, many other barriers remain: a lack of awareness, gender inequality (investment decisions are often taken by men while cooking is more often done by women), absence or weakness of country-adapted production chains of efficient appliances, to mention only a few.

Policy makers in African countries have a major role to play. Leary *et al.* (2021, *op. cit.*) insist on a few broad measures that could be taken: developing national standards to ensure that consumers have access to energy-efficient, safe, durable and user-friendly appliances; developing a range of financing options that would break down the high upfront costs into manageable repayments aligned with how people currently pay for biomass fuel; and redesigning utilities' "lifeline tariffs" to include e-cooking.

11. Republic of Zambia, *Zambia Sustainable Development Goals Voluntary National Review 2020*, June 12, 2020, available at: https://sustainabledevelopment.un.org.

12. S. Batchelor, *Is It Time for Solar Electric Cooking for Africa?,* Gamos Working Paper, May 2013. See also S. Batchelor, *Africa Cooking with Electricity*, Gamos Working Paper, August 2015.

Lifeline tariffs subsidize the first few kWh of electricity each month to enable access to basic energy services for poorer households. A lifeline tariff allowance of 100 kWh/month would suffice for most households to cook all their food with energy-efficient appliances such as EPCs. An allowance of 50 kWh/month would allow them to cook half their food but save much more than half of the energy from other fuels. A lifeline tariff of $0.10 would make battery-supported e-cooking cost-effective for most grid-connected households currently purchasing cooking fuels.

Policy makers in donor countries, international and national aid or development agencies, as well as NGOs also have an important role to play. When UK Aid pushed the preexisting MECS program to another level with a multi-million-pound grant in 2019, its initiators highlighted the disconnect between clean cooking and electrification policies, most often completely separated in national administrations but also in international bodies. Accordingly, they called for a deep paradigm change towards integrated policies promoting access to electricity and clean cooking altogether.[13] Cooking has thus become key to unlocking modern energy access, enhancing grid extension and off-grid solutions.

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13. S. Batchelor, E. Brown, N. Scott and J. Leary, "Two Birds, One Stone – Reframing Cooking Energy Policies in Africa and Asia", *Energies,* Vol. 12, No. 1591, 2019.

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