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Editorial

Editorial for Special Issue: "Clean Energy Innovations: Challenges and Strategies for Low and Middle Income Countries"

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1. Introduction

All the papers in this Special Issue situate their research in the context of a failing clean cooking strategy and the potential contribution of electricity to this.

In the creation of this Special Issue, the editors noted that significant progress has been made in the use of clean energy in low- and middle-income countries over the last 20 years. Almost 1 billion people have gained access to electricity in developing Asia since 2000, with 94% of the region having access to electricity in 2018, compared with 67% in 2000. In Africa, the number of people gaining access to electricity has doubled, from 9 million a year between 2000 and 2013 to 20 million people between 2014 and 2018 [1], outpacing population growth. Kenya and Uganda currently have surplus grid electricity and are now building into their policy instruments a focus on cooking. IRENA [2] state that the coming decade will be the 'renewable technology' decade. The cost of renewables is competitive with conventional technologies, and the resulting modern energy is cost-effective in many contexts, even within Low- and Middle-Income Countries (LMICs). Thus, there is a large amount of progress being made as we move towards 2030.

Nevertheless, there remain 760 million people who do not yet have access to electricity, and, perhaps more importantly, there are between 3 and 4 billion people who do not have access to modern energy cooking services. There are promising innovations such as energy-efficient electrical cooking appliances, the off-grid use of those appliances on mini grids to enhance the profitability and revenue of such grids, pay as you go approaches, and innovations in infrastructure and subsidies for LPG.

Given the focus of the Special Issue, it is not surprising that a majority of the papers published discuss the potential for a clean energy strategy that leverages electrical infrastructure to provide an alternative strategy for clean cooking. The rationale for this alternative strategy was laid out in Batchelor et al. [3]. Population growth is outstripping the current clean cooking intervention strategies [4,5], and urbanization is challenging many rurally focused strategies. UK Aid called for a new strategy, something other than 'business as usual' [3]. The alternate strategy suggested leveraging the gains in electricity infrastructure to provide a genuinely clean cooking service.

Subsequently, how can the innovative use of electricity for clean cooking be integrated into national and local planning? Should it be integrated? Six domains for the challenges and strategies seem to emerge from the body of work captured in this Special Issue of the journal. These are:

- Policy environment;
- Supporting finance;
- Technical impact on grid networks;
- Affordability;
- Socio-cultural acceptance and impact;

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- Environmental impact.

Across all these issues is the idea of integrated planning. For too long, clean cooking has been discussed as separate from modern energy access planning.

2. Policy Environment—Reframing the Problem

The situation of electricity gains has not just evolved in the last three years, but has been consistent over the last decade. The possibilities of electrical cooking have thus increased. Additionally, energy-efficient cooking devices are accessible and affordable.

Ockwell et al. [6] build on this landscape of change by considering how innovation systems evolve. They note that "what is effectively being considered is a process of significant technological change, with accompanying social changes as a result of, and in order to enable, new technology use" [6]. They caution against a purely technological focus and suggest that the socio-cultural and political dimensions of technological change are important features of the processes. They relate the five dimensions of innovation systems to networks of stakeholders, who intentionally seek to foster and learn from each other [7,8]. They suggest that the stakeholders should coalesce around a shared vision and encourage diverse experimentation with practices and technologies. Indeed, their summation of the dimensions and processes of innovation, and the subsequent evidence of how these were applied to the Lighting Africa programme in Kenya, echoes Batchelor et al. [3], who called for a shared vision in modern energy cooking services.

In order to understand the changing landscape, Price et al. [9] re-analysed Multi Tier Framework data to show the linkages between the two, and particularly linked these data to the increasing urbanisation of the world. As briefly alluded to above, urbanisation is changing the policy environment. Whereas hard to reach rural areas were the priority 20 years ago, the urbanisation of LMICs suggests that addressing urban poverty is now urgent, that the next 20 years will be characterised by increasing urbanisation, and that cooking with polluting fuels in urban areas is detrimental to health, the local environment, surrounding environment and the economy. Price et al. [9], link their research with fuel stacking behaviours.

Bisaga and To [10] focused on displacement settings within a policy environment. They echoed the challenges described above, noting that there were interventions for improved cooking solutions in displacement settings, but related that very few involved modern energy cooking. Bisaga and To [10] pointed to two significant emerging trends, the longevity of being displaced—the mean duration of exile experienced by refugees stands at between 10 and 15 years. The exact proportions in each category are not clear but, in 2019, an estimated 2 out of 3 IDPs and 60% of refugees were in urban or semi-urban areas. Urbanisation once again suggests that it is possible to provide modern energy cooking services, yet research on access to MECS among displaced populations in urban areas is scarce, and the legality and status of the displaced can be a significant barrier.

3. Supporting Finance—Results Based Financing (RBF)

Several papers consider the impact of upfront capital on households. Stritzke et al. [11] published a review of RBF and considered how it might apply to modern energy cooking services. They noted that RBF was used frequently to varying degrees of success and that it held promise for the new generation of innovations within modern energy cooking services. Robinson et al. [12] presented an analysis of one such RBF model applied in Nepal. Using an approach called TIME (Technology Implementation Model for Energy), they evaluated the Practical Action RBF coordinated production and distribution of 40,000 Tier 2 and Tier 3 stoves. It is interesting to see how their findings resonated with Ockwell et al., and their hopes for a more ideal innovation system. Robinson et al. concluded that the programme needed more effective communication, particularly in terms of the roles assigned to the many stakeholders. They noted that the advent of 'possibilities', i.e., innovation in induction stoves for a modern energy cooking service, caused people to hesitate over accessing the lower tier stoves; the second round of RBF was based on behavioural change and verification of use was not monitored and often reported with errors in the data.

4. Technical Impact on Grid Networks

While it is generally accepted that grid provision is substantial in developing Asia, and is improving in Sub-Saharan Africa, there remain 760 million people who do not have access to electricity. However, despite this statistic, ESMAP identifies 4 billion people that do not have access to modern energy cooking services, and suggests that 3.2 billion of these do have access to grid or off-grid electricity. Sánchez-Jacob et al. [13] elaborate on this and consider whether the additional loads created by cooking might cause problems for the grid. They model three scenarios in Rwanda: a Basic Scenario—to meet just the basic services in a household; a Complete Scenario—basic services and electricity for cooking the entire daily cooking load; and a Stacking Scenario—basic services with half of the daily cooking load, carried out with energy-efficient electric appliances, and the other half with another cookstove. As acknowledged by Price et al., stacking is common, and Sánchez-Jacob et al. analyse this aspect since it is the usual process of transition from traditional to clean cooking solutions.

Importantly, in addition to showing that electricity is a cost-competitive scenario when compared to LPG and charcoal, these authors show that electric cooking substantially changes the least-cost distribution of the electrification modes and the kWh cost, which is important for national planning. They conclude that "Cooking with energy-efficient electric appliances and renewable energy in grid and off-grid settings is the most effective way to meet the three targets of SDG 7—universal access, efficiency, and renewable energy—and to contribute towards complying with the Paris Agreement." This is an interesting statement in light of Čukić et al.'s [14] analysis of Rwanda, focused on LPG.

4.1. Off-Grid Provision

When we consider rural areas, the context is more complex. Firstly, the market dynamics are different. In more remote areas people collect their fuel, and, in market communities, people stack purchased fuels with collected fuels. Therefore, there is a reluctance to monetise fuel, turning the labour of collection into real cash payments made to either a utility, mini grid operator or solar home system distributor. Therefore, the affordability of electric cooking in comparison to alternative fuels decreases. Secondly, the tariffs charged by mini grid operators vary considerably and are, in general, significantly higher than the grid tariff. This is necessary to recover their investment costs, a factor that Scott and Coley [15] discuss. Kweka et al. [16] illustrate the dynamics of adding energy-efficient appliances, specifically electric pressure cookers, to very remote communities on the lake shore of Tanzania. Their research coincided with the Tanzanian government changing the rules on tariff charges, providing an excellent opportunity to observe the sensitivity of the relationship between consumer and tariffs.

Kweka et al. continue to confirm that electricity was displacing mainly charcoal—this is logical since charcoal is purchased and not gathered—and show how the use of the EPC reduced time taken, not only for fuel gathering, but for the preparation and actual cooking processes.

Kweka et al. are not the only authors within this Special Issue to highlight the possibilities of using mini grids. In Nepal, Clements et al. [17] build on their field data of Micro Hydro Power (MHP) to model the effectiveness of adding cooking loads. Their detailed electric cooking load modelling functionality was developed to represent Nepali cooking practices, scalable to the approximate widespread uptake of electric cooking, and adaptable to other cookers and contexts. Scott and Coley also measured the load profile of communities on mini grids and noted that appliance ownership was governed by a number of factors, not least occupancy and socio-economic status.

Keddar et al. [18], considered the aspect of reliability. Could a mini grid actually support a scaled uptake of electric cooking using energy-efficient devices? They modelled the grid with and without eCooking loads and concluded that mini grids adequately supported high levels of eCook penetrations without causing any serious network constraint issues that would require network reinforcement. They also considered the costs involved and noted that the costs would be lower when efficient appliances were used and smart monitoring was implemented.

4.2. Solar Home Systems

Van Buskirk et al. [19], positioned their research from a household perspective rather than a community mini grid. It was previously thought, since Solar Home Systems struggled to innovate a simple lighting system that could replace kerosene lamps, that to cook on such a system would impossible. However, as suggested by Batchelor [20], with the ongoing drops in price of PV technology and energy storage, a 'cost effective' system can now be created. 'Cost effective' is written in quotes because the actual cost effectiveness of a system depends on the context and the alternatives. While the grid and mini grid eCooking responses described above are generally implemented in areas of dense population, which necessitates a market economy for cooking fuels (i.e., even the wood is purchased), by definition SHS are ideal for remote, rural, low-density areas, where people can collect wood. Therefore, there is no easy monetary substitution in terms of household economics to pay for the SHS, no matter how cheap.

In Van Buskirk et al., they addressed this context directly. They present a very cheap solar electric system, one that can be adapted to include either storage or no storage. These authors admit that this does not solve the context problem if wood is considered free and the value of quality of life is not considered worth the monetary expense, and thus suggest that climate impact and other externalities should be accounted for.

5. Affordability

The above discussion on the policy environment, financing and grid strengthening assumed that cooking with electricity would be cost-effective for households. Leach et al. [21] directly address this question. They present a suite of models that represent the technical, economic, human, and environmental benefits and impacts of delivering electric cooking services with a life-cycle perspective. Their paper illustrates the combined model by applying it to case studies for transitions of households from traditional fuels to electric cooking. Their conclusion is that electric cooking can be cost-effective at a household level (i.e., a wise use of household finances), but they also incorporate the value of the externalities such as the reductions in human and ecological impacts. These impacts can be used for RBF (as discussed in Strikze et al.). These authors also analysed the networks to show how much electric cooking could be accommodated on existing grids and find a very positive answer—that much can be accommodated by existing infrastructure. They noted that this was mainly due to diversity effects in the nature and timing of cooking practices (which is supported by evidential data from Kweka et al. and Clements et al.). They conclude that there will be positive overall benefits in health, ecosystem, and resource impacts in most contexts and, with typical electricity supply infrastructures, most countries could support the transition of a significant number of households.

6. Socio-Cultural Opportunities

In Leary et al. [22], there is a wide-ranging discussion of what makes the innovation of eCooking attractive to the consumer. They noted that the cost effectiveness described in Leach et al. was predicated in energy-efficient appliances. Leary et al. found that energy-efficient appliances were also very popular for their ability to deliver a genuinely clean cooking experience that highly valued time savings and convenience. "Automated electric cooking appliances control the cooking environment and switch off automatically, freeing up the cook's time to focus on other things. In comparison, even an LPG stove must be regularly monitored to ensure the food does not burn" [23].

When considering household characteristics, they discuss changing lifestyles and raise the idea of a range of co-benefits for both genders. Leary et al. also drew attention to increasing urbanisation, and they noted the importance of both fuel and appliance stacking. They issued a word of caution, noting that false perceptions around cost, taste and safety could hold back households from adopting eCooking, and that the high cost and steep learning curve for new energy-efficient appliances, the lack of awareness/availability/after-sales service for energy-efficient appliances, and the reluctance of male decision-makers to authorise appliance purchases could be substantial barriers to this.

In terms of changing lifestyles, Scott et al. [24] presented research on consuming foods and modern eating habits. They searched outside the actual household kitchen, from wider society in urban settings to the choice of foods and whether they were pre-prepared. As mentioned previously, the cost of energy used to cook food depends on multiple factors, such as the type of fuel used, the type of cooking device, and the type of food cooked; additional factors include the cooking techniques used, and the skill of the person(s) responsible for cooking.

Kelkar et al. [25] take a more conceptual view of the sociocultural barriers and study the economic inequality of women and anchor their discussion in India's LPG policies. They base their paper on mixed methods research across five states. Picking up on changing norms, they focus on two 'troublesome' issues. There is a social reluctance to recognise women's unmediated authority in the management of energy, land, and other factors of production. Secondly, the consequence of this is that, if women belong to a household that has access to and uses modern energy, they do not have the decision-making powers to procure the appliances they require. This issue is addressed in the Pradhan Mantri Ujjwala Yojn, a scheme by the India government to supply LPG to the poorest households. Over 80 million units were given to women in their own names, irrespective of their marital status. Data analysis shows that many of these units did not have LPG as their primary fuel, with low averages of refill throughout the year. This relates back to the discussion on fuel stacking in other countries (Price et al.).

7. Other Modern Energy Infrastructure

This Special Issue contains research on other fuels. In Čukić et al. [13], the authors describe how the National Master Plan of Rwanda is seeking to promote the scaling up LPG. They point out that 90% of Rwandans use biomass, and that the government seeks to focus on LPG as its modern energy cooking service, in order to move towards the SDG7 universal access target. While the policy sets a realistic use of LPG of 45% by 2030, the paper uses three scenarios to analyse the situation—a business as usual, an intervention scenario and a policy scenario. The paper analyses the effect of these scenarios, focusing on health and environmental benefits. They show that for the policy scenario of 404,000 Disability Adjusted Life Years (DALY) would be saved, as well as reducing premature deaths of 7660. These health savings consider labour time and productivity, and equate to USD 19.5 m economic benefits. They also point to the 'not cutting down' of 243 million trees which would have its own impact on carbon capture that we discuss further below.

Čukić et al. drew attention to the possibility of renewable bioLPG as a homegrown fuel. They elaborated on the findings from another paper in the Special Issue, Chen et al. [26]. BioLPG, which is chemically identical to fossil-derived LPG but can be derived from fully renewable sources, is now an emerging possibility. Chen et al. showed how it can be produced from feedstocks, such as municipal solid waste (MSW) from appropriately engineered landfills sites. Since bioLPG is renewable, it can secure international investment and contribute to a net-zero carbon world. If generated internally in a country like Rwanda, it would mitigate Rwanda's exposure to fluctuating international oil prices and the imported LPG costs. It can be blended with 'regular' LPG; therefore, if Rwanda set up an infrastructure for the distribution of LPG use, then bioLPG could utilise that infrastructure.

An alternative MTF Tier 5 experience can be achieved by utilising Biogas. Black et al. [27] noted that biogas is versatile and country-specific policies in many countries include it as part of waste management, renewable energies and climate change. In particular, they note that Anaerobic Digestion was promoted in developing Asia and Africa as a waste management and bioenergy opportunity. Interestingly, picking up on the above discussion of infrastructure, a key constraint of biogas use is a lack of distribution infrastructure.

Finally, Strikze et al., Van Buskirk et al., and many others called for externalities to be taken into account. While monetary cost is the most common definition of affordability, the world is becoming increasingly aware of impacts on climate and the environment. Lee [28–30] presents the results of a life cycle assessment of a mini grid, designed for construction in Malawi. This analyses the cradle to the end-use of this mini grid configuration, for a grid sized for lighting, refrigeration and phone charging, as well as a grid sized for electric cooking (e-cooking). Building on the previously mentioned field trials [14,16,17], the paper considers what the main contributors to environmental impact are, and whether they are worthwhile in the long-term, regarding the environmental transitioning from biomass to mini grids.

8. Conclusions

The body of work captured in the 20 papers in this Special Issue presents innovative new ways of thinking and a new strategy for addressing clean cooking. It provides evidence as to why investment in modern energy infrastructure should include cooking loads. Whether it be transitional modern energy infrastructure, such as LPG and non-renewable electricity, or the increased use of renewable energy generation to supply fuels for cooking with the associated decentralisation of generation and use, these papers address the current challenges and present new strategies. They reframe the problem away from 'how can biomass stoves be improved' to 'how can investment in modern energy infrastructure be leveraged to make greater movement towards fulfilling SDG 7 (access to modern energy for all inclusive of modern energy cooking services)'.

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