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Economic and social feasibility pilot of ethanol fuel for clean cooking in upland Sierra Leone

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ABSTRACT
Ninety-seven percent of Sierra Leonean households prepare food over wood or charcoal, a practice that leads to adverse health and environmental consequences. In this pilot study, we introduced ethanol cookstoves to households in Bo, Sierra Leone. We assessed their potential as an alternative to biomass fuels and the only existing improved cookstove, butane gas. Ethanol cookstoves were economically competitive with butane stoves, but could not outcompete biomass fuel (wood and charcoal). The cookstoves displayed significant benefits to women in time savings and comfort, but raised concerns around alcoholism, unequal access to technologies, and other gendered constraints in the cultural context.

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Improved cookstove; gender equity; ethanol; biomass; Sierra Leone

Introduction
Throughout the developing world, reliance on cookstoves fuelled by natural biomass, such as wood and charcoal remains ubiquitous. Over 40% of the world’s total population relies on these fuels for cooking and household activities (World Bank 2018). Burning of these biomass fuels leads to formidable health and environmental concerns; indoor air pollution from burning “dirty” fuels is responsible for about 3.8 million deaths per year (World Health Organization 2020). This health burden falls disproportionately on women and children, who spend more time in the kitchen than men.

In Sierra Leone, fuel collection for an increasing population has accelerated the clearing of woody biomass. Wood that is normally collected from fallowed land cannot be recovered when fallows shorten to increase production, which drives wood collectors into virgin land. Ecologically, the removal of trees further decreases terrestrial stored carbon, reduces biodiversity and natural habitat, and leads to lower ecological resilience as droughts and floods become increasingly common (Fargione, Plevin, and Hill 2010). This was painfully witnessed in the August 2017 landslide outside Freetown that killed over 1000 people (Gibbens 2017).

Therefore, it is important to explore systematically alternative fuels for cooking, including their economic feasibility relative to existing options and to the constraints that shape household decision in this domain. Such an exploration requires piloting and experimentation grounded in the realities of daily life in these contexts. In this paper, we describe the lessons learnt in one such pilot in the Bo region of Sierra Leone.

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Background

Ethanol is being explored as an improved fuel for cooking across several continents (Gaia 2019). A biofuel sourced from starch-heavy plants rather than petroleum, ethanol is considered by some a “clean fuel” because the burning of the fuel gives off no black carbon or particulate matter, and in a limited definition, releases only the CO₂ that the plant feedstock source took in when growing. It is liquid and not a compressed fuel like butane gas, the only existing improved energy option in the Bo region of Sierra Leone.

In 2014, as the result of extensive foreign direct investment, Sunbird Bioenergy completed construction in northern Sierra Leone. Its purpose was to export 85 million litres of ethanol each year to the European Union. It has expressed interest in building out the market locally to support the country in which it operates – both as an economic endeavour and as a matter of social conscience. At the time of this study in late 2018, Sunbird was exploring the possibility of utilising locally grown cassava as a starch source, which could prove more climate resilient and appropriate for the region than the existing feedstock of sugar cane. One goal of our research was to support Sunbird Bioenergy in determining the feasibility of a local market for cookstoves that run on ethanol.

When it comes to improved cookstove adoption, data from the UNFAO have confirmed that “per capita consumption of both fuelwood and charcoal generally decreases with an increase in income” – therefore suggesting that biomass fuel is gradually abandoned for “cleaner” alternatives as income increases. This is known as the “Energy Ladder” and is clearly evident across meta-studies of stove adoption (Arnold, Köhlin, and Persson 2006; Lewis and Pattanayak 2012).

However, many additional factors besides income influence stove decisions, including social and cultural affinities. In many cases, “stove stacking” or “fuel stacking” occurs where families adopt a cleaner or more efficient technology, and use it to varying degrees alongside their open fires or other “old” technologies (Hosier and Dowd 1987; Masera, Saatkamp, and Kammen 2000). Masera and colleagues (Masera, Saatkamp, and Kammen 2000) argued that no clear evidence exists for the fuel ladder at all; a more appropriate mentality is that of a “multiple fuel” model, where one recognises that a move to clean fuel is more often an adoption of an additional fuel source rather than an outright substitution.

In general, introducing a new technology is complicated, and our study revealed that ethanol cookstoves are no exception to this rule. Beyond functioning on its own, a new technology has to be integrated into the economic, social, and development context of a household, community, and country. Here we focus on the economic feasibility of the cookstoves and ethanol, as well as social feasibility. This includes the potential to improve the cooking experience for women, and explores inequities in gendered access to technology.

Research setting

As a result of corruption, civil war, and the Ebola epidemic of 2014, Sierra Leone currently sits ninth from the bottom on the UN Human Development Index. Overall, the prevalence of commercial energy (grid-supplied hydropower, petroleum, and coal energy) throughout the country remains extremely low. As of 2016, only 20.3% of the population had at least partial access to grid electricity (~6%) or generators (~13%) for private energy use, including cooking; in contrast, the average access to these technologies across all of Sub-Saharan Africa is 42.8%. Of those with access in Sierra Leone, these were almost exclusively in urban centres (98%), and primarily the capital of Freetown (UNDP 2012, 2019).

Our study area was Bo City, the capital of the Southern Region of Sierra Leone, and four surrounding villages. Bo Region is located in the south-centre of the country and had a population of over 574,000 in the last official census in 2015 (Statistics Sierra Leone 2017). Bo region is an agronomic region well known for cassava production, and its capital city is considered the primary educational and economic centre of Southern Sierra Leone – though still far behind the country’s capital city of Freetown in the Western Area province (Figure 1 (OpenStreetMap 2021)).
For residential energy needs, essentially all households (98.7%) in Bo district rely on biomass fuel as their primary fuel source for cooking (Statistics Sierra Leone 2017). This heavy reliance on biomass as fuel has exerted predictable pressure on forests. In their 2015 renewable energy policy, the government of Sierra Leone confirmed that from 1990 to 2010, the country lost 2.72 million hectares of forest or 12.6% of its total land area (Government of Sierra Leone 2015). Currently, the country still has 43% of its land area forested, higher than most Sub-Saharan nations; however, the rate of depletion of wood increasingly exceeds the replenishment rate, especially around urban areas (UNDP 2019).

Methods

We conducted a three-month, multi-faceted study in 2018 to understand the potential of ethanol as an energy source for cooking and to better understand how this alternative fuel would fit into the economic and social setting of Sierra Leone. We included an initial energy market analysis survey using structured interviews of people along the biomass energy value chain, as well as consumers of biomass fuel and the only existing improved cooking option, butane gas. In a stove comparison and price acceptability study, we placed ethanol stoves in 24 households, assessing the stoves' efficiency and acceptability compared to biomass fuel (primarily) and butane gas. Finally, we assessed potential adoption of the ethanol cookstoves through a behaviour and response analysis. In this section, we explain each of these components of the study in greater detail.

All prices listed are real prices (not PPP) and the exchange rates used are those at the time of the study (October 2018; 1 USD = Leone 8500; prices have since fluctuated).

Cookfuel value chain analysis

We first conducted interviews with 228 individuals to understand the existing biomass energy market. For this energy market value chain analysis, we interviewed 30 charcoal retailers and 30
wood retailers in Bo. We interviewed 55 wholesalers and producers of wood and charcoal and 79 consumers of wood, charcoal, and butane gas across 13 neighbourhoods in the city of Bo, and four villages outside the city for suppliers. These villages were Banda Juma (east of the city), Cocofili and Benduma (south of the city), and Pundegumahun (north of the city). We also interviewed 34 individuals involved in the market in the capital city of Freetown to gain an initial understanding of variations in market dynamics and fuel price between the capital city and Bo.

Participants were chosen through a convenience sampling method in marketplaces. Participants received a bar of soap as token compensation for their participation. All interviews were structured for each group along the value chain. Interviews lasted 20 min, on average.

The individuals interviewed for our energy market value chain analysis came from across the economic spectrum. Villages where woodfuel was sourced represented the least economic means, with women wholesalers sometimes walking up to four hours round-trip daily to the city to secure an additional profit of $0.12–$0.36 each day. Consumers in possession of a butane gas stove represented the highest level of income, and were often college students in the regional university.

**Ethanol stove implementation study**

Once we understood the existing landscape for the cookfuel market, we sought to compare the efficacy and acceptability of the ethanol cookstoves against and among biomass and butane gas (Figure 2).

We placed 24 ethanol stoves in households across the community. During a group orientation, households were instructed to use only the ethanol stove and fuel for all household tasks and meal preparation, replacing their biomass or gas usage entirely. While the use of multiple types of fuel in one household is common (fuel stacking), we wanted to first gain an understanding of the average consumption rate if ethanol were to replace all alternate fuels. Households received free ethanol fuel for cooking for 2.5 weeks. During this time, households were visited around three times per week to interview participants, observe stove use, and replenish fuel. We measured fuel use through a regular collection of empty fuel bottles as well as self-reported use.

After 2.5 weeks of zero-price fuel, we implemented a pricing system and households were informed they were no longer required to use fuel for all household tasks but could purchase fuel which would be delivered when requested. During this time we were looking for both willingness to pay and ethanol fuel’s potential fit alongside other fuels – whether “fuel stacking” would naturally occur. We began selling fuel at Le 8000 (~$0.95 USD) per litre (in line with government-mandated petrol prices). After two weeks, we adjusted to a discounted price of Le 6000 (~$0.70 USD), a price determined to be more competitive with the price of butane gas. We then sold it for another three weeks at that amount. During this time, families were no longer visited on a set schedule and fuel was delivered by hand or by motorbike when requested. We also conducted one of two standard interviews for all households: one interview for households that purchased any amount of fuel, and one for households that did not.

**Inclusion criteria and demographics of participating households**
The cookstoves used in our study were double-burner Dometic Cleancook NOVA-2 ethanol stoves. Inclusion criteria required participating household member(s) to:

- attend the orientation session
- have a working mobile or WhatsApp number
- cook every day
- include one semi-literate household member to complete the log sheet
- be able to pay a Le 30,000 (~$3.50) fully refundable deposit for the stove
- remain in the town throughout the study.
The 24 households in our ethanol stove study were more affluent than the average wood and charcoal consumer. Through observation of valued assets, it is reasonable to say that about 40% of participating households were in the upper 30% of the national population, and upper 10% for the Southern Region (Statistics Sierra Leone 2017). Four participating households earned over Le 100,000 (∼$11.80) per day, six earned between Le 50,000 and 100,000 (∼$5.90–11.80), and nine earned between Le 10,000 and 50,000 per day (∼$1.18–5.90). Typical jobs held by participants in our study included NGO workers, teachers, contractors, and small business operators.

All participants possessed a higher level of education than the average consumer in our fuel market analysis. In addition to secondary school, several women reported participating in vocational programmes, university, or certificate programmes. These levels of education suggest greater comprehension and ability to engage with new technologies, a principle well established across technology adoption studies (Polar et al. 2017; Doss and Morris 2000).

**Conceptual frameworks**

Socio-economic and cultural systems shape technology development and adoption (Manfre, Rubin, and Nordehn 2017). Knowing this, we utilised theories on technology adoption, perception, and...
appropriateness to design this study and explored the theoretical frameworks of community, social, and individual choices, as well as gendered relations to guide our interview questions and analysis.

At the core of the issue of technology adoption is whether the technology is indeed appropriate. Here, an appropriate technology would be one that was easy to use, affordable, and not bound to fail based on community, social, or gendered interactions. We view technology adoption similar to Rogers (2003) where the rate of adoption is influenced by the adoptee’s social support system (primarily community engagement and gendered support), positive experiences with the new innovation, communication of those experiences, and the propensity of the technology itself to be attractive and useful to the adoptee (Rogers 2003). Knowing that combining multiple types of fuel and stoves (fuel stacking) is common in developing economies, we were looking to see if or how the ethanol stove might be adopted alongside the existing fuel sources as opposed to an outright substitution (Masera, Saatkamp, and Kammen 2000).

Community engagement with a new technology is critical to adoption, and community pressure has a great influence over individual choice (Durkheim 1982). Community engagement here meant that cookstoves needed to be acceptable not just at an individual level but within the greater energy value chain system. To be adopted, ethanol cookstoves should not come at a detriment to an individual or the community, particularly women who are among the most marginalised (Reddock 2012). Therefore, we explored empowerment through gendered decision making, women’s access to assets, the potentiality of oral ethanol consumption as an alcohol substitute, and gender-differentiated experiences and preferences associated with cooking and cookstoves (Kabeer 1999).

Results

Findings from the energy market analysis

As a result of our 228 interviews, we were able to identify a production chain for the current biomass energy market that can be summarised by Figure 3.

Households spent an average of Le 2000 ($0.24 USD) per day on biomass fuel, about 7% of their average daily allocated food budget. In general, families that use wood appear to spend slightly more than families that use charcoal, despite the fact some consider it “lower” on the energy

![Figure 3. Description of the fuel value chain in Bo Province, Sierra Leone as assessed through this study. Prices listed are real prices, not purchasing power parity, using exchange rates at the time of the study. This infographic was made in Piktochart, and includes some images from Flaticon.com.](image-url)
ladder. Unsurprisingly, families that purchase a large bag of charcoal (purchase in bulk) spend less per day than families that purchase small daily rations; their overall cost is about \( \frac{3}{4} \) as much (an average of $0.18 per day rather than $0.24).

Perhaps surprisingly, our team found no correlation between household size and increased expenses on fuel. We anticipate this is because a fire or coals need to be lit, regardless, to cook a meal, and the size of the fire does not change as radically as the size of the pot required to feed more people. Where fuel was purchased from, and whether it was purchased in bulk, were greater factors in daily fuel expenses.

Of households that use a butane gas burner, almost all of them practiced fuel stacking. Rarely was the burner ever used for primary meal preparation, but instead was saved for quick, short tasks of convenience (usually under 20 min) such as boiling water, frying eggs or plantains, or reheating food. The price of gas meant that to use it to cook rice or prepare a full meal (usually over 40 min) was considered wasteful, regardless of income level. The only individuals our team could find that used butane gas burners for all food preparation were expatriates, suggesting a deep cultural influence in expectations around food preparation, rather than an economic influence.

These perceptions were further verified during an additional comparison study, where we found that if a household (of a range of 2–10 people) used an average butane gas container for all household tasks, it would last around 2.5 weeks. This is an average cost of Le 5,400 ($0.59) per day. In contrast to the average Le 2,000 ($0.24) per day spent on biomass fuel, the butane gas is almost three times as expensive. Qualitatively, many individuals also expressed fear of using butane gas because of a few high-profile explosions that had happened, and subsequently been promoted by the government to educate for safe practices when handling pressurised gas for household use.

Comparative pricing of biomass fuel versus butane gas in the capital city of Freetown versus the inland, rural city of Bo can be seen below; costs reflect proximity and access to the production system of each type of fuel. Usage of both fuel types would take about 2–2.5 weeks to deplete (Figure 4).

**Findings from the ethanol stove study**

Twenty-four households that received the ethanol burning stoves were regularly surveyed for qualitative input and usage rates. We explore qualitative input and usage behaviour first, followed by quantitative consumption rates and patterns.

![Freetown/Bo comparative costs](image)

**Figure 4.** Comparative costs of biomass fuel vs. the only existing improved fuel source, butane gas. *This infographic was made in Piktochart, and includes some images from Flaticon.com.*
The feedback on the stove and fuel was overwhelmingly positive; only two users did not like the stove (and in both cases, their husbands then used it for themselves). Some reactions focused on purely cosmetic features; the appearance of the stove (its shininess and newness) drew many praising comments from both women and men. Men proudly put the stove on display in their sitting rooms and reported their neighbours would often inquire after it. Women’s most frequent feedback included pleasure with how fast it was to light, and how quickly it cooked food, followed by its overall cleanliness and lack of smoke.

Many comments centred around the flexibility of use: the stove could be used indoors or outdoors, or set on a table or stand, versus on the ground. Women stated their satisfaction with the ergonomic benefits of not having to crouch on the ground. When compared to gas, households found the fuel more approachable, as handling a liquid that could be poured from a regular screw-cap container was perceived as less intimidating than compressed gas.

Critical feedback included some dislike of the smell of the alcohol fuel, that it would sometimes still make the bottom of their pots black, and the inability to put two large pots on the two-burner stove at the same time as the burners were too close together for most families’ large pots—an important design flaw that can be addressed by making two single-burner stoves available rather than one double-burner stove.

After the first 2.5 weeks of free ethanol fuel, it was determined that the average use rate per household was 0.9 L per day (0.2 L per adult) when used for all household tasks. The correlation with family size was very weak, suggesting a similar phenomenon as with biomass fuel—the amount of food prepared and the amount of fuel needed to prepare it are not strongly linked.

Under our pricing scheme, we then offered ethanol at Le 8000/L for two weeks and then Le 6000/L for three weeks. After five weeks of priced ethanol, 19 of 24 households purchased some amount of fuel. Ethanol was delivered upon request and purchasing by households was highly varied, with one household purchasing 20 L over this timeframe and another purchasing only 1.5 L. On average, households purchased 2 L per week.

With an average family use rate of 0.9 L per day for all household tasks, 2 L per week cannot replace biomass fuel for all household tasks. Unsurprisingly, we witnessed families integrate the ethanol in a stove-stacking practice much like the butane; they immediately started using the ethanol stove just as they would the butane, saving it for quick tasks rather than using it for intensive meal preparation.

Through measuring the rate of consumption, we learnt that the price of Le 8000 would be too expensive as a competitive market price, as it would be even more expensive than butane gas (which is sold in bulk rather than by litre). Instead, Le 6000/L (≈$0.70) was perceived as a reasonable price by most users, and calculated as likely still economically possible on the production and distribution end, depending on various infrastructural factors such as transport costs.

At Le 6000/L, this puts ethanol directly in competition with butane gas, but like butane gas, therefore unable to displace daily charcoal and wood use. At Le 2000 per day, wood and charcoal remain at roughly one-third the cost of these improved fuels (Figure 5).

In summary, these results show that ethanol stoves can be competitive with butane gas stoves and therefore a feasible market could exist for Sunbird’s ethanol by competing with the existing improved stove market (butane). However, they are not inexpensive enough to be used for all household tasks. Replacing butane with ethanol could have a moderate positive impact on health and the environment as hoped, though not as high as if biomass fuel use were to be fully displaced. Given the prevalence of stove stacking across the developing world, ethanol’s use alongside biomass is a natural fit for the fuel socially. Below, we unpack our observations from this study that are of merit, and explore through a number of lenses the questions that betray the inherent complexity of technology adoption in context and its impact on economy, society, and the natural environment.
Discussion

Below, we return to our premise that, to be successfully adopted, technologies cannot be separated from socio-economic systems and culture (Manfre, Rubin, and Nordehn 2017). We explore a number of positive and negative aspects of ethanol cookstoves and discuss issues of empowerment, gender relations, the environment, and technology diffusion.

On gender and technology

From a household’s perspective, there were many positive aspects associated with the stoves. This ranged from time saved in lighting and using the stoves, to the fact that almost all women commented on how ergonomic, clean, and attractive the stoves were. Overall, they enjoyed using them and reported that the stoves made their lives easier and better.

Although these stoves were meant for women, in general, technology is considered a man’s enterprise. As such, it was interesting to see the intersection of gendered priorities in participating households. Several of the families received stoves during the orientation because the male head of household was interested in the technology and wanted to use it himself or simply have it in his house. The exception to this was when the women had higher agency within their household structure (i.e. they lived alone or with a brother instead of a husband). Women were thankful for the ergonomic benefits and speed in preparing daily meals; men saw its value more for use in small and personal tasks of convenience.

In one notable outlier case, one woman avoided using the stove as much as possible because she reported she “hated her husband”, and he had introduced it to her – so she didn’t use it because she was asked to use it at his directive. In this case, the husband insisted on keeping the stove in the house, using it to boil water and perform small tasks for himself.

Though most women appreciated the stoves and found them easy to use, they could not independently adopt and manage their use of the stove because the cash expenses of the fuel required the involvement and authorisation of their husbands. Because ethanol costs more than biomass fuel, women often had to consult with their husbands and entreat them to buy more fuel for the stoves. This meant that ultimately, men controlled access to the technology. If men control access to this asset, women still have little agency. Until women can exercise more agency over discretionary

Figure 5. Daily fuel prices of biomass fuel vs. ethanol, if used for all household tasks. Economically, ethanol cannot outcompete biomass fuel as exhibited in all but four cases above.
spending, or until men financially attend to women’s priorities, it may be hard to build a flourishing market for this fuel.

**The importance of appeal**

Another important aspect of technology adoption is simply the attractiveness of the technology itself. As a side project, one of our team members re-designed and built this same stove with locally sourced materials, in partnership with local metalsmiths for a competitive price. This stove was met with laughter and dismissal from local women at the rough hand-quality production and scrap metal approach. It is possible the response would have been different if they had not first been introduced to a sleek, imported, manufactured stove. However, if we consider the cookstove as an asset, one must consider locally derived values around perceived beauty and how these must be taken seriously for successful behavioural and market changes to establish.

**Alcoholism**

One issue that we wanted to address directly in our study was the potential of the ethanol fuel to be consumed. We experienced no abuse of the ethanol during the duration of our study. In addition to labelling all bottles with clear imaging and messaging around flammability and toxicity, this was also due to the team’s overt urging to participants not to consume it, and saying that it would make them very sick. At no point was it explained to households that the fuel is highly concentrated refined spirit, and that it could very easily be watered down and consumed. However, this can be very easily discovered and the information made readily available. For this reason, it is critical to introduce some kind of denaturing agent (such as denatonium benzoate) before the scaling up of this enterprise in any way, to prevent consumption abuse.

Alcoholism is a highly gendered problem in many countries and Sierra Leone is no exception, with more than twice as many male drinkers (Ferreira-Borges et al. 2016). So, selecting ethanol as a “clean fuel” must be carefully monitored and managed so as not to exacerbate greatly entrenched issues around alcohol overconsumption and the burden on women associated with this practice.

**On local ethanol production**

Recognising that the introduction of an alternative fuel source could disrupt the existing biomass supply chain, and thus, for the most economically vulnerable of the population, we explored whether local villages could feasibly produce ethanol for cooking. Because technology is dependent on the socio-economic system that creates it (Manfre, Rubin, and Nordehn 2017), it became clear that a “traditional” distillation system that is used in rural villages could not be more effective at producing ethanol than the existing mechanised, scaled-up system.

We determined village-scale production systems could not efficiently yield anything much higher than 55% alcohol by volume. This would not be suitable for the stove as the water content would be far too high, which would not be economically feasible for either producers or consumers. Similar results have also been identified in Nigeria (Ohimain 2015). Additionally, traditional distillers in villages currently refine palm liquor to 40% ABV and drink it, and they can sell 5 L for Le 30,000. Under current social motivations and at our determined price point of Le 6000/L for cooking, there is no feasible incentive to distill a product several more times, requiring far more work and resources, to sell it for the same price or give it to women to cook with. It is highly unlikely that refined spirit over 90% – the quality needed for the cookstoves – can and will be produced at the village level.

Given the desire to see community-engaged alternative fuel come about, one team member is currently exploring the local production of biogas from plant waste, given that this wouldn’t compete with the alcohol market. Another possible way for communities to engage with ethanol production more fully is to grow the feedstock as a source for Sunbird; however, this must be done in a way that does not affect food security.
On Biofuel feedstock and the environment

Biofuels such as ethanol burn clean, releasing only CO₂ and H₂O, with no black carbon or particulate matter, and therefore do not contribute to overall pulmonary morbidity that develops as a result of smoke inhalation. However, a critically important question of increasing biofuels as a resource is the consequence of land use and land clearing for ethanol feedstock production. If feedstock was grown responsibly on land already cleared, the purchase of ethanol fuel may slow the persistent deforestation caused by the demand for fuelwood. But if the demand for feedstock to make this fuel causes virgin ecosystems to be cleared, or even fallsows to be further shortened, the ecological destruction this “clean” fuel might bring through increased carbon fluxes into the atmosphere may do greater damage from an ecological perspective than had there been no intervention at all (Fargione et al. 2008).

Regarding the feedstock itself, we earlier mentioned that Sunbird was interested in switching their primary feedstock to cassava rather than sugar cane. This would be a boon environmentally as cassava is both more drought and flood resistant than sugar cane, and it grows better in the regional soils. Concerns have been raised about the impact on food security, and successful execution depends on the selected supply chain and production models. Exploitative scenarios could certainly come to exist if executed poorly. However, Sunbird and the authors both believe that cassava grown for feedstock for the production plant would not affect the local food supply, and could even become available as a food source in times of hardship or oversupply in ways that sugar cane cannot. The strain of cassava used for fuel is higher in cellulose and less pleasant to consume; however, it is certainly still edible.

On improved fuel adoption and remarks for implementation

The uptake of most new technology generally begins in urban centres and spreads outward (Audretsch and Feldman 2004). Because new technologies also generally bear a higher cost, these are often first adopted by those with the means to do so (Rogers 2003). Our stove study was not an exception to this, considering just under half the participants had access to assets possessed only by about 8–10% of the population in that district. Given the nature of urban centres as sources of technology acquisition, a model for ethanol distribution would hinge on Bo city serving as a centre of distribution for the Southern Region.

Assuming Sunbird remained the primary supplier of ethanol given that village-scale production is not feasible, we estimate the most viable markets for the fuel would be in Freetown, due to the high concentration of a population that possesses significant ability to pay, followed by Mikeni, due to the short distance and therefore low transportation costs from Sunbird to the market.

We maintain that the implementation of this alternative fuel source is possible, if a variety of infrastructural pieces come together. For the fuel price to eventually be available below Le. 6000 in the Southern Region, and therefore made more widely available, further maintenance of a key road between Bo and Sunbird would need to be seen to, which would significantly decrease transportation time. The ethanol stoves themselves, which were not explored extensively in this paper, would need to be made more affordable – which could be done through two ways. The first is to have an external party intercede and acquire them through existing grants for climate-favorable development initiatives; the second is to import the fuel canister element of the stove only, and build a body around it from locally sourced materials. These two initiatives could be combined for maximum affordability, bringing down the price of the canister to one that could outcompete butane containers, while also providing employment to local metalsmiths to put together the stove body in a single-burner model more conducive to the large pots used when preparing traditional dishes.

Ideally, as the market was able to establish itself in urban centres, it would become more competitive in price and therefore accessible to more people. Even if the price didn’t drop enough to
be accessible in the rural areas, further acquisition in urban areas could likely alleviate demand for biomass fuel in urban centres, hopefully slowing the resource extraction and alleviating pressure on the biomass production chain.

Conclusion

Sierra Leone is rapidly deforesting itself in the need for biomass fuels for its growing population. In addition, burning these fuels leads to health risks, especially for women and children. Sunbird Bioenergy is poised to improve lives as well as improve economic growth for the struggling economy. For this reason, we set out to identify whether ethanol could serve as an effective replacement fuel for cooking. Our findings indicate it is unlikely that ethanol would be a competitive fuel to fully replace wood and charcoal for most of the population without the price point becoming more manageable. However, ethanol certainly gained significant traction in our study against the only other improved fuel option, butane gas.

Assuming feedstock is grown sustainably on land that has already been cleared, we suggest that ethanol is a better fuel choice than butane gas. Despite the fact our study shows the fuel serves similar demographics at a similar pricepoint, ethanol is more environmentally sound (given the above caveat), it is safer and more approachable through not being explosive and able to be sold as an uncompressed liquid, and it burns cleaner and is therefore safer for the user’s health. And despite the fact it is produced centrally, it is still produced domestically; the butane gas is imported.

People often wish to label development initiatives as “good” or “bad”, “successful” or “unsuccessful”. This project and its potential expansion, like in all things, necessitates tradeoffs. Successful improved cookstove initiatives the world over have shown to decrease pulmonary disease and improve ergonomic comfort for women, increase available time or other chores or activities, and in some cases increase women’s agency. Qualitative comments we collected align with these findings, although the gendered relationships within households complicated the adoption of these cookstoves in Bo province. There is no question that Sierra Leone needs a better cookfuel solution, and ethanol stoves may be it; however, this research sought to identify more than simply the feasibility of price. Ethanol as a solution to Sierra Leone’s cookfuel crisis will not come to pass unless the further development of this fuel domestically is undertaken with great discernment in areas of gender, access, and environmental consequence.

Notes on contributors

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Data availability

The data from this pilot study is not publicly hosted but can be supplied upon request.

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