



Scaling Clean Cooking Responsibly:

Tackling air pollution through a woman-centered model in Abuja, Nigeria



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Key Terms Defined

1. **Clean cooking solution (CCS):** Any clean cooking technology that can reduce air pollution, including LPG, ethanol, improved biomass, electricity, etc.
2. **Traditional cookstove (TCS):** The traditional cooking method in the home (open fire, mud, 3-stone fire).
3. **Adoption:** Long-term use of clean cooking technologies, as measured by sensors. Nexleaf defines adoption as the use of the CCS for 1 hour or more per day averaged over the most recent 60 days.
4. **Adoption rate:** % of households that are adopting the CCS. Our target is to see 80% of households adopting the CCS.
5. **Responsible scale:** Starting with 10 households per CCS model for 6 months to evaluate initial use and acceptance of the stove based on sensors and ensure the stove doesn't break within that time; then scaling up to 100 households to evaluate sustained use and durability; then 1,000 households to evaluate for air quality improvements.
6. **Climate Credit:** Based on Nexleaf's published methodology in *Nature Climate Change*, we give women climate credits based on their emissions reductions of short-lived climate pollutants, as quantified through the methodology. This helps them pay off the loan for their CCS. We generally do not apply the climate credit until we find a CCS that proves initial adoption. For the first phase of the project, households received a flat rate as a precursor for Climate Credits.

Executive Summary

An adaptable approach to tackling household air pollution

In Nigeria, 94% of the population uses wood, charcoal, coal, or kerosene for cooking, done over open fires. 64,000 deaths are attributed to indoor air pollution each year.¹ Household air pollution continues to be a problem because of the hazardous emissions that affect human health and the environment. Black carbon is one such short-lived climate pollutant (SLCP) with a warming impact on climate 460-1500 times stronger than CO₂ because of how it absorbs light and heats its surroundings.² **Clean cooking solutions** offer a healthier alternative to the open fires heavily used in Nigeria, presenting a major opportunity to evaluate and scale viable options for rural communities in Nigeria.



Through this joint initiative, Nexleaf Analytics and Rural Women Energy Security (RUWES), with support from CCAC, set out to reimagine how we tackle household air pollution. Rather than focusing on changing deeply-entrenched and culturally-driven behaviors of local communities, we used data to understand household behavioral patterns (*adoption*) to guide the pilot and ultimately learn which cooking solutions are worth scaling up.

This pilot was designed to assess how data can determine the usability of different clean cooking solutions (CCS) in Nigeria as well as inform financial models that can help make clean cooking sustainable for the rural poor. The data discussed in this report is from the first phase of this program, which ran from April to October of 2019, and involved sensor-based monitoring of cooking behavior of 50 households on both clean cooking solutions (CCS) and traditional cookstoves (TCS). The sensor data was coupled with survey data to provide a richer picture of the complexity of cooking and to pave the way for adaptable approaches to a seemingly intractable problem.

¹ Clean Cooking Alliance. (n.d.) *Nigeria*. <https://www.cleancookingalliance.org/country-profiles/focus-countries/3-nigeria.html>. Access date: January 8, 2020.

² Climate and Clean Air Coalition. (n.d.) *Black Carbon*. <https://www.ccacoalition.org/en/slcp/bs/black-carbon>. Access date: March 26, 2020.

For this pilot, we followed the Stairway to Scale model. Stairway to Scale was designed on the principle that CCS should be tested for basic usability at the community levels (10 households) in any given setting before increasing gradually to larger distributions (100, then 1000) only when adoption is maintained and proven. The results of this pilot support the belief that a cautious distribution model is important. Had any of the low performing cookstoves been immediately distributed to thousands of households, the adoption would have likely been low, thus preventing climate and health impact. The intervention may also have been detrimental to women if their own financing were involved.

What about measuring air quality?

There is a history in intervention after intervention of issues with a stove's durability or likeability result in dropped usage over time. Based on these trends, we have determined that sustained adoption is a precursor to air quality improvements. Thus, the first two phases of this work are to find at least one CCS that will show sustained adoption. Once we find a CCS that women will love, then we will measure air quality improvements.

Project design: Phase 1

Our implementation method is guided by sensor-based data and enriched by survey data to help us understand the best solutions that will achieve the greatest impact.

Household selection

RUWES and Nexleaf selected 50 households in the Mararaba-Burum village in Abuja, Nigeria who would cook on five different CCS for the six-month pilot period. Based on their experiences and feedback, we could learn which CCS were best suited for expanded distribution into rural Nigerian homes. Following **Nexleaf's Stairway to Scale model**, each clean cooking solution was monitored in 10 households for a period of 6 months, for a total of 50 households participating in the first phase of the pilot.³



³ Nexleaf's Stairway to Scale Model is based on the principle of responsible scale, by establishing *sustained adoption* of a stove before large scale distribution. In this model, stoves are tested with increasing numbers of households, starting with 10 and increasing to 100, 1000, and 10000.

Selection of clean cooking solutions

The main motivation for evaluating CCS in the field was to merge two measures vital to the long-term actualization of SLCP mitigation: lab emissions of black carbon; and sensor-based field evaluation of *adoption*.

The five CCS were initially selected based on publicly-available emissions test results, results from prior pilots, as well as cost and the ease of after-sales service from manufacturers. The selected CCS use different types of fuels: biomass, ethanol, ethanol gel, and LPG. The intention behind the mix of stove types and fuels was to have a basket of solutions to evaluate and identify which ones led to the highest usage. A breakdown of stove types are in Table 1.

Table 1. Clean cooking solutions selected

Stove Type
Thermoelectric Generator (TEG) forced-draft biomass
Natural-draft biomass
Ethanol
Ethanol gel
Liquefied petroleum gas (LPG)

Sensor data collection

Stove use was monitored using Nexleaf’s Bluetooth-enabled sensor devices, **StoveTrace Trek**, which track changes in temperature as indicators of cooking (pictured right). Nexleaf trained Energy Entrepreneurs from the RUWES cohort on how to install the StoveTrace Trek devices on both the CCS and TCS (traditional cookstove). Cooking was monitored throughout the pilot period using Nexleaf’s data dashboard, **StoveTrace Analytics**.



Sensor data analysis

StoveTrace Trek devices were used to quantify cooking on TCS as well as CCS in order to understand the household's cooking behavior. Sensor data was analyzed using Python. In addition to hours of cooking and comparative cooking time on CCS vs TCS, sensor data was used to calculate **adoption**.

Qualitative surveying

At the end of the monitoring period, qualitative data was collected from households through structured interviews and survey questions regarding their preferences, experiences, lifestyles, and community involvement. Interviews were conducted by RUWES staff with the aid of 2 translators. Notes were transcribed into English before analysis.

Financing

The households received payments for their participation as a preliminary test of Sensor-enabled Climate Financing (SCF).⁴

The trade-offs between emissions and adoption of cooking solutions

The ideal result for this first phase would have been to find a CCS that reduces black carbon by > 70% and is adopted by 80% of households⁵. All the CCS selected for this phase reduce black carbon emissions by at least 71% (see Table 2),⁶ with the exception of one which didn't have readily available emissions data. In this case, the popularity of that CCS was enough to encourage field testing and to see if its high usage warranted additional lab testing. However, as seen in Table 2, **none of the CCS met the standard of 80% adoption**. The highest adoption rate in this pilot—66%—is substantially lower than our original target of 80%.

⁴ SCF is a model tested by Nexleaf in India which enables climate-based financing and payments based on objective data from sensors. The payment rate will be calculated using black carbon emissions reductions rates established by stove lab testing. SCF will be used in the second phase of the program as part of the stove financing model, using earned Climate Credits to offset the households' monthly loan payment. The reason for this is that until we evaluate the stoves for durability, we do not want to subject the households to a loan repayment.

⁵ 80% was landed on as a good standard based on prior projects in India. We published the considerations that led us to enact our standard—80% of households using the CCS in the most recent 60 days—in the report "Beyond Monitoring and Evaluation," accessible at <https://nexleaf.org/reports/joint-learning-series/beyond-monitoring-and-evaluation.pdf>.

⁶ These calculations were made based on the lab test done by Aprovecho or publicly available data on BC emissions rates, and then paired with Nexleaf's methodology to calculate % reduction, as published in *Nature Climate Change*, accessible at <http://rdcu.be/mddA>.

Table 2. Emissions reduction rate compared with average adoption rate by CSS

Clean cooking solution	BC reduction compared to three stone fire (Lab results)	Average adoption rate (Sensor data)
TEG forced-draft biomass	71.9%	62%
Natural-draft biomass	Pending lab report	66%
Ethanol	99.7%	7%
Ethanol gel	99.7% ⁷	14%
LPG	~99.5% ⁸	27%

In fact, some of the cleanest CCS in terms of black carbon emissions were some of the lowest adopted, ranging from 7%-27%. The results of LPG and ethanol are noteworthy because being considered cleaner energy sources than biomass, and globally, LPG is being distributed more widely through government mandates and subsidies.⁹ However, since biomass is free in this community, there is no cost or access issue there. Whereas, for liquid fuels such as LPG and ethanol, there is a major supply chain component that factors into adoption rates.

In our data analysis, we look at ‘adoption rate over time’ and ‘average daily cooking’ to understand cooking behavior. In both of these analyses, we separate biomass stove and liquid fuel stoves because different factors contribute to the adoption of each fuel, such as accessibility and cost of fuel. Figures 1-2 below compare adoption rates of biomass stoves and liquid fuel stoves, respectively.

⁷ The black carbon reductions for the ethanol gel stove are assumed to be the same as the other ethanol option.

⁸ LPG emissions reduction rate is derived from the emissions factor from “Evaluating the performance of household liquified petroleum gas cookstoves” published in *Environmental science & technology*. Using the LPG emissions factors from the paper and the emissions factor for the Nigerian regional tradition cookstove, 3-stone fire, we calculated the emissions reduction rate to be 99.5%.

⁹ Quinn, A. K., Bruce, N., Puzzolo, E., Dickinson, K., Sturke, R., Jack, D. W., ... & Rosenthal, J. P. (2018). An analysis of efforts to scale up clean household energy for cooking around the world. *Energy for Sustainable Development*, 46, 1-10.

Figure 1. Adoption for biomass stoves.

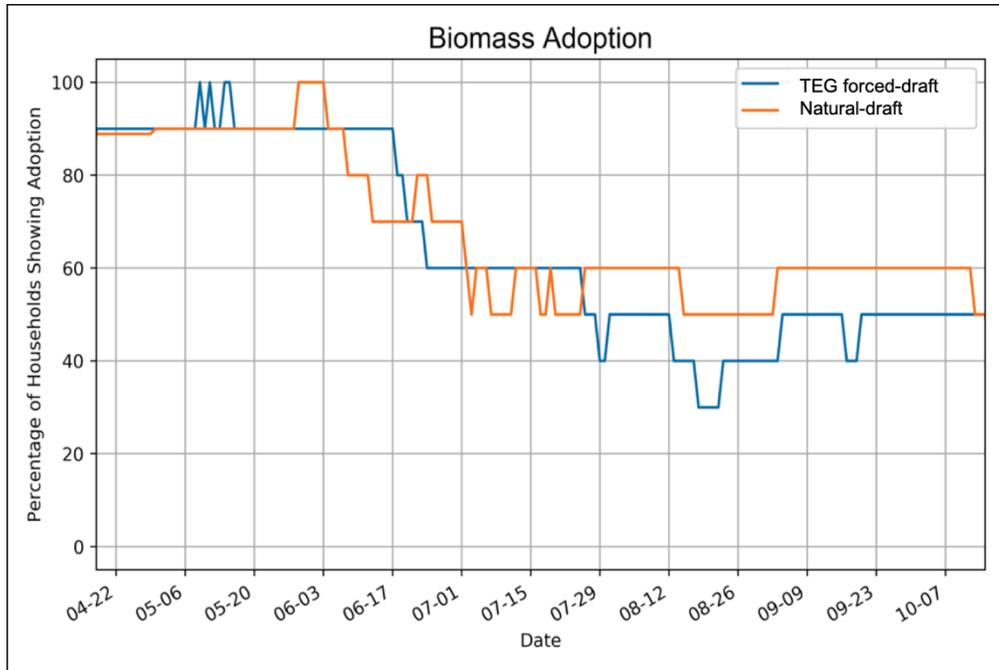
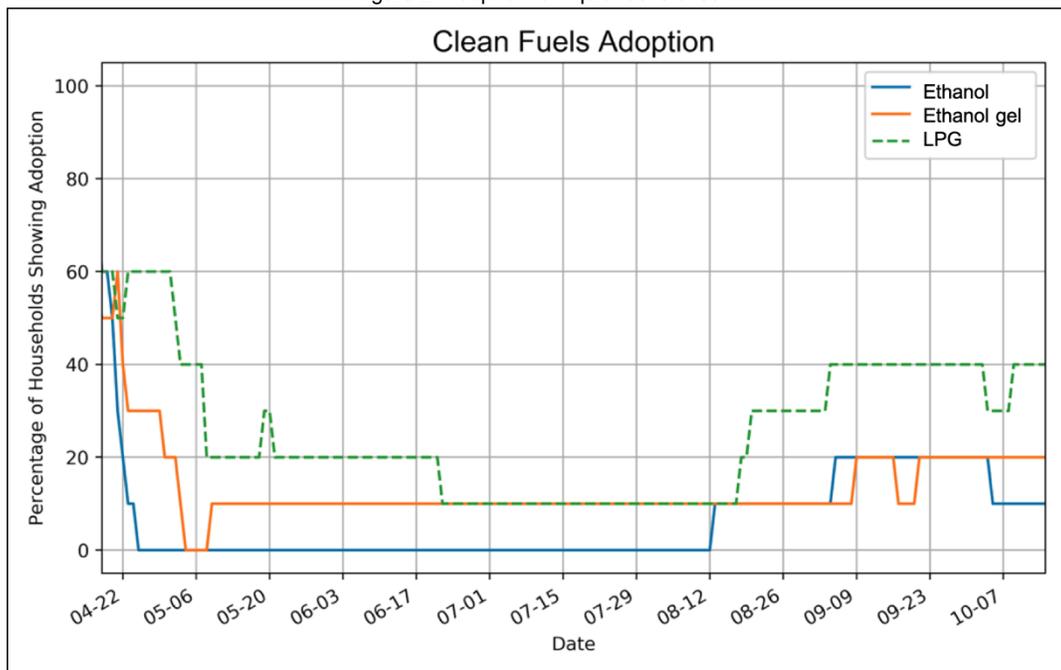


Figure 2. Adoption for liquid fuel stoves.

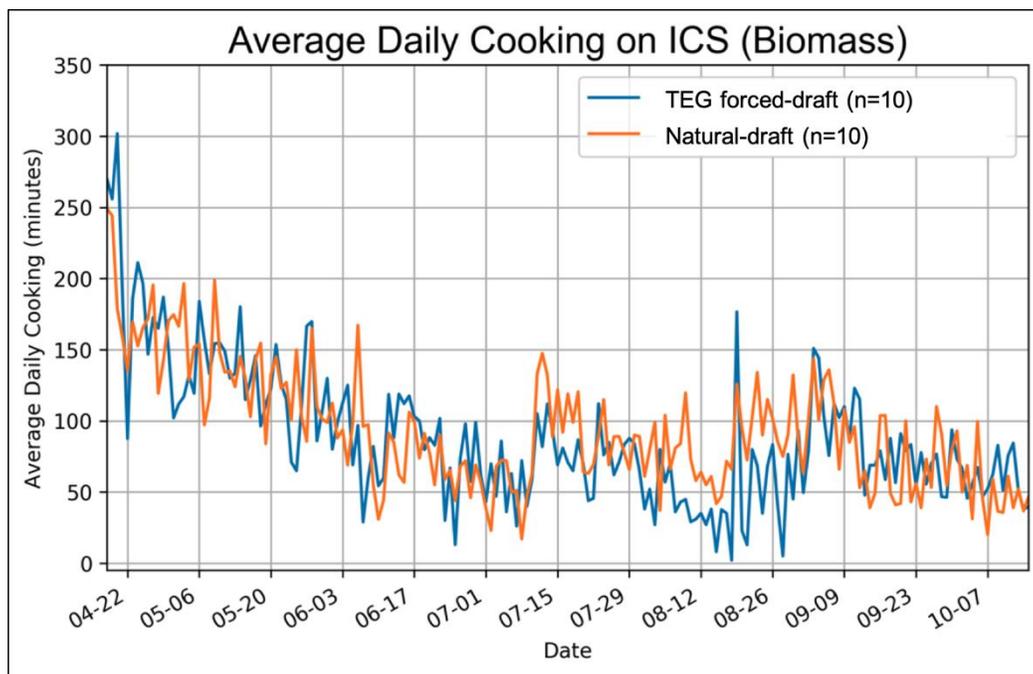


Listening to the data

Supply chain limitations

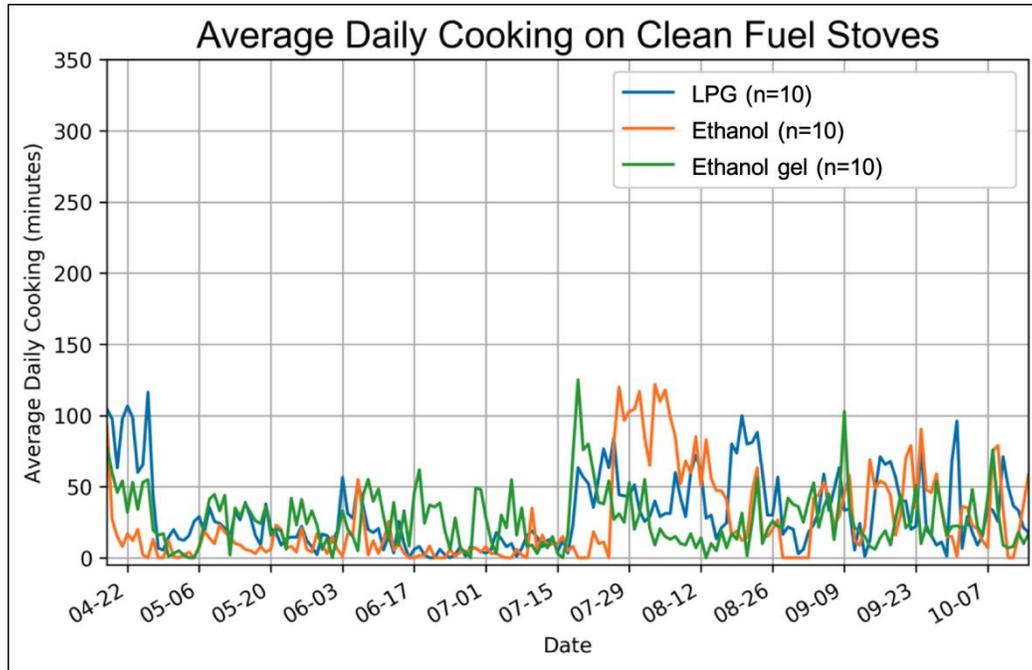
Across all CCS, the initial usage levels are very high, possibly due to the excitement of having a new piece of equipment and a fresh round of fuel. Over time, usage begins to decrease. With the biomass stoves, after the first week, we do not see daily cooking go beyond 200 minutes again. The liquid fuel stoves, however, are never used as highly as the biomass ones, with none of the stoves ever reaching above 150 minutes of average daily cooking, even during the initial peak.

Figure 3. Average daily cooking for TEG forced-draft biomass and natural-draft biomass. We can see slightly more usage for natural-draft biomass.



Initial adoption rates for the biomass solutions begin high enough to meet our standard of adoption for the first 6 weeks. Afterwards adoption drops to as low as 50% for natural-draft biomass and 30% for TEG forced-draft biomass.

Figure 4. Average daily cooking on liquid fuel solutions. LPG overall is more consistently used than other models.

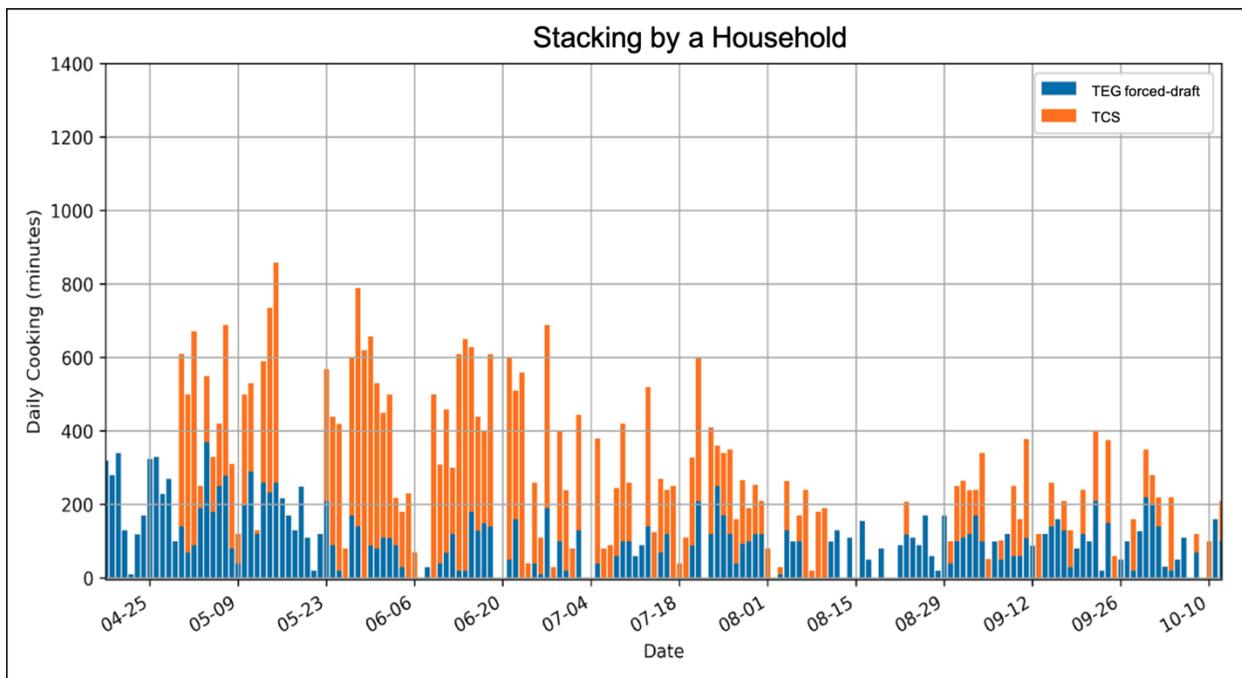


After it became apparent that fuel cost was a major barrier toward use among the liquid fuel models, a fuel subsidy was introduced in July. There is a clear increase in usage among liquid fuels around the time of the fuel subsidy; however, usage is not consistent (Figure 4). Mid-way through the project, in July of 2019, a subsidy was developed for the liquid-fuel solutions to serve as a fuel subsidy rather than a climate credit. This change to the financial incentive strategy was based on very low usage of the fuel-based solutions from sensor data accompanied by reports from households indicating they lacked the funds to purchase fuel to continue using the CCS. Households were paid based on the cost of fuel used rather than climate benefit.

Stacking

Nearly all households (98%) exhibited stacking behavior. Sometimes the CCS and TCS were used interchangeably, but often it appears they were used at the same time. This can be visualized in Figure 5, which shows daily cooking happening on both CCS and TCS. As described later from the qualitative data, it is possible that the CCS gives women the opportunity to be able to cook on two burners rather than one, which makes cooking more efficient. We also did not expect women to abandon their TCS within such a short period of time—the TCS has been their main source for cooking and lends itself to inherited cooking practices and recipes that transitioning to a different cooking method would take time and adjustment (see pg. 18 for more on how the households cooked on the CCS versus the TCS).

Figure 5. Example of a household exhibiting stacking behavior.
 Note: first few weeks of data only monitored CCS, which is why TCS data is not stacked above.



For this phase of the project, the solutions selected for monitoring were the household's pilot CCS (to gain an understanding of usability) and the household's TCS (for comparative cooking data and insight into overall cooking behavior). It should be noted that some households (13) responded that in addition to their TCS, they had another cookstove (mostly kerosene or charcoal) which was not monitored as part of this pilot. In these cases, we examined each household, the type of additional cookstove(s) and whether or not the household showed mitigated cooking on TCS. Households were split regarding this issue. 6/10 households who reported additional stoves showed significant TCS mitigation and 6/10 households showed low TCS mitigation. However, one household that showed low TCS mitigation specified that they abandoned their kerosene stove completely since the inception of the project.

It is important to note that without having sensor and qualitative data on how much households use their additional stoves and their general opinions about them, we can't draw conclusions on how additional stoves impact TCS mitigation. It seems feasible that if they enjoy their additional stove and CCS then, perhaps, they would stack those two instead of their CCS with TCS.

Understanding the Trade-offs between Adoption and Emissions

The under-acceptance of the ethanol and LPG solutions provide further evidence for the **importance of responsible scale** in cookstove interventions. While their cleanliness has the promise for tremendous impact in comparison to biomass solutions, the infrastructure surrounding those clean cooking solutions in rural areas is lacking.

Many clean cooking interventions focus on behavior change campaigns that encourage communities to accept the new cookstoves because of how much cleaner they are compared to the traditional cookstoves. However, those campaigns focus more on the emissions ratings rather than whether the cookstoves work for the households. **Scaling intentionally places the onus of success on the cooking solution itself rather than on women's ability to accommodate the product's shortcomings.**



Members of RUWES being taught to make mud *chulhas* (the regional cookstove in India) by local women in Odisha, India. The visit was part of the South-South Technology Exchange.

Adoption

The following plots (Figures 6-10) compare adoption of each CCS with that of the TCS side-by-side. In this case, we defined adoption as cooking 1 hour/day, but did not use a moving average with a 60-day window.

Figure 6. Adoption of TEG forced-draft biomass and TCS.

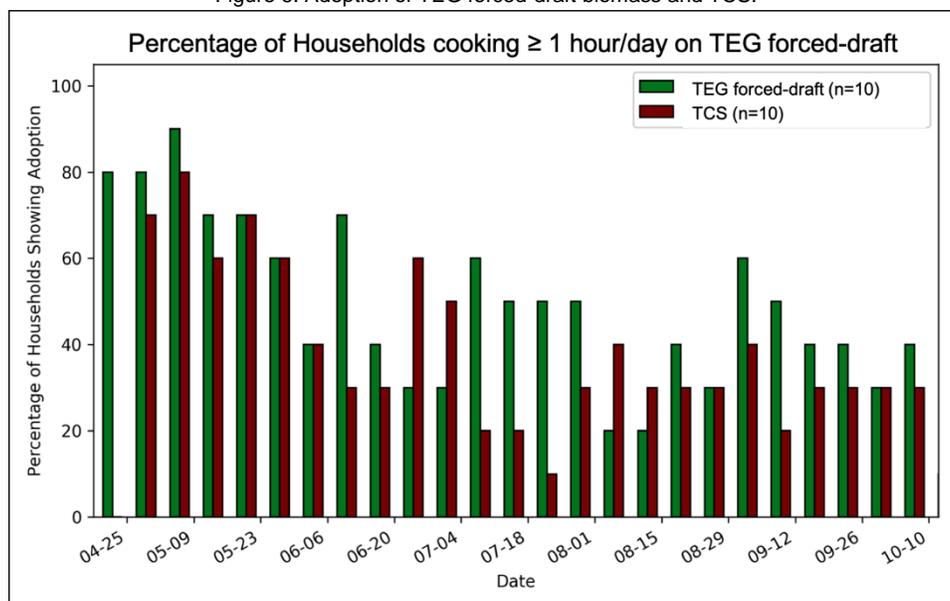


Figure 7. Adoption of natural-draft biomass and TCS.

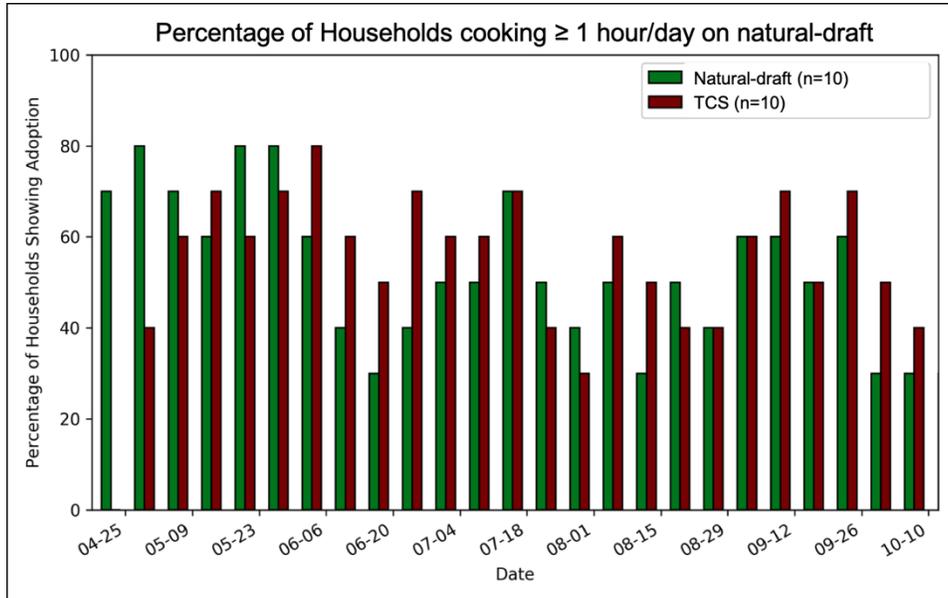


Figure 8. Adoption of ethanol and TCS.

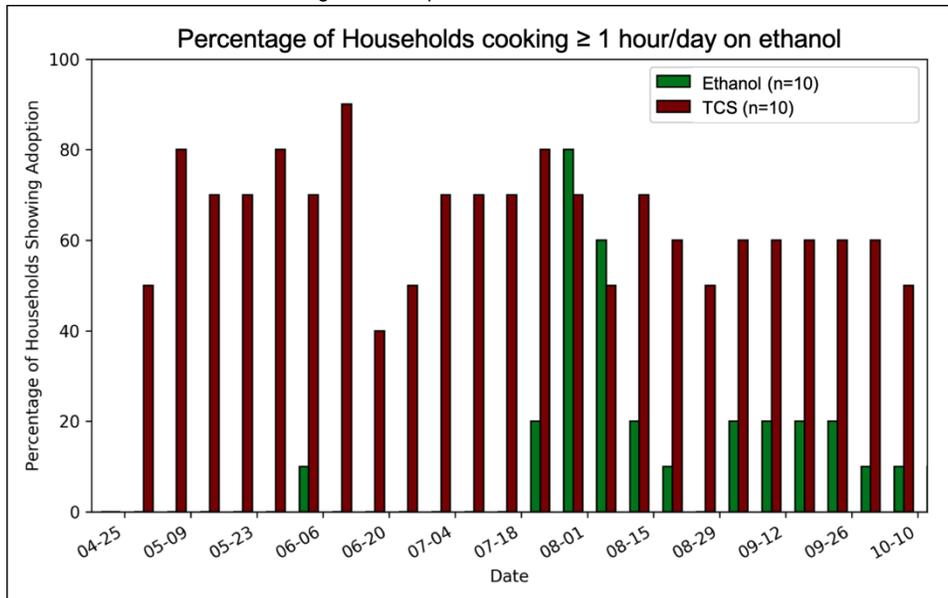


Figure 9. Adoption of ethanol gel and TCS.

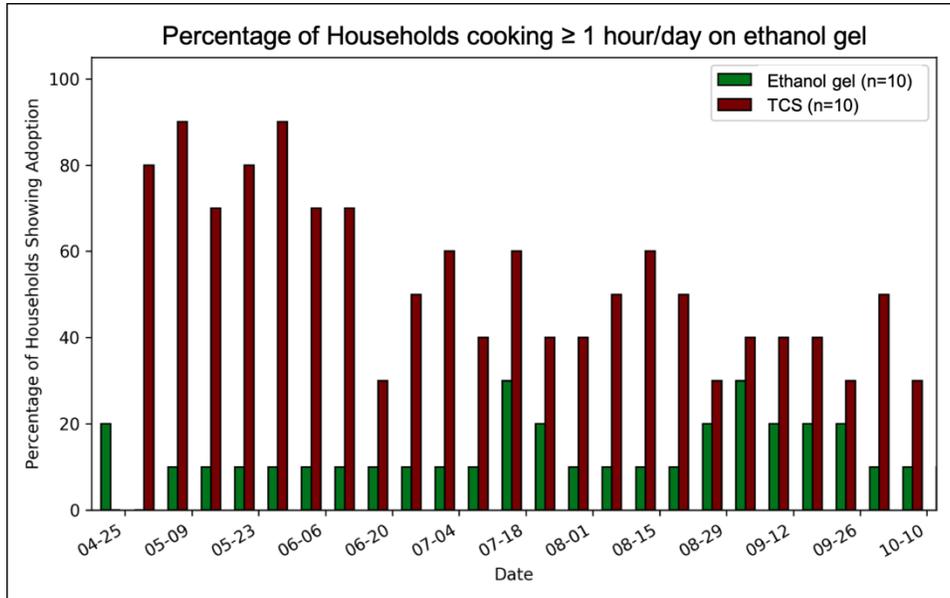
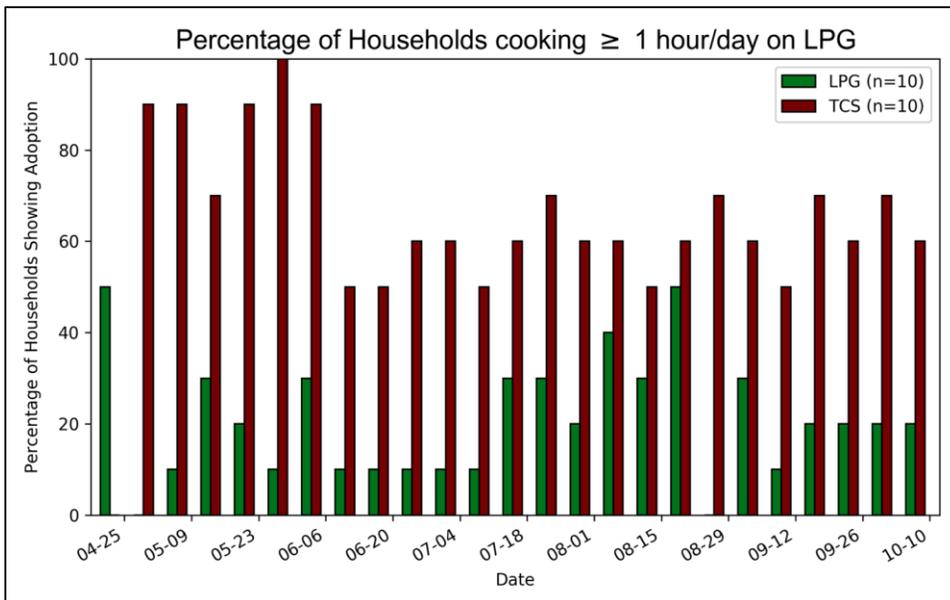


Figure 10. Adoption of LPG and TCS.



The Complexity of Cooking

The adoption results do not necessarily mean that 66% is low adoption—perhaps 66% is the highest we will see in the Abuja community. The standard of 80% adoption was developed during our investigations in India. Understanding that the Nigerian context varies greatly from the India context, the following section dives into the cultural complexities around clean cooking that affect and alter uptake of solutions. In this section, we lay out the drawbacks of the CCS that impeded their full adoption.

We surveyed households following the 6-month monitoring intervention to learn in-depth how they felt about the CCS. From this survey, we learned more about traditional cooking practices and socio-economic conditions. This section explores those findings to paint a clearer picture around the complexity of cooking, including:

- Considerations for market readiness based on willingness to pay for the solution
- Fuel cost and availability
- Culture of food
- Size: Capacity to cook meals
- Convenience: Two stoves are better than one

Pros and Cons

As part of the survey we asked a variety of questions, such as *What do you like about the stove?* and *What do you dislike about the stove?* and derived pros and cons from each. Table 3 lays out the associated feedback of each CCS. Please keep in mind that the pros and cons are opinions and not facts.

Table 3. Pros and cons by solution based on household feedback

Clean cooking solution	BC reduction compared to traditional cookstove (Lab results)	Average adoption rate (Sensor data)	Pros (Household interviews, opinions)	Cons (Household interviews, opinions)	% of HH that would take out loan (Household interviews, opinions)
TEG forced-draft biomass	71.9%	62%	<ul style="list-style-type: none"> • Lighting feature and ability to charge phone (70%) • Cooks fast (30%) 	<ul style="list-style-type: none"> • Too much smoke (30%) • It uses firewood (20%) • Too small (20%) 	50%

Natural-draft biomass	Pending lab report	66%	<ul style="list-style-type: none"> • Cooks fast (50%) • Can cook inside when it is raining (20%) 	<ul style="list-style-type: none"> • Too much smoke (50%) • Firewood has to be chopped into small pieces (30%) 	50%
Ethanol	99.7%	7%	<ul style="list-style-type: none"> • Cooks fast (60%) • No smoke (30%) • Can cook inside (20%) 	<ul style="list-style-type: none"> • Fuel doesn't last long and/or is too expensive (60%) • Too small (50%) 	30%
Ethanol gel	99.7%*	14%	<ul style="list-style-type: none"> • Doesn't require Firewood (10%) • Can cook inside (10%) • Doesn't emit smoke (20%) 	<ul style="list-style-type: none"> • Fuel doesn't last long and/or is too expensive (60%) • Too small (60%) • Doesn't cook food fast enough (30%) 	0%
LPG	~100%	27%	<ul style="list-style-type: none"> • Cooks fast (80%) • No smoke (70%) • Can cook inside (20%) • Accommodates larger pots (20%) 	<ul style="list-style-type: none"> • Fuel is too expensive (50%) 	90%

Each solution received some form of positive feedback, but we can see even if people express positive attributes about each model, it does not impact the adoption rate. Interestingly, LPG received the least negative feedback; however, quantitative sensor data shows that biomass outperforms liquid fuel models. The variability in correlation between liking the CCS and its usage highlights that qualitative data gathering alone cannot provide a full picture of adoption.

Considerations for market readiness based on willingness to pay

“Not likely at all [to take out a loan for the TEG forced-draft biomass] because of the difficulty I face in fetching and using firewood, unless of course if it is the LPG, I'll be very willing to repay a loan on such a stove.” – Top user of TEG forced-draft biomass

One important finding from this pilot is that usability of a solution is not a direct indicator of the household's willingness to pay for that solution. Willingness to pay is a usable indicator for developing marketing plans and avenues for sales. Sensor data showed biomass solutions had the greatest adoption, at over 60%. However, qualitative survey data shows that the general perception of the biomass solutions was mixed, and only 50% of households expressed willingness to take out a loan. All top three users of TEG forced-draft biomass responded that they would not take out a loan for it, as shown in the quote above from the highest TEG forced-draft biomass user.

In contrast, LPG had less than 30% adoption, thus ranking the solution below both biomass solutions in terms of usability. The feedback on LPG was overwhelmingly positive, however, with the only negative comment being the price of the fuel, and with 9 out of the 10 households expressing willingness to take out a loan. The acceptance of the household is therefore inconsistent with their expressed value of the CCS. This inconsistency is important to potential interventions because **high rates of cooking might not necessarily translate into a purchase and vice versa**. The particular inconsistency between LPG perception and behavior is worthy of further study assessing possible social and cultural reasons for its high attractiveness despite the known disadvantages of high cost of fuel.

While the response to a single, hypothetical question about willingness to pay should not be overemphasized, the response here has significant implications for financial model design. It may be that improved biomass solutions would have the greatest impact on household cooking habits, but households may be unwilling to invest their own resources in acquiring these options. In contrast, LPG may initially be more successful in being distributed to households due to their popularity and perceived value, but may ultimately not have the desired impact if use remains low.

Fuel Cost and Availability

“The fuel doesn’t last. Like if I purchase 1 canister, and I cook rice and beans just once, the fuel will finish.”

“I never used it . . . for like a month now, because myself and children have been sick, and there isn’t money to treat ourselves adequately let alone purchase fuel.”

“I use my CCS only when I’ve the fuel available or purchased, but other than that, I use my TCS frequently.”

The data from LPG and other liquid fuels shows that fuel cost is a significant barrier to adoption. As described above, LPG was overwhelmingly popular according to the interview data, but its adoption rate was less than half of that of the biomass solutions. Interview data consistently indicated fuel cost as the reason for this lack of adoption, with respondents commenting on fuel costs both in their general feedback and as a direct factor in their decision on which to use. When asked what foods they had cooked on their CCS in the last 3 days, many replied that they had not used the LPG CCS in the last 3 days as they had not resupplied their fuel for a long time.

This relationship between fuel cost and adoption is reinforced by the sensor data, which shows a clear increase in adoption after the fuel subsidy was introduced in July (see Figures 1-2). Even this subsidy was not enough to lift liquid fuel use above a minimal level, with LPG reaching only 27% adoption by the end of the pilot, and the two ethanol solutions remaining at 7% and 14%. Table 4 shows survey responses regarding whether acquiring fuel prevents them from using their CCS with adoption rate.

Table 4. Percent of households that do not use their CCS because of fuel supply compared with adoption rate.

Clean cooking solution	Percent of households that do not use their CCS because of fuel supply	Adoption rate
TEG forced-draft biomass	10%	62%
Natural-draft biomass	30%	66%
Ethanol	40%	7%
Ethanol gel	40%	14%
LPG	40%	27%

We can see that the percentage of households that do not use their CCS because of fuel supply is higher for the liquid fuel solutions. Those who were concerned about biomass fuel supply mentioned that they didn't like using wet wood because it smokes too much and that chopping wood into small pieces was burdensome.

The Culture of Food

"I cook Tuwo¹⁰ on my TCS because of the stress and issues that come with cooking it such as turning the food while on fire and how long it takes to be done."

"Tuwo masara, because I cook tuwo masara in large quantity and I use a big pot in the process which cannot fit in my CCS."

"Because I use a big pot that cannot be placed on my natural-draft biomass, also because the tuwo is not easily turned on the natural-draft biomass."

The households were asked what foods they had prepared on each CCS in the previous 72-hour period. Table 5 shows the foods named and frequency that they are mentioned for each CCS, compared with the adoption rate.

¹⁰ Tuwo is a soft and sticky dish prepared from either local rice, maize or millet, common in northern Nigeria.

Table 5. Recently cooked food and frequency compared with adoption rate.

Clean cooking solution	Foods cooked (frequency)	Adoption rate
TEG forced-draft biomass (9 different foods)	Boiling water (3) Fried wara (2) Soup (2) Potatoes (1) Tuwo (2) Pap (1) Rice (4) Indomie (1) Egusi (1) Okro (1) Yam (2) Masara (1)	62%
Natural-draft biomass (10 different foods)	Soup (3) Noodles (4) Rice (6) Boiling water (1) Moi moi (1) Pap (1) Indomie (1) Potatoes (3) Tuwo (1) Beans (1) Stew (1) Kuno (1)	66%
Ethanol (6 different foods)	Boiled potatoes (1) Soup (4) Rice (3) Yam (2) Pap (1) Small tuwo (2)	7%
Ethanol gel (4 different foods)	Rice (3) Potatoes (1) Soup (3) Yam (1)	14%
LPG (9 different foods)	Soup (6) Yam (3) Rice (6) Moi moi (1) Tuwo rice (1) Beans (1) Boiling water (1) Tuwo (2) Pounded yam (1)	27%

<p>TCS (17 different foods)*</p> <p>*Note: Sample size for TCS is higher (50)</p>	<p>Tuwo (38) Rice (18) Beans (32) Yam (25) Soup (6) Okro (9) Sweet potato (6) Egusi (3) Vegetables (4) Ogbono (1) Pounded yam (2) Boiling water (5) Wara (1) Akamu (1) Apu (1) Daawadawa (1)</p>	<p>N/A</p>
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CCS with higher adoption rates have correspondingly more responses from households and a greater diversity of foods cooked. Both the ethanol and ethanol gel have less foods that are cooked on them and received a lot of responses about not being able to cook on them because of fuel.

From these responses, there is a strong preference to prepare specific foods on the TCS. *Tuwo* is named as a food that can only be prepared on the TCS according to most households, as well as beans and rice in many households. *Tuwo* is a staple food that requires vigorous stirring: stirring which cannot be done on an CCS because of the more delicate balance of the pot on the CCS. Beans and rice are also often (though not always) preferred on the TCS because it takes longer to cook. These longer “cook-time” foods can be prepared passively on the TCS while the accompanying sauces (“soup” in the survey data) are prepared simultaneously on the CCS. These staple foods are also often cooked in large quantities on especially large pots which only fit on the TCS, though there is significant variability in pot sizes cooked on CCS according to pot size surveys.

Pot size was named as a factor when describing foods cooked on specific CCS: some foods such as *tuwo* are commonly prepared with especially large pots, which do not fit on CCS. Households were also asked about pot size specifically, and respondents’ pots were measured, see Table 6. 41/49 (83.7%) of households said that they differentiate the pots they can cook on the CCS based on size and 28/49 (57%) households said that this causes them to use their TCS over the ICS.

Table 6. Average pot size of each solution compared to adoption rate.

Clean cooking solution	Average pot size	Adoption rate
TEG forced-draft biomass	2.9	62%
Natural-draft biomass	3.2	66%
Ethanol	2.6	7%
Ethanol gel	2.3	14%
LPG	3.9	27%

Detailed measurements were taken from pots used on both the CCS and TCS. The number of pots that the household used on the CCS and TCS were recorded as well as measurements of height (cm), circumference (cm), diameter and weight (kg). Depending on these values, pots were classified by size ranging from 1-20. The largest pot size observed to be used on a CCS was classified as 10. Measurement data showed that 43/49 (87.8%) of households use smaller pots on their CCS and larger pots on their TCS. We can see that the two with the lowest adoption rate, ethanol and ethanol gel, also have the smallest average pot size.

Convenience: Two Stoves are Better than One

Before the CCS was issued to me I did find it difficult to cook 2 foods at a time. And during the rainy season, I can always use my natural-draft biomass to cook indoors with ease.

The sheer convenience of having two options for cooking was a strong theme that came up in response to multiple questions in the interviews. This qualitative data was corroborated by the sensor data which shows that almost all households, even those who have high adoption rates of their CCS, exhibit *stacking* behavior. Across different types, even those that were less popular and with lower adoption rates, there was clear value placed on simply having a second option to both speed up the process of cooking and make cooking more pleasant and convenient during inclement weather (as many three stone fires are located outside). Of the 50 households in the study, 35 reported using their CCS and TCS concurrently for certain meals.

This convenience factor could explain why adoption was so high on the biomass solutions despite the relatively low reported willingness to take out a loan and relatively high negative feedback: simply having *any* additional cooking option presents a significant improvement to women's ability to cook. In order to separate the combined factors of convenience and food preference, future studies should experiment with the introduction of 2 clean cooking solutions or a 2-burner option and assess their impact on traditional cookstove use and stacking.

Conclusions and Future Work

The benefit of scaling responsibly and data transparency

“Some think their stoves aren’t okay for their cooking needs, and would have loved to have another type. For instance, some women using the improved wood stoves would say they prefer to have been issued with LPG stove, whereas some women that were even given the LPG stove would say they wished that they were issued with the improved wood stoves so that they could easily fetch firewood from their farmland and use for free without the financial stress of having to refuel their gas cylinder every now and then.”
- Ethanol Stove user

A key learning from the project is about the complexity of scaling clean cooking impact. The quote above captures the complexity we grapple with as project leaders. The findings of this pilot have implications for how success is defined for clean cooking interventions in rural Nigeria as well as how clean cooking program design can better meet women’s needs. As the quote above demonstrates, all CCS present advantages and disadvantages, and women’s choices and perceptions take into account both cultural and pragmatic factors.

The results from this project provide evidence that the clean cooking sector operates on assumptions that need to be challenged in order to find cooking solutions that actually meet women’s needs. This study shines a light on the reality on the ground rarely explored—the combination of sensor and survey data provides a richer picture of regional cooking, and helps outline new approaches. We can see this as an opportunity to explore potential avenues for innovation in the clean cooking sector and in intervention design:

- **The assumption that the introduction of a single, well-designed CCS will result in high adoption and eventual displacement of traditional cookstoves is not supported by the findings of this project.** Our qualitative findings indicate that large pot size and common food preparation practices, along with the sheer convenience of having more than one option, present substantial reasons for women to continue the use of their traditional cookstoves.
- A market should exist for CCS designed for Nigerian cooking practices (to accommodate the heavy stirring of *tuwo* or the large pot size).
- Future interventions should explore the idea of a “clean stack,” giving women multiple clean options for cooking, as a more realistic potential path to achieving TCS displacement. It is not realistic to expect a single CCS to provide enough of a reason for a woman to stop using her traditional fire, especially when the convenience of multiple cooking options is so appealing.

It is by examining long term use of all CCS distributed that we can attempt to capture the complexity of CCS adoption and adapt interventions to meet household preferences preemptively. We all wish for a silver bullet solution or a triumphant design feature. However, expecting one solution to be the ‘superstove’ and achieve global scale is unlikely to happen as the needs and cooking habits vary greatly based on regional context. The qualitative feedback we’ve collected helped us unravel some of the complexity around cooking and begin to outline the multidimensional aspect of pulling together a ‘basket of solutions.’ When examining the data closely, we see that the only option that does justice to the local communities is to embrace the complexity and scale up what is best for that specific context.

There are limitations to the conclusions that can be drawn from this general feedback due to the nature of the question and format of the project—many households responded that they viewed the CCS as a gift, which might have compelled them to give more positive feedback. The TEG forced-draft biomass in particular is complex to evaluate, as some of the most common feedback pertained to the lighting and phone charging features rather than its function for cooking.¹¹

The next phase of this pilot project will focus on evaluating a financial model for clean cooking. Based on the adoption data from this first phase as well as criteria for black carbon emissions reduction, the TEG forced-draft biomass and LPG solutions have been chosen to test with this model. While both had imperfect results in this first stage, we anticipate that the next stage will continue to contribute towards our understanding of how clean energy interventions can better meet women’s needs as well as what assumptions should be challenged in the process.

Without objective data, we would not have been able to look at the trade-offs between all of these solutions. While ethanol was a tempting option for Nigeria since it is produced locally and is very clean, this project demonstrated that ethanol is not adoptable in Abuja and should not be scaled up. Clean cooking has the potential to alleviate serious environmental and health challenges that afflict everyone alike. However, until we begin to value rural communities as the focal points of clean cooking, the sector will continue to keep coming up short of its intended goals.

¹¹ It is not possible to tell from these responses alone how much the lighting and charging features affect household’s use of the stove, and if households are ever using the stove exclusively to charge or provide lighting, which would negate its climate benefits. Additional studies using sensors, qualitative methods, and observation are needed to assess if stoves with thermoelectrical generators (TEG) are used in this way.