Implementation and scale-up of a biomass pellet and improved cookstove enterprise in Rwanda

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Abstract

This paper reviews the experience of a for-profit firm in Rwanda promoting biomass pellets and a fan micro-gasification improved cookstove as a clean cooking alternative to charcoal. Consumers purchase locally produced biomass pellets and receive the improved cookstove on a lease basis. The cost of the pellets and stove(s) is lower than the cost of cooking with charcoal in the urban setting where our study takes place. Inyenyeri has been piloting its business model since 2012. Using data from an ongoing quantitative impact evaluation study, focus group discussions, and a series of key informant interviews, we chronicle the firm’s experience with stove choice, pellet production, and marketing, highlighting lessons for the design of private sector led clean cooking interventions.

We find that 38% of households marketed to as part of our ongoing impact evaluation study adopted the pellet and stove system, but that approximately 45% of those who adopted suspended contracts after signing up. The firm’s experience with stove choice, pellet production, pricing structures, and customer service strategies have influenced implementation, adoption rates, and scale-up. Customer preferences for specific stove attributes and willingness of stove manufacturers to modify stoves for local conditions have influenced both the firm’s choice of stove and customer satisfaction. In 2015 the firm transitioned customers from the Philips stove to the Mimi Moto, a decision which created confusion among consumers, and affected adoption rates. Despite the challenge of establishing and scaling-up pellet production in central Africa, the firm increased production 400% between 2014 and 2017 to reach 800,000 kg/year. Importing and maintaining pelletizing equipment in Rwanda is costly, the supply of feedstock, and undercapitalization of the

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firm have affected production. With respect to marketing, after experimenting with a sign-up fee and a minimum monthly purchase of pellets, the firm has decided to transition to a pay-as-you-go system to reduce perceived risk by consumers. A high-level of customer service including in home visits, free in-home repair, and home delivery of pellets are major innovations. The long pilot phase and the evolutionary nature of the firm’s activities illustrate both the complexity of building a market for clean cooking, and the time required to understand nascent markets and consumer demand.

Keywords
Africa; Cookstoves; Household air pollution; Implementation science; Renewable energy; Solid fuel

1. Introduction

Over 81% of households in sub-Saharan Africa use solid fuels (e.g., dung, crop residues, fuelwood, and charcoal) for cooking (World Bank 2015). The use of solid fuels in inefficient traditional stoves contributes to household air pollution (HAP), the largest global environmental risk factor for disease burden (Forouzanfar et al 2015). According to World Health Organization estimates, between 2000 and 2030, there will be 8.1 million premature deaths among children and 1.7 million premature deaths among adult women in sub-Saharan Africa attributed to exposure to HAP from cooking (World Bank 2015).

Rwanda provides an excellent case study for the challenges that lie ahead for mitigating HAP in Africa. Lower respiratory infection is the leading cause of total years of life lost due to premature mortality (GBD 2017). With 483 persons per square kilometer, Rwanda is Africa’s most densely populated country. The total population is expected to increase from approximately 11 million in 2016 to 16.9 million in 2032. Rapid growth is coupled with a rapid urbanization; urban dwellers will double from approximately 15% to 29% by 2030 (GOR 2016; NISR 2017). Meeting demand for energy services for this dynamic and growing population is a major challenge. The delivery of clean, accessible, affordable, and sustainable energy for cooking is a pressing issue.

Nearly all (99.7%) of Rwanda’s household cooking energy comes from solid fuels, with firewood being the dominant cooking fuel (95.7%) in rural areas, and charcoal (50.1%) and firewood (45.4%) the major fuel sources in urban areas (World Bank 2014; Ndegwa et al. 2011). Rwanda has one of the highest rates of non-renewable biomass utilization globally; the fraction of non-renewable biomass consumed by households exceeds 50%, implying considerable pressure on remaining forest resources (Bailis et al. 2015). The Rwandan government’s Economic Development and Poverty Reduction Strategy II (EDPRS) prioritized reduction of woody biomass energy consumption from 94% in 2009 to 50% by 2018 (Government of Rwanda 2016).

At the same time, markets for clean cooking technologies are limited. In 2013, over 50% of stoves in the Rwandan improved cookstove (ICS) market were basic (i.e. offering only modest gains in combustion efficiency) using charcoal and fuelwood as input fuels. Only
0.3% of the ICS market were stoves that could accommodate modern fuels such as liquefied petroleum gas (LPG), electricity, alcohol-based fuels or biogas (World Bank 2014).

Rwanda has been a testing ground for several clean cooking initiatives. Between 2010 and 2012, the Government of Rwanda Energy, Water and Sanitation Authority in partnership with Dutch SNV encouraged rural households to use the locally produced clay improved fuelwood cookstove (the Canarumwe, and urban households to use the locally produced charcoal ICS (Canamake). In 2014, in a major government initiative, the Ministry of Health and environmental health technology suppliers Del Agua, in formal agreement with EcoZoom freely distributed 300,000 wood rocket stoves (EcoZoom Dura) and advanced water filters to cash-constrained rural households (World Bank 2014). This effort, financially backed through the Clean Development Mechanism, failed to generate sufficient funds through carbon finance to sustain the program. As a result, efforts to bring the program to scale failed (World Bank 2014, 2015).

The challenges of high burden of disease from HAP, population growth rates and associated pressure on resources, and latent demand for modern energy services requires considerable innovation in marketing models and public policy to support the clean cooking sector. Specifically, innovation is required in the supply of sustainable clean fuels, and in access to affordable clean cooking technologies. The household energy sector is guided by the Rwanda Energy Policy, Energy Sector Strategic Plan, and Rwanda specific targets under the rubric of the global Sustainable Energy for All (SE4ALL). Ensuring the consistent supply and sustainable use of woody biomass for fuel is one of the major challenges Rwanda faces in achieving SE4ALL goals. Together, these programs have the following objectives: (a) bridge the 20% gap in biomass energy production and consumption towards a sustainable solution; (b) by 2030, all Rwandan households should use more efficient cookstoves than currently in use; (c) charcoal losses should be reduced by 30% in 2018 from the 2009 baseline through use of improved technologies and enhancements in its value chain; and (d) advancement of substitute cooking fuels including biomass pellets, biogas digesters, and LPG (GOR 2016).

Quick analysis of the scope of the problem and proposed timelines and progress to date suggests that the Government of Rwanda will not meet the stated targets. Innovative business models supporting development of the clean cooking sector are urgently needed.

1.1 Inyenyeri A Rwandan Social Benefit Company, Ltd.

Inyenyeri describes itself as a ‘social benefit company’. This type of private sector entity combines the qualities of traditional for-profit company and non-profit/NGO charters to create a hybrid entity ideally suited to social enterprises. Inyenyeri has been operating in Rwanda since 2011. The Inyenyeri model couples the sale of locally produced biomass pellets with the lease of one of the cleanest burning biomass cookstoves. Inyenyeri currently leases a fan micro-gasification cookstove called the Mimi Moto™ which has been evaluated in a laboratory setting as an International Workshop Agreement (IWA) Tier 4 stove (CSU 2015). At present, the Inyenyeri model involves having customers sign a contract to purchase a supply of biomass pellets and receive the stove or stoves, on a lease basis. Pellets are produced in a pelletizing factory on the shores of Lake Kivu from sustainably sourced...
biomass feedstock (e.g., eucalyptus trees and branches). Inyenyeri focuses on marketing the pellets because fan micro-gasification stoves are far too expensive for almost all Rwandan households. By pricing pellets competitively with charcoal, households can adopt cleaner fuels and technologies at a cost on par or below the cost of their baseline household cooking system. As part of their business model Inyenyeri offers free delivery, training, repairs, and replacement of stoves.

Inyenyeri is located in Gisenyi, Rubavu District (Figure 1) in northwestern Rwanda. Gisenyi is Rwanda’s fifth largest city with a population of over 83,000 people (World Population Review 2018). Inyenyeri chose Rwanda for its operations due to the pressing need for clean cookstoves and more efficient biomass fuels in-country, and due to the relative ease of doing business.

During the past 5 years Inyenyeri has continuously updated its business model, has used different improved cookstoves, experienced challenges with sustaining the quantity and quality of pellets needed to grow its customer base, and experimented with its’ marketing model. The aim of this article is to highlight what Inyenyeri has learned, the constraints it has faced, and how it has evolved and innovated. Inyenyeri’s experience is critical to understanding the potential for a sustainable biomass solution to be brought to scale in the region.

2. Methods, Sources and Approach

Several data sources were used for this study including data from an ongoing impact evaluation, a series of focus group discussions, and interviews with Inyenyeri staff.

2.1. Impact Evaluation

To provide data on rates of adoption and sustained use, and to provide contextual information on drivers and barriers to adoption we use data from baseline (2015), first midline (2016), and second midline (2017) data collections of a large household-level (N=1,462) randomized controlled trial in Gisenyi, Rwanda (Jagger et al. 2018 In review; Das et al. 2018). For this study, 1,500 households were randomly selected from the total population of households in 22 neighborhoods in Gisenyi where Inyenyeri planned to expand its operations. Households were then randomly assigned to treatment (N=1,000) or a delayed entry control group (N=500). The ‘treatment’ was being marketed to by Inyenyeri at neighborhood-level cooking demonstrations and through leafleting. Some households were visited by an Inyenyeri customer service representative who provided an in-home demonstration of cooking with pellets and an improved cookstove and explained and answered questions about the Inyenyeri contracting and payment plan. Baseline (2015) and endline (2018) surveys include the full sample of 1,462 households and involve a structured household survey and 24-hour monitoring of carbon monoxide exposure of the primary cook.

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1The IWA framework rates cookstoves on four indicators (efficiency, indoor emissions, total emissions, safety), each along 5 Tiers (0: lowest performing to 4: highest performing). For each indicator, the Tiers boundaries are defined by quantitative values determined by laboratory testing. The WHO Guidelines for Indoor Air Quality stipulate that only Tier 4 stoves are have low enough emissions to mitigate burden of disease associated with household air pollution (GACC, 2018).

2The Mimi Moto stove is sold in Zambia by Emerging Cooking solutions for US$140.
in the household. Greater than 90% of households use charcoal as their primary fuel at baseline.

A sub-sample of randomly selected households (N=180) nested within the broader sample of 1,462 was selected for the midline 1 and midline 2 data collection efforts. We conducted an intensive analysis of HAP related health symptoms, accident and injury, and analysis of socioeconomic impacts of adoption of pellets and the improved cookstove. We also undertook repeated measures of personal exposure to carbon monoxide (CO), fine particulate matter (PM$_{2.5}$), polycyclic aromatic hydrocarbons (PAHs), and objectively measured stove use monitoring. Households within the 180 household sub-sample fall within the treatment group.

In 2016, 30 households from the sub-sample were involved in a qualitative study of drivers and barriers to adoption and sustained use of Inyenyeri pellets and stoves.

### 2.2. Focus Group Discussions

For this study we supplement the ongoing data collection described above in Section 2.1 with data collected during focus group discussions in June 2017. We purposively selected five neighborhoods from among the 22 impact evaluation study neighborhoods. In addition to neighborhood leaders, social affairs leaders, and community health workers, our focus groups had representatives from savings and credit cooperatives, agricultural groups, artisan groups, moto-taxi groups and churches. Discussion guides included questions related to community projects and activities, household- and community-level drivers and barriers to adoption of clean fuels and improved cooking technologies, a series of targeted questions about Inyenyeri’s pellet/improved cookstove package, community involvement with Inyenyeri’s marketing process, and impressions and experiences with Inyenyeri and other non-government or private household energy programs. Guides were first developed in English and translated into Kinyarwanda. We trained one Rwandan research assistant to conduct focus group discussions. Focus group discussions were conducted in neighborhood community centers; the research assistant took notes in Kinyarwanda and later translated them into English.

### 2.3. Key Informant Interviews

We conducted structured interviews with Inyenyeri staff. We interviewed Inyenyeri’s marketing staff and customer service representatives with the aim of understanding Inyenyeri’s pricing mechanism, changes to the marketing plan during program roll-out, barriers and drivers of adoption and sustained use, implementation of the program and maintenance of customer base in the face of pellet production constraints and plans for scale-up. We also interviewed staff at the Inyenyeri pellet factory to gain insight into the stages of the pellet production process, quality control; constraints in the pellet production process, repair and maintenance of infrastructure, production trends over the last five years; and plans to overcome pellet production limitations in the long-run. We visited Inyenyeri’s rural feedstock collection hubs and pellet production factory and interviewed staff in those facilities. Finally, to supplement our data on take-up collected in 2016 and 2017 for the sub-sample of 180 households, we worked with Inyenyeri staff to determine the customer status
of the other households in our treatment group. Key informant interviews were conducted in the staffs respective offices; notes were taken in English.

The study was reviewed and approved by the Internal Review Board at the University of North Carolina at Chapel Hill, and by the Rwanda National Ethics Committee and the National Institute of Statistics of Rwanda.

3. Inyenyeri Timeline and Summary of Activities

Table 1 provides a timeline and summary of the number of customers, details of different stoves used, experience with pellet production, pellet prices relative to charcoal prices, an overview of contract terms, and the evolution of Inyenyeri’s customer service model.

4. Adoption

Adoption rates within our randomized controlled trial study group are presented in Table 2. From the full sample of 1,101 treatment group households, we subtract the households lost from the sample due to attrition (25%)\(^3\), and consider adoption for the 875 households remaining in the study group in 2017 (far right column Table 2). Overall, 38% of treated households (i.e. those who were marketed to by Inyenyeri), adopted the pellet/stove household energy system. Twenty-two percent of households adopted and remained customers and 17.1% adopted and then suspended or terminated their contract. An additional 32% signaled interest in signing up for Inyenyeri but had not done so as of June 2017. The most common reasons cited for not signing-up are lack of funds to pay the sign-up fee, inability to pay for fuel in one monthly payment, and preference for purchasing fuel in smaller quantities. We observe similar trends for our subsample of 180 households more intensively studied (see columns 2 and 3 in Table 2).

Including households that fall within our study, Inyenyeri’s urban customer base grew from about 400 households in 2014 to approximately 1,800 households in 2017. The firm has plans to scale-up to 20,000 new customers by the end of 2018 by adding 12,200 new households in Rubavu District and 3,000 households in Nyabihu District. With support from the United Nations High Commission for Refugees, the Belgian government, and the Ikea Foundation, the firm is piloting pellets and Mimi Moto stoves with 300 households in Kigeme Refugee Camp in southern Rwanda, with plans to scale up to 3,800 households by the end of 2018. The firm is also exploring the Kigali market with plans to enroll 1,000 households in 2018.

In the sections below, we discuss in detail Inyenyeri’s experience with different improved cookstoves, pellet production, and development of their marketing model over the period 2012-2017. These three dimensions of the household energy business influence adoption rates and plans for scale-up.

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\(^3\)High rates of attrition are due to the urban nature of our sample and the location of Gisenyi on the border with Goma, Democratic Republic of Congo.
5. **Stove Choice**

Inyenyeri’s initial pilot activities involved the Lucia\(^4\) (2012) and Champion\(^5\) (2013) (top-lit up draft or TLUD) improved stoves. These stoves rely on natural draft, unlike the Philips and Mimi Moto stoves which are forced draft stoves (i.e. require a power source to push air to the combustion chamber). Though no laboratory data are available, in a field setting Inyenyeri staff reported that they performed little better than the traditional three stone fire. Food was easily burned, and pots were blackened, making it hard for customers to differentiate them from the baseline technology.

In 2014, Inyenyeri decided to transition to the best available fan micro-gasification stove on the market at the time. They leased the Philips stove, a fan micro-gasification stove that burns biomass in a ceramic-lined stainless-steel combustion chamber (Figure 2, right) to customers. Forced draft stoves require a power source to charge the battery that powers the fan. They were distributed with a solar panel and the ability to plug into an electrical outlet. While most households in Gisenyi are connected to the power grid, electricity supply is unreliable making the ability to charge the stove using a solar panel an essential component of the system. Stoves were imported from the Philips manufacturing facility in Lesotho at a cost of about $80 USD/stove. In the laboratory the Philips stove rates as an ISO Tier 3 stove (jetter et al. 2012).

The experience of customers with the Philips stove was not entirely favorable. They reported several problems with the Philips stove including difficulty controlling the temperature, exceedingly high cooking temperatures (a problem for cooking rice, a local staple food), pot blackening, and electrical faults with the charging system. Inyenyeri found that people sometimes used charcoal rather than pellets in the Philips stove. Use of charcoal in gasifying stoves is inefficient, damaging to the stoves, and presents an obvious problem for business models predicated on the sale of pellets. Misinformation about what fuel to use in the stove led Inyenyeri to provide more guidance to customers on the use of fan micro-gasification stoves from 2016 onward.

To address customer dissatisfaction, Inyenyeri proposed several innovations to Philips to improve both combustion efficiency and user satisfaction. Their suggestions received a limited response from the company, making innovation and customizing the stove for Rwandan consumers difficult, and motivating Inyenyeri to look for another stove.\(^6\) The decision to change stoves as they were starting to scale-up came at a cost to Inyenyeri who reports losing more than $US2 million in capital investment on imported Philips stoves during their initial effort to incorporate and try out different fan micro-gasification stoves into their business model.

In 2016 Mimi Moto came on the market (Figure 2, left). The Mimi Moto, designed in The Netherlands and manufactured in China, has performed in the laboratory at an IWA Tier 4

\(^4\)For more information on the Lucia improved cookstove see [https://www.engineeringforchange.org/solutions-library/products/lucia-stove/](https://www.engineeringforchange.org/solutions-library/products/lucia-stove/).

\(^5\)For more information on the Champion top-lit up draft stove see [http://www.drtlud.com/](http://www.drtlud.com/).

\(^6\)Philips has since discontinued the stove and has withdrawn from the cookstove sector.

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rating. In a laboratory setting, an ISO Tier 4 fan gasifying stove used in tandem with biomass pellets can obtain exposure reductions of up to 80% relative to the traditional 3-stone fire (Jetter et al. 2012), which are in line with what is required to reduce the prevalence of respiratory illness associated with exposure to HAP (Clark et al. 2013). Inyenyeri was among the first stove program implementers to purchase the Mimi Moto. The Mimi Moto is imported in Rwanda at a cost of approximately $60 USD/stove in modest container volumes.

When Inyenyeri transitioned from the Philips stove to the Mimi Moto, their tagline was: “A New Star is Born”. The Mimi Moto has had considerably higher customer satisfaction both due to improved cooking performance, but also because customers generally like its appearance (Seguin et al. 2018). The modern look of the stove makes it an aspiration good for some consumers. In focus group discussions participants said that Mimi Moto stoves are hygienic (can be used in the living room and cooking area), and “light immediately”. Focus group participants state “the Inyenyeri system is modern”, and the “Mimi Moto is clean like LPG, does not damage cooking pots as charcoal does, and does not emit smoke”. A community health worker mentioned that “people understand that air pollution can cause diseases, such as respiratory illness; lungs once damaged cannot be replaced, and Inyenyeri can be a solution”. Other community members stated that “Mimi Moto stoves cook food fast and are durable, that Inyenyeri explains the system well and its customer service representatives are approachable”.

According to interviews with Inyenyeri staff, a major factor in the relative success of the Mimi Moto stove is the willingness of Mimi Moto to work closely with Inyenyeri to improve the stove. Communication on design features has been regular between Inyenyeri field staff and cookstove engineers, allowing for innovations in temperature control, the addition of a windscreen to increase efficiency by reducing wind-induced heat loss, and adjustments to the size of the removable fuel chamber. Mimi Moto has worked with Inyenyeri to improve the efficiency of the stove so that it requires fewer pellets for the same type of cooking events.

A unique dimension of the Inyenyeri business model is that it is leasing the best available fan micro-gasification stoves to households by building the stove cost into the pellet purchase price. This means that if the fuel is priced competitively with charcoal (i.e., the baseline fuel), the pellet and stove system should not increase energy expenditures in the household. The other main clean cooking competitor in Rwanda liquefied petroleum gas (LPG), is currently much more expensive than the Inyenyeri system. A two-burner Jiko LPG stove and cylinder (12 kg) costs 125,000 RWF ($US149), and a three-burner Jiko LPG stove and cylinder costs 130,000 RWF ($US155). After the initial capital investment in the stove and cylinder, each additional cylinder used is 12,500 RWF ($US15).

Inyenyeri has experimented with several cookstoves. They currently use the best available (i.e., with respect to combustion efficiency) stove on the market the Mimi Moto. In interviews with Inyenyeri staff they indicated that their goal is to continue to use the best available fan micro-gasification stove to consumers. If a stove emerges that performs better than the Mimi moto they are willing to change to that stove. However, Inyenyeri’s experience with transitioning from the Philips stove to the Mimi Moto highlights the
challenge of this approach in a market where there is limited information about stove attributes and where consumers are learning about the benefits of new technologies.

6. Pellets and Pellet Production

The Inyenyeri business model is dependent upon a sustained quantity and quality of biomass fuel pellets. Sustainable production levels to support current customers, and scaling-up production to meet demand from new customers has been an ongoing issue. Challenges have included acquisition, efficiency and maintenance of pelletizing equipment, and supply of appropriate biomass feedstock. Due to problems with pellet production in 2015 and 2016, Inyenyeri faced obstacles to signing up new households due to fears that they would not be able to consistently supply pellets to their customers.

6.1. Pelletizing equipment: capacity and output

In 2012, Inyenyeri started with a modest sized factory with equipment imported from the United States, producing a small quantity of pellets. By 2014, they had scaled-up pellet production to an average of 470 kg of pellets per day. In 2017, a new factory was producing 1,500 kg/day. As indicated in Figure 3, scaling-up pellet production has been successful in recent years. The largest gains in production were achieved in 2016 and 2017 with the introduction of a larger production facility, acquisition of drying equipment, and much higher investment in maintenance of pelletizing equipment. In some years rains and high humidity in November/December have led to wet feedstock, which is a problem for a pellet production without adequate drying equipment. Unreliable electricity supply including load shedding and power surges have also been a problem for sustaining production levels. Additional challenges include set up, maintenance, repair and sourcing of replacement parts from remote locations.

In 2014, based upon pellet production data provided by Inyenyeri (Figure 3) we estimate that total annual pellet production was approximately 171,213 kg. With a customer base of approximately 400 households, 37 kg of pellets were available per household per month, providing enough energy to support exclusive cooking for a small family with one stove.

By 2016 Inyenyeri more than doubled pellet production to meet demand for approximately 1,000 customers. There are plans for installation of a new production plant in 2018 with capacity of 2.5 tons per hour (compared to the old plant’s capacity of 2 tons per day).

6.2. Feedstock Supply

A major challenge for pellet production is biomass supply including type, quantity, quality, and moisture content. Small tree branches generally make up 25-50% of the feedstock for Inyenyeri; the remaining share is from other sources including sawdust and elephant grass.

The firm started pelletizing in 2012 with the majority of feedstock supplied by rural customers collecting biomass (e.g., branches with less than 10 cm diameter, sawdust and elephant grass), and bringing it to depots. Feedstock brought by rural customers provided adequate supply to produce pellets for both urban customers to purchase, and to supply rural

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7 Inyenyeri stopped using elephant grass as feedstock in 2017.
customers who traded biomass for pellets. The company has experimented over time different exchange rates (i.e., biomass kg to pellet kg) for rural customers starting with 4:1 for wood and 6:1 for elephant grass in 2012. The current exchange rate is 8:1 but is reduced significantly in exchange for a small payment per kg of pellets (e.g., 3:1 with you paying 100 RWF or 12 cents/kg for pellets). Urban customers pay cash for pellets; there is no provision for exchange of biomass.

Given the quantity of feedstock required for scale-up, rural biomass collectors cannot supply all that is needed to support pellet production. Since 2016, Inyenyeri has been working with the Government of Rwanda to source feedstock from government-owned eucalyptus plantations. Eucalyptus stems and branches are good feedstock as the oil in the wood mixes well and serves as a binder. Eucalyptus leaves are excluded from feedstock due to customer reports that pellets with high eucalyptus leaf content change the flavor of food. Eucalyptus wood is also desirable as the other major components of the feedstock, sawdust and elephant grass have properties that make them difficult to use in pellets. For example, sawdust from hardwoods is difficult to process (i.e., it gums up the machinery), and elephant grass in excess supply starts to rot, which makes it difficult to run through the pelletizing machine. Moisture content of feedstock has been a major challenge for pelletizing due to high humidity in the region during the two rainy seasons. For optimal combustion, finished pellets should have a moisture content of 8 to 10%. To achieve that moisture content feedstock needs to be relatively dry. To address this issue Inyenyeri imported drying equipment from India in 2016.

7. The Marketing Model

Since piloting activities began in 2012, Inyenyeri has experimented with their marketing model including testing different contracting options, developing customer service support, and troubleshooting consumer behaviors perceived to influence adoption and sustained use.

7.1. Contracting and Payment

The basic contracting model rolled out in 2014 was payment of a sign-up fee of 5,000 RWF (~US$6) paid once at the time of signing. Initially three packages were offered: (a) Basic (single or small size family; 30 kg; one stove; 6000 RWF (~US$7/month)), (b) Preferred (average household size of five in urban areas; 45 kg and two stoves; 9000 RWF (~US$11/month)), and (c) Deluxe (wealthier households with large families or desiring multiple stoves; 60 kg and three stoves; 12000 RWF (~US$14.5/month)) (Table 1). Because the Deluxe package was not very popular it was phased out in 2017. The sign-up fee was also removed in late 2017 due to customer feedback that it was a financial obligation that made the pellet/stove product less appealing. In 2018, Inyenyeri is getting rid of prescribed packages and going fully to a pay-as-you-go system.

In 2015, due to customer demand for a pay-as-you-go option (vs. bulk monthly pellet purchases), the firm started to sell pellets on per kg basis for 125 RWF/kg ($US0.15/kg). Initially households were able to purchase as many additional kilograms of pellets as needed. In 2016, the pay as you go pellet prices was increased to 200 RWF/kg ($US0.24/kg), with the hope that expanding their customer base would generate some profit at their
revised rate. Due to production constraints in late 2016 (Figure 3), customers were limited to purchasing five kilograms of pellets at a time. In response to price increases and pellet quotas some customers suspended or terminated their membership. This trend is reflected in Table 2. To the best of our knowledge, Inyenyeri’s contracting approach is novel and their experience provides useful information on the efficacy of a formalized system with regular payments outside of a more traditional microlending framework.

In focus group discussions participants indicated that Inyenyeri is expensive to enroll in, signing a monthly contract was strange and unfavorable, and that being required to purchase pellets once per month was limiting and ‘stressful’. Because of the formal contractual requirement, some respondents perceived Inyenyeri as being ‘for rich men’. Customers who did not use their full monthly pellet supply perceived they were at risk of having their stoves taken away if they did not buy pellets every month, though they reported liking the system very much. Our focus group discussions also verified that the increased price of pellets (from 125 RWF/kg to 200 RWF/kg), and limited (relative to charcoal) locations for pellet sales were barriers to adoption.

A central premise of Inyenyeri’s business model is that pellets should be less expensive than charcoal, the baseline fuel in Gisenyi. The price also needs to be high enough to cover pellet production costs. Between 2012 and 2017 Inyenyeri pellets were priced consistently lower than charcoal. On a per kilogram basis charcoal was 40% higher than a kilogram of pellets (see Table 1). The quantities of charcoal vs. pellets to support household cooking is not the same. For example, a household with four people uses approximately 60-80 kg of charcoal per month, whereas the same household exclusively using the Inyenyeri pellet/stove package would use roughly 45-60 kg of pellets. The comparison in terms of cost of the charcoal to the Inyenyeri household energy system for the same household of four people in 2017 is 16,500 – 22,000 RWF ($US19-25) using charcoal vs. 9,000 – 12,000 RWF ($US11-14) using the Inyenyeri system (Personal communication, Inyenyeri staff). Given steady increases in the price of charcoal Inyenyeri should remain price competitive. In neighborhood focus group discussions, participants discussed the rising price of charcoal and erratic electricity supply as a problem and cited stable pellet costs as a benefit of Inyenyeri.

7.2 Customer Service

A high standard of customer service provision is part of Inyenyeri’s business model. Inyenyeri has a team of customer service representatives (CSRs) that are in regular contact both in person and by telephone with customers. To ensure consistency of program implementation across staff, every two months Inyenyeri conducts trainings and evaluates the performance of their Customer Service Representatives. For example, during training, different scenarios and customer complaints are presented to evaluate if Customer Service Representatives respond appropriately. The Inyenyeri CSR team conducts neighborhood-level cooking demonstrations, door-to-door marketing, and in-home demonstrations. If households want to sign a contract, they visit Inyenyeri’s office in Gisenyi. Stoves and pellets are delivered to their house and CSRs train the primary cook on how to use the stove.
Customers receive an Inyenyeri ID card and both CSRs and Inyenyeri reception contact information in case of any problems.

Customer service includes attention to stove repair and maintenance issues. Free stove repair has been available since 2014. In 2016, 38% of Inyenyeri customers in our randomized controlled trial sample indicated they had a problem with their stove. Of those who experienced a maintenance issue 75% of issues were resolved within one week either by replacing or repairing the stove. In 2017, Inyenyeri started offering in home stove repair; previously customers had to take stoves to the Inyenyeri stop, which could be as far as one kilometer away. Visits to households have emerged as important to help identify whether the stove is performing as it should. For example, the removable burn chamber of the Mimi Moto can deteriorate after several months of use; Inyenyeri replaces chambers at no cost. As an additional service, in 2016 Inyenyeri offered free home delivery by bicycle taxi to customers purchasing 30 kg or more of pellets.

Our focus group discussions revealed that some customers were unaware of repair services and others faced difficulties in getting technicians to repair stoves. Checking in on customers and providing new information was an important driver of adoption. Lack of time to understand and practice with the Inyenyeri system was identified as a constraint to adoption. Focus group participants suggested that pellets and stoves could be given to potential customers on a trial basis, before having customers commit to signing contracts. Because Inyenyeri has removed all sign-up fees and minimum purchase requirements, trying out the pellet and stove is now risk free.

7.3. Training

According to interviews with Inyenyeri staff, customers require a high level of training to use pellets and micro-gasification stoves efficiently and effectively. In 2015 they started offering in-home training on use of stoves and pellets and put into place a system of following-up with customers by phone and in person to answer questions and ensure proper use. Follow-up visits occur one week and one month after sign-up. Training involves instructions, complete with visual aids, on how to use the stove (e.g. not turning the heat regulator knob to the maximum, as that burns food), correct charging, pellet loading, lighting, temperature control, and recommendations for what quantity of pellets to use to cook different food types (Figures 4A and 4B respectively). Customer service representatives also provide information on proper handling of pellets. The two main issues that have emerged are proper storage in a dry place, so pellets do not take on moisture, and excessive handling or incorrect storage such that pellets get crushed or otherwise deteriorate during storage.

7.4. Stove Stacking and Persistent use of Charcoal

As with many improved cookstove programs, stove stacking (i.e., continued use of baseline technology alongside new technologies) has been a persistent challenge (Fig. 5). In each round of our randomized controlled trial household data collection we asked households to estimate the share of meals cooked using different cooking technologies during the past 30 days. We find that among Inyenyeri adopters, approximately 65% of cooking is still taking
place on portable charcoal stoves, fixed charcoal stoves, and traditional 3-stone stoves. This
finding is consistent with findings in Barstow et al. (2014) who find that 71% of improved
cookstove using households in Rwanda continued to use baseline cooking technologies.
Inyenyeri CSRs meet with households continuously providing information and advice to
motivate them to use the Mimi Moto and pellets exclusively. Information such as is
contained in Figure 4b – which outlines the correct quantity of pellets to use for different
cooking tasks helps consumers gain confidence with cooking with the Inyenyeri household
energy system.

8. Conclusions and Implications

Understanding the potential for implementation and scale-up of a pellet and fan
microgasification cooking system is important for sub-Saharan Africa, and for other settings
in the developing world where solid fuels dominate the household energy mix, and where
markets for modern fuels and clean cookstoves are nascent. This paper has reviewed the
experience of Inyenyeri, a for-profit social benefit company in Rwanda, who for the past five
years has been experimenting with how a private sector firm can bring pellets and micro-
gasification to scale. Other than Emerging Cooking Solutions in Zambia\(^8\), we know of no
other pellet/cookstove promoter in sub-Saharan Africa operating at the same scale.

The experience of Inyenyeri provides insights into the challenges related to improved
cookstove selection, pellet production, and the structure of the marketing model, which have
relevance for private, non-governmental, and government entities endeavoring to promote
pellet/ICS household energy systems.

Inyenyeri’s experience with two major cookstove designer/manufacturers illustrates several
points. First, determining the correct stove for a given context is challenging. Inyenyeri has
experimented with several different improved cookstoves to find the best available fit for
their consumer market. For example, stoves must be well suited to local conditions including
cooking the types of foods prepared in the region, and the cooking utensils (e.g., pots) and
kitchen environments in the region. Inyenyeri’s experience with Philips was unfavorable due
to the technical performance of the stove, and their lack of interest in making design
adjustments to the stove to suit Rwandan conditions. In contrast, Mimi Moto has been more
favorably received by consumers, and stove designers have worked closely with Inyenyeri
staff to internalize feedback from users to adapt to local conditions. The Mimi Moto is
currently being piloted in 10 countries in sub-Saharan Africa. Its high IWA rating, combined
with the attention the firm is giving to working with implementing partners offers promise
for the scale-up of fan micro-gasification stoves. Finally, in nascent markets, changing
technologies mid implementation may have a negative effect on adoption rates.

Inyenyeri’s experience with pellet production raises important questions about the most
effective institutional structure for pellet production. The capital investment required for
building large pelleting factories and the challenges of maintenance and repair in central
Africa have been obstacles to scaling-up pellet production. Relying on a single pelletizer is a

\(^8\)See [http://supamoto.co.zm/](http://supamoto.co.zm/) for information about Emerging Cooking Solutions.
problem in an environment where maintenance is a challenge. The efficacy of a
decentralized vs. centralized system of pellet production (i.e., a few large-scale factories vs.
several small to medium-scale enterprises) should be considered. Pellet producers in Africa
might look to China, where small and medium-scale production of densified biomass fuels
including pellets and briquettes is an emerging income generating activity (Chen et al.
2009). Obtaining both quality and quantity of feedstock been a challenge for Inyenyeri.

Inyenyeri’s experience with developing their business model is perhaps the most
informative. After several years of experimenting with contracting models involving sign-up
fees and packages of pellets and stoves they have decided to adopt a simple pay-as-you-go
system in 2018. The strong desire for consumers to purchase fuel in small increments at high
frequencies has been a major factor in this decision. Inyenyeri has found that regular in-
person interaction with consumers is essential. While this is labor intensive, the potentially
high adoption could enable the company to amortize these costs among its dense customer
groups. Inyenyeri’s experience with customer service provision raises interesting questions
for scalability. As the company grows they will need to consider the powerful influence of
peer networks both in support of (Jagger and Jumbe 2016), and at odds with (Seguin et al.
2017) adoption and sustained use of improved cookstoves (Lewis and Pattanayak 2012).
They will also need to consider replacing in-person trainings with behavioral change
communication campaigns and other marketing and training techniques.

The evolutionary nature of Inyenyeri’s experience illustrate both the complexity of building
a market for a clean cooking solution, and the time commitment required to understand the
market and consumer demands. The potential of pellet and fan micro-gasification cooking
should continue to be explored, particularly in settings where widespread distribution of
affordable LPG and electricity fueled cooking systems will be realized in the distant future.
Inyenyeri represents an important test case for understanding how to achieve a clean cooking
system using a renewable biomass source in sub-Saharan Africa.

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Inyenyeri has pioneered biomass pellet and fan micro-gasification stoves in Rwanda.

Improved cookstoves should be modified based on consumer input.

Establishing a pellet production facility in central Africa is costly and complex.

Sign-up fees and minimum purchase packages are not favorable for scale-up.

Home visits, pellet delivery, and stove repair improve consumer satisfaction.
Figure 1:
Map of Rwanda showing location of Gisenyi (Source: World Atlas, 2017)
Figure 2:
Mimi Moto (left) and Philips (right) fan gasifying improved cookstoves
Figure 3:
Quarterly pellet production 2012 – June 2017, kg
Figure 4A and 4B.

Inyenyeri’s poster manual for customers
Figure 5.
Share of cooking in households in past 30 days by stove/fuel type for randomized controlled trial sub-sample of households (%)
Table 1:

Evolution of Inyenyeri Timeline and Summary of Activities

|                                | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|--------------------------------|------|------|------|------|------|------|------|
| Rubavu District customers, total households | ~50  | ~60  | ~400 | ~400 | ~1,000 | ~1,400 | ~12,200^2 |
| Nyabihu District customers, total households | 0    | 0    | 0    | 0    | 0    | 0    | 3,000 |
| Kigeme Refugee Camp customers, total households | NA   | NA   | NA   | NA   | NA   | 300  | 3,800^2 |
| Kigali, total households | 0    | 0    | 0    | 0    | 100  | 1,000 |
| Stove marketed (IWA Tier Lab/Household usage) | Lucia (NA/1) | Modified Champion (NA/1) | Philips (3/2 or 1) | Philips (3/2 or 1) | Mimi Moto (4/2) | Mimi Moto (4/3 or 2) | Mimi Moto (4/3) |
| Pellet production (kg/year) | 31,283 | 27,794 | 171,214 | 130,800 | 408,766 | 790,048^4 | NA |
| Pellet price, RWF/kg | 75 | 100 | 200 | 125 | 200 | 200 | 200 |
| Charcoal price, RWF/kg | 175 | 207 | 232 | 244 | 244 | 275 | 363 |
| Contract terms: | | | | | | | |
| Sign-up fee, RWF | NA | NA | 5,000 | 5,000 | 5,000 | 5,000 | 0 |
| 1 stove; 30 kg pellets, RWF | NA | NA | 6,000 | 6,000 | 6,000 | 6,000^5 | NA |
| 2 stoves; 45 kg pellets, RWF | NA | NA | 9,000 | 9,000 | 9,000 | 9,000^5 | NA |
| 3 stoves; 60 kg pellets, RWF | NA | NA | 12,000 | 12,000 | 12,000 | NA | NA |
| Pay-as-you-go for pellets | No | No | No | Yes | Yes | Yes | Yes |
| Customer service: | | | | | | | |
| Training in household | No | No | No | Yes | Yes | Yes | Yes |
| Follow-up call | No | No | Yes | Yes | Yes | Yes | Yes |
| Follow-up visit | No | No | No | Yes | Yes | Yes | Yes |
| Home delivery of stoves and pellets by bicycle | No | No | No | No | Yes | Yes | Yes |
| Repair for free | No | No | No | Yes | Yes | Yes | Yes |
| UNC-CH led randomized controlled trial | NA | NA | Yes | Yes | Yes | Yes | Yes |

^1 The exchange rate at the time of writing is approximately 828 RWF to 1 $US.

^2 The International Working Agreement (IWA) framework rates cookstoves on four (4) indicators (efficiency, indoor emissions, total emissions, safety), each along 5 Tiers (0: lowest performing to 4: highest performing). For each indicator, the Tiers boundaries are defined by quantitative values determined by laboratory testing. The protocol that has been mapped to tiers is the Water Boiling Test 4.2.3
and the Biomass Stove Safety Protocol 1.1, although the IWA framework was designed to accommodate other protocols. The emissions rates that define Tier 4 for Indoor Emissions (the highest performing tier) were determined based on the World Health Organization’s Guidelines for Indoor Air Quality for pollutant concentrations.

3. Planned scale-up in 2018.

4. Personal communication with Inyenyeri staff.

5. Monthly minimum purchase eliminated in 4th quarter of 2017 as it was identified as an obstacle to the poorest households entering the system.

6. In-home stove repair started.
Table 2:

Take-up and sustained use among randomized controlled trial treatment group households (%)

|                                | Midline 1 July 2016 N=180 | Midline 2 July 2017 N=180 | Full Treatment Group September 2017 N=1,101 | Full Treatment Group September 2017 N=875 |
|--------------------------------|---------------------------|---------------------------|--------------------------------------------|------------------------------------------|
| Adopted and sustained use      | 22.2                      | 22.2                      | 15.9                                       | 21.2                                     |
| Adopted and terminated/ suspended contract | 14.4                      | 15.6                      | 12.8                                       | 17.1                                     |
| Prospective customers          | NA                        | NA                        | 23.7                                       | 31.6                                     |
| Non-adopters                   | 39.4                      | 51.7                      | 21.6                                       | 28.8                                     |
| Moved/cannot be located        | 23.9                      | 10.6                      | 25.0                                       | NA                                       |

1. Our original treatment group was N=1,000 households. An additional 101 households have been added to the treatment group due to crossover/re-assignment of control households in the household sub-sample to treatment households (N=60), and due to cases where control group households were mistakenly permitted to sign a contract with Inyenyeri (N=41).

2. Households that were marketed to that signed contracts and consistently paid monthly pellet fee.

3. Households that were marketed to that signed contracts and decided to no longer purchase pellets.

4. Households that expressed an interest to Inyenyeri Customer Service Representatives in signing up for Inyenyeri but elected not to sign up at the time they were marketed.

5. Households that were marketed to by Inyenyeri Customer Service Representatives who did elect not to sign a contract.

6. Take-up rates adjusted for 25% attrition from treatment group sample.