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Scalable Business Models for Alternative Biomass Cooking Fuels and Their Potential in Sub-Saharan Africa



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Acknowledgements

Building on its previous work on clean cooking in Africa, the World Bank has begun to explore intervention strategies for the clean cooking sector that move beyond stoves to examine the potential for cleaner-burning biomass fuels. This report examines the potential for scaling-up biofuel supplies for cooking in Sub-Saharan Africa, specifically carbonized and uncarbonized biomass briquettes, biomass pellets, and ethanol fuel and gel. These fuels, referred to here as *alternative biofuels*, need to be considered in the same context as other clean fuel options, such as liquefied petroleum gas, electricity, and other alternative fuels like biogas when shaping the future clean cooking ecosystem. This report is meant not as an endorsement of any one of these alternatives as the desirable end-state but rather as a stimulation of a broader dialogue about the options meriting attention and support in defining a truly clean-cooking future for African households.

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Acronyms

ACCES	Africa Clean Cooking Energy Solutions
B2B	business-to-business
CAPEX	capital expenditure
Ci-Dev	Carbon Initiative for Development
DFID	Department for International Development
EnDEV	Energizing Development
EMD	Electro-motive diesel
ETHCO	Malawi Ethanol Company
FMCG	Fast-moving consumer goods
GACC	Global Alliance for Clean Cookstoves
GIZ	German Agency for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit)
GDP	gross domestic product
IWA	International Workshop Agreement (Global Alliance for Clean Cookstoves)
LPG	liquefied petroleum gas
NGO	nongovernmental organization
SACCO	Savings and credit cooperative organization
SSA	Sub-Saharan Africa

Executive Summary

Alternative biomass fuels are a promising avenue for delivering clean cooking options to Sub-Saharan households.

The current reach of alternative biomass fuels—ethanol, briquettes, and pellets—in Sub-Saharan Africa is very limited. Across the region, most rural households (95 percent) and the majority of urban households (62 percent) depend on traditional solid fuels for their cooking needs. Roughly 11 percent use clean cooking fuels like liquefied petroleum gas (LPG) or electricity as a primary cooking fuel (World Bank 2014). Fewer than 1 million Sub-Saharan households (less than 0.5 percent of region’s population) use alternative biomass fuels, defined here as pellets, carbonized and uncarbonized briquettes, ethanol, and ethanol gel.¹

Affordability limits the widespread adoption of alternative biomass fuels across Sub-Saharan Africa, especially for the roughly 50 percent of households that rely on the free collection of biomass to meet their cooking fuel needs—many are unwilling or unable to pay for clean fuels. The cost of these fuels in addition to the stoves to utilize them is unaffordable for most rural and many urban consumers. Nevertheless, a nascent market for briquettes, pellets, and ethanol is quickly growing, with many new entrants and rising interest among donors and investors.

Still, few businesses have reached meaningful scale. Fewer than 6 million liters of ethanol, 8 million liters of ethanol gel, 28,000 tons of pellets (less than 5 thousand tons of which are for sale to households), and 80–100 thousand tons of briquettes for cooking purposes are sold across the region per year. These numbers are low in absolute terms and in relation to distributed biofuel stoves, suggesting that most households only use biofuels as a secondary or tertiary backup. However, the alternative biomass cooking fuel sector is young and dynamic, including ambitious startups poised to move beyond their pilot phase. Over the next two to three years, some could reach 50,000–100,000 customers.

1. Estimates for 2015 are: 500,000 households for ethanol and gel; 20,000–30,000 households for pellets; less than 20,000 households for uncarbonized briquettes; and 100,000–400,000 for carbonized briquettes, based on the Sub-Saharan Africa Biofuel Enterprise Database (see box 2.1), and desk research.

Significant barriers to market growth must be addressed to allow alternative biomass fuels to reach scale in Sub-Saharan cooking markets.

Despite many existing and new suppliers, the biofuel system's supply side experiences numerous ecosystem-level challenges, including policy barriers such as the poorly calibrated tax and tariff regimes that make it difficult to import fuel production equipment, biofuel stoves, and fuels, especially when local supply is inadequate, as is often the case in the early stages of market development.

Beyond trade barriers, explicit government endorsement of or policies directed at encouraging a favorable enabling environment for clean alternative fuels is often absent. Limited awareness among consumers may be problematic for certain fuels, such as ethanol, which many avoid because of unfounded safety concerns. Pellets and ethanol require properly calibrated stoves in a context of highly limited availability of technology. The financing barrier for biofuel entrepreneurs is acute and pervasive, with scant global impact investment or commercial investment capital being directed at the sector. These barriers put pressure on biofuel producers and distributor margins and significantly constrain the market. Recent trends in Sub-Saharan Africa and across the world, however, are positive and reveal increasing interest from a variety of actors, including larger enterprises and policy makers. Reasons for optimism include:

The Global Alliance for Clean Cookstoves has tracked significant growth in the sale of clean and efficient stoves: over 80 million stoves were sold between 2010 and 2015;

- Research and development into fuels and stoves has increased;
- Businesses continue to be innovative with their business models and to test new markets, for example, pay-as-you-go models are being adapted from solar home systems to cooking systems and new ways to efficiently disseminate ethanol (standardized canisters) and pellets are being tried;
- Donors are enhancing returns to stove businesses using results-based financing programs to channel capital into the market by targeting production, distribution, and health;
- Impact and commercial investors are beginning to show interest in clean cooking business models; and
- The thoughtful and systematic development of policies and standards for biomass and biofuels is emerging.

Business models have not yet emerged for alternative biomass fuels and stoves that can rapidly grow to serve the clean cooking needs of households in Sub-Saharan Africa.

Despite much progress, the market is immature and questions remain regarding the viability and appropriateness of business models. Most biofuel companies in Sub-Saharan Africa have adopted a full vertical integration model to maintain control of crucial aspects of supply and distribution, but some have moved toward fuel production or last-mile distribution; and innovative business-to-business (B2B) models are emerging in the clean cooking fuel sector.

Full vertical integration is tricky to manage and more costly than filling specialized niches, but it has significant advantages in terms of its ability to control the cost, volume, and quality of the fuel supply. It is crucial in contexts where no reliable partners fulfilling the other functions exist, and it has generally been successful for stimulating production and distribution growth as demand increases. Some new players have adopted fully integrated fuel production and stove and fuel distribution models with tremendous success at the pilot stage, such as the Inyenyeri cooking pellet business in Rwanda, but they have not yet demonstrated the ability to scale. Over the long-term, those without the competitive advantage of combining production and distribution will choose between them, particularly as larger-scale producers produce more product than their captured consumers can use and need to sell to distribution-focused players.

Some biofuel enterprises are pursuing “equipment-led” B2B models. Instead of directly producing or distributing fuel, they are focused on marketing fuel production equipment and sometimes their knowledge about distribution to on-the-ground partners who are better positioned to resolve local production and distribution challenges. One B2B operating model at the pilot stage relies on digital technology—software as a service (SaaS) platforms—to link third-party fuel suppliers to customers.

A crucial decision for cooking biofuel producers is whether to pursue a centralized production model; a partially centralized model; or a fully decentralized production model, where independent or loosely affiliated actors make decisions about how, where, and how much fuel to produce. Currently, most (about 90 percent) biofuel businesses in Sub-Saharan Africa are pursuing centralized production models. When resources and geographic settings allow for it, as is the case in urban settings, this model is more likely to lead to scale than decentralized production. Reaching very poor and remote rural consumers, however, will likely require a decentralized approach.

Most biofuel businesses are focused on building their own downstream logistics and distribution infrastructure, but the most successful players are constantly seeking ways to leverage partnerships and existing market infrastructure to significantly reduce operational costs. Setting up new infrastructure at scale is highly capital intensive at the “middle mile”—port

facilities for imported fuel, storage facilities, and transportation to major off-take hubs, particularly for fuels like ethanol. New market entrants are utilizing existing infrastructure of liquid fossil fuels to store and transport their fuel to urban hubs. Distribution management can forge relationships with retail-level consumers—but dealing with maintenance, training, and sales tracking can make “last-mile” distribution cost-prohibitive, particularly in a rural Sub-Saharan context. Most biofuel businesses therefore use their own distribution channels. Over the long term, businesses making upfront investments in digital systems to track sales and maintain a direct link to last-mile customers benefit by understanding and reselling to their customers; they will be best prepared to engage in fuel-centric, per-household, results-based financing schemes.

Priority policy interventions can help shape successful business markets through this innovation phase so that the successful ones can begin growing to significant scale.

Stakeholders can engage in a variety of interventions to address market barriers, but consultations and research point to a few priority levers:

- **Linking subsidies to outcomes.** A strong consensus exists in the clean fuels sector that subsidies must be tied tightly to results to minimize harmful market distortions. Well-designed output-based and results-based financing schemes such as carbon financing and more novel arrangements are needed to boost the overall funding flow.
- **Access to finance.** Donors and sector intermediaries should deploy catalytic finance to minimize risk in transactions and “crowd-in” private sector investment.
- **Market support.** Donors and sector intermediaries should provide capacity building and business advisory support to key value chain actors to scale-up production and build out fuel and stove distribution.
- **Policy advocacy.** All sector actors, including donors and development finance institutions, can make major contributions to the uptake of cooking biofuels by advocating for and supporting the development and implementation of favorable policies for biofuel market development.
- **Knowledge.** The donor community and the intermediary clean cooking sector have major roles to play in terms of generating knowledge about public goods by conducting market, business model, and impact research on clean biofuel cooking opportunities.

Many interventions are relevant to a variety of markets, mainly because most alternative cooking biofuel markets are nascent in Sub-Saharan Africa. Their specific configuration and sequencing will depend on the market context and available partners. Development partners and governments tend to provide more support for ethanol and pellet fuels over briquettes because of their better potential impact on people's health and the environment.

Experimentation is vital, but governments, donors, and investors must also make choices. Targeted interventions focused on business models with the potential of yielding much more powerful results than broad-spectrum solutions merit greater attention in this context. A model that is successful in a particular urban context, for example, may not be so in another country—even another African country—or in a rural area.



I. The Clean Cooking Fuel Opportunity in Sub-Saharan Africa

More than three billion people globally cook with traditional solid fuels and kerosene, causing significantly negative health, environmental, and economic impacts. Household air pollution from cooking with traditional fuels leads to more than 4.3 million premature deaths per year around the globe (WHO 2016a). Illness related to household air pollution, such as lung cancer, ischemic heart disease, and acute lower respiratory infections causes at least 581,000 premature deaths per year just in Sub-Saharan Africa (World Bank 2014)—it is the second-largest health risk factor associated with death and disability in the region. Other deleterious health effects are likely attributable to polycyclic hydrocarbon emissions from solid fuel and kerosene cooking, although this has not yet been fully quantified. Women are disproportionately affected because they are typically responsible for cooking and collecting fuel. Inefficient traditional cooking fuel use in households causes around 25 percent of global black carbon emissions (World Bank 2015c); and their use contributes to forest degradation, loss of biodiversity, and localized deforestation.

The estimated cumulative annual opportunity cost for continuing to use traditional fuels in Sub-Saharan Africa is 3 percent of the region's \$32 billion annual gross domestic product due to time lost to fuel collection and slow cooking, household expenditures on inefficient fuels and stoves, and increased health-related costs for households and health care systems (World Bank 2014).

The development community has paid increasing attention and made significant investments in clean cooking over the past five years, under the leadership of the Global Alliance for Clean Cookstoves, with the World Bank, Sustainable Energy for All, the U.S. Agency for International Development, German Agency for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*, or GIZ), Department for International Development, Energizing Development (EnDev), SNV, and Nordic Environment Finance Corporation. In addition, funding from other donors, governments, carbon finance, and social impact investors have increased flows to clean cooking initiatives in Sub-Saharan Africa over the past few years.²

These investments are generating results. Annual growth in clean and efficient stoves sales increased from 2.6 million units in 2010 to 20.6 million units in 2015, 30–40 percent of

2. Author's estimates are based on data from Global Alliance for Clean Cookstoves. See GACC 2016, World Bank 2015c.

which were in Sub-Saharan Africa (GACC 2016).³ The number of mid-sized and large stove manufacturers and distributors has increased from dozens to hundreds; stove technologies continue to improve, including recent performance breakthroughs; and the level of political commitment and general enabling environment around clean cooking have increased significantly. In particular, the region has witnessed the ongoing growth of modern cooking fuels like liquefied petroleum gas (LPG) and electricity, rapid growth in efficient stove penetration, and major acceleration in the adoption of efficient and cleaner improved cookstoves, including large producers like Greenway, Envirofit, Ecozoom, and Burn, which are selling thousands of high-quality efficient biomass stoves in the region every year.

With respect to clean fuel and stove penetration, progress has been slow. An increasing number of Sub-Saharan households have clean fuel stoves, but of those tracked by the Global Alliance for Clean Cookstoves, less than 5 percent are both truly clean and efficient per IWA standards (International Workshop Agreement, Global Alliance for Clean Cookstoves). This still translates into millions of Sub-Saharan households cooking with fuels like LPG, electricity, ethanol, and biogas. However, since the population of Sub-Saharan Africa has surged by nearly 20 percent since 2010,⁴ the penetration of clean (Tier 4) cooking stoves and fuels in the region is minimal, from 9 to 11 percent from 2010 to 2016.

Several programs and organizations highlight the urgent need for truly clean and more sustainable fuels in addition to efficient biomass stoves. Stoves alone are insufficient to fully capture the health and environmental potential of clean cooking. Clean stoves must be distributed with clean or at least cleaner fuels, such as LPG, ethanol, processed biomass as briquettes or pellets, or biogas (GACC 2015b).

Among the organizations encouraging the use of specific fuels for clean cooking globally and in the Sub-Saharan context is the Global LPG Partnership, which promotes LPG value-chain development and enabling policies across numerous countries. Project Gaia promotes clean ethanol stoves and fuels through pilots, implementation projects, and policy engagement. Energy4Impact (formerly Global Village Energy Partnership International), Massachusetts Institute of Technology D-Lab, and nongovernmental organizations such as the Legacy Foundation and ProJet's Solitaires are active in value chain development for biomass briquettes. SNV has been heavily involved over the past five years in biogas promotion through its Africa Biogas Partnership Programme. Nevertheless, the overall global level of investment into clean cooking fuels in Sub-Saharan Africa, including alternative biofuels and conventional fuels like LPG, remains extremely limited (See Ashwani 2012; Clough 2012; Ferguson 2012; GACC 2015b; Mitchell 2011; Schlag and Zuzarte 2008; UNIDO 2015; and World Bank 2015a).

3. The data are difficult to disaggregate regionally, but based on historical data, roughly 30 percent are attributable to Sub-Saharan Africa with less than 25 million distributed from 2010 to 2015.

4. Based on United Nations and World Bank data, estimated growth is about 170 million households in 2010 to 200 million by the end of 2016.

Report Scope and Overview of Fuels

Holistic intervention strategies that fully incorporate fuels are being pursued for the clean cooking sector in Sub-Saharan Africa. This report focuses on the potential for scaling biofuel markets in the region for cooking as opposed to heating or industrial uses, specifically carbonized and uncarbonized biomass briquettes, biomass pellets, ethanol fuel, and ethanol gel. Models are explored for scaling the cooking fuel value chains while balancing the environmental health, social, and economic impacts of the fuels at the household and national level. While this report focuses solely on pellets, briquettes, and ethanol, referred to here as *alternative biofuels* (box 1.1), LPG, electricity, and biogas also have a role to play in a clean cooking ecosystem.

LPG presents a major opportunity for urban clean energy transition in Sub-Saharan Africa, and it is being actively explored and promoted by the industry, governments, and several global initiatives like the Global LPG Partnership (see Kojima 2011 and WLPGA 2015). Electric cooking is currently quite limited because of the very low penetration and poor reliability of the region's grid. Users of electric stoves are concentrated in a handful of countries, such as South Africa and Ethiopia, but the opportunity is ripe for further exploration. Early investigations suggest that over five to ten years, the evolution of off-grid battery technologies could make photovoltaic-fired induction cookers economically viable (Batchelor 2015). Biogas is expanding its scale on the African continent, but must contend with unique economic and technological challenges (see Smith et al. 2013 and Cyimana and Hu 2013). Methanol, is being explored as a cooking fuel in Africa by Project Gaia and commercialized at a small scale in South Africa by Proto Energy, among others, but its use depends on the promotion efforts of gas industry producers who have demonstrated scant interest in the cooking market.

Box 1.1. Overview of Biofuels Considered in this Study

Ethanol/alcohol. A liquid biofuel that can be made from a variety of feedstocks, including sugary materials such as sugar cane, molasses; starchy materials such as cassava, potatoes, and maize; and cellulosic materials such as wood, grasses, and agricultural residues.

Briquettes. Molds of compressed biomass that can be made into a variety of shapes and sizes depending on the feedstock, level of compactness and mold used. Briquettes can be carbonized to replace charcoal or be noncarbonized and replace firewood and raw biomass.

Pellets. Small, compacted, short cylinders of 5–6 millimeter diameter and shaped by pressing loose, dry biomass through a die with many holes.



TWO BURNER ETHANOL COOKER FROM SAFI IN KENYA

Ethanol is a biofuel that can be made from a variety of biomass feedstock and that can be produced as either a liquid or a gel. The two major types of ethanol each have their own production process and raw inputs. First-generation bioethanol is derived from sugar or starch produced by food crops, such as sugar cane, corn, sweet sorghum, and cassava. Next-generation bioethanol—or cellulosic—ethanol is more complex: it is produced from crop residues, lignocellulosic (woody-cellulose) materials, and other energy crops. Because it does not compete with food production, it is more sustainable than its first-generation counterpart, but only a few facilities in Europe, Brazil, and the United States have achieved commercial-scale production. Therefore, this study focuses on first-generation ethanol.

Bioethanol and ethanol gel cooking fuels offer many positive properties as a renewable, efficient, and largely safe household cooking fuels. Bioethanol for cooking is denatured with a bittering agent such as Denatonium Benzoate/Bitrex to prevent ingestion, is typically colored green, yellow, or blue, and is higher in quality and content (95–97 percent+) than other types of ethanol, such as that for beverages with roughly 50 percent content (ASTM International, 2016). Ethanol gel is made by mixing denatured bioethanol with a thickening agent, turning them into a high-viscosity colloid, and thereby increasing safety during handling.

The distinction between liquid and gel ethanol is important in the context of cooking. Because the gel burns less powerfully than the liquid, generating smaller flames, it cannot be used for some dishes and is therefore typically used as a secondary or supplemental fuel. It is largely spill-proof and easy to manage but leaves a residue and odor during cooking (UNIDO 2015). Liquid ethanol offers a cooking experience similar to that of modern fuels like kerosene and LPG. When used in quality ethanol stoves, bioethanol fuel provides a clean (Tier 4) cooking experience. Another important feature of ethanol stoves is their ability to sustain a flame for four and a half to five hours, giving it an advantage over pellet stoves that require the chamber to be refilled every 60–90 minutes.

Cooking with liquid ethanol has a strong track record when it comes to safety, but it is not entirely risk-free. Ingesting a high concentration of ethanol is dangerous, but denaturing it makes it unpalatable to humans. Severe burns can occur, but compared with kerosene, wood, and charcoal, they are relatively rare. In the 1970s, the Brazilian government discouraged the distribution of hydrated ethanol in plastic containers for household consumption due to burns resulting from multiple household accidents caused by splashing low-flash-point ethanol onto wood fires (Bizzo et al. 2004). According to an interview in the summer of 2016 with the former CEO of Zoe Enterprises, a cooking ethanol enterprise then called CleanStar NDZiLO, there had only been one instance of a severe burn caused by ethanol used as kindling even though 40,000 consumers used it daily to cook food on a daily basis on their stove over a period of years. Project Gaia has not recorded a single safety incident during its over 10 years of experience and tens of millions of household hours of ethanol cooking, hours of ethanol cooking (H. Stokes, interview, July 2016). Further, these risks can be eliminated entirely by distributing ethanol in spill-proof “closed-circuit” canisters, an increasingly accepted practice in Africa.

Briquettes are densified fuels made from a variety of renewable uncarbonized or carbonized biomass feedstocks. Carbonized briquettes are made from biomass sources that have been processed through the pyrolytic or carbonization process. Uncarbonized briquettes are directly processed from biomass through various casting and pressing processes, also known as *solidification* or *densification*.

Carbonized briquettes can replace traditional charcoal; they are mainly used for cooking and industrial uses by Sub-Saharan households and small businesses, respectively. They differ from traditional wood charcoal in their uniformity of quality and size; a lower calorific content (22–29 megajoule/kilogram versus 30–35 megajoule/kilogram for wood charcoal; reduced smoke emission from charcoal, depending on binder content; and higher ash content (10–30 percent versus less than 5 percent for wood charcoal), which typically translates into much longer cooking times (see, for example, Mwampamba, Owen, and Pigaht 2013).⁵ Uncarbonized briquettes are cheaper to make and have a lower calorific content. They emit more smoke than their carbonized counterparts, but are still far superior to burning wood.

5. Data triangulated based on sector interviews.



EVERSAVE CARBONIZED BRIQUETTES BEING PRODUCED IN KENYA

Households rarely use commercially produced, uncarbonized briquettes, but several noncommercial organizations promote their use, such as the Legacy Foundation and Project Solidaires. Uncarbonized briquettes are used at a small scale by businesses in some areas of Africa, but more typically, they are used as for heating or as an industrial fuel for industrial boilers, and energy plant feedstock, as examples.

Carbonized and uncarbonized briquettes can be burned in traditional stoves, but they both burn better in improved stoves. Carbonized briquettes are poorly suited to traditional charcoal stoves. In Rwanda, carbonized briquettes proved unacceptable to domestic users because the spherical shape of the locally produced briquette blocked the round holes in the grate of standard charcoal stoves. A consumer using the briquettes had to buy an imported stove with a grill that allows ash to fall through, raising the cost of this option (Mwampamba, Owen, and Pigaht 2013). Carbonized briquette entrepreneurs market their product alongside highly efficient charcoal stoves to ensure an appropriate technology-fuel match and to maximize end-user savings. Cooking with traditional stoves using uncarbonized briquettes is quite difficult, and enterprises in Sub-Saharan Africa that have distributed them to households must match them with a customized rocket stove, such as Greentech Gambia or a briquette stove.

Briquettes have the potential of offering a cleaner and cheaper cooking experience than traditional biomass fuels, but they still emit significant pollutants and demonstrate few health and



INYENYERI-PELLETS PRODUCED IN RWANDA

environmental benefits (Banzaert 2013; Mwampamba, Owen, and Pigaht 2013). They have a lower energy density than charcoal, are more difficult to light, and take longer to warm (see, for example, GVEP 2010). Carbonized briquettes lack the burn efficiency of charcoal and are therefore an imperfect substitute for end users. According to interviews with manufacturers and Mwampamba, Owen, and Pigaht (2013), they incur value-added taxes; and when produced with charcoal dust or charcoal fines, they contribute to the market for unsustainable charcoal.

Pellets are smaller, cylindrical, and condensed uncarbonized briquettes made of raw dried biomass. They offer high fuel efficiency and very limited emissions when used in combination with high-quality fan gasifier stoves (IWA Tier 4 for emissions and efficiency), although if used in natural draft stoves, they fall substantially below Tier 4 performance levels. Because the pellet stoves are efficient, consumers have to buy less fuel, which reduces the pressure on natural resources and household budgets.

An overview of the features and major tradeoffs for the fuels explored in this report is presented in table 1.1, which reveals that ethanol and pellets offer the greatest across-the-board potential.

From a health-impact perspective, liquid ethanol is most likely to consistently deliver Tier 4 particulate matter and carbon monoxide emissions performance, followed by pellet fuels

Table 1.1. Alternative Cooking Fuels by Type: Potential Benefits

Key Dimensions	Alternative biofuels				
	Briquettes (uncarbonized)	Briquettes (carbonized)	Pellets (with fan gasifier)	Ethanol Gel	Liquid ethanol
Health	Tier 2–3	Tier 3–4	Tier 3–4	Tier 3–4	Tier 4
Environment	Moderate benefit	Low-moderate	High benefits	Moderate-high	Moderate-high
Efficiency	12–20%, 40%+ gasifier	15–40%	40–55%	50–70%	55–75%
Safety	n/a Just like wood	n/a Just like charcoal	Very safe	Safer than liquid ethanol	Some, though low burn risk
Economics (stove)	OK with low cost, best with gasifier	OK with low cost stoves (\$5–25)	\$35–120	\$20–40	\$30–80
Economics (fuel)	More than wood, less than charcoal	Small-medium savings versus charcoal	Big savings versus charcoal	Not cheaper than charcoal	May be more than charcoal
Usability/experience	No improvement over charcoal, moderate with wood	Cooks longer than charcoal, otherwise similar	Fast cooking, a lot of control, but requires charging	Largely supplemental fuel	LPG like experience
Fit with behavior	Moderate behavior shift needed	Small behavior shifts needed	Moderate/high behavior shift	High behavior shift	Moderate behavior shift
Job creation potential	Low to moderate	Low to moderate	Moderate to high	Major opportunity	Major opportunity
CAPEX efficiency of production	Small-moderate upfront investments	Small upfront investments	Moderate investment upfront, very CAPEX efficient	Major upfront investment, low CAPEX efficiency with EMD	Major upfront investment, low CAPEX efficiency with EMD
Overall assessment	Low	Medium	High	Medium	High

Sources: Desk research.

Note: The economics of fuel category is benchmarked against traditional charcoal stoves; biofuel cooking solutions do not currently offer households any economic advantages over highly efficient improved charcoal stoves like Burn Design's Jiko Koa.

in quality fan gasifier stoves. Ethanol gel is smokier than liquid ethanol, but lab tests show that quality gel stoves can deliver Tier 4 emissions for particulate matter and carbon monoxide emissions (Masekamani, Makonese, and Annergarn 2015). Carbonized briquettes have lower emissions than traditional charcoal and demonstrate low-to-moderate particulate matter emissions (Tier 3–4) and moderate carbon monoxide emissions (Tier 3) (Amaral et al. 2016; Njenga et al. 2014; Mwampamba, Owen, and Pigaht 2013; see also Banzaert 2013, which shows higher particulate matter emissions for carbonized agricultural waste briquettes relative to the wood charcoal benchmark). Charcoal briquettes used in highly efficient stoves emit particulate matter emissions similar to those of ethanol and pellet gasifier stoves. However, in regular charcoal stoves, carbonized briquettes are closer to Tier 3 in carbon monoxide

emissions and Tier 3–4 for particulate matter emissions. The emissions performance of uncarbonized briquettes is worse than cooking with wood (Banzaert 2013).⁶

There are a variety of criteria and metrics for evaluating the environmental impacts of stove and fuel combinations, the most comprehensive of which was recently provided by the U.S. Environmental Protection Agency and Global Alliance for Clean Cookstoves. Together, they sponsored a life-cycle analysis across a range of cooking fuels (Cashman 2016). This work suggests that biomass pellets burned in gasifier stoves have some of the most positive net environmental effects, closely followed by renewable bioethanol. While uncarbonized briquettes are less attractive, they are still better than unsustainably harvested forest biomass. Carbonized briquettes are possibly worse than uncarbonized briquettes because of the emissions involved during the carbonization process, but this might be countered by the lower emissions at the level of end user.

Thermal efficiency depends on the stove at least as much as the fuel. Broadly speaking, ethanol fuel has the highest thermal efficiency at 50–70 percent; ethanol gel is in the same range; followed by pellet fan gasifier cooking at 40–55 percent; carbonized briquettes at 15–40 percent—depending on the efficiency of the stove; and lastly, uncarbonized briquettes, which have very low efficiency levels at 12–20 percent, depending on the stove used (Cashman et al. 2016; Masekameni, Makonese, and Annergarn 2015); and GACC stoves and fuels catalog. From the perspective of the end user, the thermal efficiency of the stove and calorific value of the fuel are closely tied to cooking speed, with ethanol and pellet gasifier stoves demonstrating the fastest cooking times.

Few comparative studies have been conducted on biofuel stoves, but pellet stoves combined with high quality gasifiers should rate highest, followed by biomass briquettes, ethanol gel, and ethanol liquid, although the risk of getting burned by briquettes in unimproved stoves could rise to the same level as ethanol.

End-user economics depends on the stove-fuel combination, with pellet stoves having the highest unsubsidized upfront costs, ranging from \$35 to \$120 for a fan gasifier stove and \$15–80 for a natural draft gasifier stove.⁷ Ethanol stoves cost \$35–80, although prices in some areas have been reduced to \$20–40.⁸ Ethanol gel stoves have simpler designs and are less expensive at \$20–40).⁹ Briquettes can be used with traditional biomass stoves—which

6. These findings were corroborated by interviews in the summer of 2016 with Michael Johnson of Berkeley Air Monitoring and Jacob Moss of the United States Environmental Protection Agency.

7. Estimates are based on the GACC stove catalog, available at <http://catalog.cleancookstoves.org/stoves>, and on interviews with contacts from Awamu and Mimi Moto.

8. Estimates are based on interviews with contacts from POET, CleanCook, and Project Gaia; desk research; and the GACC stove catalog.

9. Estimates are based on publicly available prices for Moto Poa, Thermosafe, and Kike stoves.

cost \$2–10, but for maximum performance, carbonized briquettes should be used in efficient charcoal stoves, which cost \$25–50.¹⁰

From the user's perspective, these fuel costs vary dramatically based on geography. Using traditional charcoal cooking as a baseline for urban households, interview evidence and actual field pricing suggest that pellet fuels used in high-end gasifiers (Tier IV in efficiency) can generate greater monthly cash savings than charcoal use in Tier III charcoal stoves.

Among the fuels covered in this report, ethanol likely delivers the best cooking experience, potentially on par with LPG in the case of high quality ethanol fuel combined with high-end ethanol stoves; followed by pellet fuels combined with top-performing gasifier stoves; briquettes; and finally ethanol gel, which offers much more limited usability.

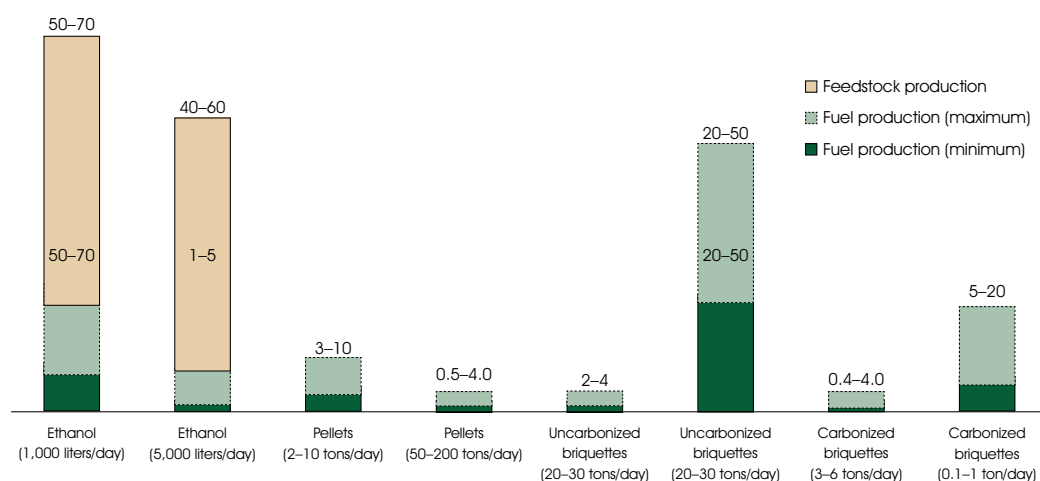
With regard to the initial behavior change required from a consumer, the order is reversed: carbonized briquettes require relatively little behavior shift compared with cooking with charcoal; followed by ethanol, which requires a change in cooking behavior but which is easy to refill and use; closely followed by pellet gasifier stoves, for which variability in cooking performance likely depends on the skill of the end user rather than the performance of the ethanol stove. Carbonized briquettes require less behavioral adaptation than other fuel-stove combinations, but the product is not the functional equivalent of charcoal. Treating briquettes like charcoal will lead to their disintegration and discourages users seeking a familiar cooking experience (Mwampamba, Owen, and Pigaht 2013).

While the question is an important one from the perspective of policy makers, there is very little research on the job creation potential of the selected biofuels in Sub-Saharan Africa. When anchored in domestic production, the ethanol value-chain holds particular promise for job creation because feedstock cultivation could potentially employ millions of small landholders. Pellet and briquette value chains depend on collected biomass or waste feedstock, a byproduct of agriculture or waste collection.¹¹ Feedstock collection and aggregation is labor intensive, but the intensity does not vary dramatically by fuel. For production, semi-industrial uncarbonized briquette production is likely the most labor intensive activity, decentralized ethanol production via ethanol microdistilleries, artisanal and semi-industrial carbonized briquette production, and then by the industrial production of pellets and carbonized briquettes. Ethanol production is by far the largest potential generator of jobs (figure 1.1).

10. The range is based on current prices for Burn Design and Envirofit charcoal stoves included the GACC stove catalog.

11. Project Gaia estimates 50–75 feedstock jobs for every 1,000 liter plant; An analysis by the Food and Agriculture Organization of the United Nations suggests a ratio of 15:1 for feedstock jobs for smallholder farmers versus ethanol processing jobs. See James Thurlow's "Economy Wide Effects of Bioenergy Developments" at <http://www.fao.org/docrep/012/i1544e/i1544e07.pdf>.

Figure 1.1. Biofuel Production and Jobs



Sources: Sub-Saharan Africa Biofuel Enterprise Database.

The capital requirements and complexity of the production process varies substantially between the options. Carbonized briquette producers typically have the lowest capital expenditure (CAPEX) requirements for commercial-scale production facilities at \$50,000–70,000 for 1 ton per day production capacity; followed by carbonized briquette producers and pellet manufacturers, at \$100,000–150,000 for 1–2 tons per day); and lastly ethanol producers at \$300,000–500,000 for a 1,000–1,500 liter per day electromotive diesel (Mwampamba, Owen, and Pigaht 2013; UNIDO 2015). The lowest barriers to entry are for briquette manufactures that can establish small-scale, semi-industrial, or artisanal production (a few tons per month) with an investment of less than \$5,000. Pellet fuel is by far the most capital efficient option at \$20–90 per household served, followed by carbonized briquettes at \$100–150, uncarbonized briquettes at \$150–200, and ethanol produced by microdistilleries at \$250–370.

Pellet fuels and ethanol are an obvious choice of focus for the clean cooking community, but there is also a case for engaging with briquette markets as part of charcoal sustainability interventions. There is a wide range of potential impacts of promoting different biofuels, with substantial variability depending on geography, stove-fuel combination, fuel quality, and investment cost. There is a strong case for promoting pellet fuel cooking approaches and ethanol cooking, a weaker case for promoting ethanol gel and carbonized briquettes, and a weak case for large-scale commercial production of uncarbonized briquette fuels. Despite their enormous positive potential, pellets and ethanol face severe challenges to production, distribution, and consumer uptake compare with less-clean fuels like briquettes.



II. Biofuel Market Assessment

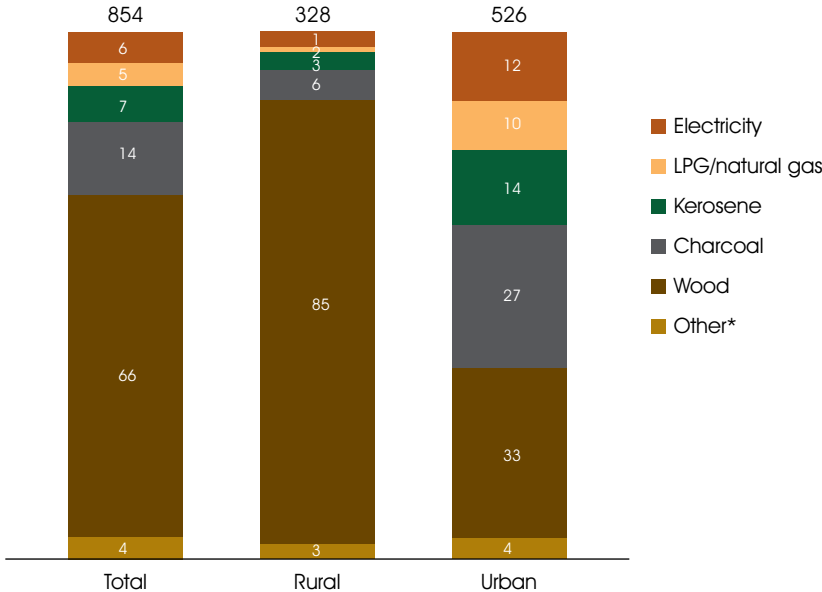
Following is an overview of the alternative biofuels market for clean cooking—ethanol, briquettes, and pellets—in Sub-Saharan Africa. The demand side is first explored, including current use and market drivers; supply-side barriers are then examined. The chapter concludes with a discussion of forward-looking trends that could have significant implications for the market’s evolution.

Demand Side

Sub-Saharan Africa remains heavily reliant on traditional solid cooking fuels. In 2010, over 90 percent of rural and 60 percent of urban households in the region (80 percent overall) were using traditional fuels (World Bank 2014).

Only about 11 percent of households in Sub-Saharan Africa cook primarily with clean fuels and stoves that comply with IWA¹² Tier 4 emissions standards. Across the region, the adoption of modern clean fuels like liquefied petroleum gas (LPG) and electricity has grown over

Figure 2.1. Fuel Types Used for Household Cooking in Sub-Saharan Africa

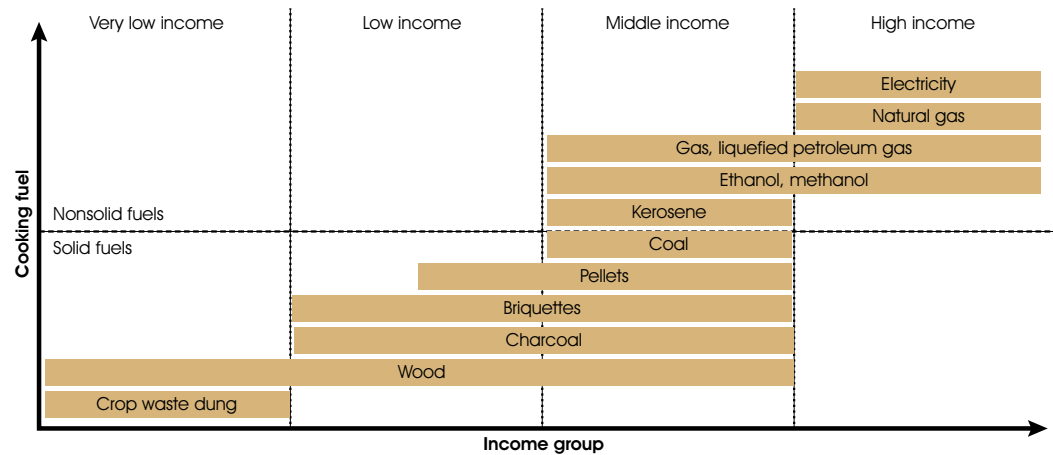


* Solid fuels, including dung, crop waste, and coal, plus a tiny (less than 0.1 percent) biofuel component.

Sources: Fuel-use database drawn on WHO 2016a and various other statistics presented in World Bank, 2014 and Kammila, et al. 2015.

12. Global Alliance for Clean Cookstoves International Workshop Agreement.

Figure 2.2. Relationship Between Income and Type of Energy Consumed for Cooking



Source: Adapted from WHO 2016a.

the past six years, but the population has surged over the same period (2.7 percent per annum) with a net effect that the relative fuel mix in late 2016 is probably similar to that of 2010. (World Bank 2014, 2015c). Demand and penetration of alternative biofuels in the region is currently very limited. Even though there has been growth in absolute terms over the past 5–6 years, only an estimated 650,000–1 million households—less than 5 percent of the population—use them.

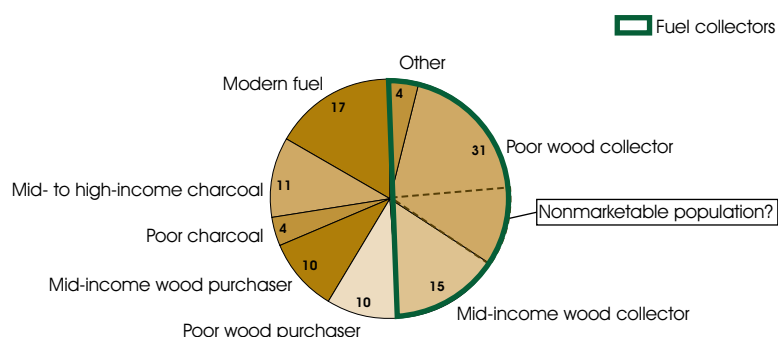
The variation in consumption patterns between rural (generally poorer) and urban (generally wealthier) consumers suggests that affordability plays a major role in limiting fuel choices. Figure 2.2 classifies various energy sources by their relative affordability. Wood appears to be a low-cost option across multiple income groups.

Carbonized briquettes and pellets are unaffordable for the poorest households but can often compete with charcoal and LPG prices (Thurber et al. 2014). Ethanol is expensive and therefore targeted toward higher-income populations, but recent efforts are seeking to produce it at costs more competitive with kerosene and LPG.

Despite the relatively high price of traditional solid fuels, affordability remains the most significant constraint on demand for biofuels and associated stoves in the region (Schlag and Zuzarte 2008). Because clean biofuels typically require an upfront outlay for appropriate stoves and fuels, they cannot compete with traditional fuels used by half of the households in the region where neither stoves nor fuel is purchased (figure 2.3).

Promoting commercial models of clean but relatively expensive stoves and fuels to poor rural biomass-collecting households is extremely difficult. A best-case scenario would be a

Figure 2.3. Population by Primary Cooking Fuel and Purchasing/Collection Behavior in Sub-Saharan Africa



Source: World Bank 2014.

results-based financing or barter model with no required cash outlay that would promote price-competitive options to purchased wood, such as uncarbonized briquettes. Inyenyeri in Rwanda and Dazin in Bhutan are helpful examples.

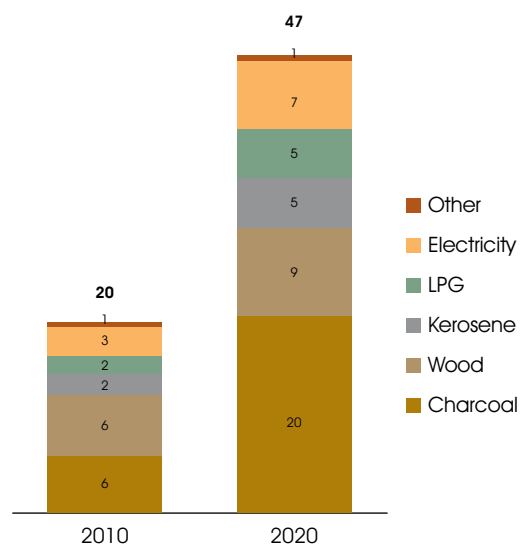
Populations living in refugee camps are considered under the wood-collector category. With careful planning, thoughtful donor responses could enable their cooking needs to be addressed with alternative biofuels. Ultimately, wood-collecting households in Sub-Saharan Africa will not gain access to alternative biofuels at scale without extensive business model innovation and/or substantial subsidies, including carbon financing and other results-based financing income streams for fuel and stove distributors.

Despite the cost-related constraints, the potential market for alternative fuels is large and growing. Half of Sub-Saharan Africa households already pay for cooking fuels, including 33 percent for charcoal and wood, constituting a substantial market with an annual estimated worth of \$12 billion in 2010—and given the population growth, this figure could double to \$29 billion by 2020 (figure 2.4 and table 2.2) (World Bank 2014). If kerosene users are included in the estimates, total expenditures are \$14 billion for 2010 and \$34 billion by 2020.

Household expenditures on traditional solid fuels are increasing due to rising household incomes, increased urbanization, and rapid population growth. The population using traditional solid biomass fuels could grow from about 700 million in 2014 to about 850–900 million by 2020 (World Bank 2014). And while fossil fuel prices have declined or stabilized in recent years, wood fuel and charcoal prices are rising due to scarcity or policy-linked shortages.¹³

13. Data for markets including Kenya, Uganda, Rwanda, and Tanzania, as well as data from select West African markets demonstrate that charcoal prices are continuing to increase across the region at 8–12 percent per year, with significant localized spikes caused by the banning of charcoal by government, seasonal shortages, and conflict-related interruptions to supply chains.

Figure 2.4. Annual Amount Spent on Cooking Fuels in Sub-Saharan Africa (in US\$ billions)



Source: World Bank 2014.

on the precise location of fuel distribution, the distribution model, and the specific cookstove used for traditional fuels like charcoal as well as alternative biofuels.

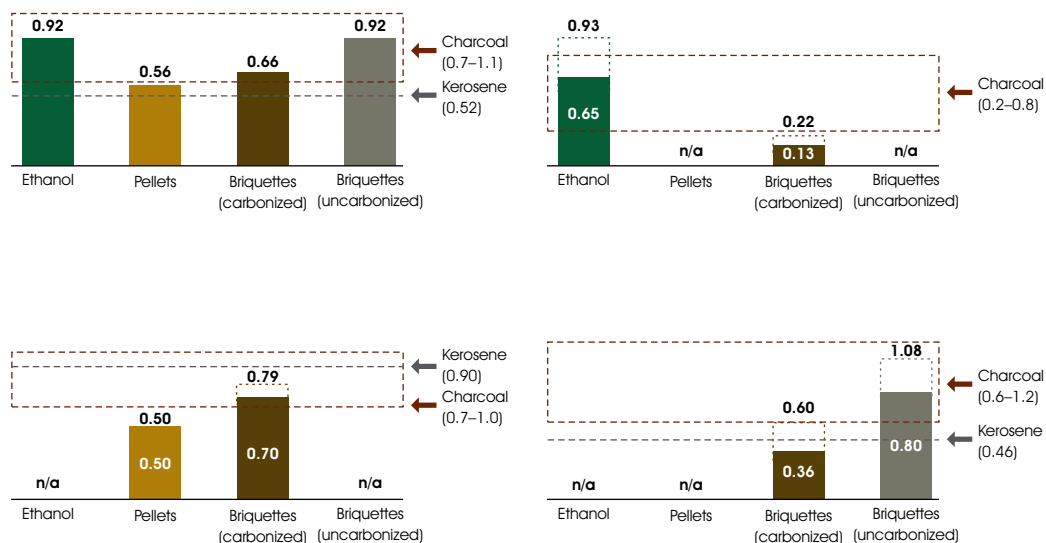
These data reveal that the average expenditure is lower for households cooking with carbonized briquettes than charcoal in the four assessed countries (figure 2.5); it is unclear whether this trend is generalizable across the 15–20 Sub-Saharan markets where carbonized briquettes are available. Despite their lower calorific value compared with charcoal, well-made charcoal briquettes burn longer than regular charcoal, potentially generating savings over traditional charcoal. However, many of the briquettes are poorly made and offer a lower quality burn.¹⁴

Carbonized briquette manufacturers and distributors may be unable to compete because of the inherent cost disadvantage compared with illegally produced, untaxed charcoal. It is also extremely difficult for charcoal briquette producers to justify higher prices per unit because most of the charcoal consumers in Sub-Saharan Africa are unconvinced by the claims—often for good reason—and the demand is price elastic. In Uganda, for example the effective cost of cooking with some locally available carbonized briquettes is higher than cooking with wood charcoal (Tumutegyeize et al. 2016). And with few exceptions among the wealthy, customers are unwilling to pay more for the “green” (environmental) and cleaner-cooking properties that the briquettes offer (Mwampamba, Owen, and Pigaht 2013).

Alternative fuel businesses struggle to match the prices of traditional options because most are still in the process of testing models to produce and distribute at scale. Moreover, many regulations penalize alternative fuels or favor traditional ones, such as kerosene subsidies, and import duties on stoves), resulting in an uneven playing field. Figure 2.5 compares the average urban and peri-urban household expenditure on biofuels to charcoal and kerosene across several East African markets. These numbers should only be seen as rough estimates, as some of the data is self-reported by biofuel distributors and has not been independently confirmed. The price range between distributors is therefore wide within a given country, depending

14. These observations are based on self-reported data during interviews with briquette manufacturers and distributors.

Figure 2.5. Average Household Expenditure on Cooking Biofuels in Sub-Saharan Africa, 2015



Note: Analysis based on data collected between the first quarter of 2015 and the first quarter of 2016, self-reported fuel distributor data, and publicly available fuel prices. Actual expenditures are used for common fuel-stove combinations and triangulated wherever possible for likely converted to daily expenditures required for a household of five to cook two and a half meals per day (World Bank 2015b).

Based on lessons learned from a few pellet fuel pilots across the region with respect to cost competitiveness, pellets are more promising than briquettes. Pellets for gasifier stoves is a lower-cost option than charcoal (figure 2.6). In Rwanda, Inyenyeri pellets used in the high-efficiency Mimi-Moto stoves also distributed by the company allow a household to reduce its cooking energy expenditure by 30 percent over the cost of charcoal, even allowing for a healthy profit margin for the enterprise.¹⁵ However, other pilots, such as Emerging Cooking Solutions in Zambia and EcoZoom pellet fuel in Kenya struggle to achieve attractive economics. The affordability of cooking with pellets continues to depend on the business model and the performance of the specific gasifier stove.

Cooking with ethanol remains uncompetitive with charcoal and in many markets with low-priced kerosene as well. As figure 2.5 shows, cooking with ethanol fuel costs more than cooking with any of the major household fuels except uncarbonized briquettes in Kenya. Safi International, which distributes ethanol in urban areas in Kenya, prices it at parity with charcoal. In Madagascar, ethanol cooking is substantially more expensive than charcoal and could require a significant scaling up of local production to change these economics. A further challenge in countries like Kenya is the low price and deep penetration of kerosene, a fuel that has experienced substantial price declines despite the elimination of kerosene subsidies due to the lower price of fossil fuels. However, ethanol's relatively high price will not likely

15. Data confirmed via interviews with a small sample of rural and urban Inyenyeri clients (n=20).

remain a permanent feature. Under a policy regime where taxes and duties are equalized relative to other fuels, ethanol could be on par or as much as 10–30 percent lower in cost than charcoal, even allowing for a profit margin. Furthermore, pricing challenges around ethanol are an early-stage feature and often due to inefficient ethanol sourcing and distribution business models. The streamlining of business models could improve the price competitiveness of ethanol over charcoal in Sub-Saharan Africa.¹⁶

Commercially produced uncarbonized briquettes are unattractive compared with charcoal or wood when used in unimproved biomass stoves or intermediate improved cookstove technologies like rocket stoves. Charcoal and wood have 25 and 70 percent of the calorific value of charcoal, respectively, and are therefore often priced to yield total cooking costs matching or exceeding traditional biomass. But when rural and peri-urban producers sell to nearby households, they can be competitive. The use of biomass gasifier stoves further improves the economics. Nevertheless, at a large scale, uncarbonized briquettes are likely to remain economically unattractive to most consumers.

Beyond fuel costs, other serious demand-side barriers hinder the uptake of alternative biofuels in the region as well (UNIDO 2015 and Schlag and Zuzarte 2008), including the cost of compatible stoves—\$20–100 per unit (World Bank 2013). These prices are beginning to decline—for example, the CleanCook ethanol cookstove has decreased in price from \$250 a decade ago to \$50 a few years ago to \$25–35 today—but they are still cost prohibitive for most households.

Access also continues to restrain uptake—the fuels and stoves remain largely unavailable compared with their traditional counterparts. For example, the region’s urban dwellers usually have to take only a very short walk—50–250 meters—to buy cooking charcoal; peri-urban and rural charcoal users have to travel 1–2 kilometers (World Bank 2009; Patel and Nyangena 2016). Alternative biofuels do not tend to be this readily accessible. Substantial investments in distribution networks are needed to ensure comparable penetration.

The level of awareness among households regarding biofuels and their advantages is low. Most are unaware of the alternatives to traditional fuels, and among those who are aware, many are unwilling to take the risk of switching, particularly if they have had a previous bad experience with low-quality options. In many markets, consumers do not fully understand the dangers of using traditional fuels and the benefits of transitioning to alternatives. A 2012 survey in Mozambique reveals that 55 percent of consumers are unaware of the long-term health impacts of traditional charcoal cooking. Only 13 percent of women surveyed in Ethiopia in 2008 believe that inhaling indoor emissions is a “cause for concern” (World Bank 2014).

Quality challenges and safety concerns also persist.

16. Based on an interview with the CEO of Koko Networks and a review of pro-forma economics (summer 2016).

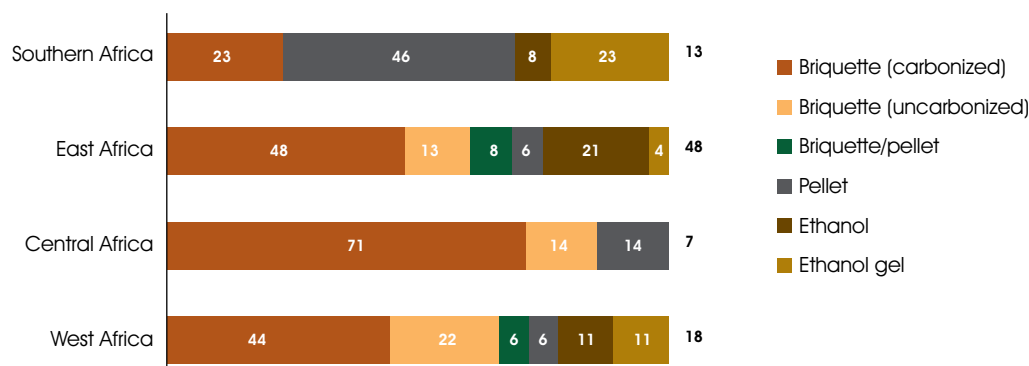
Biofuels do not always offer a better cooking experience than traditional “dirty” fuels like charcoal and kerosene because the quality of the biofuels and performance of the stoves varies. Briquettes are often produced by smaller enterprises using semi-industrial or artisanal methods with limited control, leading to wildly inconsistent quality (see Ferguson 2012). The quality of the stove also matters. Many stoves are optimized for briquette use, and much of the user experience depends on the stove-fuel combination. The performance of ethanol stoves varies widely, and fuel quality depends on feedstock quality, the level of ethanol purity or dilution, and the blending process. Low-quality ethanol generates smoke and odors, produces a lower intensity flame, and can damage stoves. For pellet gasifiers, the cooking experience between natural and fan gasifier stoves is vastly different, including ease of use and level of end-user control. Because fan gasifier technology is new, its performance varies dramatically between models.¹⁷

Alternative fuels and stoves demand of their users a shift in cooking behavior and cultural tradition (Schlag and Zuzarte 2008). The changes need to use carbonized briquettes instead of charcoal are minor; pellets and ethanol require more substantial shifts in practices. Nevertheless, these challenges pale in comparison to adopting LPG or electricity.

Supply Side

Despite the demand-side challenges, as of 2016, there are 80 businesses in the briquette, pellet, and ethanol market producing and distributing cooking biofuels across the region, (figure 2.6). As of late 2016, more than 80 businesses in Sub-Saharan Africa are focused on briquettes (53), ethanol fuel/gel (20), and pellet (13) cooking fuel production, distribution, or

Figure 2.6. Biofuel Manufacturers and Distributors by Fuel Type and Subregion in Sub-Saharan Africa



Sources: Desk research, interviews, and surveys building on the GACC fuels/stoves database <http://catalog.cleancookstoves.org/stoves>.

17. Based on interviews with Mimi Moto, Inyenyeri, and other gasifier producers; distributors; and experts, including Jacob Moss.

both.¹⁸ These enterprises, account for the vast majority (90 percent) of commercially produced briquettes, pellets, and cooking ethanol utilized in Sub-Saharan Africa. These numbers exclude nongovernmental organizations (NGOs), small, often informal small and medium enterprises, and hundreds of briquette microentrepreneurs that produce and distribute less than one ton of briquettes per month.

At least 25 Sub-Saharan countries have some level of cooking biofuel production and distribution in place, but most of the activity clusters in a handful of East African countries—Kenya, Uganda, Madagascar, Tanzania, and Ethiopia, which account for 60 percent of all cooking biofuel enterprises. Across the region, countries with relatively significant biofuel production and distribution are Kenya, with 22 percent of all biofuel enterprises; Uganda with 20 percent; South Africa with 11 percent), Madagascar with 8 percent; Ghana with 5 percent; Nigeria with 5 percent; and Tanzania with 5 percent.

Most cooking biofuel businesses in the region serve both households and institutions (53 percent) and are heavily focuses on urban customers (figure 2.7). Fewer than 10 percent exclusively serve institutional consumers; and 37 percent of ethanol and pellet companies only serve households.

The majority (63 percent) of biofuel enterprises in the region are strongly biased toward focusing primarily or exclusively on urban and peri-urban markets due to the distribution challenges and weak economics of serving rural populations. Twenty-eight percent serve both rural and urban populations, and the less than 10 percent that cater exclusively to rural areas are usually social enterprises operating within NGOs.

Seventy-three percent of currently active biofuel enterprises in the region are early-stage small or medium enterprises operating for less than five years, 34 percent began operations in the past two years, and 20 percent began just in the past year (figure 2.8). Ethanol gel producers are the most established among the enterprises—an average of 8.6 years. They are mostly clustered in South Africa, Tanzania, and Nigeria. A handful of briquette businesses have been active in Sub-Saharan Africa for 15–25 years, largely focused on institutional cooking markets. Liquid ethanol and pellet fuel enterprises, represent the most recent cooking biofuel businesses in the region, with most in or near the start-up phase.

Most of the enterprises are African-owned and based in the region; several are affiliated with larger corporations, such as Abellon CleanEnergy's pellet business in Ghana; and a few work with large regional or global fuel producers already working in Sub-Saharan Africa, such as Mumias Sugar in Kenya and ALCOGROUP. Ethanol businesses such as Safi International and Koko Networks and pellet fuel businesses such as Inyenyeri and Emerging Cooking Solutions have the highest proportion of foreign ownership and/or foreign capital. Briquette businesses,

18. The database tracks 86 enterprises, but 4 are inactive or defunct. Several enterprises distribute multiple types of fuel, such as pellet and briquette; enterprises by fuel type are therefore sometimes count twice, resulting in a total higher than 86. Informal small and medium enterprises are excluded.

Box 2.1. Methodology: Quantifying the Biofuel Producer and Distributor Landscape in Sub-Saharan Africa

Through an analysis of the *Sub-Saharan Africa Biofuel Enterprise Database*—a comprehensive database prepared specifically for this purpose—this study examines the current landscape for biofuel producers and distributors in Sub-Saharan Africa and quantifies key sector trends. An overview of the process for preparing the database follows.

Biofuel enterprise list. A list was compiled of 86 biofuel entrepreneurs in Sub-Saharan Africa from the Global Alliance for Clean Cookstoves' member database, including all 120+ players categorized as biofuel producers and distributors. This list was augmented by desk research and keyword searches in English, French, Portuguese, and Swahili for over twenty of Africa's largest fuel and stove markets. It was further supplemented by published reports on ethanol, pellet, and briquette fuels in Africa; country-level research; and sector interviews and surveys.

Scope of analysis. The Sub-Saharan Africa Biofuel Enterprise Database and related analyses excludes a number of entities:

- Artisanal and semi-industrial briquette producers and microentrepreneurs that produce less than 1 ton of briquettes per month—there are likely over 1,000 across Sub-Saharan Africa—that are supported by nongovernmental organizations (NGOs) including Energy4Impact (formerly Global Village Energy Partnership), Legacy Foundation, Projets Solidaires, UN Refugee Agency (UNHCR), Institut Congolais pour la Conservation de la Nature (ICCN) and the former Harvest Fuel Initiative;
- Noncommercial NGO or community-based organization fuel production projects, unless such projects have been established as commercial or quasi-commercial enterprises;
- Biofuel production equipment manufacturers, including ethanol microdistillery plants and pellet machine makers;

- Fuel and feedstock importers, wholesalers, and retailers not directly involved in fuel production or the market development of cooking biofuels; and
- Biofuel producers not focused on household or institutional cooking markets, such as briquette and pellet producers focused on industrial end users.

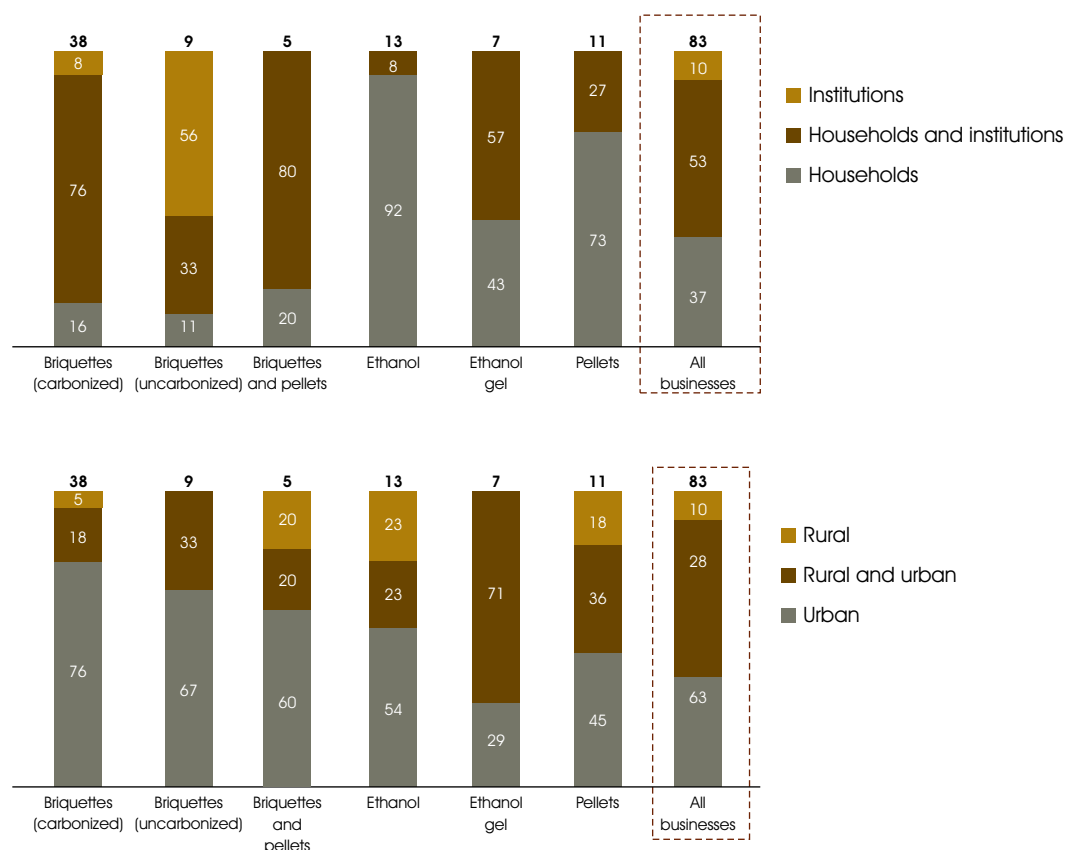
While early stage projects have been removed from the enterprise list, many of the businesses are start-ups whose sustainability is uncertain and who may no longer be active by the time of publication.

Biofuel producer/distributor surveys and interviews. In-depth surveys were conducted between the fourth quarter of 2015 and the first quarter of 2016 of 20 select organizations across a range of fuels and business models focused on ethanol, pellet, and briquette producers in Kenya, Mozambique, and Rwanda. A separate set of biofuel producer profiles were prepared for Uganda. In-depth interviews were conducted of another dozen biofuel enterprises active across Sub-Saharan. Detailed feedstock sourcing, production, distribution, financing, and business economics information was obtained and anonymized for the report.

Data standardization and analysis. Based on the research, the authors compiled extensive information and data on all 86 entities in the database and a dozen other similar organizations with a global focus.

Data validation. Much of the information in the Sub-Saharan Biofuels Enterprises Database is self-reported by the cooking fuel enterprises and could be subject to bias and inaccuracy. The data has been triangulated and validated by independent means wherever possible.

Figure 2.7. Alternative Biofuel Businesses by Customer Type and Rural/Urban Focus in Sub-Saharan Africa



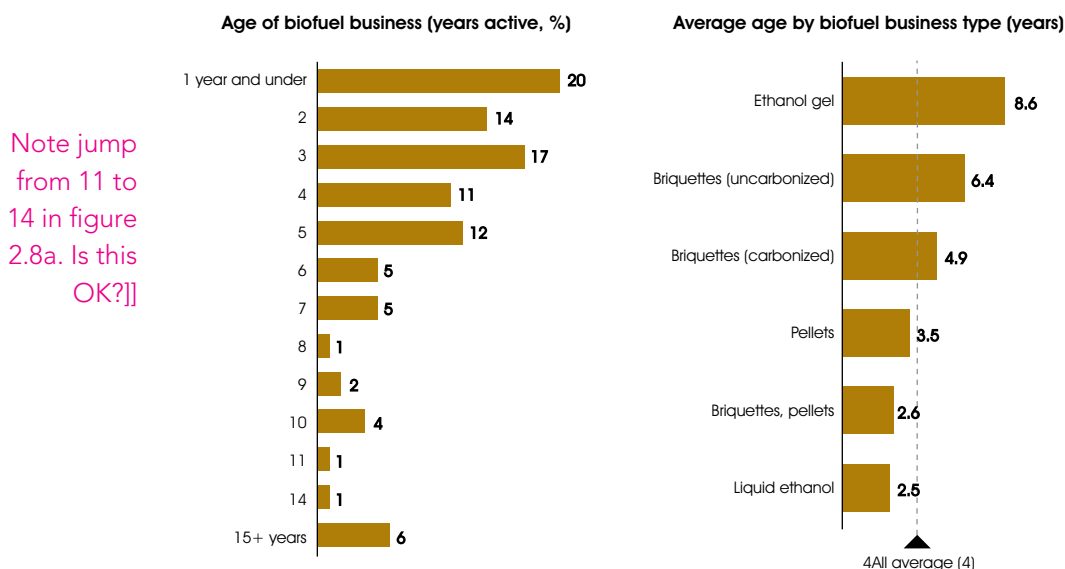
Source: Sub-Saharan Africa Biofuel Enterprise Database.

which require little start-up capital, tend to be local. But regardless of ownership, they all rely on foreign fuel processing and production equipment, including Indian and Chinese briquette presses; U.S., Danish, and Dutch pellet machines, and Brazilian ethanol microdistilleries.

Overall, only a few biofuel businesses in Sub-Saharan Africa have reached meaningful scale. Under 20 percent consistently supply over 5,000 households with cooking fuel; under 8 percent (seven enterprises) reach over 20,000 households; and only one claims to regularly reach over 100,000 households.¹⁹ Five of the top seven biofuel players in terms of household reach focus on ethanol and ethanol gel distribution. The struggle with scale is consistent with the experience of the global cooking biofuel sector, where only a handful of briquette, ethanol, and pellet fuel companies, notably in India and China, have reached significant scale of their

19. Few businesses track end-user data for carbonized briquettes; many cannot do so because of limited visibility into their distribution value chains (briquettes are often sold through third-party wholesalers and retailers). Household reach estimates are based on self-reported data by enterprises or conservative assumptions based on the volumes of fuel sold. Household reach for ethanol and ethanol gel is estimated based on the number of compatible stoves distributed or the actual number of households tracked by the fuel distributor.

Figure 2.8. Segmentation of the Biofuel Enterprise in Sub-Saharan Africa by Age of Business



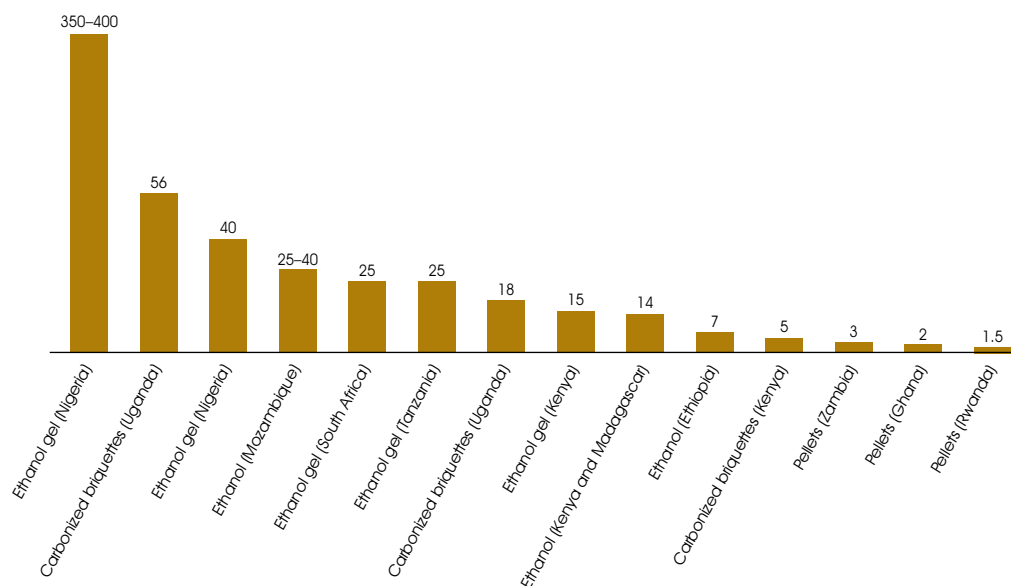
Source: Sub-Saharan Biofuel Enterprise Database.

cooking biofuel businesses (over 100,000 household customers). Figure 2.9 shows the estimated household reach of leading cooking biofuel businesses in the region identified by fuel type and country.

Annual cooking fuel sales and distribution volume in Sub-Saharan Africa remain very modest. As of 2016, the total estimated cooking biofuel consumption is less than 6 million liters of ethanol; 8 million liters of ethanol gel; 28,000 tons of pellets (only 5,000 tons of which are for household cooking); and between 80,000 and 100,000 tons of briquettes. These numbers are low, not only in absolute terms, but in terms of the number of biofuel stoves that have been distributed in the region: fewer than 80,000 ethanol stoves; 400,000–550,000 ethanol gel fuel stoves; and 30,000 fan gasifier pellet stoves, suggesting that most households only use biofuels as a secondary or tertiary backup fuel, mirroring the case of modern cooking fuels like LPG and electricity.

The cooking biofuel sector in Sub-Saharan Africa is dependent on grants, although many businesses have reported profits in recent years. Roughly half of all biofuel enterprises in the region have received donor grants or subsidies at some point, but only one third continue to rely on them for their day-to-day operations. About half of the 54 biofuel businesses reporting profits did so in fiscal 2015. When the other 30+ biofuel businesses in the region are incorporated into the analysis, however, the share of profitable businesses is closer to 30–40 percent. About 15 percent of the region’s biofuel businesses receive carbon credits.

Figure 2.9. Leading Alternative Biofuel Businesses in Sub-Saharan Africa by Number of Households Reached (thousands)



Sources: Self-reported data gathered during interviews and desk research.

Sector interviews and publicly disclosed profitability figures suggest that average profitability is lean: 5–10 percent profit margin excluding grants and 20–30 percent including revenue from grants and carbon financing streams. Businesses focused on urban areas report substantially higher profits than those focused on rural areas. However, despite the limited reach and challenging economics, the region’s young cooking biofuel sector is dynamic. Numerous businesses have expanded rapidly over the past two to three years; some ambitious startups are moving beyond their pilot phases; and some are attracting significant donor and investor attention, such as Inyenyeri for biomass pellet distribution in Rwanda and Koko Networks and Safi International for cooking ethanol distribution in East Africa; a few are expected to reach the 50,000–100,000 household scale over the next three years.

These developments are very significant for Sub-Saharan Africa. In addition to increasing LPG adoption in select countries, ethanol and pellet fuel enterprises represent major sources of potential dynamism in the shift to clean cooking. Based on historical growth rates and this financing flow, biofuel volumes and household reach could double or triple over the next two to three years,²⁰ albeit from a very low base.

The universe of biofuel producers in the region is larger than that of enterprises currently servicing the cooking fuel market. Many producers do not consider the cooking fuel market

20. This estimate is based on the likely expansion trajectory of the top 10 enterprises based on their self-reported funding commitments and growth plans for 2017–20.

a priority. Virtually all of the region's major ethanol producers currently build their business around servicing the beverage industry, such as Mumias Sugar in Kenya, or fuel blending, such as Ethanol Company Ltd. in Malawi; the cooking fuel market is merely an afterthought. One large pellet manufacturer in Ghana (Abellon CleanEnergy) produces roughly 100,000 metric tons of pellets per year and concentrates on selling them into export markets for heating and industrial uses.

The potential supply of cooking fuel from existing Sub-Saharan biofuel producers not currently involved in the cooking sector is significant. For example, current capacity exists for the production of at least 135 million liters of ethanol per year in East Africa alone—and more than three times the region's overall bioethanol capacity of 450–500 million liters per year.²¹ After being largely stagnant over the past decade, the region's bioethanol sector is on the verge of more rapid growth. The policy environment for ethanol production is improving; new ethanol fuel blending requirements are in place in some countries; and significant new ethanol production projects have been announced or launched in Kenya, Tanzania, Uganda, Madagascar, Rwanda, Ghana, and Nigeria, among others.

Commercial uncarbonized briquette and pellet players in Sub-Saharan Africa have the capacity of producing at least 200,000 tons per year—75,000–100,000 tons of uncarbonized briquettes and 125,000–150,000 tons of pellets—and perhaps as much as 400,000 tons total if the struggling capacity of South African energy briquette and pellet manufacturing is included. However, these businesses focus almost exclusively on the commercial sector—not on households. Major biofuel enterprises operating outside of the cooking space will be potential entrants into the alternative biomass cooking fuel sector when the market case becomes strong enough and when there are adequate distribution channels and intermediaries.

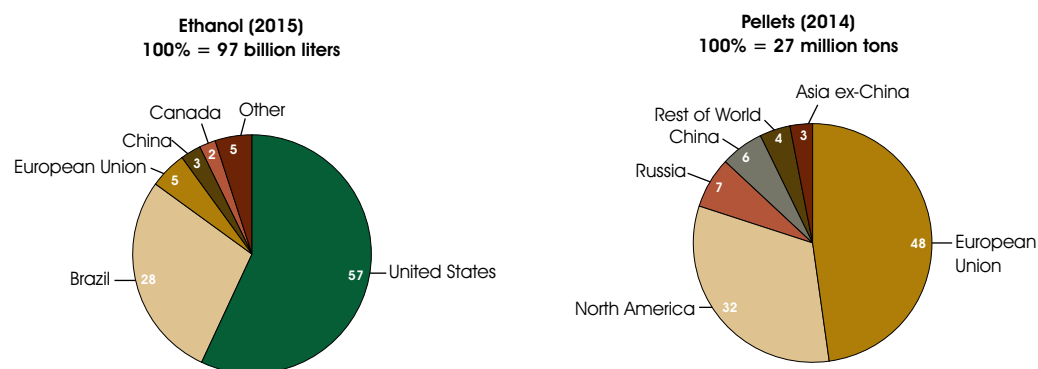
From a global perspective, Sub-Saharan Africa's biofuel industry is in its infancy (figure 2.10). Global ethanol production was 97 billion liters in 2015,²² doubling from the previous decade, with projected increases of 125–140 billion liters by 2020.²³ Large global ethanol producers include U.S. players like Archer Daniels Midland (6.7 billion liters), POET (6.4 billion liters), Green Plains Renewable Energy (5.5 billion liters), and Valero Energy (4.5 billion liters); Brazilian ethanol industry leaders like Copersucar (5 billion liters) and Oderbrecht (3 billion liters); and large European producers and traders like the Belgian Alco Group (1 billion liters). Fifty-seven percent of the global ethanol production capacity is currently in the United States, followed by Brazil at 28 percent (RFA 2016). In Sub-Saharan Africa, ethanol consumption for cooking purposes is less than 0.01 percent of global production and all ethanol production efforts combined represent roughly 0.5 percent of the global ethanol supply.

21. Estimates for bioethanol production is less than 500 million liters per year across Sub-Saharan Africa, excluding synthetic ethanol (sugar and cassava bioethanol).

22. For annual ethanol fuel production figures (about 97 billion liters in 2015), see U.S. Department of Energy Alternative Fuels Data Center at <http://www.afdc.energy.gov/data/> and the Global Renewable Fuels Alliance at <http://globalrfa.org/>.

23. Estimates based on data from the International Energy Agency, 2016.

Figure 2.10. Global Biofuels Production: Ethanol and Biomass Pellets



Sources: Renewable Fuel Association 2016; IEA Bioenergy Taskforce 2015; and Hawkins Wright 2015.

Global biomass pellet production reached roughly 27–29 million tons in 2015, quadruple the amount of the previous decade; and it is projected to increase to over 50 million metric tons by 2020 (Hawkins Wright 2015). There are a few hundred pellet plants in China and over a thousand globally. The largest, which are based in Canada, the United States, and Europe, have an annual capacity of up to 1 million tons. Key pellet production markets are the United States, Canada, the European Union, Russia, and China. Roughly half of the pellets are used for heating—particularly in the United States, Canada, Italy, Germany, and France—and half for industrial uses. From a distribution perspective, preparing pellets for marketing for heating use is similar to preparing them for cooking in that both markets require pellets to be packaged and sold in the form of 20–40 kilogram bags. Like ethanol, the volume of pellet production in the region barely figures in global totals, representing roughly 1.5 percent of global pellet production in 2015, with less than 0.1 percent used for cooking.

Carbonized and uncarbonized briquettes tell a similar story. Uncarbonized briquette production from agricultural residues stands at over 20 million tons per year, with an estimated 3,000–4,000 briquette plants globally, many of them small briquette press operations across major production markets, including China, India, Bangladesh, Nepal, Japan, Korea, Brazil, North America, and select countries in Europe and Africa.²⁴

In 2014, China produced over 4 million metric tons of uncarbonized briquettes from agricultural waste and straw, making it one of the world's largest producers. Based on historical trends, the country is now producing 5–6 million tons per year, using 600–700 briquette plants (Xu et al. 2015; Huang 2014). In India, there were 800 briquette factories with 1,500 press machines in use by 2014, producing an estimated 2.5–3 million tons of uncarbonized agriculture residue briquettes per year.²⁵ South Korea utilized over 10 million tons of briquettes and

24. Global production volumes of uncarbonized briquettes are poorly tracked. Major production markets suggest an amount closer to 10 million tons per year.

25. See African Briquet Factory's website at <http://www.afribiobmass.com/abf/investors/> and Ashton's website at <https://www.ashden.org/briquettes>.

pellets; in 2010, more than half were locally produced uncarbonized briquettes for co-firing and industrial boilers. Bangladesh had 1,200 small-scale rice husk briquetting plants in operation in 2011, producing more than 300,000 tons of uncarbonized briquettes per year, based on an average plant capacity of 80–120 kilogram/hour (Islam 2011), with the potential for producing over 1 million tons (Islam et al. 2016). Most of the briquettes were used for institutional and household cooking fuel. Estimates of uncarbonized briquette production from agricultural waste in Brazil, is 200,000 metric tons from 40 briquetting plants (Felfli et al. 2011). Combined, roughly 100,000 tons of uncarbonized briquettes are produced in Sub-Saharan Africa, representing less than 0.5 percent of global supply.

Although information on the subject is limited, global production volumes suggest that carbonized briquette production is at least a million tons per year—and possibly a few million tons—across 500–1,000 factories operating globally, which means that the 70,000–100,000 tons of carbonized briquettes from Sub-Saharan Africa represent 5–10 percent of the global total. The carbonized briquette industry is primarily centered in Asia (Mwampamba, Owen, and Pigaht 2013), particularly in countries such as India, China, Japan, Indonesia, Philippines, Cambodia, Myanmar, Malaysia, and Thailand; and it relies on sawdust and coconut feedstock. Indonesia has over 50 sizeable charcoal briquette producers, ranging in capacity from 100–300 tons per month to 20,000 tons per month. Interviews suggest that India is likely producing charcoal briquettes at a comparable scale. Production in other countries is at a much smaller scale.

The presence of a fast growing and increasingly commoditized global biofuel production ecosystem is important even if it remains largely unlinked to the cooking biofuel market in Sub-Saharan Africa. The thriving global biofuel industry is an important potential source of technical expertise, technology transfer, and business model learning from which any African-based biofuel producer or distributor can draw, even though such interregional linkages with Asia are very weak (Mwampamba, Owen, and Pigaht 2013). The existence of a global biofuel industry means that there are well-tested fuel production technologies at all scales adapted to a variety of conditions, which is invaluable for learning as well as for technical support and spare parts. And with a growing global supply, fuel can be imported to help kick-start market development before the build-out of the local ethanol supply or to backfill local production capacity if there are interruptions in domestic supply. This may not always be feasible, however, because briquettes are a thin-margin fuel best produced and consumed at or near their production source. Transportation costs, taxes, and duties combine to make importing pellets economically unattractive.

The current spot prices for ethanol in Europe and North America—\$0.40–0.50 per liter—and free-on-board prices of \$0.60–0.70 per liter in Mombasa port, for example, makes imported ethanol competitive with locally produced bioethanol. The comparability of these prices makes it conceivable for Sub-Saharan ethanol businesses to import high quality ethanol in sufficient quantities during the market build-out phase or as a medium-term business proposition for supplying cooking ethanol to urban markets with solid transportation infrastructure.

There are numerous ecosystem-level challenges to the supply side of the biofuel system. The greatest is the struggle to cost-effectively distribute biofuels to end users. Most interview participants for this study (box 2.2) highlighted this as the primary difficulty, which is corroborated by the academic and practitioner literature on the subject (Schlag and Zuzarte 2008). In the urban context, distribution requires the build out of very widespread and dense distribution networks because of its competition with ubiquitous charcoal. For rural customers, transporting fuels from production sites to rural and peri-urban fuel users is very costly. Biofuel distributors in the developed world, face few logistical barriers, but they still structure their distribution to optimize transportation distances. Road coverage is limited in Sub-Saharan Africa, transportation logistics are highly inefficient, geographic distances are vast, and population density is low, all of which make transportation extremely difficult.

Last-mile distribution is particularly complicated in the highly fragmented context with inefficient value chains that characterize rural and peri-urban Africa (Agrawal and Dutt 2013; Hystra 2013; Shukla and Bariganjan 2011). Multilevel distribution schemes with distributors, subdistributors, and retailers all claiming their share of the margin can wreak havoc on biofuel economics, particularly given the extremely price-sensitive consumer base. Processed biomass distributors could theoretically use existing charcoal distribution infrastructure, but in practice, this would be next to impossible. Ethanol distributors could tap into upstream and middle-mile storage, transportation, and wholesaling infrastructure for existing liquid fuels—(LPG and beverage ethanol)—but doing so is not easy for small-scale players. Biofuel distributors looking beyond middle-class, urban end users, often must ultimately build out their own distribution footprint using proprietary sales forces; channel partners, such as NGOs and women’s groups; and sales agents.

Changes needed in marketing and behavior further complicate the distribution of biofuels and stoves. Cooking biofuels do not sell themselves. Even if the fuel is relatively close in appearance and cooking use to its traditional counterparts, consumers need to be educated about the new products to ease their distrust and learn about optimal cooking practices. New stove-fuel cooking systems, such as ethanol and pellet gasifier stoves, make the situation even trickier. Surmounting these obstacles will require business model innovation, investments into marketing, and the development of a patient market.

Another critical supply-side challenge facing the biofuel sector in the region is the ability to secure high-quality feedstock and/or fuel sourcing. Most biofuel producers are highly sensitive to the cost of feedstock because it is their most substantial expense: 20–60 percent of net revenues. Given the sector’s thin margins, a 10 percent swing in feedstock costs and a corresponding 2–5 percent drop in the business’ profit margin can be the difference between viability and insolvency. While the supply of biofuel feedstock is practically infinite in Sub-Saharan Africa, the feedstock is often geographically distant from fuel producers and end users. The supply is also highly fragmented, requiring significant effort for collection, aggregation, transportation, and storage. Seasonal interruptions can be planned around, but other supply

breakdowns are much harder to manage. Competing demands and alternative end-users pose a challenge for price stability in nascent biofuels markets. The quality of feedstock is another major concern because the performances of ethanol, pellets, and briquettes are highly sensitive to feedstock quality and uniformity.

Box 2.2. A Deep Dive Into Sector Perspectives on the Distribution Challenge

Many of the interview participants for this study emphasized the following serious obstacles to growing an alternative biomass business: marketing challenges, making the initial sale, and delivering biofuels and stoves to consumers. Several of their observations are presented below.

“The name of the game is distribution. We made many mistakes, but likely the biggest was trying to solve both distribution and production challenges at once. We significantly underestimated the difficulty and the time to properly develop market demand and to build out a robust multichannel distribution engine, something that must come first.” – Cooking ethanol entrepreneur

“In urban areas, the greatest distribution challenge is outcompeting ubiquitous charcoal suppliers, something that can only be done at great cost with significant investment into proprietary distribution channels or by working intensively with existing distribution networks. In rural and peri-urban areas, the biggest distribution challenge are the roads (or their absence) and the need to motivate uninterested last-mile retailers with significant financial incentives that margins do not always allow.” – Briquette distributor

“Our DNA is biomass fuel production and trading, not retail channel development. We are not constrained by production capacity at the moment, the issue is developing market demand and building out distribution, which is extremely costly in Africa and may even be economically irrational given the many alternative uses for our product (i.e., in institutional cooking and industrial markets) where we can get the same sales volumes with much more limited investment of time and energy.” – Pellet fuel producer

“It took us years to figure out many aspects of the model, including optimizing feedstock sourcing, getting the right stove for the fuel, and securing financing, but by far the biggest challenge that remains is disciplined, on-the-ground fuel and stove distribution. There are so many things that can go wrong here, and getting the distribution model right and running it efficiently is a big concern” – Cooking pellet entrepreneur

Policy barriers are another key concern, the most prominent being the poorly calibrated tax and tariff regime that make it difficult to import fuel production equipment, quality biofuel stoves and components, and the fuels themselves in the early stages of market development when local supply is inadequate.

Ethanol, formally distributed pellets, and briquette fuels invariably face value-added taxes and often high import duties. Duties for denatured ethanol are as high as 25 percent in many Sub-Saharan countries,²⁶ and import duties are even more common for un-denatured ethanol (often referred to as *beverage alcohol*). Ethanol is also subject to domestic alcohol excise taxes, some of which date back to the colonial period, which can be as high as 100 percent with no differentiation between beverage alcohol and technical alcohol for household cooking fuel (UNIDO 2015; World Bank 2011). Positive changes are beginning to emerge regarding fuel duties and taxes, however, such as the recent Kenya tax and duty holiday for technical ethanol.

Tariffs on cookstoves required for ethanol and pellet use are a further policy barrier. While these tariffs are meant to create room for local cookstove manufacturers to grow, they prevent the secure supply of imported cookstoves in the interim. Duties and taxes on biofuel stoves in markets such as Uganda and Cameroon approach 50 percent, discouraging advanced market tests.²⁷

Furthermore, the lack of an explicit government endorsement for clean biofuels, poorly defined fuel quality standards, misapplied regulations, and perverse incentives exacerbate the challenge. The absence of a comprehensive biofuel framework prevents the holistic consideration of how to enable the development of these sectors. The lack of policies regulating the illegal charcoal and firewood trade is of particular concern. There are no country-level quality standards for the common categories of biofuels; and the new international standards, such as ASTM E0350, adopted in 2016 for ethanol (ASTM 2016), are not reflected in country-level regulations and policies. Impurities and the watering down of ethanol results in fuel variability, which can significantly impact the cooking experience (Project Gaia 2014).

The financing barrier for biofuel entrepreneurs is acute and pervasive. Access to finance poses a barrier across the three biofuels at all levels of the value chain—not entirely surprising given the low levels of biofuel market development in Sub-Saharan Africa. Small and medium enterprises and startups trying to secure noncollateralized financing at workable terms find it quite difficult. Private-sector financing is too expensive for early-stage enterprises, and larger corporations are unwilling to invest until they see stronger proof of market and manageable operational risks. Other than local sources of finance, relatively little global impact or commercial investment capital is being directed toward the sector—under \$12 million in 2015, according to the Global Alliance for Clean Cookstoves (GACC 2016), although investors are beginning to show rising interest. Carbon financing is relatively moribund, and new

26. Based on press searches and review of tax/tariff databases.

27. Country validated tax/tariff base.

results-based financing mechanisms to reward the various co-benefits of clean biofuel cooking are not currently in place.

Grant funding for business model piloting and scale-up from development finance institutions like the World Bank and institutions like the Global Alliance for Clean Cookstoves is extremely limited. A bulk of the already scarce donor attention and funds are still being directed to high-level ecosystem investments such as health research and clean cooking road-map development or to the promotion of basic and intermediate improved biomass cookstoves rather than cooking fuels like ethanol, briquettes, and pellets.

The quality of biofuels can be highly inconsistent, significantly affecting end-user experiences and perceptions of fuel quality and safety. Although the impact of this barrier is on end-user perceptions and therefore on demand, fundamentally, this is also a supply issue rooted in the low level of technical capacity among fuel producers.

The availability of quality stoves well suited to biofuels has proved to be a challenge in the past. Carbonized briquettes do not require a custom-built stove, but pellets and ethanol do. There are currently 10 commercialized or advanced commercial prototype stove models for ethanol and ethanol gel cooking and an estimated eight fan gasifier stove models for pellets, up from a handful of experimental models just two or three years ago. The quality of existing solutions in terms of performance and quality varies tremendously, and investments in research and development are limited.

Summary of Market Barriers and Overview of Forward-Looking Trends

A summary of the most relevant barriers to biofuel market development is presented in table 2.1.

Overall, the main market-level cross-cutting challenges are: cost-effective distribution, financing, policies, and price competitiveness. They span demand, supply, and the enabling environment and cut across all fuel types, although the barriers affect the various fuel sectors differently (table 2.2), shaping the amount and type of support required for each of the cooking biofuel to reach scale.

Cumulatively, these barriers translate into reduced margins for biofuel producers and distributors, and they significantly constrain the market. Briquettes and pellets tend to be competitively priced with what they replace—charcoal; ethanol, however, is constrained by import costs and competes more directly with kerosene. Pellets have the greatest cost advantages when combined with highly efficient pellet stoves. Ultimately, ethanol has the greatest long-term potential for clean (Tier 4) cooking, but it is also most affected by market barriers, followed by biomass pellets.

Despite the barriers, recent trends offer hope for overcoming barriers and reveal increasing interest among larger enterprises and policy makers. New players are entering the sector in the region every year, including at least 17 in 2015–16. Household incomes are increasing, and more people are moving from rural to urban areas, increasing the size of the addressable market. As traditional biomass prices increase, the demand for alternatives increases. Entrepreneurs are trying to determine how to best tap into this market, refine fuel production

Table 2.1. Summary of Biofuel Market Barriers

	Barrier	Description
Demand	Affordability of fuel—price competitiveness versus alternatives	Alternative biofuels may not be able to compete with the price points of traditional fuel counterparts like charcoal and kerosene.
	Affordability of biofuel stoves	The end consumer may not be able to afford the cost of the stove required to use pellets and ethanol.
	Access to high quality stoves/fuels (related to supply-side distribution barrier)	Biofuels and the stoves adapted to them may be unavailable in the market or may require long-distance travel to purchase compared with charcoal and other alternatives.
	Consumer awareness	Consumers may not be aware of the health risks associated with burning solid fuels or, more importantly, the existence and benefits of improved alternatives.
	Behavior change needed	Even if consumers can afford fuel and are aware of alternatives, they may be reluctant to switch from their current fuel, especially if it requires buying a new stove.
	Perception of fuel quality/safety	Consumers may not trust the durability, consistency, or safety of alternative biofuels.
Supply	Cost-effective distribution (mirrors access barrier listed in demand section above)	Producers incur high costs reaching last-mile customers; infrastructure for distribution may be underdeveloped.
	Fuel supply	Fuels may be difficult to produce or import; production facilities may require large capital investments; the high cost of electricity hinders fuel production.
	Feedstock supply	It is difficult for fuel producers to attain a consistent supply of feedstock in terms of quality, quantity, and price.
	Availability and quality of biofuel stoves	Available stoves and fuels may not operate well together in terms of efficiency and user experience.
	Fuel quality (see perception of fuel quality/safety barrier above)	Fuel quality and safety is variable, mirroring the perception of quality and safety barriers described in this report.
Enablers	Finance	Financing may be unavailable at various points in the supply chain, such as for working capital for improved cookstove producers and distributors and support for market transformation programs and research and development.
	Policy/regulation	Unfavorable policies— such as import barriers; poorly targeted subsidies; and absent, unclear, or obstructive regulatory frameworks—may inhibit the growth of the sector.
	Quality standards/testing	The limited adoption of uniform quality standards may increase the risk of actual and perceived market spoilage.
	Research and development	A lack of investment (finances and effort) into research and development could impede needed advancements to improve stove and fuel quality and to better tailor them to the cooking experience desired by customers.

and distribution models, and optimize the quality of cookstoves. Donors and the private sector are making increasing investments into the sector, and government support for cleaner fuels and cookstoves is growing, including engagement on policy issues.

Table 2.2. Comparison of Market Barriers Across Fuels

		Briquettes	Pellets	Ethanol	Rationale/comments
Demand	Fuel affordability/price competitiveness	Medium	Low	Medium-high	Briquettes comparable in quality to charcoal are expensive; ethanol costs are typically high relative to charcoal and kerosene; pellet likely lowest cost solution in most Sub-Saharan Africa from user perspective.
	Ability to pay for stove	Low	Medium-high	Medium	Pellet gasifier stove prices falling, but still highest \$35–120 relative to ethanol stove costs (\$35–80), and improved charcoal stoves for briquettes (\$15–40).
	Consumer awareness	Low	Medium-high	Medium	Consumers are relatively more aware of briquettes in Africa, but across all fuel value chains level of awareness of biofuels and their benefits is limited.
	Behavior change needed	Low	Medium-high	Medium	Pellets and ethanol require purchase of new stove; it is relatively easy to adapt to ethanol cooking from LPG but pellet cooking is a bigger behavior change.
	Perception of fuel quality/safety	Medium-high	Low	Medium-high	Briquette quality is an issue relative to charcoal; consumers are concerned about risk of fire from ethanol.
Supply	Cost-effective distribution	Medium-high	High	High	All value chains face last-mile distribution challenges; briquettes can build off of charcoal distribution infrastructure
	Fuel supply	Medium	Medium	Medium-high	Ethanol domestic production is a major CAPEX investment relative to briquettes and pellets; even with importing, securing ethanol supply is difficult.
	Feedstock supply	Low	Medium	Medium-high	In the case of domestic production, securing reliable/consistently priced feedstock is a particular challenge for ethanol; pellet feedstock may also be difficult.
	Quality stove availability	Low	Medium	Medium	There are relatively few quality stoves in market well adapted to pellets or ethanol; pellet gasifier stove quality is extremely variable.
Enablers	Finance	Low	Medium-high	High	Manufacturers and distributors in all sectors face financing challenges, but the challenge is particularly acute for ethanol given the larger capital outlays required.
	Policy/regulation	Medium	Medium-high	High	Fuel and stove taxes and tariffs impede sector development; this challenge is particularly acute with ethanol due to unclear/obstructive regulations.
	Quality standards/testing	Low	Low	Medium	Standards for ethanol production are important due to safety concerns; pellet fuel and briquette standards should also help market development.
	R&D	Low	Medium	Medium	There are relatively few R&D initiatives in any biofuel value chain, particularly ethanol, and little investment into researching biofuel impacts.

The major positive supply- and demand-side trends affecting the sector include:

- **Demography continues to be the main driver of growth for the region's biofuel sector.** Discretionary income in Sub-Saharan Africa is projected to grow by 50 percent over the next decade (World Bank 2014), which should lead to an increase in purchasing power for lower and middle-income groups. Currently, around 50 percent of the region's consumers pay for cooking fuels. The shift from self-collected firewood to cleaner alternatives is largely an urban phenomenon, and the United Nations Populations Fund projects that urbanization in the region will double between 2000 and 2030. Demand for biofuels is therefore poised to grow rapidly.
- **Rising prices for traditional cooking fuels will continue to generate opportunities for cleaner biofuel alternatives, although price shocks can have unpredictable negative consequences.** Rising prices for charcoal—11 percent per year from 2000–10, with the trend continuing ever since—continue to push consumers toward more efficient fuels and stoves. The price increases are primarily linked to growing fuel scarcity, and if governments do not turn their attention to forest sustainability, traditional fuel prices are likely to rise even higher.
- **The push to shift to improved cookstoves has witnessed real success,** with annual clean and efficient stoves sales tracked by the Global Alliance for Clean Cookstoves increasing eightfold, from 2.6 million units in 2010 to 20.6 million in 2015, representing a cumulative distribution of over 80 million stoves, 30–40 percent of which were in Sub-Saharan Africa.²⁸ While only a small share of these stoves (5 percent) are both truly clean and efficient (IWA Tier 4),²⁹ this growth in stove production and sales demonstrates the potential for the scaling up biofuel stove and fuel sales in Sub-Saharan Africa once the related fuel value chains are in place. Chinese-made stoves will likely continue to play an important role in cookstove supply, but there is an encouraging recent trend of growth in Africa-based semi-industrial higher-end stove manufacturers like ACE in Lesotho and Envirofit and Burn Manufacturing in Kenya.
- **Biofuel cookstove technology innovation is accelerating.** The number of high quality biofuel-adapted cookstoves for pellet fuel and ethanol in the Sub-Saharan market has increased dramatically in recent years. In 2015–16, several new models emerged that substantially advanced the performance frontier for the entire sector. Examples of ethanol-related innovations include: design improvements by CleanCook (formerly Dometic), new

28. These stove and fuel sales figures are difficult to disaggregate regionally, but based on historical data, roughly 30 percent can be attributed to the region (less than 25 million distributed from 2010 to 2015). Among these stoves and estimated fuel-based stove equivalents, roughly 5 percent are International Workshop Agreement Tier 4 for both emissions and efficiency, and perhaps as many as 30 percent were Tier 4 for emissions (4–8 million for Sub-Saharan Africa (GACC 2015b, 2016).

29. The Global Alliance for Clean Cookstoves defines “clean and efficient” to only apply to a small fraction of stoves Achieving Tier 4 status in terms of both efficiency and emissions. However, to only be considered efficient, a stove must demonstrate Tier 2 efficiency or higher. To be clean, it must be tested at Tier 3 or higher in terms of emissions.

ethanol cartridge stoves and fuel vending machines by Koko Networks, more safe ethanol stove designs by Safi International, and the entry of Burn Design into the ethanol sector.

The pace of innovation is similar for pellet fuels, with improved cookstove manufacturers currently engaged in prototype design and/or commercialization of gasifier stoves suitable for pellet fuels and a number of ongoing design improvements by more established Africa-focused fan gasifier stove manufacturers, including Philips and ACE.



MOTO-SAFI ETHANOL GEL AND STOVE

- Businesses continue to innovate their business models and test markets.** Few biofuel businesses have yet achieved significant scale, but progress is being made. Vertically integrated pellet fuel cooking utility business models continue to see new energy with Inyenyeri in Rwanda. Several stove manufacturers and pellet fuel producers are looking into pay-as-you-go models for biomass cooking and the integration of Angaza’s pay-as-you-go technology into cookstove prototypes such as Philips (SESA 2016). Some businesses are exploring turnkey franchise models to encourage local ethanol and pellet fuel production, such as Green Social Bioethanol and ethanol microdistilleries (Brandão 2016) and Nishant Energy’s pellet fuel factory and “stove-in-a-box” model.³⁰ Further, some large global fuel producers are actively exploring local country partnership models for fuel value chain development, including POET for ethanol.
- Donors are increasingly using results-based financing programs to enhance returns and channel capital into the market while securing results on production, distribution, and health outcomes.** Examples of new or emerging results-based financing mechanisms that already apply or could be relevant to the cooking biofuel sector include SNV stove auctions, the Nordic Environment Finance Corporation’s ethanol production incentives, the pipeline of cookstove projects from the Department for International Development and Energizing Development (EnDev), and World Bank schemes focused on efficient and clean biomass stove scale-up in Asia. Modes of implementation for results-based financing range from stove auctions in Cambodia, to ethanol production incentives by the Nordic Environment Finance Corporation and World Bank in Madagascar, to schemes focused on rewarding distributors and manufacturers for efficient and clean biomass stove scale-up or technology innovation.

30. See the Atlas of the Future profile of Nishant Energy at <http://atlasofthefuture.org/project/biomass-pellet-and-pellet-stoves/>.

- **Impact-oriented and commercial investors are increasingly exploring the market.** While the volume of debt and equity financing is still extremely low, there has been an uptick of interest and a growing pipeline of investments with clean cooking biofuel business models, particularly for integrated fuel-stove business models from impact investors such as Mulago, Jasmine, Acumen, DOEN Foundation, and Ikea Foundation; carbon finance investors such as the World Bank's Carbon Initiative for Development (Ci-Dev), Ecosur Afrique, and Althelia; and exploratory interest from commercial Africa-focused investors interested in pay-as-you-go business models.
- **Cooking biofuel policies and standards are undergoing transformation in some places.** Recent positive developments toward improving biofuel quality standards as part of the enabling environment transformation include comparative evidence on biofuel performance based on research supported by the Global Alliance for Clean Cookstoves and partners like the United States Environmental Protection Agency (Cashman et al 2016)³¹ and the rollout of global denatured cooking ethanol standards (ASTM 3050) in early 2016. From a trade-barrier perspective, important progress has been made in several countries, including the elimination of alcohol taxes on denatured cooking fuel ethanol in Kenya (GACC 2016b) and the rollout of elements of a new ethanol policy in Madagascar. National cookstove programs are being launched or scaled up in many Sub-Saharan countries, including Ethiopia, Ghana, Malawi, Nigeria, Rwanda, Senegal, and Uganda.

31. Also refer to the Global Alliance FACIT tool at <http://cleancookstoves.org/technology-and-fuels/facit/>.

III. Business Model Decision Framework

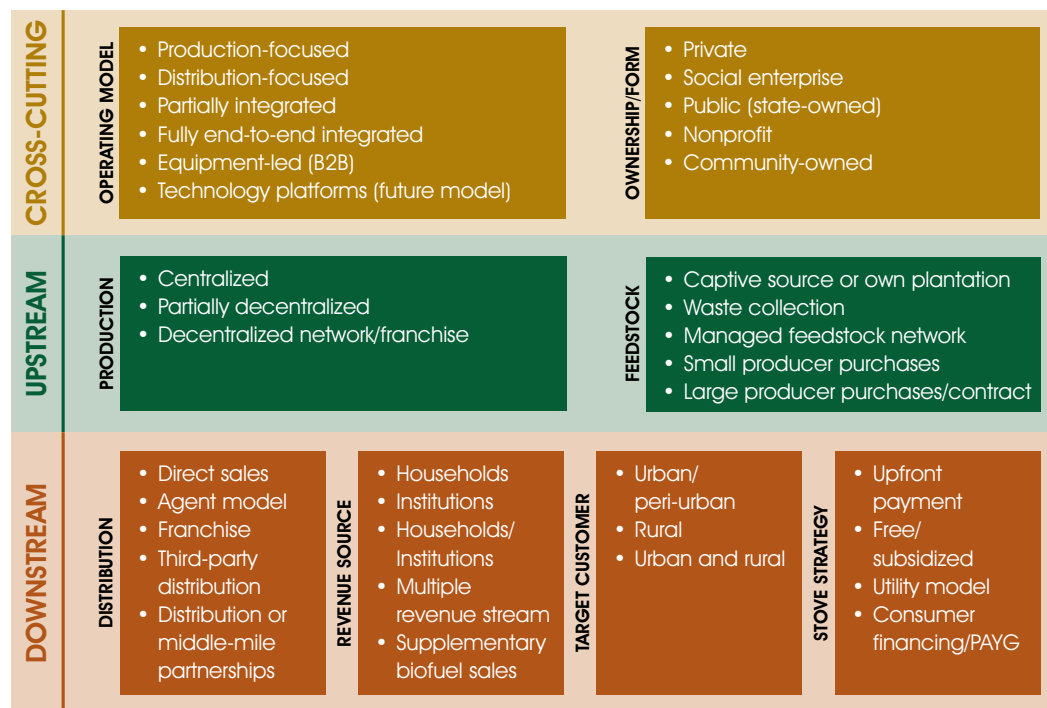
An understanding of the decisions companies make and the implications of those decisions is essential to unlocking the door to scaling up the alternative cooking biofuel sector. The previous chapter includes highlights of how business model innovation can address market barriers. This chapter provides a categorized overview of different business models (figure 3.1) and examines ones not currently being used in the Sub-Saharan biofuel market but with noteworthy future potential.

Framework of Business Model Decisions

There are several crosscutting dimensions and specific business model choices for fuel producers and fuel distributors, include the following:

- **Operating model.** Businesses choose to focus on different points in the value chain and at varying degrees of vertical integration—they are involved in activities ranging from fuel production to fuel distribution, potentially back to feedstock production and forward

Figure 3.1. Cooking Biofuel Business Model Framework



B2B - business-to-business PAYG = pay-as-you-go.

into stove manufacture/distribution. In cooking biofuel markets, this choice shapes whether the business model is primarily focused on fuel production, fuel distribution, or some combination. Greater vertical integration requires more resources, coordination, and execution skills, but allows for greater control. Other business-to-business (B2B) operational models focus on serving the biofuel value chain itself rather than on-the-ground fuel production or distribution.

- **Ownership/form.** Many businesses have a fairly organic founding process, but strategic choices around ownership, such as state- or community-owned versus privately-owned, and social orientation, such as nongovernmental organization (NGO), social enterprise, or profit-centered, can significantly influence incentives and decision making around business operations as well as prospects for scale. These decisions are potentially important levers for achieving outcomes like job creation in addition to commercial scale.

Upstream business model choices include:

- **Production model.** Those involved on the production side may adopt a centralized or decentralized (distributed) fuel production approach or a hybrid of the two. The production model decision has implications for the business' breakeven profitability point and its ability to scale. Different market contexts and operational conditions may be key determinants in deciding which of these approaches is most appropriate.
- **Feedstock sourcing.** Producers must decide how to acquire inputs for their fuels. This decision affects the level of control and confidence a business has over quality, quantity, and price.

Downstream business model choices include:

- **Distribution model.** Most businesses opt for a combination of two or more of the options for distributing fuels. As with any activity along the value chain, the tradeoff is between control over the interface with the end customer and cost. Mobile communication technology may provide greater flexibility in this regard. Where significant middle-mile logistics components to fuel distribution exist, companies face the additional choice of whether to build their own or piggyback off existing infrastructure via third-party partners.
- **Cookstove strategy.** For businesses selling both cookstoves and fuels, questions around stove distribution and pricing strategy are important because the upfront costs are a giant hurdle for many of their target customers. Decisions about whether or not to bundle stoves with fuels and if bundled, how to price the bundles—free or subsidized, upfront commercial sale, rental or utility models, or consumer financing and pay-as-you-go approaches—can significantly constrain or enable scale. The decision depends on whether

or not entrepreneurs consider the cookstoves a key source of revenue or as a vehicle for securing future revenues.

- **Revenue sources for economic viability.** A company engaged in distribution selects a pathway to financial sustainability, whether through cross-subsidizing sales to poorer households, diversifying fuel-sales between higher-margin institutional customers and households, or building out multiple revenue streams. The cooking biofuel opportunity may be an add-on or supplementary business to a company’s core or primary operations, which will shape its strategy and willingness to invest. The low margins in the biofuel sector make the revenue source dimension a critical one, with implications for profitability and reach.

Target customer. A company’s mix of urban, peri-urban, and rural customers often results from trial and error. Most businesses choose to focus on urban or peri-urban customers from a financial sustainability standpoint. Those with an explicit mission to serve rural populations must configure their business models accordingly.

Implications of Business Model Decisions

Given the nascence of the biofuel market for cooking, it is difficult to identify categorical “winners” or “losers” among the business models. Most are still being tested, and the success or failure of some is more dependent on the context in which they operate and the skills of the entrepreneur than any inherent flaw or virtue in the business model. Nonetheless, using the above categories, specific weaknesses and strengths can be identified across different market contexts. The most salient insights informed by expert and entrepreneur interviews and insights gleaned from the Sub-Saharan Africa Biofuel Enterprise Database are presented below.

Cross-cutting Business Models

No matter the specifics of its business, every biofuel enterprise must decide where in the value chain it will play—its operational model, form of ownership, and degree of profit or social orientation.

OPERATIONAL MODEL

Businesses can choose to follow several different operational models: (1) production-focused, (2) distribution-focused, (3) fully integrated, (4) partially integrated, or (5) equipment-led/B2B. However, this framework obscures the tremendous complexity around how companies operate across the value chain. Businesses in Sub-Saharan Africa, such as POET and Alco Group for ethanol, Global Supply Solutions and Green Resources for briquettes, and Abellon CleanEnergy for pellets,³² are involved in distribution, at least at the wholesale level and occa-

³² Business models can differ by geography. Abellon CleanEnergy, for example, is primarily a production-focused business in Ghana, but it pursues a vertically integrated model in India ranging from decentralized (outgrower) feedstock collection to fuel production to an institutional pellet cooking fuel business.

sionally through institutional clients and distributors, but they remain focused on fuel production. The production end of the value chain is the core of their business relationships, assets, technical expertise, and ultimately their economics. These businesses will outsource as much of the distribution role as possible and are not interested in building a retail brand of their own.

Conversely, distribution-focused businesses are not necessarily restricted to the distribution end of the value chain. Living Goods in Uganda and Vitalite in Zambia are pure cooking biofuel distributors sourcing and selling energy products to the last mile, often with other goods and services. Large distributors, including branded gas station chains like Total, distributing pellets in Zambia and, soon, ethanol in East Africa, and large supermarket chains such as Nakumatt in East Africa, which distributes carbonized briquettes and ethanol gel, can participate in biofuel and biofuel stove distribution as part of business decisions, but remain uninterested in production. Other distribution-focused businesses such as ethanol gel fuel enterprises SenCook in Senegal; Consumers Choice Limited in Kenya; and ethanol fuel distributor in East Africa Koko Networks may get involved in the final stages of production, but intentionally define themselves as retail specialists who only get involved in production when reliable outsourcing is not possible. The economics of such businesses are generated by charging margins on biofuels and the related cooking appliances.

Fully integrated businesses like Inyenyeri for pellets in Rwanda, Eco-Fuel Africa for carbonized briquettes in Uganda, or Funhol for ethanol production and distribution in Madagascar work across the entire value chain, beginning with feedstock collection, to feedstock production, and finally to delivering the fuel to the consumer. Partially integrated businesses like Eco-Carvão for carbonized briquettes in Mozambique, Habona for briquettes in Rwanda, and Moto Poa/East African Briquette Company (EABC) in Kenya, similarly straddle production and distribution functions but stop short of deep engagement on either end, preferring to work through third-party retailers and not get involved in ongoing customer management or in detailed feedstock management decisions.

Businesses that pursue a B2B or equipment-led operating model in the region, such as Nishant Energy in India for pellet manufacturing equipment; Green Social Bioethanol in Brazil for ethanol biofuel microdistilleries; and C. F. Nielsen in Denmark, Radhe Group in India, and GEMCO in China for briquettes are uninterested in fuel production or distribution, but they occasionally play a role on the ground as technical advisors or joint venture operational partners and financiers. Their core interest is typically the promotion and sale of their manufacturing equipment; their economics are based on margins on equipment sales, spare parts, and occasional advisory/consulting services.

The other category of B2B players are biofuel stove manufacturers like forced draft pellet gasifier manufacturers Mimi Moto, Philips, and ACE; natural draft pellet/briquette gasifier manufacturers Prime and Awamu; and ethanol stove manufacturer CleanCook. These companies do not involve themselves in biofuel production, but they may support biofuel market

development to drive demand for their stoves. Since biofuel markets are nonexistent in much of Sub-Saharan Africa, the involvement of these companies can be extensive.

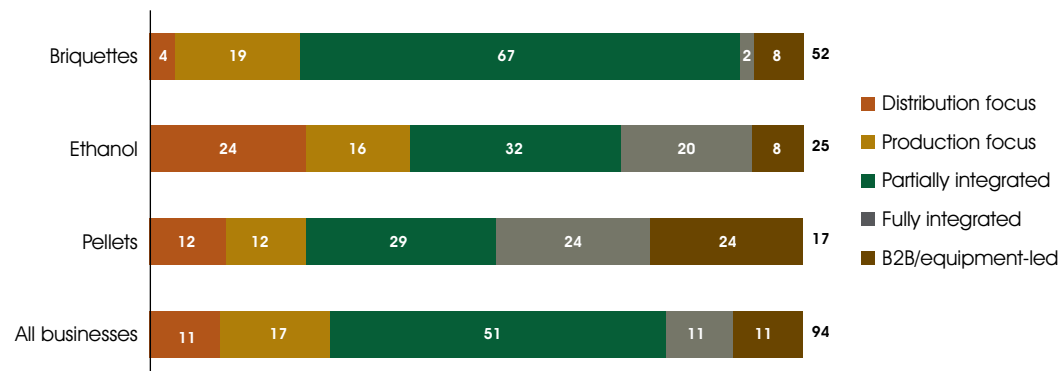
One emerging variant of B2B models demonstrated by Koko Networks in East Africa involves deploying technology platforms that can link fuel producers, stove manufacturers, fuel logistics intermediaries, and distributors to end users of technology platforms. This type of software platform typically incorporates modules like customer relationship management, payments tracking and fulfillment, maintenance/after-sales support tracking, customer communication, and fuel supply chain management and optimization. The objective of this business model is to capture a slice of the fuel revenues flowing through the platform without getting directly involved in the CAPEX-heavy fuel production, transportation, and distribution portions of the value chain. In the ideal version of this model, the company does not carry the fuel on its balance sheet but does have a direct link to the end user through the data that flows through the platform. In its earlier forms, the model entailed more hands-on involvement in fuel sourcing, transportation, and distribution, but the goal is to find a more asset-light B2B approach for scaling.

While the Koko Networks' model is experimental in the biofuel context, the idea is not unprecedented in Sub-Saharan markets. In the pay-as-you-go decentralized off-grid energy sector, players like Angaza and Lumeter are pursuing this type of B2B software platform model for third-party off-grid energy appliance manufacturers and distributors. Such players do not need to deploy capital for appliance manufacturing or for financing product distribution, energy service delivery, or consumer financing. Instead, they monetize their platform by charging fees to enterprises for platform use, typically in the form of a share of revenues. This model has reached substantial scale for Angaza, with about 60 enterprise (B2B) customers utilizing the platform to run their own pay-as-you-go businesses, reaching well over 100,000 customers as of mid-2017. Analogous B2B software platforms have been deployed in the pay-as-you-go water sector by players like Water Health International and Saarvajal. Some are experimenting with this model in the liquefied petroleum gas (LPG) space. Kenya-based PAYGO Energy, with the help of recent U.S. Agency for International Development Development Innovation Ventures funding and impact investor capital, is developing a software and hardware platform stack for pay-as-you-go LPG distribution with the goal of deploying its technology to large LPG distributors across the continent.

Vertically-integrated operating models are the dominant approach in the cooking biofuel sector in Sub-Saharan Africa. The partially integrated model—moderate-to-heavy involvement in fuel production and distribution dominates the region's biofuel sector (51 percent of enterprises tracked), and full vertical integration represents another 11 percent of biofuel enterprises (figure 3.2). Full integration is particularly common for ethanol and pellet value chains. Production-focused enterprises make up less than one fifth of the total (17 percent). Distribution-focused and B2B operating models are uncommon at 11 percent each.

Integrated models offer many advantages, particularly the end-to-end fully integrated model. On one end of the value chain, they allow for maximum control over all aspects of a business,

Figure 3.2. Operational Business Model Mix



Note: Database supplemented by nine additional businesses to include more producer, distributor, and B2B companies that reflect the diversity of operational business models but that are not involved deeply enough in biofuel production or distribution to be included in the core database.

Source: Sub-Saharan Africa Biofuel Enterprise Database.

including fuel supply, quality, and quantity; and on the other end, allows for an interface with the consumer—or at the very least with the retailer ecosystem. Vertical integration allows for the coordination of key activities and reduces transaction costs involved in negotiating agreements and moving fuel and stoves between systems. Vertical integration makes sense because of the newness of the cooking fuel market, the weakness of associated supply chains, and the unreliability of outsourcing partners. Sub-Saharan Africa is an inherently high-cost, low-capacity environment, particularly for new products targeting poor and/or rural consumers. Many biofuel businesses get involved in production because they cannot identify sustainable or high-quality sources, and importing fuel is too expensive. Others focus on distribution primarily because third-party distributors are not incentivized to push their fuels due to the low margins relative to other products. Green Bio Energy, for example, has discovered that briquettes do not sell themselves in Uganda and has oriented its business to play a more active role in distribution and marketing.

Even though vertical integration is difficult to manage and costlier and riskier than other operating models, it still holds the potential for high rewards and success at achieving scale. Thus far, the fully integrated model has emerged in cases where success in production and distribution is linked to the same factors, such as microdistilleries producing in last mile communities, or situations where customers also supply feedstock or produce fuel. Cooking fuel utility businesses like Inyenyeri are the most important variant of the fully integrated operational model.

Some of the unique challenges faced by vertically integrated models include higher upfront capital requirements to build-up and manage production and distribution, the need for time and patient capital to allow for the experimentation needed to optimize an integrated model, greater operational complexity once the model is running, and management bandwidth and staff capacity—factors which also make these models riskier, as highlighted by experiences in

the cooking fuel sector. It is worth noting that the largest global examples of biofuel cooking businesses to date, CleanStar/NDZiLO in Mozambique for ethanol (40,000 households at its peak) and First Energy/Oorja in India for pellet cooking (450,000 households) have also been among the most visible past failures. Although it continues to operate in a curtailed form as Zoe Enterprises in Maputo, the CleanStar/NDZiLO business failed for a variety of reasons, but the over-arching challenge was the cost and complexity of building and running a fully integrated operating model. Repeated setbacks and business model complexity can exhaust the patience of even the most impact-oriented and risk-tolerant investor. The experience of First Energy/Oorja was similar: the feedstock price spike in India caused the company to move away from the household cooking business.

Still, the reward can be high for getting the integrated operating model right. Highly integrated businesses can maintain higher service and product quality under difficult market and infrastructure conditions—essential when dealing with a skeptical, risk-averse consumer and when facing ubiquitous competition from traditional charcoal markets. More importantly, vertically integrated biofuel businesses appear to achieve greater scale in terms of the number of households served with cooking fuel in a shorter period of time. Out of over 90 tracked biofuel businesses, 8 of 10 of the largest, measured in terms of the households served, utilize partially or fully integrated models.

Beyond the cooking energy context, vertical integration has been a feature of many successful businesses focused at the base of the pyramid. A high level of operating model integration has been used by many large scale, successful enterprises in the solar lighting product sector, such as Greenlight Planet, which sold five million solar lanterns in five years, and D-Light, which sold more than 13 million; in rural mini-grids; and in clean water provision, such as WaterHealth International, which supplies more than 1 million households, Naandi, which supplies more than 100,000 households, and Saarovajal, which supplies about 60,000 households. The fast-scaling, pay-as-you-go energy businesses in Sub-Saharan Africa like M-KOPA, Mobisol, and Offgrid Electric are additional examples of highly integrated models. Combined, the pay-as-you-go energy sector now reaches nearly 1 million households in the region (as of the first quarter of 2017). Of course, while some vertically integrated models have succeeded, other have failed, such as Husk Power Systems, which chose to pull back from vertical integration to a leaner model, including franchising, to reduce operational complexity and costs.

Technology can help mitigate many of the costs and risks associated with vertical integration. Digital and mobile technologies can lessen the potential downsides of the operating model. Technology is universally acknowledged as the special sauce that has made the pay-as-you-go energy sector successful in Sub-Saharan Africa and is enabling the fast-growing decentralized water utility business model. The most immediate benefits of digital technologies likely sit at the distribution end of the spectrum because enterprises can use mobile infrastructure and digital applications to reduce their costs and control complexity. On the production side, technologies such as mobile-to-mobile communications and remote sensors can be used to monitor and manage production assets in the field and streamline the efficiency of value chain logistics.

Such use of technology does not require pursuing a B2B model. For example, Eco-Fuel Africa, a Ugandan briquette business that remains highly integrated, manages a very decentralized feedstock collection model on the production side and a large agent network on the distribution side by deploying technology at three levels: interfacing with feedstock producers via SMS; managing its feedstock collection efforts via SMS; managing sales via mobile phones or tablets; and maintaining links with consumers.³³ Koko Networks has built a proprietary cloud software platform to manage fuel sourcing, transportation logistics, customer relationships for sales, and communications with end users. It will deploy this system as part of its market scale-up in 2017 to ultimately pursue a cost-effective, asset light model for ethanol fuel distribution. While technology cannot fully eliminate the complexity of last-mile fuel delivery to households, it can be hugely helpful from a logistics streamlining perspective, even when ongoing delivery of a physical product is required.

The imperative for vertical integration in the cooking biofuel sector is likely to decrease over time as biofuel markets mature, consumer demand grows, and a greater number of fuel suppliers and distributors appear on the scene. Ultimately, those with no competitive advantage in combining production and distribution will opt for one or the other, particularly as large-scale producers look to outsource to larger distribution networks. Producers will likely avoid the distribution challenge and its costs but will be less able to control how their product is marketed. Businesses focused on distribution will avoid capital expenditure requirements but will eventually have to accept and pass on prices dictated further up the supply chain.

Vertical integration is important, but fully integrated models are not the only way forward. Few businesses have or will have the management capacity and capital to launch fully integrated fuel utility models in Sub-Saharan Africa—and there is no need for it anyway. Starting at one end of the value chain and integrating other pieces over time, partial vertical integration can be successfully achieved. Because distribution has proven to be more challenging than production, businesses focused on optimizing distribution first may be able to reverse-integrate production.

Experience shows that it is far more difficult for those who specialize in production to forward-integrate distribution because of the challenges and opportunity costs of building out robust, cost-efficient, and scalable distribution infrastructure at the last mile. Local Sub-Saharan players who already specialize in biofuel production at scale, such as the Malawi Ethanol Company (ETHCO) and Mumias Sugar in Kenya, are often unwilling to aggressively pursue cooking opportunities because the transition from serving a few large institutional customers to building and servicing a low-margin, high-volume retail market is a major business-model pivot. Businesses specializing in large-scale production of biomass briquettes and pellets in Sub-Saharan Africa, such as Abellon CleanEnergy in Ghana or Tassouma briquettes in West Africa, face a similar calculus: they will typically prioritize the off-take markets that are already

33. See Eco-Fuel Africa Unreasonable Institute profile at <http://stealth.unreasonableinstitute.org/wp-content/uploads/2010/12/Executive-Summary-Unreasonable-Institute.pdf>.

established or that can be built with a relatively small investment in distribution rather than taking the plunge into last-mile retail fuel distribution.

However, working with or through large existing biofuel producers is still possible. Many are quite interested in finding additional markets for their fuel, but donors and/or entrepreneurs approaching them must be realistic with respect to incentives. Several players in the ethanol sector have already expressed an interest in expanding into the cooking ethanol market if they can find appropriate partners. For example, the Madhvani Group, one of the largest diversified conglomerates in East Africa, has announced an interest in exploring bioethanol cooking as part of its scale-up of domestic bioethanol production in Uganda.³⁴ The company has an interest in marketing its technical ethanol as a clean cooking fuel across the East Africa region but is seeking government incentives to justify its investment in the new business. ETHCO has already been engaged in cooking projects as a supplier of ethanol gel fuel as part of the Millennium Gelfuel Initiative, a World Bank-funded project that began in 2000 as a public-private partnership to demonstrate the commercial viability of gel-fuel cooking. In 2016, ETHCO began jointly supporting a bioethanol cooking fuel production and distribution pilot with the Malawi University of Science and Technology and has expressed interest in supporting cooking bioethanol market development in the country. Global ethanol players like POET and ALCO Group that have an interest in Sub-Saharan clean cooking may have more resources to co-invest in market development; they remain on the lookout for local partners and favorable policy environments.

For biofuel enterprises choosing not to be vertically integrated, the decision between production and distribution is driven by business capacity and the scale of proven demand. Most businesses start with what they know and then specialize further. On the production side, it is important to note that scaling will require significant guaranteed off-take demand or very patient investors. For instance, some market experts consulted for this report estimate that the minimal market scale required to reliably justify the establishment of domestic cooking ethanol production capacity is 25,000 households, which amounts to roughly 6 million+ liters of ethanol per year. Of course, much smaller-scale production capacity can be put in place using ethanol microdistilleries like the model being pursued by Project Gaia and its partners, including Green Social Bioethanol. However, critics maintain that these latter models will never achieve scale. On the distribution side, businesses must have confidence in their knowledge of local-market context and ideally have existing local retail networks and partnerships that will allow them to piggyback off existing customer channels.

Regarding B2B operational models, such as equipment-led fuel production franchise approaches, there is no clear verdict on their potential for scalability. Players like Nishant Energy, Green Social Bioethanol, C. F. Nielsen, and similar actors could serve as entry points into the biofuel cooking market promotion, but their ability to scale is highly uncertain.

34. See Kakira Sugar Limited's presentation to NAMA Donor Coordination Meeting, June 7-8 2016, Helsinki, Finland at https://www.nefco.org/sites/nefco.org/files/pdf-files/kakirasugar_barungi.pdf.

The fundamental challenge is that much must go right in markets like Sub-Saharan Africa—when in fact many things often go wrong—for fuel production and distribution initiatives to succeed.

Achieving repeated successes with individual entrepreneurs multiplies the challenge, introduces new principal-agent incentive risks, and likely raises the overall probability of failure. The difficulty is highlighted by the experience of Project Gaia, which—despite many important contributions to bioethanol cooking market development and some other notable successes—has been unable to set up or scale viable ethanol microdistillery franchise models in Sub-Saharan Africa.

B2B operational models face the particular challenge of maintaining fuel quality at scale in the absence of central quality control functions. Even when the economics for B2B franchising models work well on paper, the reality can be daunting. For example, Project Gaia and its partner Stockholm Environment Institute (SEI) set up electromotive diesel in Ethiopia in 2015, plant construction took much longer than anticipated, leading to significant cost overruns. Finding individual local franchisee entrepreneurs with requisite skills, aligned incentives and values, and access to local financing is a challenge often underestimated by backers of the B2B model. The cost involved in the search for and management of franchisees, for example, has been a major obstacle to successful equipment-led franchise models in the distributed water sector. Players like Husk Power Systems found it arduous to transition to a light touch B2B model in their earlier Sub-Saharan biomass plant expansion efforts (Lassiter and Misra 2016).

Nevertheless, the B2B franchise model merits more experimentation, particularly given the complexity of serving rural populations. Aside from innovative models like Inyenyeri that harness rural markets to urban ones, or in the absence of large-scale government subsidies or donor results-based financing schemes to boost rural cooking biofuel economics, the alternative to trying B2B models may be doing little or nothing.

FORM OF OWNERSHIP AND DEGREE OF PROFIT/SOCIAL ORIENTATION

In addition to its overall operational model, another major overarching decision for a biofuel enterprise is its form of ownership. It can be structured as private; hybrid, such as a social enterprise; public, such as a state-owned enterprise; nonprofit, such as an NGO; or community-owned, such as a community-based organization.

Private-sector models predominate the region's cooking biofuel sector. No precise estimate is available on the number of nonprofit entities (NGOs and community-based organizations) directly involved in briquette fuel production and distribution. But the number is certainly in the dozens and perhaps even over a hundred across Sub-Saharan Africa. Creating such an estimate is extremely difficult because most NGO-led efforts are tiny in scale and are embedded

in rural livelihood programs, internally displaced person camp interventions, and community empowerment activities rather than being large-scale standalone initiatives.³⁵

The precise reach of nonprofit initiatives is unknown, but it is generally thought to be relatively small. Larger NGOs such as ARTI in Tanzania and community-based organizations such as Nakabale and TEWDI in Uganda are in a different category, however, because they have incubated relatively standalone social enterprises, sometimes jointly owned and run by communities, focused on briquette production and distribution.

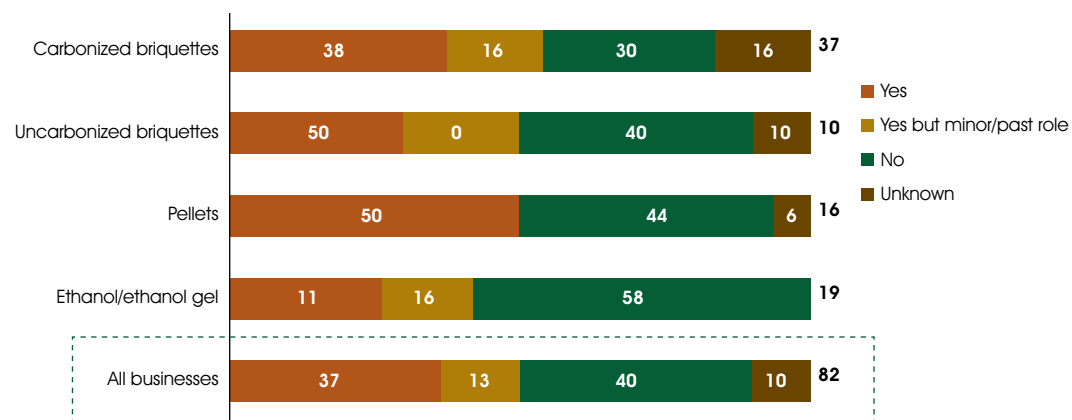
Public sector models are typically more limited in scope, primarily consisting of scattered biofuel production pilots used to demonstrate a specific briquetting process to a particular feedstock. Examples include research organizations such as TATEDO in Tanzania, which engages in some briquetting projects, and *Institut Congolais pour la Conservation de la Nature* (ICCN) in the Democratic Republic of Congo, which has been involved in briquette market development for years. Government-owned companies in Sub-Saharan Africa are few, so examples of state-owned corporations engaging in biofuel production for household cooking markets are quite rare, but the Sugar Corporation of Ethiopia producing and supplying ethanol to Project Gaia for the Jigjiga camps is one.

Among private sector models, roughly a third of the biofuel enterprises tracked in the Sub-Saharan Africa Biofuel Enterprise Database self-identify as social enterprises, but the overall level of social businesses—defined as enterprises willing to trade off returns for social impact—is higher. One proxy for this is the willingness of a business to accept grant funding. At least half of the region's biofuel businesses have done so in the past, and more than a third (about 37 percent) still rely on it for sustainability (figure 3.3). By contrast, ethanol businesses tend to be more purely commercial in their positioning.

Different ownership structures are suitable to different goals. Purely private models, public models, and social enterprises are all potentially suitable options for achieving scale, although most successful global examples tend to put the private sector in the lead role of a public-private partnership structure, including NGO's. Private companies are best incentivized to expand and take advantage of economies of scale in production and distribution while at the same time managing costs. Social enterprises can likewise reach very substantial scale but typically need to compromise on profitability in their attempts to balance profit and impact. For example, Inyenyeri accepted a pile of sticks or biomass waste of about 10 kg in exchange for 6 kg of pellets. They then used this biomass waste to produce pellets, which they swapped for more raw waste biomass.

35. NGOs that support biofuel market development but do not directly manage biofuel production or distribution, such as Energy4Impact, Projets Solidaires, and Legacy Foundation, were excluded from the analysis.

Figure 3.3. Reliance on Grant Funding by Type of Biofuel Enterprise in Sub-Saharan Africa



Source: Sub-Saharan Africa Biofuel Enterprise Database.

A state-driven model could be successful at achieving scale in some countries, but few if any examples exist of governments successfully producing and distributing biofuel via large parastatal enterprises. Instead, public sector-led models typically involve local government units playing a distribution role or much more rarely a fuel production role in collaboration with private enterprises. One can look to China for inspiration, for example, where the biomass pellet industry is supported by the government through subsidies, marketing assistance, and technical training, including a Green Energy Demonstration Counties program. China's program appears to be growing based on central government subsidies but has not been independently assessed, and its impact at the household level and its prospects for long-term sustainability are not yet clear.

Initiating a government-led programs like China's requires robust execution capacity at the local government level and efficient systems of interaction and financing between the central and local governments. With few notable exceptions, such capacity does not exist in Sub-Saharan Africa.

A better model to explore in most areas is public-private partnerships, where private enterprises or social enterprises are contracted to provide fuel production and even fuel distribution services at the local level under the oversight of local or regional government bodies. Rural energy service companies using mini-grid models for energy provision or analogues from decentralized water distribution, such as Naandi Community Water Services, may be the appropriate role models for this type of approach.

The history of the clean cooking sector suggests that NGOs and community-owned businesses that rely primarily on grants are unlikely to reach scale beyond their discrete project contexts. Nonetheless, NGO-based models may be necessary for markets that are difficult to serve,

which is often the case for extremely poor and rural areas. Camps for internally displaced persons IDP camps, as an example, could be well suited for NGO-driven biofuel production and delivery models, although even in that context, their own social enterprises may be better positioned to provide efficient delivery and higher quality standards because of their for-profit orientation.

Upstream Business Models

PRODUCTION MODEL

The most significant decision a producer of cooking biofuel makes regarding its business model is whether to pursue a centralized production model, a partially centralized model, or a fully decentralized model in which independent actors make decisions about how, where, and how much fuel to produce.

The important dimension of centralization here is not the number of production facilities but the level of central oversight and control. Deciding to produce fuel in separate, typically smaller, and geographically distributed production sites is operational and logistics optimization. In contrast, devolving all or some production responsibilities to independent actors—by managing a producer cooperative or network or by setting up a franchise for fuel production—is a strategic business model choice. Ethanol industry giants demonstrate this tendency most clearly. For example, POET has more than 30 individual bioethanol facilities producing 6–7 billion liters of ethanol per year, but its production model cannot be said to be truly decentralized because central management control, consistent quality standards, and common processes are applied across all facilities.

Most biofuel businesses in Sub-Saharan Africa are currently pursuing a fully centralized approach. About 87 percent of businesses producing fuel has adopted a centralized approach to fuel production—not surprising since most of the biofuel companies in the region are small operations for which highly centralized fuel production is a natural starting point. For larger operations, central production is common, ranging from large production facilities located at or near a major feedstock source, such as Global Supply Solutions in Kenya; to central aggregation of waste byproducts for briquetting plants, such as Sanivation and Habona. Others may produce fuel at one central plant but plan to pursue a multiplant model by building new plants near major off-take markets to balance economies of scale against transportation costs. MotoCharcoal, a start-up in Zimbabwe with an innovative carbonized briquette production technology, is starting with one central facility but plans to strategically build new briquetting plants across the country. For some producers, the deployment of multiple plants is tied to a hub-and-spoke model for feedstock collection; onsite preprocessing, such as drying, and aggregation for final production of fuel at larger plants.

Distributed production models are very uncommon in the Sub Saharan market. Fully decentralized production models involve independent entrepreneurs. The role of the central organization in such decentralized production schemes can range from a lean capacity-building

or training function, such as the Global Village Energy Partnership/Energy4Impact DEEP program for small-scale briquette producers in East Africa; to producer cooperative models; to highly structured franchising schemes such as Phambili Energy in South Africa.

The benefit of decentralized production is that it allows for very small-scale production and distribution in proximity to remote feedstock sources or end-user populations, beneficial for serving dispersed populations or remote rural regions. However, operating these models can be more costly than centralized options. Furthermore, some elements of this model may prove difficult or impossible to manage effectively in a decentralized fashion because fuel quality depends heavily on professionally managed production operations. These issues are often compounded by the time required to identify a sufficient number of willing and able entrepreneurs and to control execution risks. In the ethanol sector, the distributed model in the form of microdistilleries has gained attention in recent years.

An example of a biofuel company in Sub-Saharan Africa that has piloted the microdistillery model is Green Social Bioethanol (Green). They provided entrepreneurs in Nigeria with ethanol microdistillery equipment; the entrepreneurs produce and distribute the fuel. While the ethanol production cost curve suggests that per unit costs between producing at scale and producing in microdistilleries can be comparable, that does not account for the additional costs of quality control and demand aggregation across multiple smaller sites.

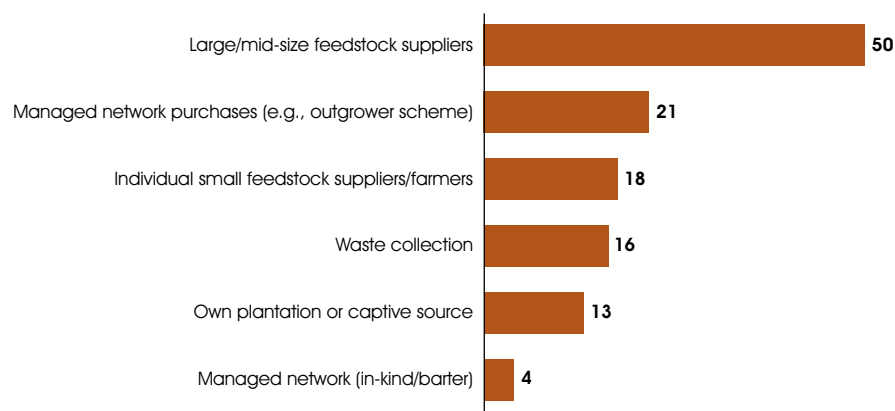
Between the centralized and decentralized production approaches sits a hybrid option of partially decentralized production. Enterprises that pursue this model, such as Eco-Fuel Africa and AEST in Uganda, Eco-Carvão in Mozambique, and J-Palm in Liberia, devolve some of the production function to decentralized producers who are asked to carbonize the feedstock prior to it being transferred to headquarters for briquetting. The model is particularly appropriate for carbonized briquettes, but can be extended to other contexts and has the advantage of decentralizing production responsibilities and costs while retaining centralized quality control.

FEEDSTOCK SOURCING

Another important business model decision for biofuel producers is how and where to source their feedstock. In order of decreasing control, fuel producers can choose to: (1) grow their own feedstock or source it from a large, closely allied supplier; (2) directly manage the collection of feedstock from food, municipal, or human waste; (3) set up and/or manage outgrower schemes (also known as contract farming) of feedstock supply from small feedstock suppliers or growers; (4) purchase their feedstock from a small number (2–20) of mid-sized and large suppliers often using long-term contracts; and (5) purchase or collect feedstock from tens or even hundreds of small and medium-sized individual producers at market prices without formal outgrower arrangements or sourcing contracts.

A range of sourcing models are seen across the region's biofuel enterprise landscape, with most enterprises having only moderate control over their feedstock. Very few enterprises—13 percent—have their own feedstock plantations or captive sources, but many exercise moderate

Figure 3.4. Feedstock Sourcing Business Model: Frequency in Sub-Saharan Africa



*Companies often use multiple feedstock sourcing approaches, so the numbers do not add up to 100%

Source: Sub-Saharan Africa Biofuel Enterprise Database.

control through managed supplier networks like outgrower schemes that utilize cash (21 percent) or barter/in-kind payments (4 percent); see figure 3.4. A small but growing proportion (16 percent) rely on their own waste-collection efforts, and half source their feedstock from large suppliers, with a substantial but uncertain share of those having locked in the supply with short- or medium-term contracts. Eighteen percent buy their feedstock from small suppliers without a preestablished agreement.

Although it is theoretically possible to secure a stable supply, price, and quality of feedstock under any of these models, businesses that grow their own feedstock have the maximum control, and experience less risk of feedstock supply disruption. But doing so is costly and operationally cumbersome. Green Resources is one of very few biofuel companies in Sub-Saharan Africa with their own feedstock plantations. A large Norwegian-owned forest plantation company in East Africa, Green Resources uses its forestry byproducts for briquette production even though briquetting is a minor revenue stream for their overall business. Several Sub-Saharan players do not have their own biomass plantations but are considering incorporating them to lock in a sustainable source of high-quality feedstock. Obio Hamy is researching locations and options for its own cassava cultivation to serve as an input for its ethanol distillery. Abellon CleanEnergy in Ghana is in the process of setting up an agroforestry project to cultivate short rotation energy crops like bamboo to supply its pellet plant. Eco-Carvão in Mozambique is exploring expansion into large-scale cocoa farming to supply its carbonized briquette facilities.

A potential variant of the grow-your-own model for feedstock security is a joint venture or very-long-term sourcing contracts with major “captive” feedstock producers. Examples include Global Supply Solutions, a fast-growing Kenyan-based briquettes business, which has entered a long-term agreement with Del Monte Kenya Limited, which owns a 10,000-acre pineapple

farm in Kenya, to source pineapple leaves for use as feedstock. GreenTech in Gambia negotiated a long-term free access contract to the dumping site for groundnut shells from the Gambia Groundnut Corporation. Captive sourcing arrangements of this sort gives the fuel producer significant certainty but can also be highly risky when the captive source is the sole source.

Waste collection models are another approach to ensuring feedstock security that are rapidly growing in popularity in Sub-Saharan Africa. Waste collection covers a range of feedstock, including municipal waste in all its variety, organic market waste, and human waste. For some of the biofuel enterprises pursuing this model, waste collection is the enterprise's primary business, with fuel briquetting being just another revenue source for monetizing the core waste asset. For other companies, waste collection is primarily a feedstock sourcing strategy, with the underlying waste being collected from households and businesses at no cost. Sub-Saharan biofuel enterprises that rely on waste collection include innovative companies such as Sanivation in Kenya (human waste briquetting) and enterprises collecting and processing municipal and market waste such as Habona in Rwanda, Madacompost in Madagascar, Masupa Enterprises in Uganda, Bioenergy-Burundi, and Kemit Ecology in Cameroon. Since waste collection is by its very definition focused on feedstock that is decentralized, predictable, and low value, it can be a powerful strategy for securing a controllable and reliable feedstock source.

The managed network, or outgrower feedstock sourcing model, also provides extensive control over feedstock and requires less capital to deploy than a plantations or waste collection. Success in working with outgrowers largely depends on the quality and management of the relationships with individual feedstock suppliers. While these arrangements can be structured to minimize capital outlay by, for example, placing risk on suppliers/farmers, the most secure outgrower schemes involve binding supply contracts with outgrowers. These agreements can be risky because individual farmers can experience shocks or other buyers could outbid the feedstock purchaser— but after some piloting and adjustment, they can be quite reliable. A typical example of the numerous instances of this model in Sub-Saharan Africa is Global Bamboo.

Businesses that do not secure close control over feedstock sources generally use a strategy of feedstock source diversification. Roughly half of the biofuel businesses tracked in the region must secure 3–20 mid-sized or large feedstock suppliers, such as saw mills and agricultural processors, to help manage the risks of feedstock supply failure. The use of contracts with mid-sized suppliers provides only a modicum of security given the difficulty of contract enforcement in most Sub-Saharan country contexts. In some cases, feedstock diversification strategies can be highly formal, such as the molasses tenders by Obio Hamy in Madagascar to supply its ethanol microdistillery, or such as the collection points organized by Eco-Carvão in Mozambique where farmers bring coconut husk feedstove on designated days.

Often, the diversified feedstock sourcing approach is applied in a more ad hoc manner that includes a patchwork of individual agreements with institutional feedstock producers and relationships with tens or even hundreds of small feedstock producers (such as charcoal dust

suppliers). This approach can lead to significant operational complexity and uncertainty about feedstock volumes and prices but nonetheless can be an adequate starting point for early-stage biofuel businesses.

Downstream Business Model

DISTRIBUTION MODEL

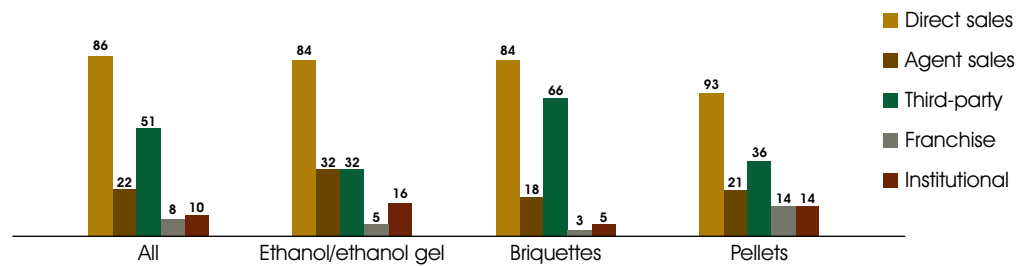
For enterprises involved in the distribution of cooking biofuels, a wide array of business model choices exist, ranging from higher to lower levels of company control over distribution, including direct sales through in-house staff or proprietary stores and kiosks, sales-agent models, distribution franchise approaches, third-party distribution through wholesalers and retailers, and institutional partnerships.

Most of the region's biofuel businesses distribute their fuel by combining proprietary distribution channels with either third-party retailers or wholesalers or with sales agents. According to the Sub-Saharan Africa Biofuel Enterprise Database, enterprises whose distribution models are known (n=76) rely primarily on multichannel systems. Roughly one third (35 percent) of biofuel enterprises rely solely on direct sales through their own distribution staff or proprietary retail footprints. The rest combine direct sales with third-party wholesale or retail arrangements (34 percent), pair direct sales with sales-agent models (13 percent), or eschew direct sales entirely and only rely on some form of third-party distributor, such as the United Nations High Commissions for Refugees, large NGOs, microfinance institutions, savings and credit cooperative organizations, and internal displacement camps). Exclusive reliance on direct sales is particularly common among early-stage businesses whose small scale of sales during does not warrant the use external distributors at the start-up phase. It is also common among biofuel businesses primarily focused on institutional cooking and heating markets rather than households.

While exclusive use of direct sales is relatively uncommon, some reliance on direct sales staff or proprietary retail footprints is widespread. Roughly 86 percent of all Sub-Saharan biofuel enterprises and 93 percent of pellet distributors utilize direct sales as one of their distribution channels (figure 3.5). The next most common model across all fuel types is third-party distribution at 51 percent. Two-thirds of briquette enterprises use the model, which is not surprising because briquette fuel does not need to be bundled with special stoves, requires the least amount education for consumers, and can theoretically leverage some of the same distribution networks in urban areas as traditional cooking charcoal. Other common models include sales agents (22 percent), institutional partnerships (10 percent), and various types of franchise models (8 percent).

While the benefits of direct distribution include greater control over marketing and the customer relationship, the model has a downside in terms of cost and operational complexity. Given the underdeveloped nature of the cooking biofuel market, cooking biofuels do

Figure 3.5. Prevalence of Distribution Models in Sub-Saharan Africa by Fuel Type

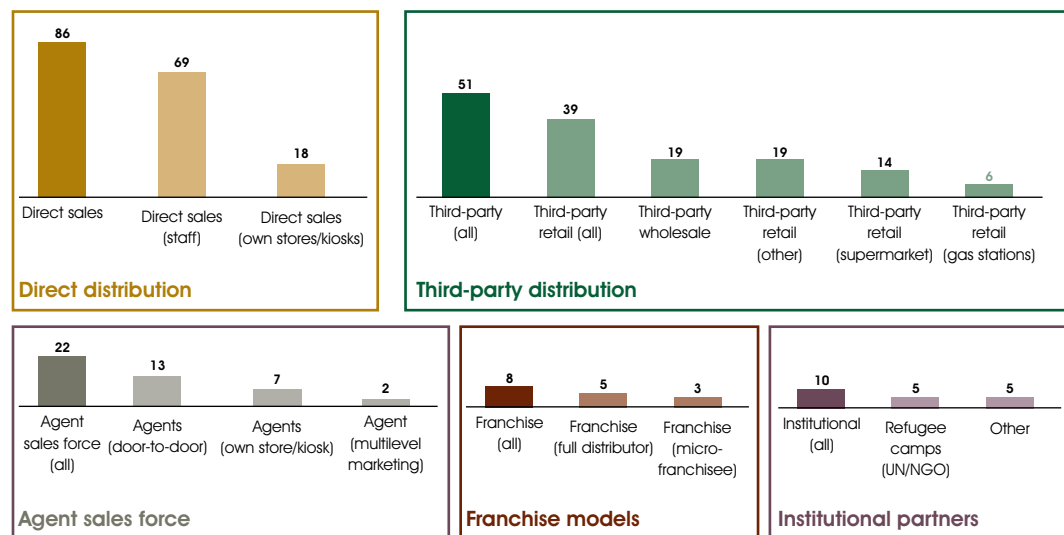


Note: Distribution model frequencies do not add up to 100 percent because enterprises typically combine several distribution approaches and channels.

Source: Sub-Saharan Africa Biofuel Enterprise Database.

not sell themselves; they require a complicated initial sale, including intensive education for consumers. Like the early stages of the solar lighting market, extensive control over marketing and distribution and proximity to the end user may be necessary if companies are to rapidly build a market for their products. In addition, biofuel companies must monitor the quality of fuel delivery and learn from the customer’s experience to quickly adjust the fuel, the stove (if bundled), and their business model to reach a greater market scale.

Figure 3.6. Biofuel Distribution Business Models in Sub-Saharan Africa by Subtype (share of all biofuel enterprises using distribution business model)



Note: Distribution model frequencies do not add up to 100 percent because enterprises typically combine several distribution approaches and channels.

Source: Sub-Saharan Africa Biofuel Enterprise Database.

Not all direct distribution models are equally resource-intensive. Of the region's biofuel companies with a direct sales staff (69 percent), most have small sales and marketing teams of 3 to 50 people (average of 5–10). Less than one fifth of companies (18 percent) distribute fuel through proprietary stores or kiosks (figure 3.6) due to the extremely high cost of building and maintaining a last-mile footprint at any scale. Notable examples of companies committed to a branded store footprint include Inyenyeri for pellets; the Funreco/FP Mesic consortium, which sells ethanol under the Funhol brand in Madagascar; and the Green Char briquettes kiosks in poor urban areas in Kenya. Branded retail footprints are particularly common for ethanol cooking fuels, with nearly every ethanol player in Sub-Saharan Africa and beyond having some variant of this model, though often combined with franchise models and third-party distributors as they scale, including former CleanStar/NDZiLO in Mozambique, Obio Hamy in Madagascar, Safi International in Kenya, and POET/Novogaz in Haiti.

One of the advantages of direct distribution is the ability to mitigate payment collection risks and to collect data about customers and their preferences. Using the biofuel company's own staff to manage the collection of payments for fuel distribution and delivery can mitigate one of the major risks of biofuel business models. Additionally, some businesses, including Inyenyeri, cite customer relationship tracking as critical to identifying new opportunities and adaptations to existing products, thereby to the strengthening of the business. Working through agents and third-party distribution partners does not preclude having a relationship with the customer, but doing so often calls for an additional layer of training, management, or technology. For payments, businesses can rely on mobile ecosystems like M-PESA in places where it is widely used. Furthermore, enterprises can deploy technology for customer tracking, as is in the case for companies like Eco-Fuels Africa and Koko Networks. While setting up the necessary systems can be cost- and time-intensive, those who make the upfront investment in a system to track sales and maintain direct links to fuel end users reap long-term benefits, not only by understanding their customers but by being ready to engage in fuel-centric and results-based financing schemes.

Nearly every biofuel business in Sub-Saharan Africa that has reached significant scale combines direct distribution with some variant of the sales-agent model. While direct sales are a common starting point for biofuel distribution, biofuel businesses in the region that have grown beyond the 5,000–10,000 household customer scale inevitably transition to sales-agent or sales-force models to reduce their fixed cost burden and operational overhead in new or harder-to-access territories. Different distribution models among biofuel companies include door-to-door agents recruited by the biofuel enterprise or “borrowed” from NGO partners (13 percent); store or kiosk-based agents (7 percent); or agents embedded in multilevel marketing schemes (2 percent). Microfranchise distribution models (less than 3 percent of Sub-Saharan businesses) are also essentially sales forces, except agents are expected to pay for the product upfront or contribute their own resources in some way to market development in exchange for a higher share of sales. These models have some common features, including commissions-based or revenue-sharing compensation for agents and a strong focus on female sales forces to reflect the gendered nature of the cooking ecosystem.

Door-to-door agents in base-of-pyramid product marketing models (like “Avon Ladies”) have been widely used to distribute products like solar lighting appliances, water filters, and fast-moving consumer goods across the developing world by companies like Living Goods and Solar Sisters. In the biofuel sector, examples include the First Energy use of local female entrepreneurs as sales agents, Greenheat International in Uganda, Adapt+ in Uganda, and Vitalite in Zambia. Eco Fuels Africa is an example of a store- or kiosk-based agent model. Multilevel marketing models are most common for Nigerian biofuel businesses, such as Zagos International, the producers and distributors of ethanol gel under the ThermaSafe brand, and Green Energy and Biofuels. Some of the biofuel players with the largest household footprints have hundreds or even thousands of agents, such as Safi International with a sales force of 300 along with its affiliated ethanol stores/kiosk network; Eco-Fuels Africa in Uganda with over 2,300 largely rural and peri-urban agents; and Green Energy and Biofuels in Nigeria with nearly 25,000 agents involved in its multilevel marketing platform.

Although third-party distribution requires biofuel enterprises to relinquish control over the customer relationship compared with direct and agent models, this can serve as an important path to scale. Direct-sales and agent-sales models allow biofuel businesses to capture a greater margin across the value chain, establish and maintain a strong brand, and maintain a direct relationship with the consumer. However, the costs of building out and maintaining robust last-mile distribution channels are often prohibitive for small enterprises. Because of the steep working capital requirements for distribution footprint build-out, the pace of scaling up a cooking biofuel sector business will remain constrained unless there is an increase in commercial and impact financing to utilize direct sales and agent models. At least in theory, third-party distribution allows businesses to bypass such constraints at the cost of some loss of control and reduced margins. Retail partners typically seek margins of 5–15 percent, and wholesale distributors add another 10 percent to the cost stack in most Sub-Saharan countries.

Thirty-nine percent of the region’s biofuel businesses engage in third-party distribution, including working directly through retail distribution partners such as small and mid-sized retailers (19 percent), supermarkets (14 percent), and gas stations (6 percent). Some biofuel entrepreneurs have found ways of tapping into existing wholesale distribution networks (19 percent), thereby reducing the cost of searching for retail partners at the cost of giving up additional margin and increasing retail stove and fuel costs. Third-party distribution can be particularly effective in the context of urban and peri-urban customers, including small provincial town markets that are often well served by well-established local distributors. Third-party distribution is far less effective as a solution for rural distribution because existing distribution networks often do not reach the last mile across rural Africa.

Briquette players such as ARTI energy in Tanzania and GreenChar in Kenya have had the most luck working through local wholesaler networks to gain access to national-scale wholesale distribution. However, this approach is uncommon for ethanol or pellets. Broadly speaking, wholesale distribution is a genuinely difficult path for biofuel companies to follow because wholesale distributors in Sub-Saharan Africa tend to be highly risk-averse gatekeepers

who are reluctant to promote products that are new, untested or that require market development and complex sales approaches—like stoves and fuels that must be marketed together as a package.

Retailers are more willing to explore cooking biofuel distribution, but rolling up hundreds of subscale retailers is an arduous task. Partnerships with existing retailer networks are more desirable in urban contexts, such as large regional supermarket players like Nakumatt, Shoprite, and Pick 'n Pay) and gas stations like Total). There are numerous examples of biofuel businesses securing shelf space with large retailers of this type for briquettes, such as Chardust in Kenya, East Africa Briquette Company in Tanzania, Green Bio Energy in Uganda, and Global Bamboo in Ghana; ethanol gel, such as CCL in Kenya, Zagos in Nigeria, and Greenheat and DGN in Southern Africa; and pellets, such as Emerging Cooking Solutions in Zambia distributing through Total gas stations. However, most of the fuel sold through such channels is a premium cooking product like high-quality briquettes for barbeques, which target the region's middle-class consumers rather than pursuing mass market distribution to base-of-the pyramid customers. Given the rapid growth of formal retail formats, strong relationships with large retailers are likely to be an increasingly important channel for customer acquisition and servicing for branded biofuel products.

Franchises are another potential path to building biofuel distribution, but few businesses have yet succeeded in scaling such models. Franchising has not yet fully proven an ability to generate and sustain scale in the Sub-Saharan biofuel market or for most early-stage businesses serving the base-of-the-pyramid customers. Technology, such as common customer relationship management software and payments platforms for franchisees, as well as simple and low cost franchise packages, hold the potential of reducing operational complexity and talent-related hurdles for potential franchisees.

A growing list of Sub-Saharan biofuel businesses are pursuing franchising distribution models, including ethanol players like Safi International, with a franchised kiosk/store model, and Koko Networks, with a model of franchised ethanol vending machines housed within urban retailers and high-traffic businesses like hairdressers. Briquette distribution franchises or micro-franchises have been established by players like Eco-Fuels Africa in Uganda and Eco-Carvão in Mozambique. Early-stage pellet distribution franchises have been set up by Khaya Power and 5 Star Stoves in South Africa and by Emerging Cooking Solutions in Zambia.

Innovative partnerships with unconventional but large-scale partners can help unlock distribution at scale. High-potential partners include those with existing last-mile distribution networks, such as pay-as-you-go solar companies; those with wide coverage through existing points of sale, such as microfinance institutions and downscaling commercial banks like Equity in Kenya; and organizations in close relationships with discrete groups, such as large employers with thousands or tens of thousands of employees and internal displacement camps). Consumer's Choice Limited, as an example, sells cookstoves and ethanol gel through savings and credit cooperative organizations and microfinance institutions. Enterprises and NGOs like

Adapt Plus, Gaia, and Inyenyeri have partnered with the United Nations High Commissioner for Refugees to address the cooking fuel needs of internal displacement camps. Emerging Cooking Solutions has a growing pipeline of contracts with large employers to supply their employees with clean stoves and pellet fuel using payroll deductions as an effective financing and risk mitigation scheme. Securing such large distribution partners and maintaining relationships with them requires a major investment of management time and energy for small biofuel startups. Furthermore, the number of such potential partners is limited, making this a supplemental distribution model rather than a primary one.

Examples from outside the clean cooking sector reinforce the importance of strategic partnerships for scaling, particularly where a consumer durable product is involved. For example, Greenlight Planet makes use of microfranchising and institutional partnerships, training microentrepreneurs to sell its solar lanterns in nonelectrified villages. However, in order to scale in a cost effective way, they have leveraged partnerships with like-minded organizations that had already achieved high rates of coverage, including microfinance institutions, petroleum companies like TOTAL, and social ventures like Sunny Money and One Acre Fund (Benhayoune 2015).

Emerging distribution innovations suggest that new distribution models are on the horizon. There is much ongoing innovation within biofuels distribution models that is not easily captured in the discrete distribution archetypes described above. The most promising new distribution models are those that are allowing biofuel enterprises to access entirely new distribution platforms or are addressing the high-touch, high-cost nature of typical interactions with biofuel customers through technology and customer engagement redesign. Perhaps the most important such innovation or set of innovations is the fuel and stove utility distribution model, which involves selling the cooking energy service through a pay-as-you-go approach rather than distributing biofuel or biofuel stove distribution. Examples include Inyenyeri, Khaya Power, 5 Star Stoves, and Gaia Association in refugee (jigjiga) camps in Ethiopia. Another interesting distribution innovation is the parallel agent model, which allows a biofuel player to superimpose a light but customized sales force over existing retail footprints in order to glean benefits from models while accelerating the pace of scale-up. Another emerging innovation involves leveraging technology-enabled pay-as-you-go energy approaches or using the distribution footprint of the existing market to access the growing number of consumers already plugged into pay-as-you-go relationships for the provision of energy or water services.

Beyond last-mile distribution business model decisions, another important downstream business model dimension involves the handling of infrastructure challenges related to middle-mile fuel distribution. Transporting fuel in bulk from production or importation sites to intermediate logistics hubs or wholesaler depots before they move on the last-mile retail distribution to consumers can incur substantial costs. The middle-mile obstacle affects all of biofuels covered in this study, but the problem is particularly acute for ethanol fuel, which requires specialized

infrastructure for fuel imports, including pipes to transfer the fuel from specialized liquid fuel cargo ships to port storage facilities, fuel warehousing sites at ports and at intermediate fuel storage hubs near major off-takers, and specialized transportation infrastructure for liquid fuels.

For pellets, middle-mile infrastructure will become a major cost driver as businesses scale because they will then have to contend with increasingly complex storage and transportation logistics. However, the safety concerns are not the same as those posed by ethanol, which are far more complex and the solutions far costlier, likely requiring millions of dollars in middle-mile capital expenditure (CAPEX) investment if scale is to be reached.

Ethanol players operating in rural areas are often left with no alternative but to invest in their own infrastructure, which is one of the reasons that decentralized microdistillery-based ethanol fuel distribution models are being explored for reaching rural households. Increasingly centralized fuel infrastructure requires additional investments in the middle mile, and this would likely make centralized ethanol production and distribution models even less viable in rural areas.

On the other hand, in urban ethanol markets there are alternatives to building middle-mile infrastructure from scratch, such as the existing liquid fossil fuel infrastructure. Existing gasoline infrastructure can easily be adapted for ethanol, ranging from port fuel importation equipment, petrol fuel transportation storage tanks and vehicles, and urban gas station networks that can serve as either last-mile distribution points or middle-mile hubs.

From the perspective of ethanol cooking fuel players, utilizing existing gasoline infrastructure for ethanol is likely a necessary condition for scale. By leveraging existing infrastructure, ethanol players can avoid hundreds of millions of dollars in CAPEX investments that would otherwise make their models economically unviable. From the perspective of the liquid fossil fuel industry, the idea of partnering with the ethanol-cooking sector may also be beneficial. By opening their middle mile to ethanol fuel, the major gasoline players in Sub-Saharan Africa could first capture direct incremental revenue streams for their existing sunk-cost infrastructure, allowing for improved infrastructure investment economics, an important consideration given the level of slack utilization for liquid fuel infrastructure in some places. Less directly, the large petrol fuel companies would see benefits in the form of increased value delivered to their gas station franchisee networks. Placing an ethanol fuel storage tank on petrol fuel station premises should significantly improve the value proposition for petrol station operators by giving them an attractive incremental revenue stream and helping them sweat out their existing infrastructure assets. Since the ethanol cooking market is still at an embryonic stage, such partnerships have yet to be signed, but advanced conversations are now taking place with major players like Total. An announcement of market-level partnerships of this sort is highly likely in the near future.

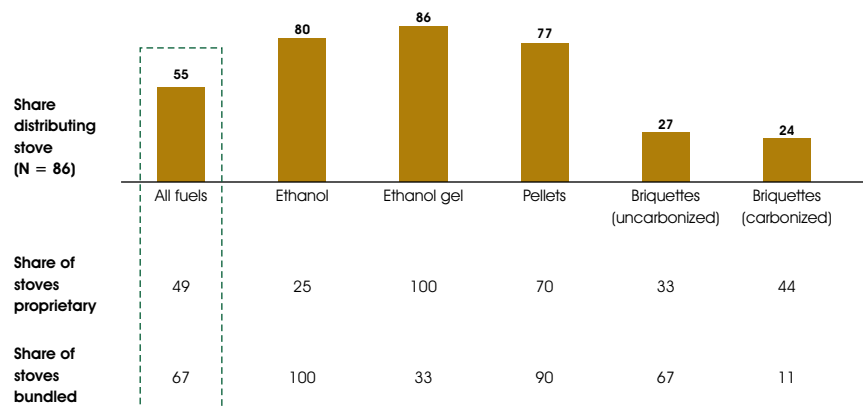
COOKSTOVE INTEGRATION

Another key choice for a biofuel distributor is whether or not to sell cookstoves in addition to fuel. If the decision is yes, the distributor can then choose one of the following stove distribution and pricing strategies: provide the consumer with the stove at no cost or at a substantially subsidized rate to incentivize the uptake and use of fuels; sell the stove at its full price paid upfront by the consumer; offer consumer financing or installment payments until the cost of the stove is fully paid; or distribute stoves at no upfront cost as part of a utility model in which the stove belongs to the biofuel enterprise.

Fifty-five percent of all biofuel enterprises in Sub-Saharan Africa distribute stoves. As shown in figure 3.7, stove distribution is standard practice for ethanol (80 percent), ethanol gel (86 percent), and pellet fuel enterprises (77 percent), but is rare for uncarbonized and carbonized briquettes (27 percent and 24 percent, respectively). Half of the biofuel enterprises distributed stoves (49 percent), with almost one quarter having their own proprietary stove. Two-thirds of the biofuel enterprises that distribute stoves bundle them with their fuel, strongly encouraging a stove purchase for those households or institutional customers who are already using the fuel. This practice is especially common with ethanol (100 percent) and pellets (90 percent). For other fuels, stoves are optional add-ons sold to interested customers.

Recovering the full cost of a stove is not the primary consideration of biofuel enterprises that view the cookstove as a vehicle for securing a stable stream of fuel sales. The greater concern is getting the customer to quickly and exclusively transition to the new fuel. Enterprises therefore subsidize the price of stove as much to the extent they can afford, distributing stoves at cost, below cost, or for free. Subsidies are particularly common for ethanol stoves, whose market price of \$50–100 (declining to \$25–40 among newer models) has in the past served as a major barrier to fuel uptake. CleanStar Mozambique heavily subsidized the CleanCook

Figure 3.7. Stove Distribution by Biofuel Enterprises in Sub-Saharan Africa



Source: Sub-Saharan Africa Biofuel Enterprise Database.

ethanol stove (50–80 percent) during its market launch and scale-up, which contributed to strains on the business' economics. Using funding from donors and corporate sponsors, SAFI International subsidizes some of the stoves they distribute in East Africa, particularly among poor urban consumers. Nishant Energy encourages its franchisees to distribute its institutional cookstoves at no upfront cost but to recoup the margin through fuel sales and carbon revenues.

At the other end of the spectrum are enterprises for which stove sales are an important incremental revenue source or a critical source of margin for achieving profitability. For many biofuel enterprises, particularly carbonized briquette players, stove sales are just another source of revenue; it is virtually impossible to ensure that a stove buyer will use their fuel rather than other carbonized briquettes or traditional charcoal. Green Bio Energy, for example, currently reaches more households with its cookstove sales than with its fuel sales. This approach is also very common for ethanol gel enterprises that sell their relatively low-priced stoves for the full price of \$20 to \$40 upfront—a sensible approach due to the limited quantity of ethanol gel fuel sold per year per stove making it extremely difficult for such enterprises to subsidize stove costs by recouping their margins with fuel sales. Examples include Zagos/ThermSafe and Green Energy Biofuels in Nigeria, SenCook in Senegal, and Greenheat, and Bioheat, both in South Africa.

Some biofuel businesses try to innovate to reduce upfront affordability barriers for consumers. Even for relatively low cost stoves, making customers purchase a stove upfront at the full price poses a major constraint to uptake and creates a greater barrier for high-cost ethanol and pellet stoves. Some enterprises get around this by arranging consumer financing or by pursuing installment sales. For example, Emerging Cooking Solutions allows customers to pay for cookstoves through payroll deductions or fuel and lighting subscription packages. The Kenyan ethanol gel and stove distributor CCL has explored consumer financing by partnering with microfinance institutions and savings and credit cooperative organizations.

Fuel utilities take an innovative approach to the affordability barrier by providing stoves for free or for a nominal upfront deposit while retaining ownership of the devices. Inyenyeri, for example, provides free pellet cookstoves in rural areas, which contributed to its ability to quickly capture large shares (60–70 percent) of rural village business within a few months and achieve nearly full saturation of rural areas. In urban areas, Inyenyeri has experimented with the free-stove approach as well as requiring a low upfront nonrefundable deposit of \$7. Because the stove is never fully the property of the consumer, utility businesses continue to hold the stove as part of their inventory, which requires extensive upfront capital expenditures and assumes the risk of customer nonpayment. If the utility business model is robust and the economics are proven, the CAPEX challenges can be resolved with commercial financing mechanisms such as asset-backed finance models and securitization approaches that are currently being explored at scale by pay-as-you-go energy providers or through targeted donor and government support tied to actual stove and fuel uptake.

REVENUE SOURCES FOR ECONOMIC VIABILITY

In pursuing an economically viable revenue model, biofuel businesses can choose to start as a cooking-focused business that sells to households, institutions, or both; and can choose to pursue multiple revenue streams, such as noncooking products and services, or enter the cooking biofuel market as a supplementary revenue stream.

Because cooking biofuels must be competitively priced against traditional fuels, biofuel businesses find it hard to achieve high profitability while focusing exclusively on household customers. Some Sub-Saharan biofuel businesses (10 percent) have dealt with this challenge by focusing primarily on institutional cooking customers. Examples include Chardust in Kenya, Kampala Jellitone in Uganda, Tassouma briquettes in Côte d'Ivoire, Abellon CleanEnergy in Ghana, and Nishant Energy in India and East Africa. There are examples of businesses more focused on the household market that then retrenched over time to refocus on the more profitable institutional market, such as Chardust in Kenya and First Energy/Oorja in India. However, most biofuel enterprises in Sub-Saharan Africa serve both institutional and household cooking markets (53 percent), and a significant proportion (37 percent) concentrates exclusively on household cooking consumers.

Margins from household cooking consumers are often low and require revenue diversification—particularly important for fuel-production businesses that must operate at minimum capacity to balance their costs. To address this issue, many household-centric biofuel enterprises earn margin on products like cookstoves and rely on their institutional cooking customers as an anchor revenue stream. Several household pellet fuel players in Sub-Saharan Africa are actively exploring opportunities for pellet off-take by institutional clients including prisons, schools, and the military to grow their revenue base. While initially targeting institutional customers to secure larger sales with lower transaction costs can theoretically serve as a good way to enter the market, no prominent examples of successful transitions from institutional to household consumers yet exist.

Other levers for improving economic viability include diversifying into products and services beyond the clean cooking market to develop a multirevenue-stream model. Most Sub-Saharan biofuel entrepreneurs consulted for this report agree that multiple revenue streams are important for boosting profitability. This is true even for utility business models that are already competitive with traditional fuels and realizing healthy gross margins. After cookstove sales, which are widespread among biofuel enterprises (55 percent), the most common revenue diversification schemes involve sales of biofuels for industrial purposes, such as Global Supply Solutions in Kenya and Phambili in South Africa; the sale of solar lighting products, such as Vitalite in Zambia and SenCook in Senegal; Khaya Power in South Africa, ARTI in Tanzania, Green Heat in Uganda, Almighty Services Plus in Benin, and Emerging Cooking Solutions in Zambia; waste collection or waste processing revenues, such as Sanivation in Kenya and Habona in

Rwanda. Some businesses are capitalizing on their connections with end users by seeking to monetize the consumer relationship more broadly through advertising and selling data.

For some businesses, revenue diversification runs in the other direction with their primary business laying in other markets, but cooking fuel represents an interesting incremental revenue stream. Examples of businesses with this model include large global biofuel producers like POET and Alco Group and regional biofuel producers like Mumias Sugar that primarily target beverage and fuel-blending markets for ethanol, forestry product sales (examples include Green Resources in Tanzania, Global Bamboo Products in Ghana, and J-Palm in Liberia) or industrial energy and household heating with pellets, such as Abellon CleanEnergy. The stability provided by a primary revenue stream provides the foundation for piloting cooking business models but also means that the businesses will not prioritize the household clean cooking market in the presence of more lucrative revenue streams elsewhere.

TARGET CUSTOMER GEOGRAPHY

Beyond customer type—institutional or household—Sub-Saharan biofuel distributors need to target their customers by geography. They can choose to target primarily urban or peri-urban customers, primarily rural customers, or give substantial attention to both rural and urban markets. As previously noted, there is a strong urban bias among the region's biofuel enterprises. Sixty-three percent are primarily focused on serving urban markets; 37 percent serve both urban and rural markets; and fewer than 10 percent focus exclusively on rural areas.

Choices regarding targeted customer geography have major implications across nearly all business model dimensions (table 3.1). The economics of serving a rural versus an urban population are dramatically different given the disparate levels of the consumers' ability to pay and openness to new cooking technologies, not to mention the supply-related cost implications involved in serving dispersed rural populations.

Distribution-focused models can be made profitable much more easily in urban areas. Among biofuel producers, a rural focus implies more decentralized production models and distributed feedstock sourcing to reduce the cost of getting the product to the customer. In urban areas, producers can utilize centralized models, and waste collection players have some unique advantages. Among distributors, the rural versus urban decision is likely the most critical. Unlike urban focused businesses, rural distribution models cannot rely on third-party distribution networks, which are either nonexistent or inappropriate in the context, making agent models or partnerships necessary. A rural focus requires companies to engage in more diversification of revenue sources, and biofuel stove distribution to rural areas will require subsidies and innovative utility models. The task is extremely challenging, but commercial and social enterprise models are beginning to emerge that could reduce needed subsidies.

Table 3.1. Targeting Customer Geography: Implications of Business Model Decisions

		Urban	Rural
Cross-cutting	Operational Model	Distribution-focused models are more likely to scale in urban markets as the more accessible consumer and stronger economics allow for fuel purchases and, in some cases, importation.	Production-focused and vertically integrated models may be required for success in rural settings given the need to lower product costs and benefits from greater value chain control.
	Ownership/Form	Private model is more likely because economics of urban biofuel market are more appealing, though more social models (e.g., social enterprise, NGO, CBO) useful for serving urban slum dwellers.	Hybrid (i.e., social enterprise), nonprofit, and public sector public private partnership models are important for scaling in the rural context given the lack of viability of the commercial models in most rural settings.
Producers	Production model	Centralized production is a better fit for producing at scale for the population density of urban areas while maintaining quality levels for commercial-scale operations.	Decentralized production-focused models may be necessary to serve dispersed, low-income, rural populations because such models allow for production near rural customers and lower last-mile transportation costs.
	Feedstock	All feedstock models could work for urban-focused biofuel players, but waste collection has some unique advantages for carbonized/uncarbonized briquette enterprises targeting urban customers due to the proximity to urban feedstock sources.	Managed outgrower schemes and large feedstock purchases from agribusinesses often best fit for rural-focused models because they lend themselves to feedstock-to-fuel loops within rural communities.
Distributors	Distribution model	Much greater opportunity to lean on third-party distribution because of existing distribution infrastructure in urban markets, even for reaching the urban poor.	Own channels, agent models, and partnerships (where available) are far more important than third-party distribution for reaching rural population.
	Cookstove pricing	Upfront, consumer financing, and installment payment models are viable given the greater wealth in urban markets and, for consumer financing, greater access to financial services.	Free/subsidized or utility models may be needed to distribute stoves at scale in rural areas, although consumer financing may be possible in some areas (e.g., SACCO).
	Revenue Source	Model focusing only on households is much more possible in relatively dense and wealthy urban markets.	Household and institutional models and revenue stream diversification are important to financial sustainability because serving rural households alone is not profitable.

IV. The Path Forward

This chapter provides a detailed and systematic review of the many potential intervention levers that could address the market barriers presented in this report and unlock the potential of existing and emerging cooking biofuel business models in Sub-Saharan Africa, including examples and case studies from the biofuel sector and other analogous industries about how interventions can be deployed. Setting aside country-specific considerations, this review as well as consultations with sector stakeholders points to several cross-cutting intervention pathways. This chapter provides an outline of broad principles for advancing the alternative cooking biofuels agenda, applicable to all private and public stakeholders, including governments, donors, investors, biofuel project implementers, and entrepreneurs.

Because of their aspirational nature in terms of high efficiency and limited toxic emissions, this research supports an increased focus on ethanol and pellets and a relative de-prioritization of briquettes to optimize impact with respect to health and environmental outcomes. Carbonized briquettes have demonstrated commercial promise in some markets but may merit less support than cleaner biomass alternatives. Uncarbonized briquettes show even less promise.

Overall, donors and governments should prioritize upstream public goods and market-level business model support programs and interventions, giving the highest priority to knowledge-based public goods and targeting research and development into fuel-stove technologies and market facilitation mechanisms.

When funders do provide fuel production support, they should focus on engaging with more centralized production models and enterprises that are more likely to lead to scale. Decentralized and socially distributed fuel production models that involve the training of tens of thousands of households on artisanal fuel production techniques or hundreds of small franchisees—such as ethanol micro-distilleries—have their place in the clean cooking ecosystem but likely lend themselves better to nongovernmental organizations and implementation partners than development finance institutions or impact investors.

While experimentation is the order of the day, governments, donors, and investors will need to make some hard choices regarding priorities, business models, and intervention tools. The panoply of business models covered in this report make it clear that there are multiple pathways to scale and that many models are still highly experimental or are being replicated from other sectors and integrated into the clean cooking biofuel context for the first time. More trial and error, including a tolerance for failure, is needed to identify successful business models in order to achieve the potential of clean cooking fuels.

However, experimentation does not mean that all models are equally valuable. Beyond prioritizing specific cooking biofuels like ethanol and pellets and favoring distribution over production support, sector funders and implementers will need to make tough choices among specific business models that have higher potential for scale. Whenever possible, support should favor:

- Business models that crowd in large-scale private sector partners and capital;
- Support for new breakthrough technologies for biofuel cooking;
- Support for decentralized production and distribution models and other innovative approaches specifically tailored to rural African context; and
- Downstream business model innovations with the potential to dramatically reduce costs and to scale rapidly.

Targeted interventions focused on higher potential business models should yield results that are significantly more powerful in terms of household-level impact, reach, and economic sustainability than broad-spectrum donor interventions. Results-based financing programs should favor cleaner solutions, and grants should be targeted at market supply and demand bottlenecks.

Potential Pathways for Engaging with Sub-Saharan Markets

Even when successful models are identified in a particular context, the appropriate pathway for an intervention will differ among countries and from rural to urban settings. When considering the prioritization of country-level interventions, a key issue is how developed the country's cooking ecosystem is and what the opportunity costs are for using biofuel alternatives. Figure 4.1 outlines the potential tradeoffs between more and less developed cooking markets.

In more advanced clean cooking markets like Kenya, South Africa, and Uganda, where large numbers of households already face very high fuel opportunity costs by, for example, paying for charcoal or kerosene, and where basic clean or improved cooking market infrastructure exists, government and donor intervention models should focus on *market-based interventions* and close collaboration with existing private sector players—large and small—to nudge the existing cooking mix to cleaner fuels, likely starting with urban areas and then extending to hard-to-serve rural populations using policy levers such as tax and tariff reductions to reduce fuel and stove costs and business model innovations such as barter and cross-subsidy models. Direct subsidies in such markets should be avoided outside the confines of carefully designed and temporary results-based financing mechanisms to minimize the risk of market spoilage. In less-developed cooking markets or in areas with poorer, more rural populations not currently reliant on purchased cooking fuels, subsidy-driven models may be appropriate in conjunction with a focus on supporting biofuel business models that are less commercially based, less

Figure 4.1. Approaches for Countries at Differing Stages of Development of the Clean Cooking Market

Key market features	<p>Active clean cooking markets</p> <ul style="list-style-type: none"> • Relatively high share of consumers purchasing high-cost but inferior fuels (charcoal or kerosene) • Substantial number of actual or potential large local biofuel suppliers • Examples of local cooking biofuel distribution businesses • Existing ecosystem of Tier 2–4 stove producers and distributors (even if not biofuel) that focus on the market • Registered carbon financing projects for stoves/fuels or cooking results-based financing 	<p>Early-stage clean cooking markets</p> <ul style="list-style-type: none"> • Population predominantly focused on fuel collection rather than on purchased cooking fuels • Relatively low cost of alternative fuels • Limited potential for local market biofuel supply (e.g., lack of appropriate feedstock or lack of production capacity and know-how even if feedstock exists) • Nonexistent or underdeveloped stove producer and distributor ecosystem • Limited stove/fuel financing options
Suitable interventions	<ul style="list-style-type: none"> • Market-based approaches to nudge country toward cleaner fuel mix • Subsidy schemes tightly targeted via results-based financing • Focus on developing production capacity (where demand proven) or bringing in larger fuel volumes via imports 	<ul style="list-style-type: none"> • More subsidy-based approaches in absence of viable market models, particularly for rural areas • Focus on seeding distribution and building market demand rather than production/supply-side approaches • Beyond focus on introducing cleaner/Tier 4 biofuels and stoves, consider supporting briquette markets to move customers up the energy ladder

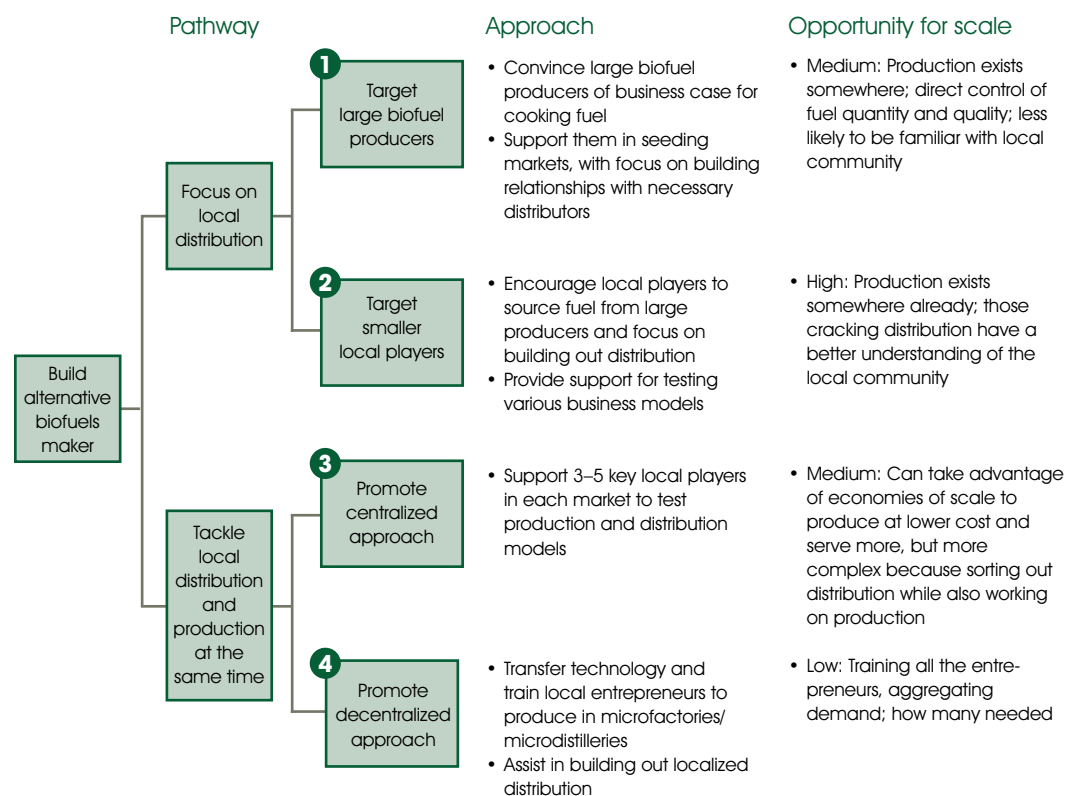
centralized modes of fuel production and distribution, and possibly less clean fuels that can prime the market for cleaner fuel interventions in the future.

Beyond tailoring the approach by the degree of market development, another way of thinking about market intervention pathways is to consider appropriate entry points for the intervention. Figure 4.2 provides an overview of key decision factors and presents the resulting four potential market entry pathways in terms of the type of distributors or producers targeted for support and the investment and degree of business model centralization pursued to develop the market.

These pathways and the resulting considerations for the selection, prioritization, and sequencing of interventions depend on three major decision points:

- If focused on local distribution, should the intervention work through large biofuel producers (local or foreign) to engage them in local distribution or focus efforts on technical assistance and investment in local distribution specialists who then determine the appropriate fuel supply options?
- Should local distribution be prioritized or should the invention tackle both local distribution and production by, for example, supporting vertically integrated players or parallel investments into fuel production and distribution enterprises at the country level?
- If tackling distribution and production simultaneously, should centralized or decentralized approaches for fuel production and distribution be supported?

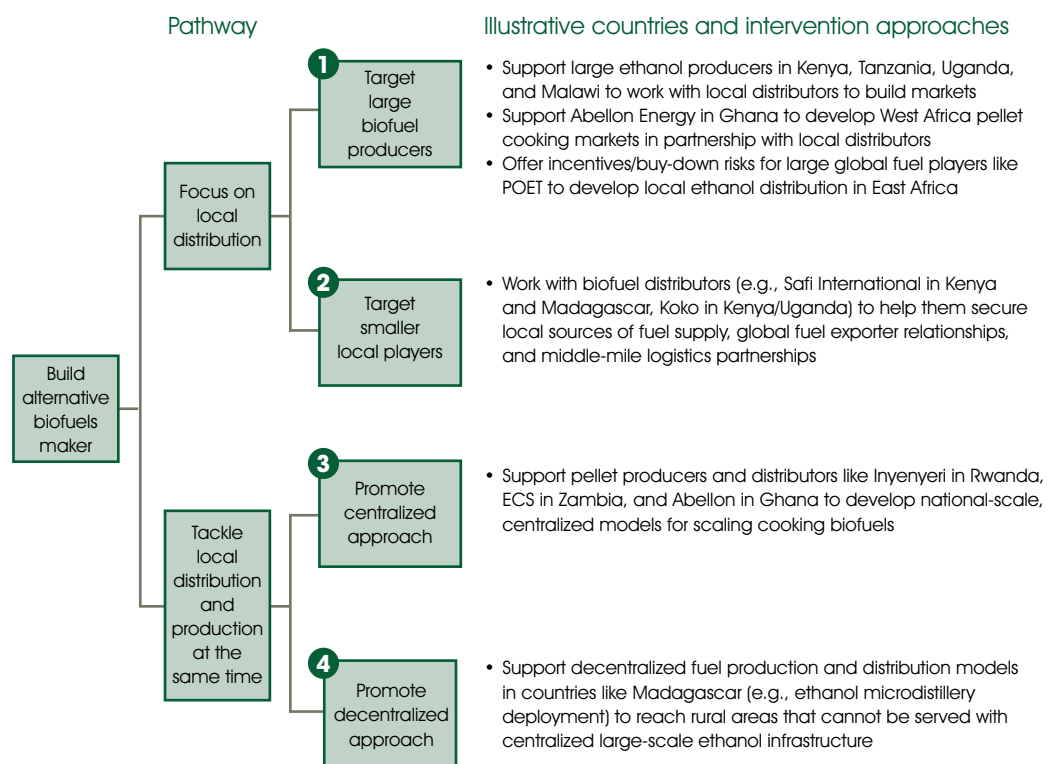
Figure 4.2. Overview of High-level Options for Market Engagement in Sub-Saharan Africa



The first significant decision is whether to focus on local distribution or a combination of distribution and production. While many businesses begin as producers because they lack other local options or are unable to import fuel due to issues of scale, distribution problems, such as the absence of cost-effective last-mile delivery and middle-mile fuel logistics for ethanol delivery, remain the most difficult problems to address. Ultimately, far more piloting is required on the distribution side to create new cooking markets.

To build out distribution, engaging with smaller local distribution specialists rather than large biofuel players is the preferred pathway. If it is possible to broker relationships between large suppliers of biofuels (local or foreign) and local distribution specialists, initial engagement to support the latter to build out their distribution networks is arguably more promising because of the local players' experience with market and consumer needs. Discussions with large-scale local biofuel producers like Abellon in Ghana, which is focused on export markets, suggest that there is real interest in working within the local distribution ecosystem. Even if distribution players do not have a local fuel supply partner, they can still import fuels like ethanol at market prices from major global players like POET, at least in the early stages of market development.

Figure 4.3. Mapping Pathways to Specific Interventions at the Country level in Sub-Saharan Africa



Biofuel producers often prefer to wait for the successful pilots of smaller players before brokering long-term supply partnerships. Willing partnerships between large biofuel producers—local and foreign—willing to share some of the market risk with local distributors appears to be a powerful approach to market development for ethanol, although much ultimately depends on context. With nearly absent local pellet production (with only four or five markets in Sub-Saharan Africa) and given the inordinately high costs of pellet fuel transportation, market development for pellets needs to address production and distribution simultaneously.

A centralized approach to production in urban markets will more likely lead to scale than a decentralized one, but the latter can be more appropriate for rural and dispersed populations. Production cost curves compared with transit logistics suggest that recent innovations have allowed smaller, locally-based entrepreneurs to produce at a comparable cost to those in large centralized factories because the costs of aggregating decentralized feedstock supply are significant. Even the larger micro-distilleries would require setting up about 50 decentralized plants (assuming capacity of 5,000 liters per day) to supply the same quantity as one large plant (assuming capacity of 250 kiloliters per day). Establishing and managing so many enterprises creates enormous technical and execution risks. Quality control across multiple plants run by different operators is hugely challenging.

Although decentralized and small plants do not present the best initial path to scale in most markets, they might be needed in markets where capital is limited or where populations are dispersed, such as Madagascar. Furthermore, as population-dense cities become saturated and players increasingly target less-dense cities, decentralized approaches may prove to be the most effective way to further scale.

Various pathways suggest various intervention entry points, but they are not mutually exclusive. Multiple pathways can be used to develop or support the alternative biofuel market for cooking in a particular country. In fact, multiple approaches may be necessary when considering outcomes beyond scale or when market constraints are particularly limiting. Nevertheless, certain archetypes are a better fit than others in specific countries. Figure 4.3 illustrates how different pathways could be mapped to specific interventions at the country level.

Summary of Promising Interventions

Five avenues for moving the cooking biofuel sector forward in Sub-Saharan Africa appear most promising as interventions for governments, donors, financiers, and entrepreneurs. They are presented in turn below.

1. Significantly increase the level of clean cooking sector support while linking subsidies to outcomes. There is a growing consensus in the clean cooking sector that while market-based solutions are the best tool for promoting clean cooking, substantial donor support is crucial, likely in the hundreds of millions of dollars, to shift the current trajectory of fuel and stove use. If, for example, subsidy levels for clean cooking solutions to mitigate deaths related to household air pollution were aligned with the level of annual funding to combat malaria, tuberculosis, and HIV/AIDS (\$3,000–5,000 per death per year), the equivalent amount of subsidy for the region would be about \$3 billion (Kamila et. al. 2014). Based on mortality figures related to household air pollution, this translates into a subsidy of about \$100 million per year for countries such as Kenya, Mozambique, Madagascar, and Uganda; and \$300–400 million for larger countries in the region such as Nigeria, Ethiopia, and the Democratic Republic of Congo.³⁶

Catalyzing subsidies at this scale will not only require a step-change in donor support but also significant national-level commitments at a level rarely seen in Sub-Saharan Africa. Biofuel and biogas subsidies in China and past subsidies for liquefied petroleum gas (LPG) in India may provide a sketch of the scale involved.

The subsidies may seem extremely large, but they are proportional to the enormous opportunity costs involved. The World Bank has estimated the opportunity cost for the region from cooking with traditional stoves and fuels at \$32 billion per year—up to \$58 billion under one

36. See 2015 Global Burden of Disease data for annual deaths from Household Air Pollution at <http://vizhub.healthdata.org/gbd-compare/>, which shows 18,000–23,000 deaths per year in Kenya, Mozambique, and Uganda; and 63,000–80,000 per year for Ethiopia, Democratic Republic of Congo, and Nigeria.

scenario (World Bank 2015c). Other estimates reach numbers as high as a \$232 billion for the annual opportunity cost to the region from the economic impact of deaths related to household air pollution alone.³⁷

There is a growing recognition of the need for increased clean cooking support, but at the same time, a strong consensus is emerging around the idea that subsidies for biofuels and related stoves must be tightly tied to results to minimize harmful market distortions. Well-designed results-based financing schemes, including carbon financing, which would not otherwise be compensated by the market, should be used to boost the overall subsidy flow to the clean biofuel sector and to correct market failures by aligning future returns with rewards for successful production and distribution of fuels and biofuel appliances meeting valuable outcomes in the realms of health, such as the reduction of deaths and Disability Adjusted Life-Years; the environment, such as carbon dioxide and black carbon abatement; and social concerns, such as a reduction in time poverty among women. Potential uses for national- or regional-scale subsidy schemes based on results-based financing include innovation in technology and business models, market-entry pilots, and efforts to scale.

2. Broaden access to finance. Beyond increasing the flow of targeted results-based subsidies for the biofuel sector, donors and governments should deploy much greater volumes of catalytic financing and innovative finance mechanisms to de-risk financing across the biofuels value chain and crowd in higher levels of private sector investment in cooking fuels.

In addition to concessionary working capital finance and early-stage equity investments, potential government and donor interventions could include forward-financing mechanisms to help convert future results-based financing and carbon finance revenue streams to near-term debt financing; guarantees for large producers to supply fuel upfront to local businesses to build out distribution networks; risk-sharing arrangements; and support for innovation in consumer financing models.

3. Enhance market support. Donors, governments, and sector intermediaries should provide or fund technical capacity building and business advisory support to key cooking biofuel value chain actors to scale production, boost consumer awareness, and build out fuel and stove distribution infrastructure. Support could come in a variety of forms, including:

- Advisory and capacity-building support for local fuel producers;
- Business model innovation and capacity-building support for distributors;
- Market linkage mechanisms to help global businesses and local partners identify one another;

37. See OECD Development Centre analysis at <http://www.oecd.org/dev/emea/air-pollution-africa.htm>. The disparate opportunity cost estimates are due to different assumptions used for the economic value of deaths and Disability Adjusted Life-Years.

- Government and nongovernment schemes for customers and areas where purely market-based approaches will not work; and
- Consumer awareness campaigns to promote the uptake of clean biofuels.

4. Promote better policies around biofuels. Governments and donors should advocate for and support the development and implementation of policies favorable to cooking biofuels to ensure a conducive enabling environment for their production and distribution at scale and/or for initial biofuel market development given the precarious economics of first movers. Key biofuel policy recommendations should focus on:

- Reducing taxes and tariffs on biofuel stoves, biofuel production equipment, and biofuels themselves;
- Eliminating subsidies for kerosene and calibrating policies for charcoal and firewood sectors to incentivize the switch from traditional biomass to clean biofuels, LPG, and electricity;
- Engaging on biofuel quality standards to supplement existing standards regimes focused on stoves (International Workshop Agreement—or IWA) and biofuels, such as the national harmonization with the new ASTM 3050 standard for cooking bioethanol;
- Eliminating specific licensing regulations that effectively restrict technology transfer and/or complicate the development of fuel value chains; and
- Ensuring that national policy roadmaps for access to clean cooking energy incorporate ethanol, pellets, and briquettes as well as improved biomass stoves.

5. Improve sector knowledge. Funders and intermediaries of the clean cooking sector should continue to invest in market intelligence, best practices capture and dissemination, and technology improvement research and development for cooking biofuels and stoves, including:

- Research on the impact of biofuels—many gaps persist in the evidence base regarding the potential affects of cooking with high-quality biofuels and biofuel stoves;
- Market and business model research to help build the business case for new investments, enhance the capture of lessons learned, and strengthen the exchange of best practices; and
- Research and development efforts around clean cooking biofuels and biofuel stoves.

Linking Interventions to Market Barriers

Major donors and intermediaries in the biofuel sector are already utilizing the interventions described in the previous section for briquette, pellet, and ethanol value chains in Sub-Saharan Africa, but the Global Alliance for Clean Cookstoves is currently the only actor with a comprehensive biofuel strategy that entails enabling environment as well as supply- and demand-side interventions (box 4.1). The World Bank, the German Agency for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*, or GIZ), and the Dutch development community are among those currently considering holistic biofuel intervention strategies. Moving the clean biofuels agenda forward will demand that interventions be designed to address both supply- and demand-side market barriers.

Biofuel demand. Many demand-side market barriers require consumer education and awareness-building interventions (table 4.1). Direct subsidies for biofuel or biofuel stoves can serve as an important potential intervention lever, but they have not yet been utilized for the region’s ethanol, pellet, and briquette fuels; there have, however, been precedents with LPG in

Table 4.1. Demand-side Market Barriers—Intervention Mapping

Barrier	Key interventions
Fuel affordability/ price competitiveness	Policy. Lower taxes/tariffs on clean cooking fuels.
	Policy. Remove subsidies for less-clean fuel alternatives such as kerosene.
	Policy. Introduce and implement regulations on traditional fuel markets.
	Subsidy. Subsidize cooking biofuels for targeted populations.
	Research and development. Support fuel production technology innovation to reduce fuel costs.
Ability to pay for stove	Finance. Design/catalyze private sector consumer financing schemes.
	Subsidy. Fully or partially subsidize biofuel stove costs for end users.
	Research and development. Support the design of cheaper biofuel stoves.
Consumer awareness	Promotion. Help develop and support national awareness campaigns.
	Promotion. Support marketing effort of individual biofuel enterprises.
	Business development services. Support distributors on marketing strategy/skills.
Behavior change	Promotion. Help develop and support national awareness campaigns.
	Research and development. Invest in developing fuel formulations that are increasingly desirable to the consumer.
Perception of fuel quality/safety	Promotion. Help develop and support national awareness campaigns.
	Promotion. Conduct education campaign about issues such as ethanol safety focused on policy makers and other community influencers.
	Knowledge. Support high-quality research on fuel safety.
	Policy. Introduce or strengthen global and national quality standards and testing programs for biofuels and biofuel stove-fuel combinations.

Box 4.1. Global Alliance for Clean Cookstoves: Integrated Cooking Biofuels Strategy

The Global Alliance for Clean Cookstoves is a public-private partnership, hosted by the United Nations Foundation and launched in 2010, which aims to save lives, improve livelihoods, empower women, and protect the environment by creating a thriving global market for clean and efficient household cooking solutions, with the objective of 100 million households globally gaining access to clean and efficient cookstoves and fuels by 2020. The Alliance works with a network of more than 1,600 public, private and nonprofit partners to accelerate the production, deployment, and use of clean and efficient stoves and fuels in developing countries.

As part of its work, the alliance pursues a holistic set of programs and interventions to foster an enabling environment for clean and efficient stoves and cooking fuel, to strengthen sector supply via increased innovation, capacity, and investment and to boost sector demand through awareness building, affordability improvements, and behavior change.

Expanding access, affordability, and scale for clean cooking biofuels, including ethanol, pellets, and briquettes, is a core part of the strategy with a range of interventions integrated into the alliance's work, including research on the availability, environmental and health impacts, and sustained adoption of clean fuels; capacity building and innovation support via grants and advisory support for individual fuel enterprises to help them scale sustainability; consumer-awareness programs focused on national-level awareness campaigns of cooking biofuels and their benefits; investment into standards and testing to strengthen fuel standards and testing capacity at the global and local levels; and policy and advocacy activities to improve the enabling environment for biofuels (e.g., tariffs, taxes, and subsidies).

The alliance's support for individual biofuel enterprises in Sub-Saharan Africa has included grants and advisory support for two briquette manufacturers in Uganda, an ethanol gel player in Nigeria, a pellet producer and distributor in Zambia, an ethanol gel promoter in Kenya, a player developing a new pay-as-you-go business model for cooking ethanol in East Africa, and a pellet cooking utility enterprise in Rwanda.

other sectors. While donors and governments typically have no direct role to play in consumer financing, indirect interventions that facilitate consumer finance provision by the private sector can be a major lever for affordability. Finally, while less direct in their effects, policy interventions such as taxes and tariffs on biofuels and supply-side levers like investment into research and development and capacity building for fuel enterprises, can also play a critical role in promoting biofuel demand by addressing the affordability obstacle to the uptake of biofuels.

Table 4.2. Supply-side Market Barriers: Intervention Mapping

Barrier	Key Interventions
Cost-effective distribution and marketing	Finance. Finance storage and logistics infrastructure for fuel distribution or distribution footprint build-out, such as stores and kiosks and sales agent network recruiting.
	Business development services and capacity. Provide strategy and operations advisory support to help develop and refine effective distribution models and/or identify partners.
Fuel and stove supply	Finance. Provide or otherwise facilitate (for example, through a risk-sharing arrangement) seed funding and expansion capital for biofuel and stove production facilities.
	Finance. Provide financing for upfront stove bulk purchases by distributors.
	Market linkage. Aggregate biofuel stove demand and link it with supply through stove auctions or other market linkage platforms and events.
	Market infrastructure. Support establishment of strategic biofuel reserves and related infrastructure to help sector manage through supply interruptions.
	Market infrastructure. Invest in distributor ecosystem at the country level.
	Policy. Remove or reduce taxes on biofuels and stoves to improve the sector's economics as it scales up, and incent private sector investment.
Feedstock supply	Financing. Facilitate working capital to allow biofuel producers to pursue long-term feedstock supply diversification strategies or grow proprietary sources.
	Policy. Link sustainable forestry policies to feedstock cultivation (for example, specialized biomass plantations) and support/incent ethanol biofuel feedstock production.
	Capacity building. Advise biofuel producers on feedstock sourcing strategies.
	Research and development. Invest in research on biofuel feedstock by identifying more sustainable and higher quality feedstock crops or production processes, as an example.
Fuel and stove quality	Policy. Explore differentiated tax and tariff tiers linked to stove and fuel quality.
	Research and development. Support research on higher quality biofuel stoves and cooking fuels.
	Standards. Build or expand fuel-testing infrastructure, such as specialized equipment.
	Standards. Support standards development and national standards harmonization.
	Research and development. Support research on higher quality biofuel stoves and cooking fuels.
	Standards. Build or expand fuel-testing infrastructure, such as specialized equipment.
	Standards. Support standards development and national standards harmonization.

Biofuel supply. Major supply-side barriers, including fuel distribution, fuel production, feedstock sourcing, and fuel and stove quality necessitate a mix of financing and capacity-building interventions along with research and development support, knowledge investments, and an appropriate policy environment. Financing is likely the primary bottleneck across the supply side of the biofuel value chain. Financing support is needed by biofuel entrepreneurs to source quality feedstock, import fuel at bulk (if that is their model), establish and expand fuel production facilities, build out distribution networks and physical distribution footprints (retail stores or kiosks), extend credit down to last-mile distribution partners, and absorb the cost and risk of purchasing biofuel stoves upfront from third-party vendors for onward distribution to fuel clients when fuels and stoves are bundled.

Donors, governments, and sector intermediaries have a broad range of potential tools at their command to meet these financing needs, ranging from targeted equity and debt investments, credit guarantees, and other risk-sharing mechanisms to incentivize lending by financial institutions. Capacity building is another important supply-side intervention lever, ranging from technology transfer and advisory support for fuel producers to marketing support and business development services for small and medium-sized biofuel enterprises.

Fiscal policy, particularly tax and tariff reductions likewise represent an important lever because they can lower producer and distributor costs and thus boost thin sector margins. Finally, under the broader policy and enabling environment rubric, engaging on fuel standards and fuel/stove testing infrastructure is important to help monitor and resolve fuel and stove quality issues (table 4.2).

Some key cross-cutting interventions also merit attention. Given that all the biofuel value chains explored in this report are heavily underfunded, face strong policy challenges, are affected by variable stove and fuel quality, and are highly opaque from the perspective of market intelligence, appropriate interventions are critical to help move the sector forward.

Select Intervention Levers

Some of the major government and donor-focused intervention levers merit further examination of their potential role and appropriate context based on experience to date.

A. Demand-side Interventions

Key demand-side intervention levers that deserve more detailed analysis and exposition are consumer-awareness building, consumer finance, and consumer-focused subsidies. Some policy considerations that affect the ability and willingness of consumers to pay as well as fuel quality standards are addressed separately in the section on cross-cutting interventions.

AWARENESS BUILDING AND BEHAVIOR CHANGE CAMPAIGNS

Many of the demand-side biofuel market barriers can be addressed through consumer education and awareness-building interventions. Naturally, biofuel enterprises already build consumer education into their marketing activities, but this is extremely costly and time consuming for an individual biofuel enterprise. National or even regional consumer-focused campaigns could be designed, funded, and delivered by international donors and national governments, often with the help of specialized intermediaries.

Donors and governments can play an active public role to support such efforts (see, for example, GACC 2011). Prominent recent examples of clean cooking campaigns most notably include the behavior change programs funded by the Global Alliance for Clean Cookstoves,

including the 2016 FumbaLive campaign in Uganda focused on improved biomass stoves, an ongoing urban-focused clean cooking campaign in Bangladesh, an upcoming campaign in Nigeria focused on the uptake of LPG in collaboration with McCann Global Health/Africare, and a multichannel campaign in Kenya through partners like the Mediae Company and Practical Action (GACC 2016a). These campaigns employ a variety of outreach tools, communication channels, and creative concepts, including a new cooking-focused reality TV show (*ShambaCook*), radio programming, mobile messaging, roadshows, street theater, and below-the-line experiential marketing. By supporting these integrated communication campaigns, the alliance expects to reach up to 20 million people with messaging about clean cooking.

While hugely encouraging, these campaigns only focus on a handful countries and are highly resource intensive; this is also the case in other sectors (\$1 million for Ethiopia national off-grid lighting campaign by Lighting Africa, for example). In addition, although branded as clean cooking campaigns, with few exceptions—such as LPG in Nigeria and fan-based pellet gasifiers in Bangladesh—they are largely focused on improved rather than truly clean stoves. There is therefore a significant opportunity for incremental donor and government funding channeled through the alliance or independent campaign efforts specifically focused on clean biofuels—especially pellets and ethanol—and build on the growing experience of the current clean cooking behavior change campaign portfolio.

Given the novelty of these campaigns in the clean cooking context, the literature on the efficacy of these initiatives is very limited. What evidence does exist on the experience of sectors such as off-grid lighting and health suggests that there is merit to using behavioral approaches and clearly defined theories of change prior to the launch of a campaign; designing interventions to operate on multiple levels; deploying multichannel integrated communications combining above- and below-the-line marketing; and engaging change agents and community leaders in campaign delivery, including gender-sensitive messaging (Goodwin 2015).

Past campaigns have also yielded some negative lessons about approaches that are less effective and those that should be avoided. For example, campaigns must be carefully sequenced to ensure that the stove and fuel supply are ready for scale when the consumer promotion is launched. Even when governments are heavily involved, clean cooking campaigns should ideally be coordinated by private sector entities or specialized intermediaries like a marketing firm with experience in national behavior change.

A clear lesson from a messaging standpoint is that campaigns focused largely or exclusively on the health benefits of clean stoves and fuels are ineffective. Several studies have shown that health messaging often has a minimal effect on cookstove purchases because adoption is influenced by multiple factors that are linked in complex ways (Johnson, Lambe, and Ochieng 2016). Stove/fuel economics and price are a much more compelling element of behavior change communications, combined with aspirational and status-oriented messages focused on

the “modern” aspects of the cooking solution and emphasis on factors like convenience, time savings, and the cleanliness of the kitchen, suggesting that clean cooking fuel donors and governments engaged on the issue must think more broadly about how they achieve the public health goals associated with cleaner cooking through consumer education approaches not narrowly focused on health outcomes for households.

CATALYZING CONSUMER FINANCE

While donors and governments typically have no direct role to play in consumer financing for biofuels and stoves, they can stimulate consumer finance flow using innovative finance mechanisms, most notably including various types of credit guarantees provided to consumer finance institutions or to intermediaries that provide consumer finance institutions with wholesale financing. The crux of the consumer financing challenge for biofuel stoves is that typical consumer financing solutions available in developing Sub-Saharan markets, such as microfinance loans, are not attractive to financial institutions because of the low loan amounts and high transaction costs involved. Thus, as noted in a review by the Global Alliance for Clean Cookstoves, clean cooking technologies, including biofuel stoves, are often too expensive for many consumers to pay up front and not expensive enough to be cost effective for financial institutions like microfinance institutions and banks (GACC 2015c).

There are several emerging examples of public and donor sector risk-sharing facilities and innovations to promote consumer financing of clean and improved stoves. Furthermore, there are relatively ample examples of such arrangements from outside of the cooking sector. In the off-grid lighting context, for instance, there are numerous models for supporting consumer financing of portable solar lighting products and small-scale solar home systems with prices in the same range as biofuel cookstoves at \$30 to \$150 each, and they both often rely on similar distribution channels.

Two interesting models not specifically tailored to the clean cooking sector are U.S. Agency for International Development’s DCA interventions and IDCOL in Bangladesh. In both instances, credit guarantees were provided by international development finance institutions, but analogous guarantees could also be developed and deployed by governments. There are many examples of this in other sectors, including credit guarantee schemes for smallholder farmer financing. Examples of how donors can stimulate consumer finance specifically tailored to the clean cooking context include the innovative Department for International Development-seeded and carbon-finance-supported *Revolving Fund* for ethanol stoves that has been deployed for Safi International in Kenya by ClimateCare and the support for KUSCCO in Kenya provided by the Global Alliance for Clean Cookstoves.

While these examples point to the potential to catalyze consumer financing for the cooking biofuel sector, such approaches will not be applicable in every market. Of course, as illustrated by the IDCOL case in Bangladesh, donor-supported consumer financing facilities and

risk-sharing mechanisms can be designed much more broadly, theoretically allowing for the extension of such approaches to ethanol and pellet fuel stoves once appropriate market conditions are in place.

CONSUMER-FOCUSED SUBSIDIES

There is increasing agreement in the development community that achieving universal access to clean cooking biofuels and high-performing biofuel stoves will be impossible without significant subsidies. At the same time, a strong consensus has emerged that subsidies for biofuels and related stoves, whether from the public sector or the donor community, need to be well targeted and tightly tied to results to minimize harmful market distortions. This section tackles the specific question of how governments and donors should address end-user subsidies for stoves and fuels.³⁸

The history of consumer-focused subsidies for clean cooking is a complicated one, and the question of whether and how end-user subsidies should be provided has been hotly debated in the sector (see World Bank 2015). While there are some common threads, the considerations for biofuel compared with biofuel stove end-user subsidies are distinct because fuel subsidies by definition involve ongoing costs and thus tend to present much more significant fiscal burdens. Despite some caveats and challenges, discussed below, well-crafted end-user subsidies can do a great deal to propel the Sub-Saharan biofuel cooking sector forward, and they represent an area where governments and the donor community are well positioned to lead.

Much can be learned from experiences with improved biomass stove subsidies. Many examples exist of consumer-focused stove subsidies as an element in national clean cooking programs, beginning with large-scale national programs in countries like India and China in the 1980s and 1990s. While implementing organizations and national governments have increasingly moved away from highly subsidized product deployment programs toward more market-based approaches, end-user subsidies are still a feature of many national cooking initiatives with respect to lower-income and rural households (World Bank 2015c; GACC 2011). End-user stove subsidies range from partial stove price subsidies (20 percent subsidy for stoves in Ethiopia, for example) to—less commonly—fully subsidized stove give-away programs for low-income populations. One recent example of the latter is the distribution of 180,000 Envirofit stoves to households in Honduras under the government's *Vida Mejor* program. An analogous example in Sub-Saharan Africa is the currently suspended Nigeria government plan to spend 9 billion naira to distribute 750,000 free stoves to low-income Nigerian households.³⁹

38. It is important to note that this discussion centers specifically on subsidies for cooking consumers rather than indirect subsidies to support stove and fuel manufacturers and distributors, including full or partial subsidies offered directly to the consumer through stove or fuel give-away programs, voucher-based cash transfers, or subsidies channeled through intermediaries contractually obligated to use subsidies to reduce end-user prices.

39. Funds for the program were formally allocated in late 2014, but only 15 percent of the budget was actually released, the contract with the cookstove manufacturer was eventually suspended, and the project is still currently mired in controversy.

Despite a few successes, the landscape of stove subsidy programs is littered with failures that contain many lessons for funders. Past stove subsidy program challenges include poor technology and vendor selection; misappropriation of resources due to nontransparent subsidy mechanism designs; inefficiencies due to overly centralized and noncompetitive stove procurement and distribution mechanisms; insufficient after-sales support, and poor subsidy targeting (World Bank 2015c). These challenges can be mitigated by well-designed stove subsidy programs that draw on best practices, such as well-targeted subsidies with built-in exit strategies linked to high quality stoves.

With regard to cooking fuel subsidies, while national subsidy schemes have not yet been implemented for ethanol and pellets, there are many analogous examples of subsidy programs for fuels like LPG, with important lessons in the biofuel context. Clean cooking fuels have achieved the widest reach in Sub-Saharan Africa in places where governments have injected significant end-user fuel subsidies into the sector, including Senegal, Cameroon, Côte d'Ivoire, and Ghana for LPG; and South Africa, Zambia, and Zimbabwe for electric cooking. Beyond Africa, fuel subsidies are widely acknowledged to be a critical driver of energy transition and uptake of clean LPG cooking fuel by low-income populations in countries that include China, India, and Indonesia in Asia as well as Brazil, Mexico, and Ecuador in Latin America (WLPGA 2015).

The classic example of such fuel subsidy schemes in Sub-Saharan Africa is the *Butanization* program in Senegal. Elements of the program were successful over the short-term but ultimately could not be sustained. The success of LPG consumer subsidy programs can be replicated for ethanol and pellet fuels by Sub-Saharan governments and donors who can afford it, but some important lessons regarding the potential downsides should be considered. Obvious caveats include the aggregate fuel subsidy costs, the exposure of governments to fiscal risks, and negative trade balance implications. When poorly designed, fuel subsidies are liable to capture by upper-income consumers and special interests, with subsidized LPG being deflected for use in vehicles or for unsanctioned cross-border trade with countries where LPG is unsubsidized. A global review of 20 LPG subsidy programs in 2012 concludes that only 4 percent of traditional untargeted LPG subsidy schemes reach the lowest income quintile, and an average of 54 percent of the subsidy value was captured by the highest income quintile (Granado et al. 2012).

The aggregate subsidy cost is a particularly difficult issue for less-developed Sub-Saharan countries that may lack the means to replicate the cooking fuel subsidy models of middle-income countries. At their peak, like the *Butanization* program, LPG subsidies in Senegal constituted 0.2 percent of the nation's gross domestic product (GDP); in Ghana, they were 0.5 percent, which is comparable to India prior to the Direct Benefit Transfer of LPG (DBTL) program at 0.4 percent, and in Indonesia they are currently about 0.5 percent of GDP (WLPGA 2015). These subsidy levels are probably unaffordable in most Sub-Saharan countries.

In conclusion, while large-scale biofuel consumer subsidy programs will probably not be appropriate for all Sub-Saharan countries, they could work well for governments with the disposable resources to address the tremendous opportunity costs that traditional cooking fuels represent or that are looking to redirect subsidies from less efficient fuels like kerosene to clean cooking energy. At the very least, even in resource constrained environments, well designed biofuel stove subsidies can be a path toward promoting the uptake of biofuels by urban consumers who can afford the ongoing biofuel costs.

B. Supply-Side Interventions

There is a panoply of potential supply-side biofuel market intervention levers accessible to donors, governments, and other sector intermediaries. This section primarily focuses on illustrating potential interventions involving producer and distributor financing, with an emphasis on innovative finance mechanisms and market infrastructure interventions. Other important supply-side interventions that are unaddressed here, including investments into biofuel sector research and development, market intelligence and evidence-based collection, and capacity building and business development services for market participants, are more self-explanatory or are covered separately in the cross-cutting policy and enabling environment section later in this chapter.

BIOFUEL PRODUCER AND DISTRIBUTOR FINANCING

Financing needs are omnipresent across the supply side of the biofuel and biofuel stove value chains. Biofuel players involved in stove production have financing needs for stove manufacturing and distribution. In theory, donors, governments, and other cooking sector intermediaries have a broad range of potential tools at their command to meet these financing requirements. In practice, however, financing is a major constraint for nearly all existing and emerging biofuel entrepreneurs, particularly those that are approaching or have entered the growth and expansion phases and have requirements beyond donor-driven, seed-grant capital.

Equity for clean cooking business is scarce, and few biofuel cooking enterprises are of interest to social enterprise or more commercially minded equity investors. Traditional financing through commercial banks or commercial lending institutions is not a viable option for most enterprises in the absence of substantial collateral. Early-stage and often unproven business models, the inability to predict future cash flow from sales, a lack of certainty around carbon finance revenue streams, relatively low returns on investment, a lack of customer credit histories, and often an informal economy within which these businesses operate mean enterprises struggle to access finance from local and regional banks. Working capital is the most significant financing gap across the board. Even the most commercial cooking biofuel players in the region struggle to find expansion capital beyond proof-of-concept grants from donors and early-stage investments through impact investors and overseas donors. Carbon financing streams have declined in recent years due to the uncertainty of the carbon market.

A few financing facilities and funds, several of them supported by or in partnership with the Global Alliance for Clean Cookstoves, have appeared in recent years to fill some of these financing gaps despite the challenges. From the standpoint of grant financing, the alliance's Spark Fund, Pilot Fund, Catalytic Grant Fund, and Capacity Building facilities supply essential grant funding to enterprises experimenting with new biofuel business models. In collaboration with the Deutsche Bank's Community Development Finance Group, the alliance has also created a \$4 million Clean Cooking Working Capital Fund that provides capital loans and loan guarantees to enterprises that are not able to access traditional financing.

Grants. In addition to funds from the alliance, small to mid-sized grants of \$50,000 to \$500,000 are available for biofuel enterprises through donor programs funded by players that include the World Bank, German Agency for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*, or GIZ), Energizing Development (EnDev), and the Department for International Development. However, this funding tends to be ad hoc and focused on specific markets where these donors are already active in the clean cooking sector. More substantial grant funding for biofuel businesses could potentially be secured from the U.S. Agency for International Development's Development Innovation Ventures fund, which has already provided significant resources to improved biomass cookstove enterprises⁴⁰ and early-stage grants to briquette players. To date, the fund has not been accessed by ethanol or pellet fuel enterprises.

Equity. For players seeking equity, a handful of impact investors have begun exploring the clean cooking biofuel sector and are open to taking small equity positions. For larger equity investments, the Dutch development bank FMO's Access to Energy Fund, a fund of about 100 million jointly initiated by the Dutch government and FMO to support private-sector energy access projects, has shown some interest in biofuel cooking and has the capacity to deploy early-stage development equity, later-stage equity, and subordinated debt/senior loan instruments.

Debt financing and guarantees. For debt financing, development finance institutions like FMO and more social funders like Shell Foundation have an increasing interest in funding cooking fuel enterprises and have been in talks with cooking biofuel producers. OPIC has extended debt financing to several cooking enterprises (for example, Burn Design and Envirofit) and is open to engaging with biofuel businesses. More commercial players, such as Althelia, are exploring larger-scale debt financing agreements for biofuel enterprises that have secured substantial carbon financing. Beyond straight debt provision, many donors and development finance institutions are interested in providing credit enhancements to clean cooking and biofuel companies with instruments including partial credit guarantees, loan loss reserves, and loan guarantees. The Shell Foundation, for example, has provided loan guarantees to Envirofit;

40. Development Innovation Ventures' three-tier system offers \$25,000 to \$150,000 for companies at the proof-of-concept or initial testing stage; \$150,000 to \$1.5 million for positioning for scale, and \$1.5 to \$15 million for enterprises transitioning proven solutions to scale. Investees included Biolite and Burn Design.

and Energy4Impact (formerly Global Village Energy Partnership) runs a loan guarantee facility that has been used by mid-sized cooking enterprises to help secure local bank financing. The U.S. Agency for International Development's Development Credit Authority planned to target \$25 million toward financing clean cookstoves and cooking fuels through innovative credit enhancement instruments in 2015 as part of a larger \$100 million fund co-guaranteed by the Swedish International Development Agency (SIDA) and private-sector partners like AlphaMundi, Calvert, and Signina Capital.

Despite these growing financing sources, the clean cookstove sector is still a nascent industry for financiers. To shift perceptions among the investment community, additional efforts are needed to fund disruptive innovation for companies at the growth stage to demonstrate success and validate more commercial investment into the sector. Donors and national governments can do this by funding existing vehicles like the ones described here. One idea is to set up or support a debt fund (for example, through risk guarantees) specifically tailored to financing mid- to- large-size capital expenditure investments into fuel production, fuel processing, and fuel transportation/logistics. Other ideas include supporting biofuel stove importation credits, biofuel importation working capital, and buy-back guarantees for fuel or stove suppliers.

INVESTMENTS IN MARKET INFRASTRUCTURE

An increased flow of finance to cooking biofuel enterprises and donor-funded technical assistance can make a major difference in many Sub-Saharan markets but are likely insufficient to impact millions of lives in the near term. The fundamental weakness of fuel business model economics outside of high-cost urban charcoal markets, the uncertainty around critical supplemental revenue streams, the absence of efficient and accessible last-mile distribution value chains, and the vagaries of stove and fuel supply suggest that in most Sub-Saharan markets, clean cooking fuel ecosystems will develop very slowly absent “big push” supply-side interventions by donors and governments.

Subsidies targeted with results-based financing mechanisms in conjunction with policy shifts can enhance private sector economics and thereby the overall business case for cooking fuel production and distribution. Such solutions will still leave major gaps, however, because they implicitly require the private sector to shoulder the burden of building out market infrastructure at the early stage. Governments and donors therefore have roles to play in filling these infrastructure gaps with “market infrastructure” investments. Examples of such interventions across the fuel supply chain include: (1) fuel reserves to cushion interruptions in fuel supply, (2) distribution challenge funds to incentivize the build-out of stove/fuel distribution infrastructure, (3) innovative platforms to de-risk the supply of fuel and biofuel stoves to early-stage clean cooking markets, and (4) various financial innovations that can systemically unlock the flow of carbon finance or results-based funding to the sector as a whole.

With regard to the promotion of fuel supply infrastructure, stakeholders consulted for this study suggest several public sector infrastructure interventions. Proponents of ethanol cooking,

for example, propose that governments and donors incentivize the sharing of existing upstream fuel infrastructure, including LPG port facilities and warehousing depots for ethanol importation, storage, and transit.

While fuel supply interruptions can indeed be a major issue, lessons from existing strategic fuel reserves suggest that putting such infrastructure in place can be a very costly endeavor that requires a developed ecosystem of suppliers. Furthermore, strategic reserves can be quite controversial. Arguments for such reserves are often framed in terms of national energy security and tend to come to fruition only when the fuel in question—like LPG—reaches sufficiently high levels of household or business penetration.

Further downstream, there is another public role in helping to establish and promote fuel distribution infrastructure. Most cooking biofuel sector stakeholders believe that direct government involvement in fuel distribution would be highly inadvisable because not only would they serve as a forum for corruption while displacing private sector investment.

There are, however, other alternatives for infrastructure investments that can promote distribution build-out. For instance, taking the example of India's LPG distribution market, governments can provide strong regulatory incentives for fuel distributor recruiting and training in underserved areas. Another alternative is to replicate and scale results-based financing models that specifically target the build-out of fuel distribution value chains by, for example, extending or replicating the example of the World Bank's Uganda Distribution Challenge Fund for cookstoves to the biofuel context.

Once fuel supply is secured and distribution value chains are in place, another important infrastructure gap in most Sub-Saharan cooking biofuel markets is the mismatch between market demand and supply, highlighting the potential need for public sector and donor investments into precompetitive, neutral market linkage platforms. Local clean cooking sector distributors want to access high quality cooking appliances and secure supplies of fuel, often from international providers. However, most domestic distributors lack the scale and the financing to absorb the risk of importing stoves and fuel products at a scale sufficient to reach sustainability. International stove and fuel suppliers struggle to aggregate local distributor orders to reach sufficient scale to make it worth their while to export their products to new markets. This type of circular challenge is common for early-stage markets and can significantly slow market development until scale and trust are sufficiently built up between producers and importers.

Donors and governments can help resolve these market bottlenecks through innovative interventions for the public good, ranging from low-cost market entry insurance to auction-based models for aggregating supply and demand and de-risking supply chain linkages. A better approach may be to institutionalize stove and biofuel market linkage auctions along the model designed and piloted by SNV's Stove Auction platform in South East Asia, which appears to have generated excellent results over the past year but which is currently limited to promoting the importation and uptake of high-performing biomass gasifier cookstoves.

Figure 4.4. Results-based Financing: Potential Points of Intervention

	Research and development	Piloting	Scaling
Point of intervention	Development of clean cookstove/fuel technology	Decision regarding business model	Distribution to households
Objective of results-based financing	<ul style="list-style-type: none"> Meet technology gaps in the clean cooking sector through prizes and competition 	<ul style="list-style-type: none"> Prove out certain business models over others by de-risking the pilot stage 	<ul style="list-style-type: none"> Facilitate last-mile distribution and scale up clean cooking fuel businesses
Advantages	<ul style="list-style-type: none"> Can lead to creation of several players in clean cooking technology space in addition to winners 	<ul style="list-style-type: none"> De-risking initial stage allows businesses to experiment with different innovative models 	<ul style="list-style-type: none"> Incentives per unit sold attracts large distributors with established networks
Ways to implement	<ul style="list-style-type: none"> Introduce tiered grants based on the testable efficiency/health benefits of stoves or production technology to ensure multiple participant challenges 	<ul style="list-style-type: none"> Provide initial shipment/ supply of stoves or fuel to businesses to experiment with different innovation models 	<ul style="list-style-type: none"> Allow some degree of upfront financing so distributors can procure supplies (auction?) Design monitoring framework that includes focus on usage over the long run.

C. Cross-cutting Enablers

Beyond specific demand- and supply-side interventions, governments, donors, and other sector intermediaries have a critical role to play in establishing and supporting cross-cutting interventions that affect the entire biofuel and biofuel stoves value chain. This section illustrates these cross-cutting intervention levers, offers a few case studies of experimental interventions of this type in Sub-Saharan Africa as well as lessons from other regions, and provides examples of how governments and donors can work with the private sector to architect fuel transition approaches like the Indonesia LPG conversion program.

RESULTS-BASED FINANCING FOR CLEAN COOKING BIOFUEL ECOSYSTEM

Results-based financing can be used to channel financing to businesses while guaranteeing the intended positive outcomes of clean cooking. This funding can be disbursed in a variety of ways and at different points in the cooking fuel value chain. Three specific points of intervention for this approach in the alternative biomass fuel sector stand out: research and development, piloting, and scaling (figure 4.4).

RESEARCH AND DEVELOPMENT

In terms of technology, gaps exist in the optimization of stoves for alternative fuels like pellets or ethanol. The private sector views investment in research and development to address this issue as an unprofitable venture. In this context, prizes and competitions, which can be considered forms of results-based financing, can attract players willing and able to develop efficient

technology. To maximize the number of potential participants for any prize, tiered awards based on the testable efficiency or health benefits of the competing stoves or production technologies can be introduced. This could also diversify the set of innovators and innovations to the clean cooking field, although this is highly unlikely in the Sub-Saharan context. Another approach could involve adapting the auction mechanism previously used for cookstove sales in Cambodia (C-Quest Capital) through advanced market commitments, with the donor guaranteeing a price/market for the product being developed.

Two main risks must be acknowledged with regard to the planning of results-based financing for research and development. The first is the danger of inducing superfluous research, which would result in an inefficient allocation of the resources possessed by the involved players. The second is a question of ownership: do winning businesses have the right to profit from their technology or will the mandate of the involved institutions require companies to relinquish their intellectual property rights over the innovation?

PILOTING

Results-based financing can be introduced at the pilot stage for businesses in the clean cooking sector. De-risking the initial supply of expensive feedstock by producers or the procurement of stoves and fuel by distributors can allow businesses to test and prove certain practices over others. Given the lack of tested business models, the variety of regulatory environments, and the dynamic market settings, results-based financing interventions make sense.

Financiers can issue development impact bonds to pilot certain models in the market. The funds would be repaid to investors with an interest rate based on measured results, such as households reached during the pilot. A slightly riskier model for the benefactor could involve the donation of initial supplies needed to begin a clean cooking business, followed by close monitoring of initial rollout.

SCALING

The advantages of results-based financing for clean cookstoves and fuels include the ability to attract large distributors with established networks that can be matched up with businesses specializing in the production of alternative biomass fuels. Downstream results-based financing also allows consumers who are not yet convinced of the value of cleaner cooking fuels to experience the product at a lower price, overcoming the barriers imposed by a lack of consumer awareness and willingness to pay for the benefits of alternative biomass fuels.

The implementation of results-based financing schemes at this level involve grant contracts structured to disburse payments based on meeting specific performance targets, either to outputs or outcomes. Attention needs to be paid to making financing available upfront while designing a comprehensive monitoring framework that includes a focus on the long-run adoption of clean fuels.

There are several risks that need to be managed in the case of results-based financing on a per-unit basis. One is simply that the lack of up-front financing or capital may inhibit certain businesses from entering the clean cooking market at all. Another is that incentivizing increases in the quantity of clean cooking products distributed may lead to a decline in quality, efficiency, and health benefits, which go unnoticed. In an extreme case, consumers may be coerced into receiving services they do not want because of the temptation to exaggerate reported figures. Finally, there is a real danger of consumers regressing to traditional fuels like charcoal and kerosene after the results-based financing is phased out.

Thus far, results-based financing for clean cooking has been primarily focused on the scaling, per-unit approach and more specifically on the sales and distribution of cookstoves. This is largely because implementers of such schemes in the clean cooking space have aimed to address the disconnect between cookstove suppliers and end consumers. In addition, the difficulty of tracking fuel use relative to the deployment or use of cookstoves poses a significant barrier to the monitoring and verification of per-unit schemes focused on the fuels themselves. Interviews with key players have reaffirmed the idea that current results-based financing for clean cooking is largely focused on the sales of stoves because tracking fuel sales to consumers has proven to be impractical.

Results-based financing experts and participants have identified a few recurring issues in programs deployed thus far. As mentioned previously, payments under per-unit schemes are generally not upfront, which means that many smaller businesses with unmet capital requirements are excluded. Companies that act as intermediaries in the monitoring and verification of progress on results-based financing targets have voiced concerns that many implementers can be deterred by the cumbersome and complex reporting requirements imposed by donor institutions.⁴¹ Finally, the lack of measures to de-risk the initial stages of the clean cooking businesses keeps producers and distributors from making the necessary initial purchases and investments to test the market and optimize their business models for scale.

Both implementers and participants need to experiment to find appropriate results-based financing models for scale. Some clean cooking fuel businesses are adopting models that interweave the tracking required by per-unit results-based financing schemes because this serves the dual purpose of strengthening distribution and customer relationships. In an approach based on harnessing the potential of new technology, Green Development, a Norwegian carbon credit trading company operating primarily in Madagascar, has started requiring its distributors to track customers and cookstove/fuel sales through a smartphone application specifically designed for the purpose.

41. Based on interview with contact from Green Development.

Table 4.3. Programs for Clean Cooking: Examples of Results-Based Financing

Results-Based Financing Program/Study	Purpose and Mechanism	Lessons Learned and Results
Mekong Stove Auction (Cambodia)	<p>Accelerate market for clean cookstoves</p> <ul style="list-style-type: none"> • Increase actors in market and improve access to cleaner energy. <p>Auction for stoves where producers are sellers and buyers are locally based distributors/retailers</p> <ul style="list-style-type: none"> • Sellers consign their stoves 	<p>Benefits for sellers include guaranteed prices with results-based financing and cash incentive for each sale on buyer side.</p> <p>Pilot results: Two stove models auctioned, 980 sold, 8 registered bidders.</p> <ul style="list-style-type: none"> • Model has worked well so far and the clearing price has already been going up. <p>Many distributors limited by a lack of up-front financing for purchasing on consignment.</p>
World Bank Clean Stove Initiative (Indonesia)	<p>Use results-based financing to promote adoption of clean cookstoves.</p> <p>Develop three-star rating system for defined clean stoves.</p> <p>Two-stage payment process: 70 percent of incentive disbursed with stove sales; the rest is given after households are checked for use.</p>	<p>Indonesia’s commercial clean stove market is limited to low-capacity, artisan producers without government support.</p> <p>Key lessons: Importance of identifying appropriate institutional arrangements, having a flexible design, and consulting relevant stakeholders to ensure their buy-in.</p> <p>Some potential entrants are deterred by a lack of up-front financing.</p>
UCB and Berkeley Air Monitoring Group (Lao PDR)	<p>Attempt to try and quantify health benefits of clean cookstoves</p> <p>Develop a salable health benefit to attract investors by linking carbon to Disability Adjusted Life-Years</p> <p>Based on measurements in 72 households in 3 villages of Xonboury District</p>	<p>When used as the only cookstove, the cleaner ACE-1 stove reduced average kitchen pollution levels by about a factor of four compared with traditional biomass stoves</p> <p>If this performance were maintained for three years with 75% long-term adoption and usage, dissemination to 25,000 households would reduce disability-adjusted life years by about 1,200 in this population (70 percent reduction in children).</p>

Some implementers are thinking critically about measuring and guaranteeing the outcomes of transitioning to alternative biomass fuels, which is also conducive to making the market more attractive to investors through salable benefits. One example is the HAPIT model developed by the Berkeley Monitoring Group and the University of California, Berkeley. It was designed through rigorous testing to quantify the health impact of using alternative biomass fuels. More specifically, the key output here is the cost estimate per averted disability-adjusted-life-years saved. In addition to using health outcomes to spur investment in this space from actors like the BIX Fund, institutions are carrying out results-based financing interventions in the developing world that employ multiple forms of innovative financing.

Additionally, aggregate-level results-based financing for research and development and business model innovation merits more attention. Given the newness of the sector, a careful consideration of the aggregate level is important to fully understand the market’s potential.

A program like the stove auction in Cambodia would be ideal for achieving these outcomes given the well-defined results-based financing incentives for both producers and consumers and the role of the auction as a platform to match the supply of clean cooking fuels with demand.

POLICY AND ENABLING ENVIRONMENT FOR COOKING BIOFUELS

Creating a favorable policy environment is a key intervention for addressing the market barriers to alternative biofuels, especially in the case of ethanol. Littered with kerosene subsidies, excise taxes, and obstructive/unclear regulatory frameworks, these policies need fresh examination and rectification if clean biofuels are to make serious inroads. Although national governments are the main player in implementing these policies, they may be reluctant to act. Thus, donors and intermediaries may need to be more active in building the overarching case for biofuels. Ultimately, government buy-in not only sets the foundation for policy change, but also drives national awareness and stimulates demand.

Three critical outcomes for the development of the alternative biofuel sector can be achieved through policy levers: (1) creating a favorable playing field for alternative biofuels, (2) ensuring the availability of cookstoves to utilize these fuels, and (3) guaranteeing clean biomass fuel quality.

To create a favorable playing field, governments can take measures regarding domestic and trade policy. On the fiscal policy side, governments can:

- **Remove taxes on ethanol.** Ethanol is often taxed at a high rate—as if it is meant for consumption. Kenya recently acknowledged this distinction and removed the excise tax on denatured ethanol (GACC 2016b).
- **Remove subsidies for kerosene.** Kerosene subsidies contribute to ethanol’s lack of price-competitiveness with its traditional fuel counterpart. The government of Nigeria recently announced the end of the kerosene subsidy, which led to a 66 percent price increase (Opeyemi 2016).
- **Provide value-added tax exemptions on clean biomass fuels.** While no examples of such exemptions currently exist in Sub-Saharan Africa, Project Gaia discusses tax exemptions on ethanol to make the fuel price-competitive (Gaia 2014).
- **Formalize the charcoal and firewood sectors.** Formalizing the charcoal and firewood sectors ensures that these fuels are sold at their “true cost,” allowing their alternative biofuel counterparts to better compete. Experience has shown that such an approach is actually quite difficult to accomplish because the fees or taxes are extremely difficult to collect and frequently lead to opportunities for bribery and corruption.

On the trade policy side, country governments can:

- **Provide import duty exemptions for biofuel production equipment.** Businesses in the briquetting and ethanol sectors have to import production equipment frequently (Mwampamba, Owen, and Pigaht 2013). Ukraine put a value-added tax and duty exemptions in place on imported machinery and equipment for biofuel production in 2011 (WTO 2016b), which is increasing the share of biofuels by as much as 20 percent (USDA Foreign Agricultural Service 2009).
- **Reduce shipping regulations.** Nonexistent or unclear regulations around the shipping of biofuels can prolong the import process and make doing business unpredictable. Clarifying them and related bureaucratic mechanisms is important.

In terms of ensuring the supply of quality cookstoves, governments can phase out the import tariffs on them. For example, the Kenyan government recently reduced the import duty on energy-efficient cookstoves from 25 to 10 percent (GACC 2016b). An alternative approach to import tariffs on cookstoves is to provide exemptions for new cookstove producers, such as on the first 1,000 cookstoves a foreign producer shifts into the market, gradually phasing them back in for subsequent imports. This approach allows foreign producers to test the market for their cookstoves while giving local production room to develop.

Inconsistently produced fuels often suffer quality issues, which hurts demand. Guaranteeing quality fuel production is therefore key to developing and growing demand for biofuels. In recent years, the clean cookstove market has pushed to adopt stove standards, as demonstrated by the adoption of provisional International Organization for Standardization/International Workshop Agreement standards for stoves (World Bank 2014). The fuel sector could benefit from a similar push.

Some supportive biofuel policies have been passed, but they suffer poor implementation, partly due to a lack of government commitment but even more to limited capacity. Thus, another way that donors can intervene is to provide technical assistance and capacity building services to the governments crafting policy reforms, even though they do not yet have the necessary expertise to implement them.

Coordination is key to efficiently and sustainably design and implement the key policy levers described above. Governments should develop regulatory frameworks to guide the different stakeholders involved in implementing them. Some already have such frameworks, such as the Biomass Energy Strategy in Rwanda (2009) and the biomass and charcoal policies in Kenya (2012–13). Tanzania is working with international partners such as the United Nations Industrial Development Organization to develop them (World Bank 2014).

Biofuel businesses often have trouble navigating policy in Sub-Saharan Africa because they often lack transparency and specificity. Donors can help address this challenge by periodically

publishing reports on “market friendliness” from a biofuel-relevant policy perspective. These reports could summarize publicly available information on taxes, tariffs, and regulations; provide insights on the steps required to get through various applications; and data on how the policies are implemented on the ground.

Sub-Saharan governments should draw on lessons about the cooking energy transition beyond the region as they consider their policy engagement strategy. The experience of countries like China in rolling out and managing holistic subsidy and policy engagement programs for the promotion of biofuels and biomass (briquette and pellet) for the clean cooking sector holds many interesting lessons. Beyond individual policy levers, the experience of clean cooking fuel energy transition from outside India also holds important institutional lessons. The case of Indonesia’s LPG Conversion Program is relevant to governments thinking through the role of government compared with the private sector in the cooking energy transition.



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List of Interviews

Name	Position	Organization	Fuel type
Brady Luceno	Director of Cooking Fuels	POET (Novogaz partner)	Ethanol
Bruno Mallmann	Project Engineer	Green Social Bioethanol	Ethanol
Camilla Fulland	CEO/Program Manager	Prime/Differ	Pellets/briquettes
Eduardo Mallmann,	CEO	Green Social Bioethanol	Ethanol
Eric Reynolds	CEO	Inyenyeri	Pellets
Ethan Kay	Strategy	Biolife	Pellets
Gaston Kremer	Project Manager	Green Social Bioethanol	Ethanol
David Gerard	CEO	Green Bioenergy	Briquettes
Greg Murray	CEO	Koko Networks	Ethanol
Harry Stokes	Director	Project Gaia	Ethanol
Havard Norstebo	General Manager	Green Development	Ethanol
Jacob Moss	Senior Advisor	Environmental Protection Agency/ U.S. Department of State	Cross-cutting
Jean Kim Chaix	Director (formerly)	The Charcoal Project	Pellets/briquettes
Matthew Owen	Director/Co-Founder	Chardust	Briquettes
Michael Johnson	Senior Scientist	Berkeley Air Monitoring	Cross-cutting
Peter Scott	CEO	Burn Manufacturing	Pellets/Ethanol
Sylvia Herzog	COO (formerly)	The Charcoal Project	Pellets/briquettes
Tayo Oguntoyinbo	CEO	Green Energy Biofuels	Ethanol (gel)
Ted Orbrink	CEO	Clean Cook (ex Dometic)	Ethanol
Tom Osborn	CEO	Green Char	Briquettes



