MARKET POTENTIAL:
BIOETHANOL FOR CLEAN COOKING

MOZAMBIQUE

pivot | GLOBAL BIOETHANOL COALITION

Contents

The *Market Potential: Bioethanol for Clean Cooking Mozambique* is the product of a research project initiated by Pivot Clean Energy Co. for the purposes of investigating target geographies in terms of their current state of energy access within household energy, potential rates of transition to bioethanol from current cooking trends, and projected future volumes and associated costs. This country specific report is intended to be used in conjunction with *Market Potential Methodology* in order to understand the conclusions and context.

The country report was prepared by Adam Collins, Master's student at University of Colorado - Boulder (CU), under the overall guidance of Pivot's Executive Director Alicia ElMamouni. Pivot is grateful to Rita Klees for her facilitation of the CU Practicum program, and to the University of Colorado for providing such opportunities for their students.

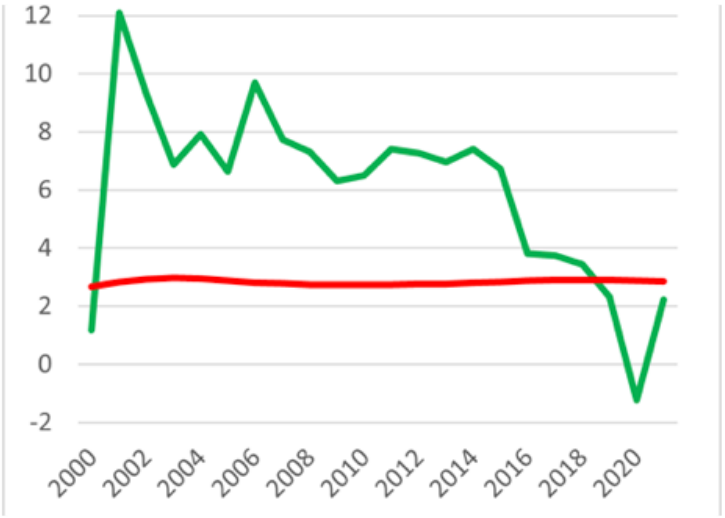
MOZAMBIQUE The Market Potential for Bioethanol as a Clean Cooking Fuel

Introduction | Mozambique at a Glance

Mozambique has reduced poverty in all forms over the last 15 years, but recently economic growth has stagnated. From 2001 to 2015, Mozambique's real GDP grew around 7.3 percent annually, past the population growth rate of 2.8 percent during the same period (World Bank, 2018). That growth is largely attributed to the expansion of the services sector, agricultural sector, and investments in megaprojects (through foreign investment) which contributed to more than 2.8 percent of the growth until the middle of the 2010s (World Bank, 2018).

Although growth accelerated during that period, a hidden debt scandal in 2016, cyclones in 2019, and COVID-19 in 2020 propelled population growth to outstrip real GDP (Salvucci, 2021); GDP growth, as a result, has yet to reach the level observed in 2015. New research has even suggested that while the monetary poverty count has dropped by almost 20 percent (92.8% to 71% in 2015), the absolute number of poor people and the subsequent expenditure gap between the wealthy and poor in Mozambique has increased over time (approximately 3% annually for both) — positively impacting the wealthy only in urban areas (Embassy of Sweden, 2019).

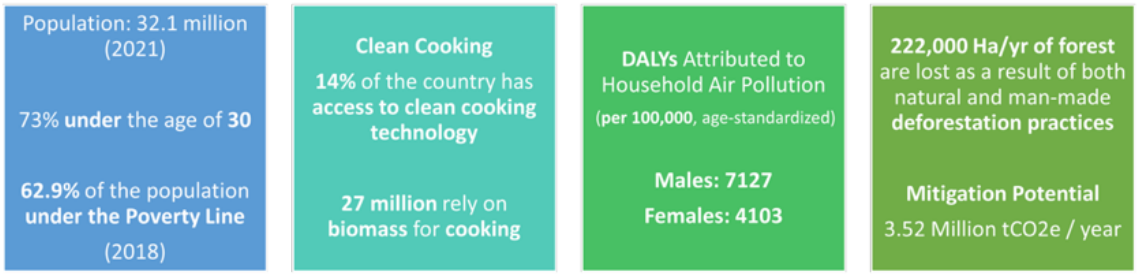
Figure 1 - Real GDP and Population Growth Rate (%)



Note: Graphic made with data from the World Bank (n.d.).

This gap is supported by 71 percent of the population and 25.5 percent of GDP in the agricultural sector compared to only 24 percent and 55 percent in the services sector, respectively (Embassy of Sweden, 2019). In order to bolster growth and continue to decrease poverty, a more diverse macroeconomic expansion is needed. With Mozambique's transition to the services industry and decline in agricultural productivity (despite 3 out of 4 working in agriculture), the biofuels sector may be a comprehensive market to transition to more diverse, sustainable development and higher living standards. Bioethanol, as a cooking fuel, is one of those transitional biofuels, and the specific focus of this report. To help set the stage, Figure 2 showcases a few important figures related to the clean cooking sector and growth potential in Mozambique.

Figure 2 - Quick Facts about Mozambique



Note: Data retrieved from the World Bank (n.d.), FAO (2020), CCA (2022), and WHO (2022) assessments.

The Cooking Landscape

Cooking Fuels and Access to Clean Cooking Technology

Access to Clean Cooking Technology (CCT) has been on the rise in urban areas since 2000 (NAAC) (Figure 3) (WHO, 2022). Despite this and considering the consumption setbacks from the impact of COVID-19, **the majority of Mozambicans still rely on biomass as their primary source of cooking fuel** (Figure 4) (World Bank, 2022). The decrease in rural reliance on CCT over the same period may be attributed to an increasing wealth inequality where expenditure on cooking fuel is, instead, a matter of convenience and affordability rather than health and environmental impact. **Biomass (71%) and charcoal (21.6%), as a result, remain the dominant cooking fuels** in Mozambique overall (WHO, 2021). With the prevalence of stove and fuel stacking—the practice of using more than one cooking fuel on a regular basis in the home based on cultural practices, fuel availability, and/or cost—those numbers may be higher (Mudombi et. al, 2018). Other fuels (<2%) encompass options like bioethanol that are not listed but have a small presence in country; that number remains low, but is slowly rising. The market switch from biomass (typically firewood) to charcoal from 2000 to 2019 across both groups is considered the result of the growing charcoal supply chain and better cooking attributes comparatively; charcoal, in other words, is considered an important transitional fuel for the Mozambican people (Mudombi et. al, 2018).

Figure 3 - Projected Access to Clean Cooking Technology 2000 - 2030

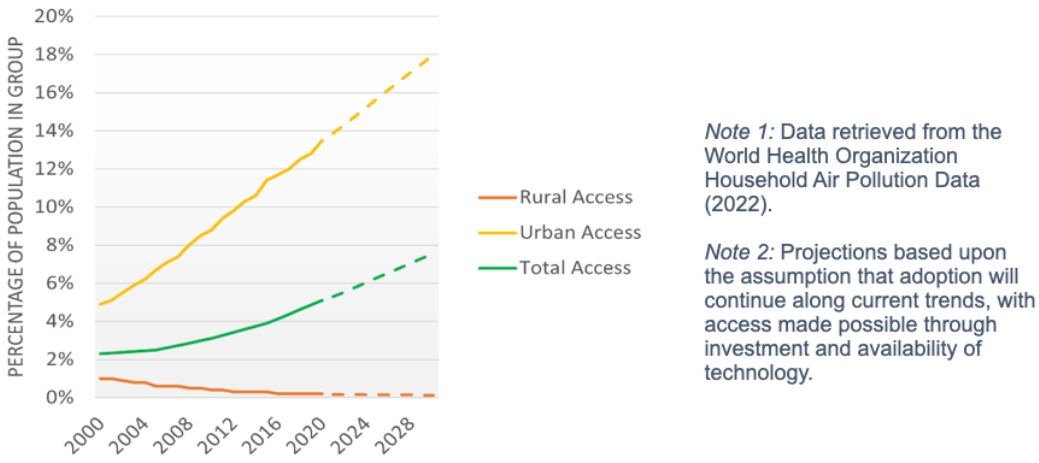
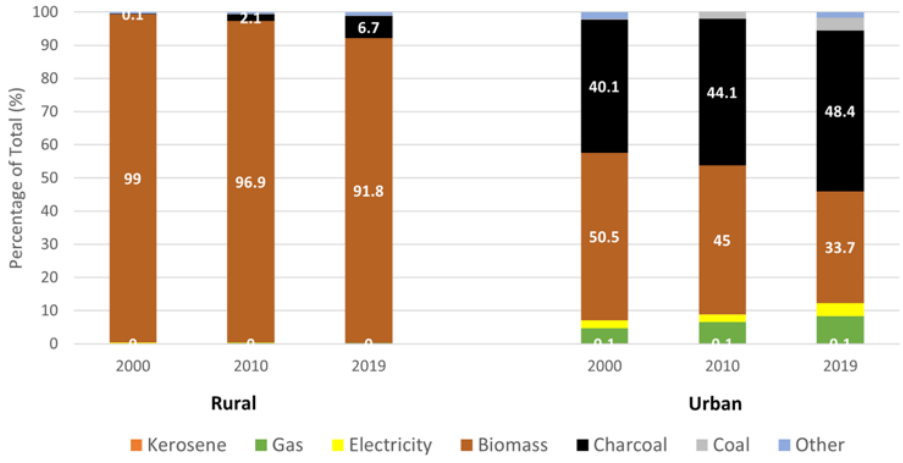


Figure 4 - Urban and Rural Cookstove Fuel Type Distribution 2000 - 2019



Note: Data retrieved from the World Health Organization Data (2021).

Existing Health and Environmental Impacts of Cooking Fuel in Mozambique

Continued dependence on polluting fuels carries with it serious health and environmental risks. A short analysis has been conducted to determine the impact in each of these categories using the assumptions noted in Appendix A. In general, the impact is calculated by looking at the projected number of households that could switch to bioethanol over the next 8 years and attributing the associated impacts to those respective populations.

The associated health impact is calculated using the HAPIT Household intervention tool. HAPIT currently uses background disease rates and relationships between exposure to PM2.5 and health outcomes to provide two outputs: disability-adjusted life years (DALYs) and deaths (HAPIT, 2022). DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population (WHO, 2022).

Environmental impacts were calculated using the estimated fuel consumption and dry combustion CO2 emission factors for each fuel. The results of this analysis are shown in Table 1. It is important to note that both of these calculations do not consider the impacts of stove-stacking; the percentages of national fuel use per household only incorporate primary fuel use and do not include users who prefer the use of more than one fuel (ESMAP, 2020). In other words, the impact may likely be larger.

Table 1 - Potential Health and Environmental Impact of Dominant Fuels in Mozambique

IMPACT	Firewood	Charcoal	Gas	Coal
Health *(deaths and DALYs due to household air pollution from PM2.5)*	5,040 DALYs 144 Deaths	16,763 DALYs 492 Deaths	N/A	789 DALYs 18 Deaths
Environment & Climate *(GHG Emissions)*	62.35 million kgCO2	169.6 million kgCO2	396 thousand kgCO2	303 thousand kgCO2

Note 1: Assumptions are noted in Appendix A.

Note 2: Impact values are the cumulative totals from years 2022 to 2030.

Although Mozambique recognizes the health and environmental harm of the continued use of polluting fuels, the lack of affordable and accessible clean fuel options plays a major role in perpetuating existing trends (Table 2).

Table 2 - Availability and Affordability of Various Cookstoves and Fuel

Cooking Fuel	***Availability Assessment***	***Affordability Assessment***
Biomass	No main source for firewood and was generally sourced equally and easily from municipal markets, roadside sellers, home sellers, and own collections. One study has noted that the typical time to collect in Maputo was 47 minutes (Mudombi, 2018).	Compared to LPG (1.3 USD/kg) and Charcoal (0.45 USD/kg), firewood is generally sourced locally or from markets at a much lower price or at the cost of productivity instead (MECS, 2022). Mudombi et. al notes a similar finding where the price of firewood is generally considered negligible (Mudombi, 2018).
Charcoal	Available through home sellers, municipal markets, and roadside sellers. The typical time to collect in Maputo was 24 minutes (Mudombi, 2018). Other studies have found that low-income urban households depend almost completely on charcoal for cooking (91.2%), with this dependence being lower for middle- (28.9%) and high-income households (10.2%) (Nyambane, 2020).	Charcoal is the most favorable fuel because it is perceived as having higher security, providing insurance for future use, being more flexible and cheaper, great for foods that take a longer time, easier to access AND use, and people are already accustomed to it (Premer, 2018). It is also estimated that low-income households spend approximately 24% of their total income to purchase charcoal every month, while an average-income household spends about 15% of total income. Poor households essentially pay double the price for charcoal because they purchase it in small quantities, unlike high-income households (Nyambane, 2020). In Mozambique, it is estimated that the charcoal sector employs between 136,000 and 214,000 people on a full-time basis Charcoal production account for a large fraction of rural livelihoods, offering valuable income diversification especially considering that in most rural areas of the country formal employment and income opportunities are very scarce and infrequent (Nyambane, 2020)
Gas	Generally bought at fuel stations. The typical time to collect in Maputo was 25 minutes (Mudombi, 2018).	Expensive fuel (especially with regard to the tanks). A complete stove and tank unit will cost the user an initial investment of around $80.00
Bioethanol	Ethanol is typically sourced from fuel stations or local neighborhood stores where available and generally only in Urban Areas. The typical time to collect in Maputo was 30 minutes (Mudombi, 2018).	Surveys suggest the lack of availability and affordability have led to decreased use for prior users (30% of respondents said they didn't use the fuel because both the stove and fuel were expensive while 47.4% discontinued the use because it was expensive) (Mudombi, 2018). This is changing with the onset of a new company called YAZU that is looking to increase access and affordability. To be competitive with charcoal (purchased as 70 kg bags), ethanol would need to sell for 0.47 USD/l. To be competitive with charcoal purchased in small quantities, it would need to sell at 0.90 USD/l. (Nyambane, 2020).

Cookstove and Cooking Fuel Market

Modern cooking fuels are available, but increased use will be highly dependent on consumer awareness, affordability, and especially accessibility. Table 3 showcases a summary of the existing market players and projects where collaboration may be useful.

Table 3 - Bioethanol Cookstove and Fuel Market in Mozambique

Bioethanol Cookstove	Bioethanol Fuel
Manufacturer, Distributor, or Project	
Yazu Mozambique - A franchise of Green 66, the business operates within Maputo and handles logistics, warehouse, and sales teams, and ensures adequate fuel and stove supply, quality, and customer care. **Green 66 Innovations -** A stove manufacturer located in South Africa, and owner of YAZU Mozambique, supplying stoves, fuel, and managing business operations.	**Yazu Mozambique** - Imports bottled bioethanol fuel for distribution in Maputo to complement the bioethanol stove business. Distribute through flagship locations and local store owners. **CleanStar -** CleanStar Mozambique (CSM) was a venture started in 2012 with the goal of providing safe and modern ethanol-based cooking solutions to low-income urban households. No longer in existence, the company reported sales of approximately 30,000 ethanol stoves and 70-140k L of ethanol per month over the course of several years.
Key Barriers to Scale	
• Mozambique is uniquely placed to become a major supplier to such a market given its biophysical characteristics, significantly underutilized agriculture potential, well-developed sugar production sector and own blending mandates. With that said, attention to transport, fuel storage, and production is low (Hartley, 2019). • Biofuel policies in Africa are largely designed at the national level yet such "introverted" biofuel markets can take a toll on the actual potential of biofuels expansion in the region. For example, countries such as Mozambique, Zambia and Zimbabwe have high sugarcane production potential and can easily exceed their existing ethanol targets. However, their small vehicle fleets confine the size of their national biofuel markets. On the other hand, South Africa has by far the largest private vehicle fleet in SSA while at the same time has relatively low sugarcane productivity compared to some of its neighboring countries. This means that there is huge potential for South Africa to import feedstock/biofuels from neighboring countries such as Mozambique and Zimbabwe (Gasparatos, 2015). • Stove design and functionality have been past issues; where malfunctions did exist, however, newer technology has been developed to better the efficiency, ease of use, and safety for a better consumer experience overall (Mudombi, 2018 and Premer, 2018).	

Mozambique is also uniquely positioned to utilize their existing crops and farmland for boosting local production and fuel availability, particularly from sugarcane and cassava. Sugarcane has been approved by the government for biofuel production because of low production costs, high output, and non-food status, along with providing an alternative market for the commodity. Improving yields and including more small-holder farmers in expanding bioethanol production in Mozambique could help alleviate some of the availability challenges with the fuel.

Clean Cooking Related Policy

Policy, as it pertains to the clean cooking industry, is in its nascent stages. Table 4 summarizes key policies that align with or are focused on a specific clean fuel outcome for the future. Table 5 demonstrates the current tariffs and Value Added Tax on both bioethanol fuel and cookstoves for liquid fuel.

Table 4 - Summary of Policies Related to Clean Cooking

Policy	***Coordinating Administration***	***Impacts on Clean Cooking Sector***
National Biofuel Policy Strategy (2009)	Inter-ministerial Commission on Biofuels (CIB)	Provides the framework and general set of guidelines for the development of the biofuels industry. Also approves sugarcane as a feedstock crop for bioethanol. Decree No. 58/2011: codifies the mandatory blending parameters, in force as of January 2012.
Nationally Determined Contribution (NDC) (2018)	National Directorate of Climate Change of the Ministry of Land and Environment	One of the first countries to receive payment for results under the Forest Carbon Initiative with the World Bank as a result of decree 70/2013: Regulating Procedures for Project Approval for the Reduction of Emissions from Deforestation and Forestry Degradation (REDD). Promotes low carbon urbanization which includes 4.6.2.1.4: Massification of LPG and a goal to increase the number of people with access to gas stoves to 309% compared to 2018—but specifically for Cabo Delgado/ Pemba, Zambézia/Mocuba, Nampula e Tete.
2013-2025 National Strategy for Climate Change (ENMC)	National Directorate of Climate Change of the Ministry of Land and Environment	National Climate Change Strategy aims to reduce vulnerability to climate change and improve the living conditions of the Mozambican people. In particular, 4.6.2.1.1. aims to improve access to renewable energies and reduce the use of fossil fuels; it does note any plans for clean cooking.
SADCREEESAP (2016)	Ministry of Mineral Resources and Energy	Regional Renewable Energy Targets: - Cooking or heating-efficient devices penetration to 15% by 2030. - Ethanol blending ratio with gasoline to 20% by 2030.
The Economic Acceleration Stimulus Package (2022)	Ministry of Economy and Finance	VAT rate reduction from 17% to 16% and also lowers the Corporate Income tax rate from 32% to 10%, in the agriculture and urban transport sectors. Allocates 10% of tax revenue from natural resources to the development of provinces where extraction occurred. Also includes a mandatory blending of imported fuels with Mozambican biofuels. Creation of a mutual guarantee fund that allows national banks to provide financial resources for small and medium-sized Mozambican companies.

Table 5 - Bioethanol Fuel Tariffs and VAT

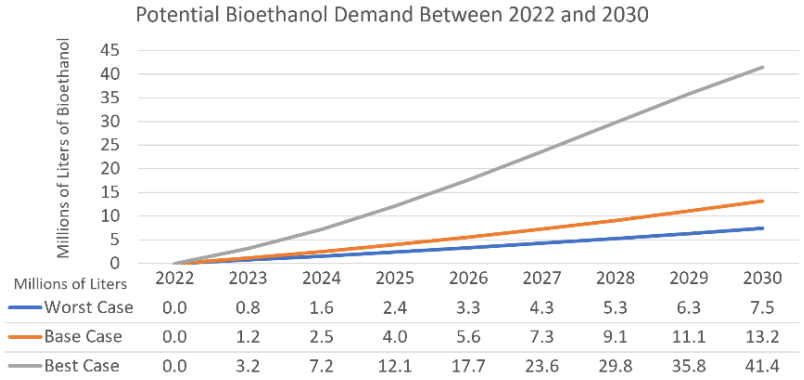
Product Type	*WTO Code*	***Tariffs***	***VAT***	***Total***
Bioethanol Fuel	220720	20%	16%	**36%**
Cookstoves for liquid fuel	732112	20%	16%	**36%**

Bioethanol Cooking Fuel Projections and Cost Comparison

Based on the methodology referenced, as well as population, fuel use, and urbanization trends, the following projections were calculated for potential bioethanol cooking fuel demand across three different scenarios (Figure 5). Three scenarios were created to showcase the variability of transitioning from kerosene, charcoal, or gas fuels to bioethanol. Both preference—wanting to use a different fuel despite being able to afford bioethanol fuel—and growth of access—possible uptake and infrastructure growth—are dependent not only on the location but also on the market conditions in the future.

Figure 5 - Potential Bioethanol Demand for Low, Base, and Best Case Scenarios 2022 - 2030

Scenario	Preference to switch to ECF (% of Total HHs by 2030)	Access to Clean Cooking Technology (% Increase from Baseline by 2030)
Worst Case	10%	0%
Base Case	15%	Projected Values
Best Case	35%	25%



Millions of Liters	2022	2023	2024	2025	2026	2027	2028	2029	2030
Worst Case	0.0	0.8	1.6	2.4	3.3	4.3	5.3	6.3	7.5
Base Case	0.0	1.2	2.5	4.0	5.6	7.3	9.1	11.1	13.2
Best Case	0.0	3.2	7.2	12.1	17.7	23.6	29.8	35.8	41.4

Given the conditions above, the uptake of bioethanol as a cooking fuel seems promising. In fact, compared to the cost of conventional fuels like charcoal and gas, bioethanol is sometimes more cost-effective for the consumer—just lacking in available infrastructure (Figure 6). While bioethanol has a lower calorific value (27.00 Mj/kg) compared to LPG (46.60 Mj/kg) and Kerosene (43.10 Mj/kg), bioethanol stoves generally have higher efficiency (60% vs. 55% and 35% respectively). On a national level, the same can be seen; overall, the cost for households that may shift to bioethanol is overall less expensive compared to the existing cost of available fuels (Figure 7).

Figure 6 - Average Annual Fuel Consumption to Meet 3,500 MJ Household Consumption

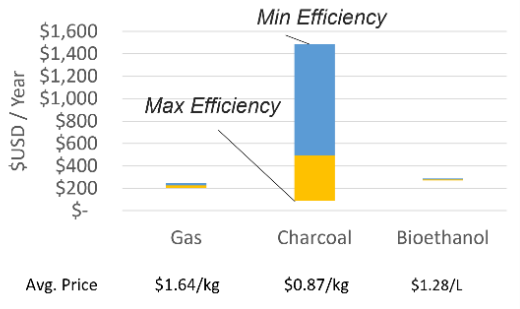
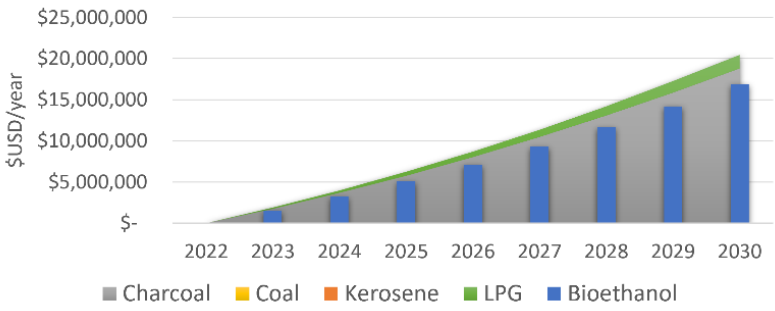
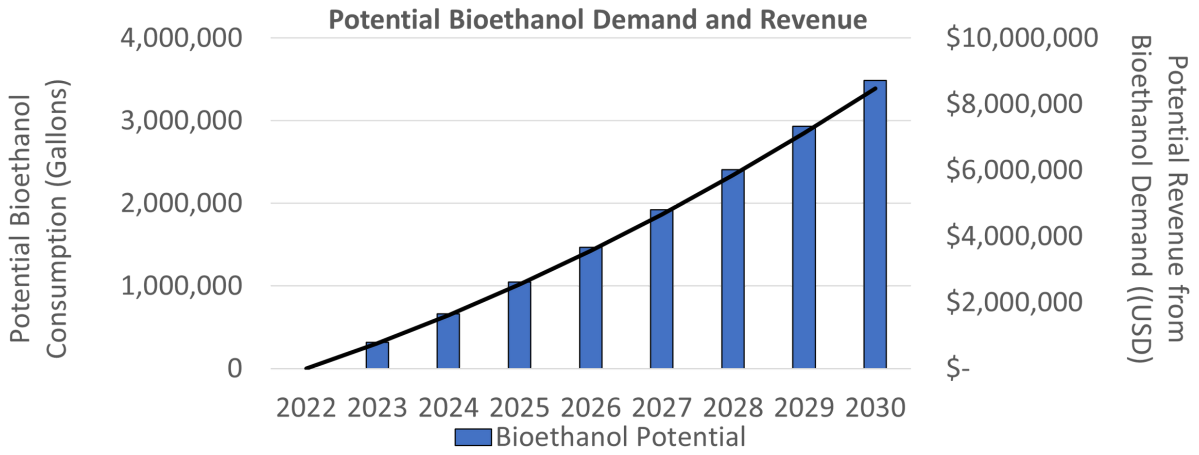


Figure 7 - Dominant vs Bioethanol Fuel Costs for Households Transitioning to Bioethanol



The combined benefits from a lower cost and high potential demand also suggest great revenue for producers. Using Trading Economics, the potential revenue has been calculated over the years (Figure 8). The revenue is based on the existing bioethanol price and base case scenario for potential demand; revenue and potential are calculated in gallons and USD.

Figure 8 - Potential Bioethanol Demand and Revenue



Recommendations and Conclusions

With regard to Mozambique's potential for transitioning to bioethanol cooking fuel as part of their clean energy portfolio, the following considerations should be noted:

1. **Need is high and demand for improved cookstoves has been demonstrated in Mozambique**, especially when considering the health, environmental, social, and economic impacts that will accompany a transition to clean fuels.

   Recommendation: Collaborate with groups such as the Clean Cooking Alliance and local organizations to demonstrate the business case and benefits. With the appropriate government and private sector entities involved, a transition can be expedited and encourage activities such as social campaigns for civic education.

2. **Existing policy, goals, and infrastructure geared towards bioethanol and clean cooking are limited or nonexistent.**

   Recommendation 1: Support government policymakers to understand the multiple benefits of creating parity within their regulatory framework for fuels.

   Recommendation 2: Encourage reduction or exemption of VAT on clean fuels and clean cookstove technologies.

   Recommendation 3: Encourage reduction or exemption on import duties for bioethanol and clean cookstoves; these could be temporary and serve to create market demand and encourage local production and manufacturing.

   Recommendation 4: Discuss establishing targets specific to clean cooking and bioethanol within national energy policy or NDCs.

   Recommendation 5: Encourage adoption of ASTM E3050: Standard for Denatured Ethanol for Cooking and Appliance Fuel.

3. **While initial adoption existed, higher initial cookstove costs and lack of fuel availability discourages new and existing customers.**

   Recommendation 1: Leverage the use of subsidies or cost reductions through programs like Results-Based Financing, when possible, to reduce the cost on initial cookstove purchases.
   Recommendation 2: Continue to work with the government to reduce taxes and duties on clean fuel options, resulting in lower distribution and end-user costs.
   Recommendation 3: Favorable government policy will also grow demand, and encourage local production and manufacturing, continuing to drive costs down over time.
   Recommendation 4: The co-benefits related to the adoption of bioethanol cookstoves such as health, safety, and the environment should be emphasized in advertising campaigns rather than focusing solely on the possible economic benefits of switching (e.g. bagasse in 2013 produced 16% of total electricity production and 20% of local demand in Mauritius) (Lacey, 2017).

4. **A high projected demand for bioethanol and an immature market suggests the potential for revenue for both local and international parties.** There is a great amount of arable land available in the country, with the potential for local bioethanol production to grow significantly; this could also help meet local content requirements that exist, as well as create additional trade opportunities. Even more, Mozambique has a well-established sugar industry (3rd largest in Mozambique) and a high percentage of small-holder production over commercial production (12.5%).

   Recommendation 1: Consider the use of bioethanol outside of cooking fuel and explore local or regional options for export—especially within economic groups like SADC.
   Recommendation 2: Examine Local Content Requirements and how they may impact volumes for import, export, and local production capacity.
   Recommendation 3: Leverage existing agricultural knowledge from international groups that can inform on appropriate farming techniques, inputs, and allocate resources to improve yields and utilize existing farmland more efficiently.

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Appendix A

Projected Number of Households that may Switch to Bioethanol Cooking Fuel

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fuel	Charcoal	Charcoal	Charcoal	Charcoal	Charcoal	Charcoal	Charcoal	Charcoal	Charcoal
Yearly HHs	0	3,546	7,439	11,683	16,277	21,221	26,512	32,148	38,122
Total HHs	0	3,546	10,985	22,668	38,945	60,165	86,678	118,826	156,948

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fuel	Coal	Coal	Coal	Coal	Coal	Coal	Coal	Coal	Coal
Yearly HHs	0	131	296	498	739	1,021	1,347	1,717	2,135
Total HHs	0	131	427	926	1,665	2,686	4,033	5,751	7,885

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fuel	Kerosene	Kerosene	Kerosene	Kerosene	Kerosene	Kerosene	Kerosene	Kerosene	Kerosene
Yearly HHs	0	9	19	30	44	58	75	93	112
Total HHs	0	9	28	58	102	160	235	328	440

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fuel	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG	LPG
Yearly HHs	0	642	1,363	2,168	3,057	4,033	5,096	6,248	7,489
Total HHs	0	642	2,005	4,173	7,230	11,262	16,358	22,606	30,095

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fuel	Biomass	Biomass	Biomass	Biomass	Biomass	Biomass	Biomass	Biomass	Biomass
Yearly HHs	0	1,102	2,301	3,588	4,953	6,381	7,858	9,365	10,883
Total HHs	0	1,102	3,402	6,991	11,944	18,325	26,182	35,547	46,430

Fuel Characteristic Assumptions

Fuel Type	Unit	Low Fuel Cost (USD) per Unit	High Fuel Cost (USD) per Unit	Average Fuel Cost (USD) per Unit	Net Calorific Value (MJ/kg)	Stove Efficiency	kg/L
LPG	kg	$ 1.64	$ 1.64	$ 1.64	46.60	55%	
Charcoal	kg	$ 0.30	$ 1.44	$ 0.87	28.20	22%	
Coal	kg	$ -	$ -	$ -	26.70	28%	
Bioethanol	Liter	$ 1.28	$ 1.28	$ 1.28	27.00	60%	0.783

Note 1: Fuel costs are sourced from local experts.

Note 2: Fuel Net Calorific and Efficiency Values are sourced from Dalberg, 2018.

HAPIT Health Impact Calculator Assumptions

Country	Mozambique		
Possible HHs (by 2030)	395,194	% Using Intervention	100%
Average HH	5	Intervention Useful Life	1
Kids <5 per HH	1		
Adults per HH	4		
Total Individuals	1,975,971		

Fuel	PM2.5 Emissions (micrograms/m3)
Kerosene	100
LPG	47
Charcoal	160
Coal	82.3
Bioethanol	50
Biomass	500

Appendix A

Environmental Assumptions

Stove	Avg. gCO2/kg Fuel
Charcoal	2740.0
Kerosene	71.3
Gas (LPG)	55.9
Coal	98.3
Ethanol	64.9