MARKET POTENTIAL:
BIOETHANOL FOR CLEAN COOKING

METHODOLOGY

BY ADAM COLLINS

pivot | GLOBAL BIOETHANOL COALITION

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The *Market Potential: Bioethanol for Clean Cooking Methodology* is the product of a research project initiated by Pivot Clean Energy Co. (Pivot) for the purposes of determining the identification of key geographies primed for expansion of bioethanol use in household energy. This methodology is intended to be used in conjunction with individual country reports that demonstrate the current state of energy in a given country, examine rates of transition to bioethanol from current cooking trends, and project future volumes and associated costs.

The methodology 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.

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Introduction | Clean Cooking Crisis: Bioethanol as a Renewable Alternative

Cooking is a fundamental part of life; it unites groups, is ingrained in culture, and is a basic task that contributes to a healthy and productive life. As such, most individuals around the world utilize whatever fuel is readily available and economical. Although it is not unusual to see the use of electric and gas stoves in higher-income countries, it is almost non-existent in many lower and lower-middle-income countries (World Bank, 2019). In fact, in 2021, 2.4 billion (30%) people cooked using fuels like kerosene, biomass (wood, animal dung, and crop waste), and coal. These fuels, while useful, result in multiple adverse impacts, including higher levels of household air pollution, which ultimately causes the deaths of three million people each year (WHO Newsroom, 2021). These cooking practices are inefficient, unsustainable, and also disproportionately affect a major part of the population. The same groups exposed to household air pollution are also prone to feel the impacts of climate change and pandemics like Covid-19 more heavily (IEA, 2021). Covid-19, for example, led to supply-chain disruptions and energy price increases, resulting in increased poverty and even a backslide into biomass fuels. Such impacts can then lead to lower productivity (time poverty) as a result of time spent on fuel procurement, lower efficiency fuel use, and decreased health—especially in children and women who are the primary owners of household tasks like cooking and cleaning (Clean Cooking Alliance). Improving the way the world cooks will not only save lives, but it will improve the livelihoods of those impacted. Attacking the issue itself- clean fuel access - is imperative to changing the narrative of harmful cooking around the world.

Bioethanol, one alternative to cooking with biomass, is a sugar or starch derived fuel that provides a low-carbon option to improve energy security and contribute to better health and socioeconomic outcomes. Although electricity from a renewable source is an optimal energy option for household cooking, access to electricity is limited and generally comes at higher costs; in fact, one billion people lack access to electricity and are forced to use biomass or kerosene as their main fuel source (WHO, 2021). As a result, bioethanol as a solution aims to attack the root of the problem: the energy source. Compared to the “dirty fuels” noted above, and discounting electricity, bioethanol provides one of the cleanest solutions available on the market. When bioethanol is utilized as a fuel in a cookstove, the amount of denaturant and/or hydrocarbon in the cooking fuel is very low or non-existent, resulting in clean combustion, and therefore lower percentages of respiratory or cardiovascular disease. In addition to bioethanol’s health benefits, the fuel is not only produced more sustainably with lower carbon intensity, but is also derived from a variety of sources other than fossil fuels (USDA, 2017). The versatility in a fuel derived from different starches or sugars can offer both energy security and job opportunities in areas where access to crude oil resources are not available (Rass-Hansen et. al., 2007). In order to truly understand and evaluate the total benefits of bioethanol, the economics of the fuel are also important to consider, and market-specific research is necessary to help expand proper and sustainable growth.

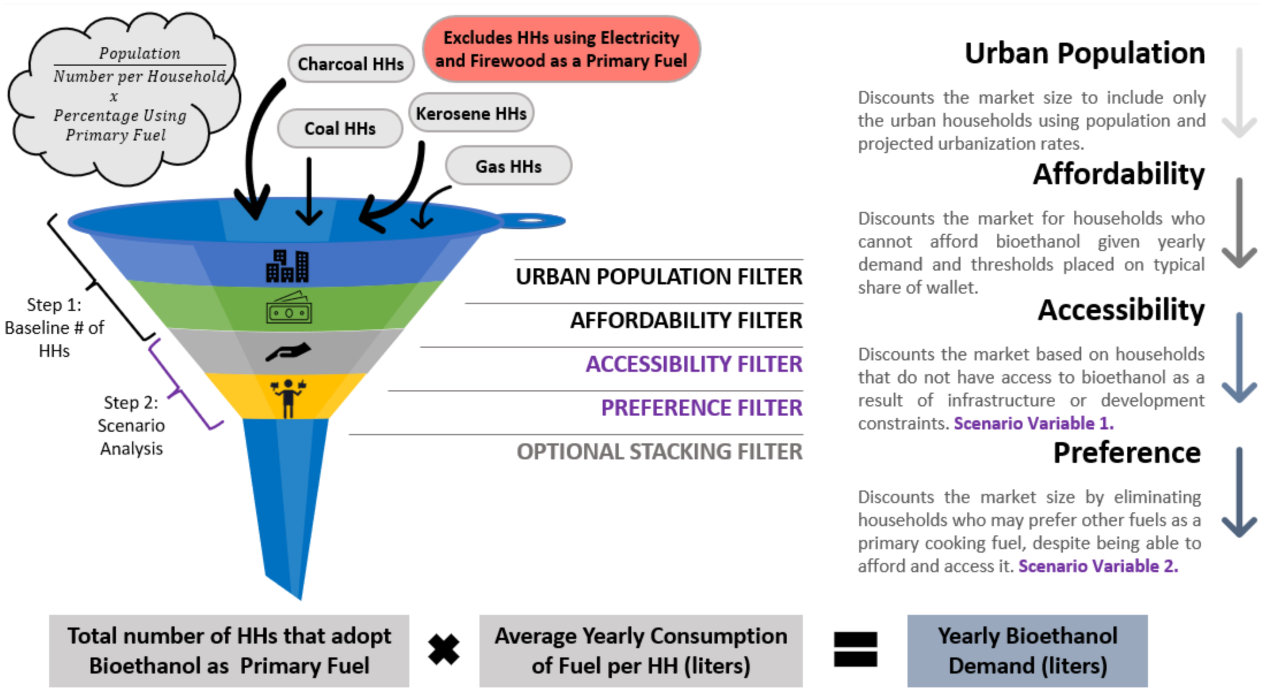
Objective of Analysis

In conjunction with Pivot's mission—To improve human health, protect our global environment, and create green jobs by accelerating the transition to renewable bioethanol to meet modern household energy demands— the following study aims to determine the market potential for bioethanol as a sustainable, clean cooking fuel in multiple markets and geographies in Africa. In order to properly project bioethanol cooking fuel demand, a number of different components are included in each country's report; while it is possible to enter a market with good intentions, there are country-specific obstacles that could prevent sustainable growth and should be taken into consideration during the initial stages of a project or business. Every report completes a contextual analysis to understand existing and potential market conditions for the bioethanol industry: the bioethanol fuel market, the bioethanol cookstove market, and any related policies or associated organizations. Rather than propose solutions for all possible transition scenarios, this analysis aims to focus on the potential impact and production given current conditions and goals. With consideration of the bioethanol market and existing energy supply, this analysis may provide market-specific solutions to the clean fuel transition. The outcomes of this research will then present estimated fuel use potential, estimated socio-economic impacts of bioethanol, and a set of recommendations.

Methodology

The output of this research is two-fold. For one, it looks to determine clean cooking trends across Africa and mark potential indicators for increased bioethanol consumption. Secondly, it estimates the demand for bioethanol over an eight-year period, between 2022 and 2030, to correspond with the target date for the 2030 Sustainable Development Goals (SDGs). The combination of these efforts can properly prioritize country markets and provide estimates for future bioethanol consumption– specifically in the cooking sector. Potential indicators were chosen in conjunction with SDGs related to clean cooking and any existing or associated development indicators (see Page 3). The steps for this analysis are derived from three main sources. The contextual analysis utilizes the framework from Abubeker Yimam which looks at the biofuel sector from a sustainable and socio-economic impact before completing a SWOT Analysis (Yimam, 2021). This analysis, similarly, examines the sustainability of a biofuel, but focuses solely on the cooking fuel and cookstove market access, availability, affordability, and policy. To calculate the potential demand and reduced impact from bioethanol, on the other hand, a methodology was developed through Dalberg Global Consulting's publications: Triple-bottom-line Analysis of Cooking Fuels in Kenya and the Kenya Ethanol Cooking Fuel Masterplan (Dalberg, 2018 and Dalberg, 2020). After projecting potential demand through a filtering process (Figure 1), health impact is calculated with the Household Air Pollution Intervention Tool (HAPIT) and environmental impact through dry combustion CO_2 emission factors for each fuel. The remainder of this report outlines the steps to calculate demand potential as well as an indicator trend analysis for targeted groups. Sources for all other data are noted in the references section and subsequent country reports when necessary.

Figure 1 – Bioethanol Demand Methodology



The primary indicators analyzed and their descriptions, sources, and SDG overlap are noted below:

	Indicator	Description / Rationale	Source	SDG Overlap
1	Labor Force Growth Rate	Labor force growth becomes an extremely important factor when unemployment is also low; focusing on labor force growth rates can prioritize between different countries.	World Bank, 2021	1. No Poverty
2	Urban Population Growth Rate	With more than 80% of the Global GDP generated in cities, urbanization can contribute to sustainable growth if managed well by increasing productivity, allowing innovation and new ideas to emerge.	World Bank, 2021	1. No Poverty 8. Decent Work and Economic Growth
3	Corruption Perceptions Index (0-100)	Corruption usually entails illegal and deliberately hidden activities, which only come to light through scandals or prosecutions. The sources and surveys which make up the CPI are based on carefully designed and calibrated questionnaires, answered by experts working in each area. Consideration of corruption is essential to building proper networks for individuals rather than authoritarian leaders.	Transparency International, 2021	8. Decent Work and Economic Growth

4	Household Air Pollution Attributable Death Rate (per 100,000, age standardized)	As part of a broader project to assess major risk factors to health, the mortality and burden of disease resulting from exposure to household air pollution from solid fuel use for cooking was assessed. The majority of the burden is borne by the populations in low and middle-income countries.	World Health Organization, 2021	3. Good Health and Well-Being
5	Population with Reliance on Clean Cooking (%)	"Clean" is defined by the emission rate targets and specific fuel recommendations (i.e. against unprocessed coal and kerosene) included in the normative guidance WHO guidelines.	World Health Organization, 2020	7. Affordable and Clean Energy 15. Life on Land
6	Population with Access to Electricity (%)	Access to electricity is represented as a percentage of the population with access to electricity. Electrification data is collected from industry, national surveys, and international sources. Although cooking with electricity is necessary, access may be limited.	International Energy Agency, 2020	7. Affordable and Clean Energy
7	Existing Biofuel Blending Mandates (Y/N)	A biofuel use mandate is a law that requires transportation fuel suppliers and retailers to sell biofuel-blended fuel. Biofuel mandates are great initial steps to promoting biofuels within the country.	Biofuels Digest	7. Affordable and Clean Energy 8. Decent Work and Economic Growth
8	Biofuel Blending Targets (Y/N)	See reasoning above.	Biofuels Digest	7. Affordable and Clean Energy 8. Decent Work and Economic Growth
9	Renewable Energy Targets (Y/N)	See reasoning above.	ClimateWatch	7. Affordable and Clean Energy 8. Decent Work and Economic Growth 15. Life on Land
10	Net Annual Forest Change	'Forest area net change' is the sum of all forest losses (deforestation) and all forest gains (forest expansion) in a given period. Net change, therefore, can be positive or negative, depending on whether gains exceed losses, or vice versa. Forest change is a particularly important indicator to understand biomass consumption and the impact of dirty fuels.	FAO	15. Life on land
11	Gender Inequality Index	The Gender Inequality Index is a composite measure reflecting inequality in achievements between women and men in three dimensions: reproductive health, empowerment, and the labor market.	United Nations Development Program, 2021	5. Gender Equality

In order to estimate bioethanol demand, two primary variables are required: **the number of households that will primarily use bioethanol** and the **typical fuel consumption per household per year**. While typical fuel consumption varies per household per year, this analysis assumes **each household of five consumes 3500 mega-joules of cooking fuel per year**. It is important to note that while this **analysis focuses solely on the urban population**, the methodology can similarly be used to calculate demand in rural areas. To determine the number of households that may use bioethanol as a primary fuel, four different drivers were considered:

- Demographic Trends
- Cooking Fuel Use Trends
- Primary Reliance and Access Trends
- Preference

Using that information, total demand can be calculated as follows:

1. Project yearly values for population (#), urban population (%), cooking fuel type (%), and access to clean cooking technology (CCT) (%) with any data from 2000-present.
2. Determine the base number of households (HH) that use kerosene, gas (LPG/biogas/natural gas), charcoal, or coal (excluding electricity and biomass) by multiplying the population and the cooking fuel type percentage for each projection year and then dividing by the number of individuals per household.
3. Filter for Percentage of Population in Urban areas by multiplying the number of HHs by the urban population percentage in each projection year.
4. Filter for Affordability in a few steps:`
   a. Determine the Annual Cost of Bioethanol at current prices in the country. Where a price is not known, an average is used:

      Annual Cost of Bioethanol = (3500MJ pser year) / (net calorific value of fuel x stove efficiency x .789 kg/L of Bioethanol)*Cost of Bioethanol

   b. Find the percentage of monthly household income that is dedicated to cooking in typical urban households in the country using Household Surveys where possible.
   c. Use the World Bank Development Indicators to find the twenty percent (20%) income share metrics for each country.
   d. Use the income groups to create a distribution and then calculate the income for each group using total urban or rural consumption data where applicable.
   e. Find the percentage of households that could afford the current cost by using the income distribution above and multiplying by the percentage of income dedicated to cooking. Compare the monthly cost of bioethanol to the monthly income.
   f. Multiply the percentage of households that can afford the current cost by the number in the previous filter.

6. Three scenarios are created to showcase the variability of transitioning from kerosene, gas, charcoal, or coal to bioethanol. Each scenario was calculated by multiplying the base number of HHs that could switch to bioethanol with both the preference and access values. The scenarios are summarized, with values shown below:

   - The worst case scenario sees little increase in access to clean cooking technology and little preference to switch. This preference may be the result of initial costs, tradition, lack of awareness, or local infrastructure.
   - The base case scenario follows projected trends to access and assumes that fifteen to thirty-five percent of those who could switch to bioethanol will. This trend assumes that access will rise with existing trends and preference will increase as technology, awareness, and local infrastructure grow correspondingly.
   - The best case scenario assumes the best possible outcome with access increasing by greater than twenty-percent by 2030, and preference greater than thirty-five percent amongst households that may switch. The best case scenario assumes urban households will more rapidly switch to bioethanol as infrastructure and policy develop accordingly.

Scenario	Preference to switch to bioethanol (% of total HHs by 2030)	Access to Clean Cooking Technology (% increase from baseline by 2030)
Worst Case	5-10%	10%
Base Case	15-35%	Projected Trend
Best Case	>35%	>20%

7. Calculate the number of liters of bioethanol using the following equations:
   a. Annual HH Fuel Consumption [L] = 3500MJ / (net calorific value of fuel x stove efficiency x .783 kg/L of Bioethanol)
   b. Total number of Liters = Annual HH Fuel Consumption x Sum Number of HHs per Scenario with fuel type total.

Fuel Type	Unit	Fuel Cost	Net Calorific Value (MJ/kg)	Stove Efficiency [Min, Max]	kg/L Conversion
Kerosene	Liter	Country Dependent	43.10	35% [25, 45]	0.817
LPG	Kg	Country Dependent	46.60	55% [50, 60]	N/A
Charcoal	Kg	Country Dependent	28.20	22% [12, 43]	N/A
Coal	Kg	Country Dependent	26.70	28% [ ]	N/A
Bioethanol	Liter	Country Dependent	27.00	60% [58, 62]	0.783

After total demand is calculated, cost comparisons can be made by calculating the cost of equivalent amounts of fuel used across households with the same equations above and then multiplying by the cost of each equivalent fuel and the number of HHs.

Primary Country Indicators and Trends

While indicators have been analyzed for each country, averages or typical values for each indicator have been calculated as well, for economic blocs. The diversity of Africa's geographic landscape, culture, economy, and population suggest that adopting regional strategies–especially with regard to renewable fuels–is essential to successful, sustainable development; this means, in other words, understanding market trends, regulatory frameworks, and overall quality of life is particularly key. The most recent Intergovernmental Panel on Climate Change (IPCC) Assessment has noted that enabling conditions are key for implementing, accelerating, and sustaining adaptation in human systems and ecosystems (IPCC, 2022). Rather than individual choices as the key determinant, however, the IPCC has emphasized that development is the result of political commitment, institutional frameworks, goals, and a number of other instruments working collaboratively (IPCC, 2022). Consideration of all indicators is, therefore, imperative.

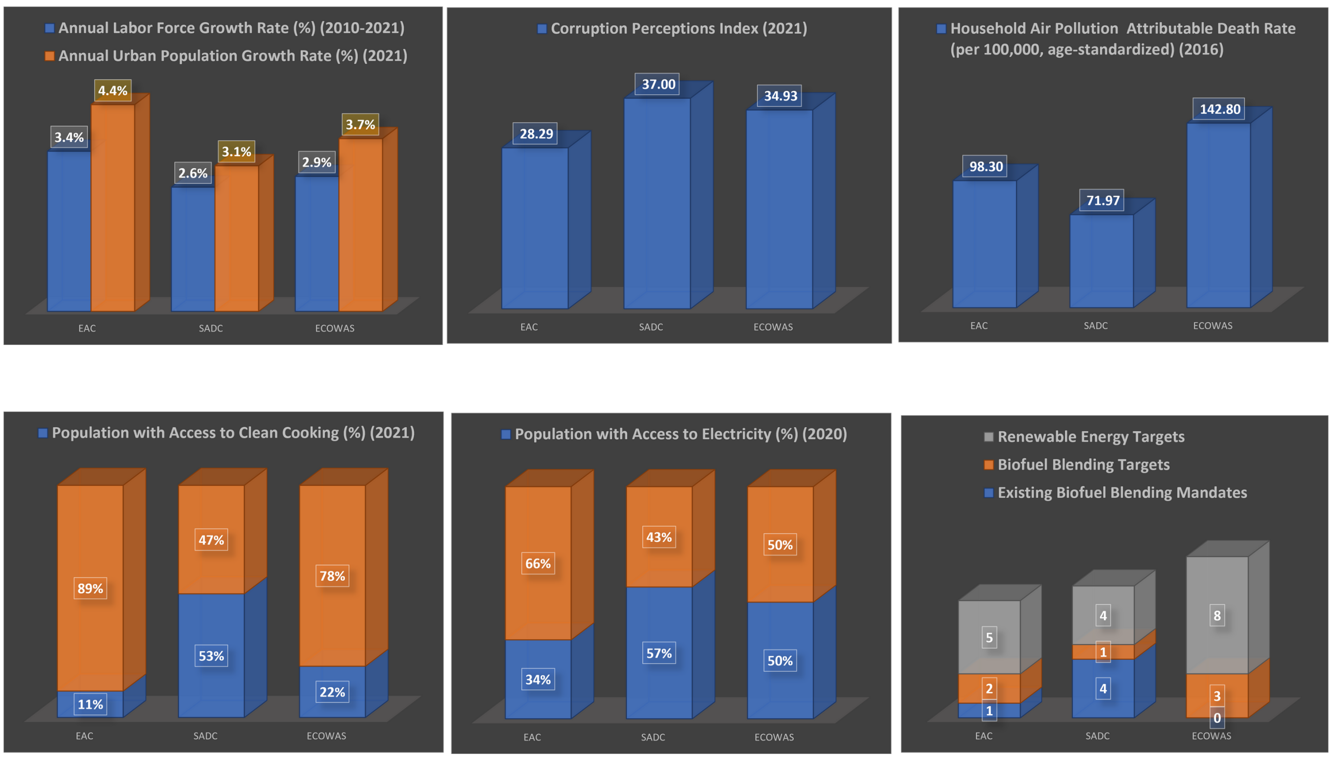
Group Trends

Nine of the eleven indicators have been compared across economic blocs as shown in Figures 2 and 3 below. While Figure 2 demonstrates all of the economic blocs and overlap, the three regional economic blocs of focus were the East African Community (EAC), the Economic Community of West African States (ECOWAS), and the South African Development Community (SADC), represented through the data in Figure 3.

Figure 2 – African Economic Blocs and Overlap

In general, Annual Labor Force Growth Rate and Annual Urban Population Growth Rate are increasing across each bloc. Compared to the world average of 1.7% urban growth annually– and dropping—this suggests that the economic growth and job availability will need to rise to meet that demand. With regard to clean cooking, ECOWAS and EAC fall short on both access to clean cooking, electricity, and biofuel targets/policy which may equate to higher death rates attributable to household air pollution than their SADC counterparts. EAC and ECOWAS groups, as such, may require more financial investment and time to generate change.

Figure 3 – Primary Indicator Trends by Economic Bloc

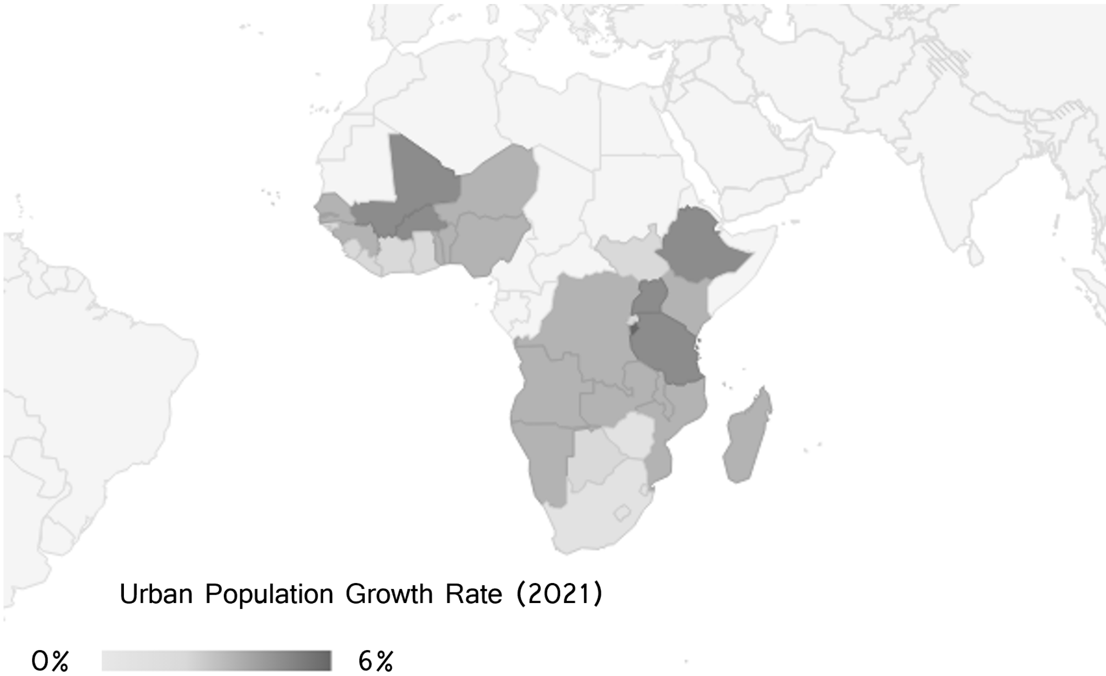


EAC: 6 States, 173 Million. **ECOWAS**: 15 States, 350 Million. **SADC**: 15 States, 277 Million.

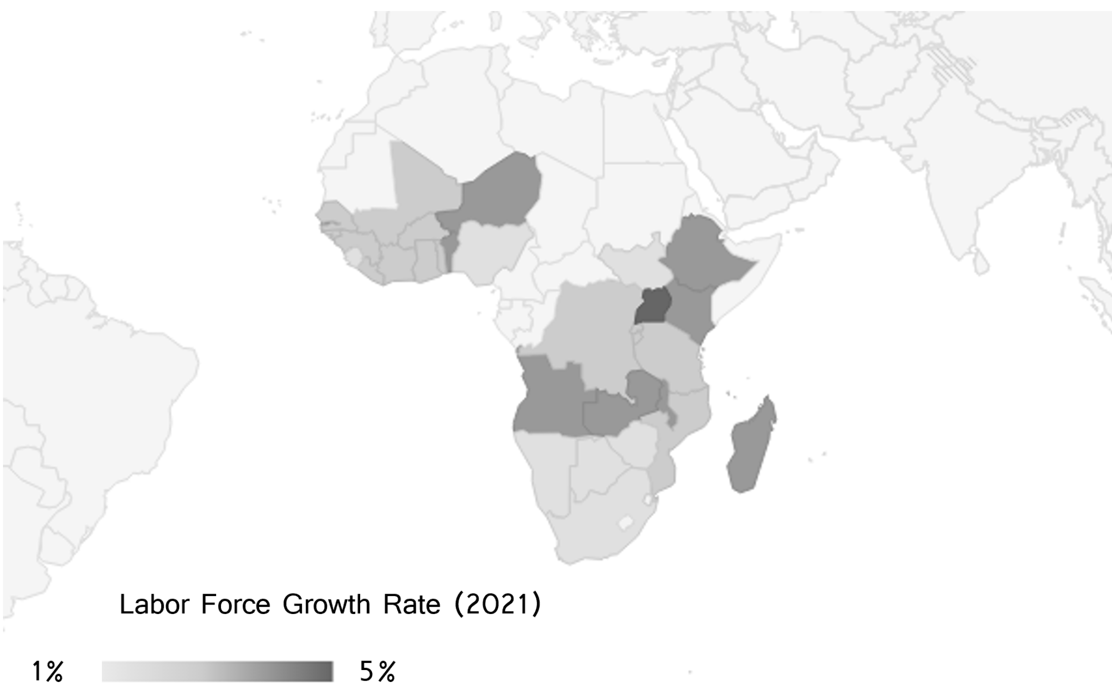
Country Trends

Below are the primary indicators graphed by country and mapped accordingly. Indicators 7, 8, and 9 are not mapped, but included instead in the analysis above. Countries not included in the country analysis may not have data associated with that indicator.

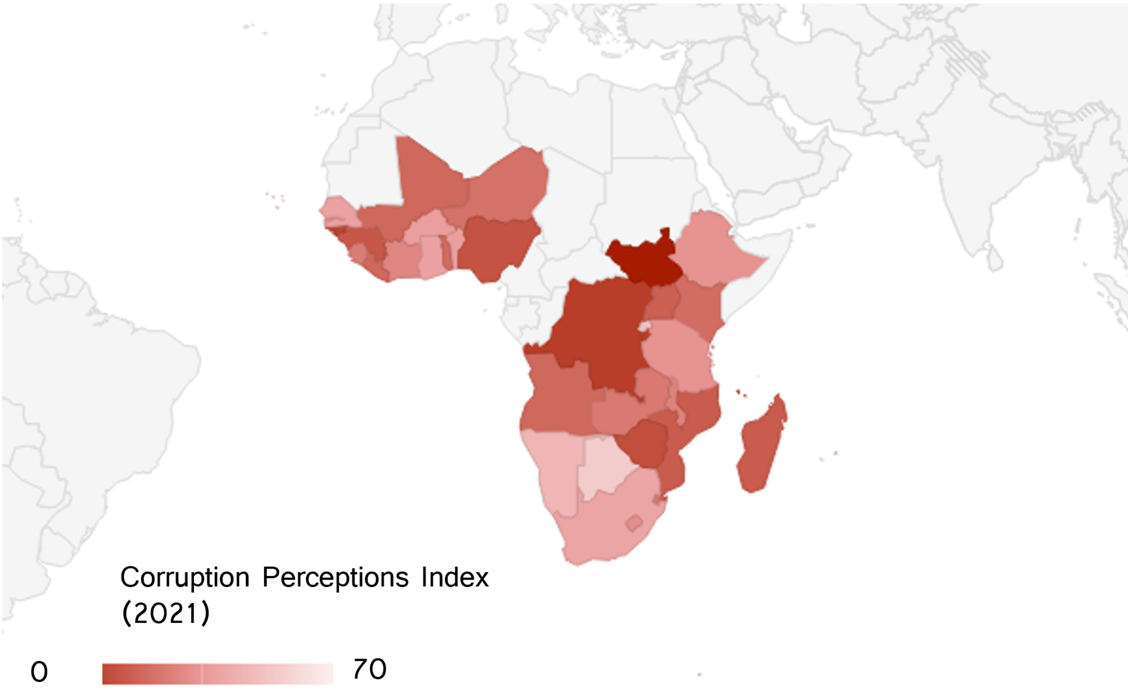
Indicator 1 - Urban Population Growth Rate (2021)



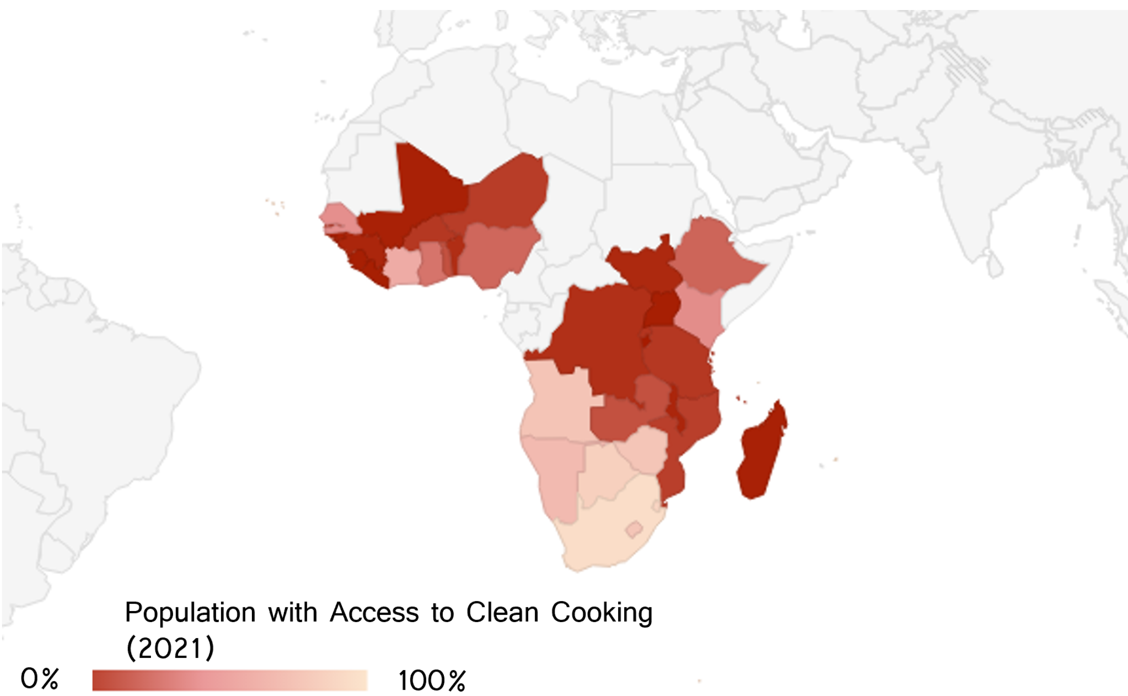
Indicator 2 - Labor Force Growth Rate (2021)



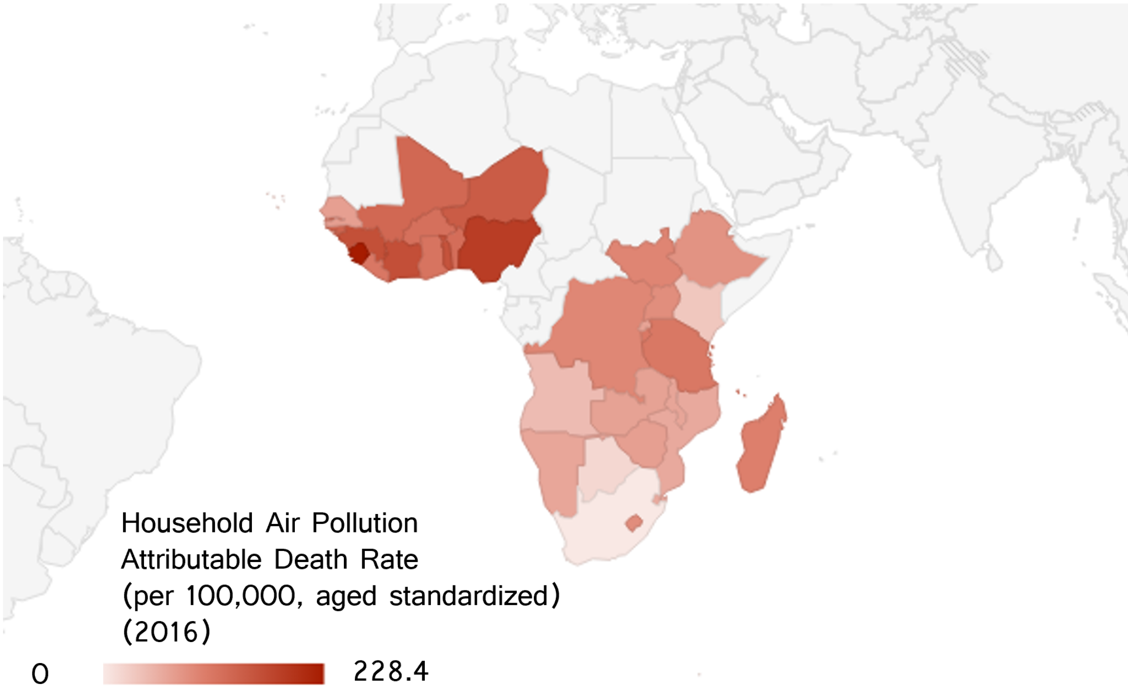
Indicator 3 - Corruption Perceptions Index (2021)



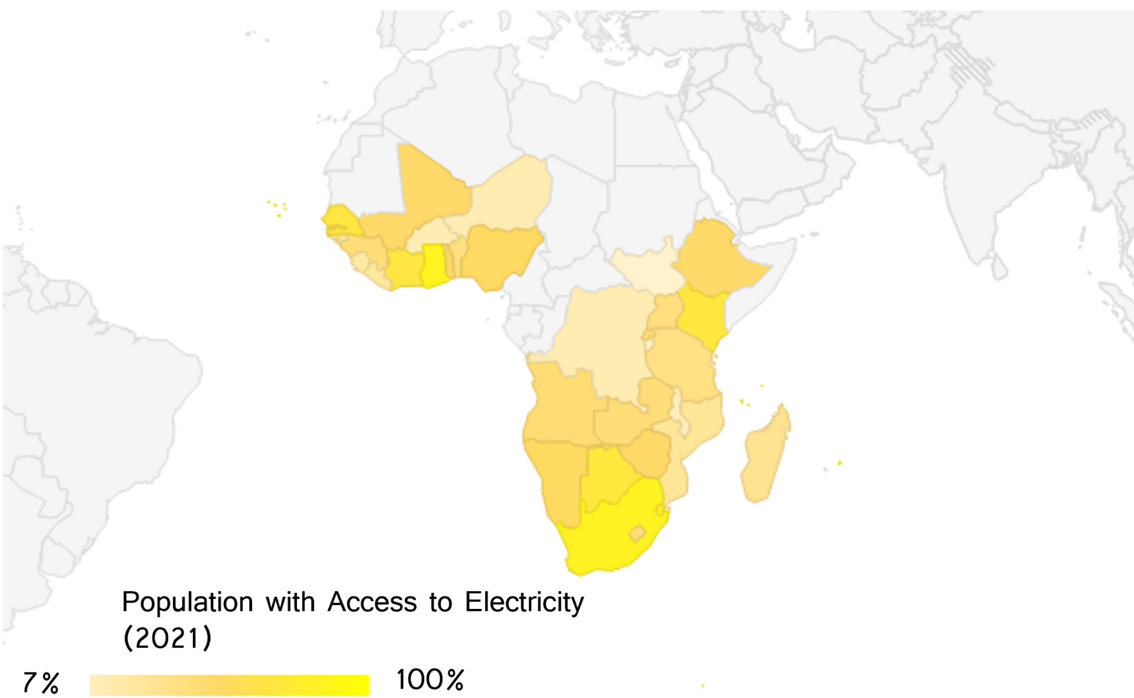
Indicator 4 - Population with Access to Clean Cooking (2021)



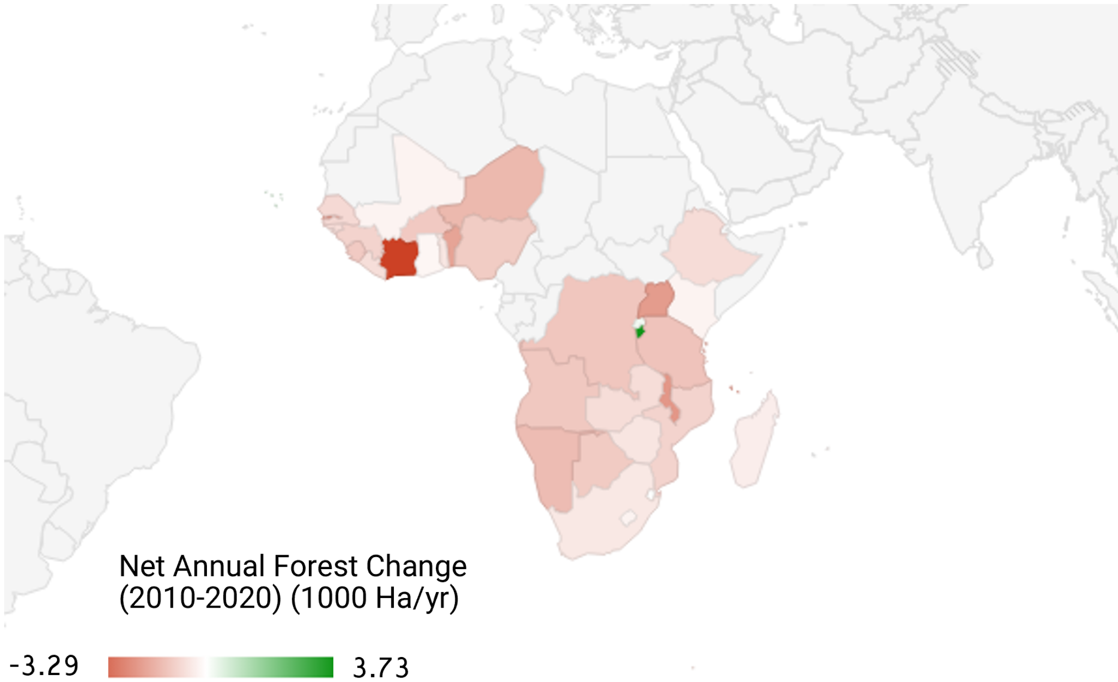
Indicator 5 - Household Air Pollution Attributable Death Rate (2021)



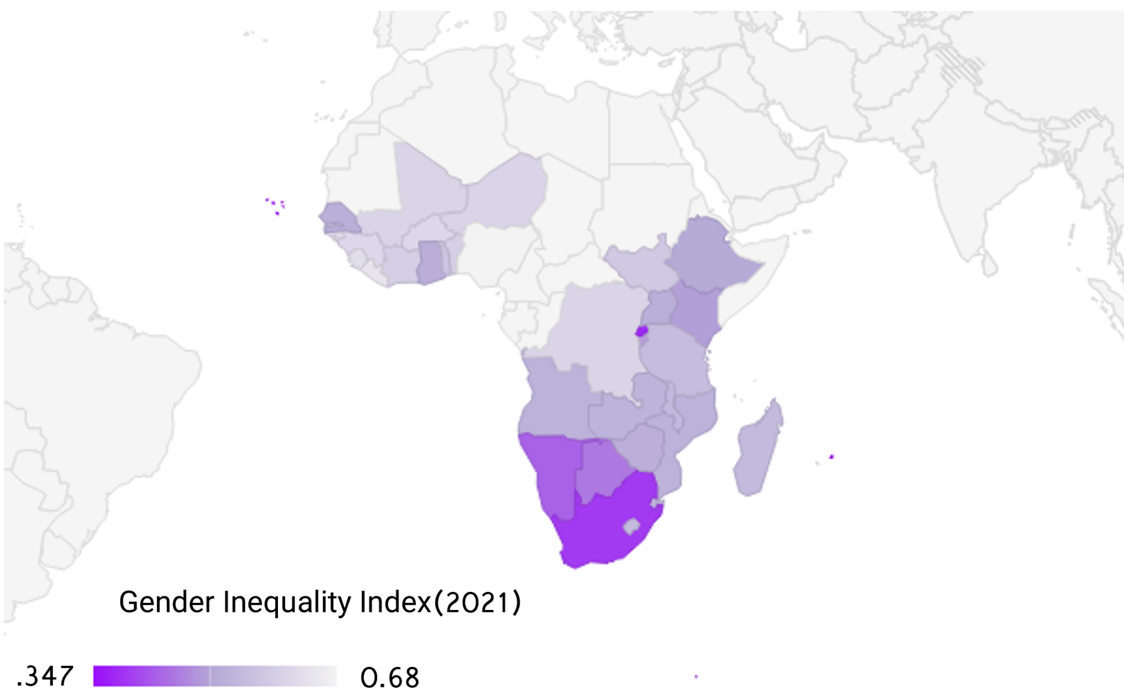
Indicator 6 - Population with Access to Electricity (2021)



Indicator 10 - Net Annual Forest Change (2010 - 2020)



Indicator 11 - Gender Inequality Index (2021)



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