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Biofuel Production in Ghana: Exploring the Opportunity

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Abstract

Currently, Ghana imports most of the gasoline and diesel used to power its vehicles. This situation has led to an excessive dependence on imported fuels, which is compromising Ghana's energy security, exposing the domestic fuel market to the devaluation of the local currency and to the high volatility of international oil prices, while at the same time contributing to the deterioration of the balance of payments.

The local production of biofuels in the country, such as bioethanol and biodiesel to blend with gasoline and diesel, could reduce Ghana's dependence on imported fuels. In turn, this would help to solve the country's energy security and improve the trade balance, as well as improve fuel quality, reduce emissions, support agricultural development and create jobs. Blends of fossil fuels with biofuels are standard in many countries. Countries that successfully produce ethanol and biodiesel include Brazil, Thailand and the United States.

To assess the feasibility of producing biofuels to meet a potential E10/B10 policy (where E10 is a mixture of 10% ethanol and 90% regular gasoline and B10 is a mixture of 10% biodiesel and 90% regular diesel), the prospects of using maize, cassava, sugarcane and oil palm—the crops with the highest potential—were examined under five different scenarios. Cassava seems to be the best option for producing ethanol in Ghana, given the current level of production. In fact, 30% of the estimated waste from cassava production—or 5.4% of its total production—would be sufficient to fulfill an E10 mandate. However, considering cassava's status as a subsistence crop, effective planning would be needed to avoid affecting food security.

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The potential of the other crops assessed (oil palm, sugarcane and maize) is limited, at least with the current levels of production. There is room to improve the yields of these three crops. If Ghana's maize yield increases to match the world average, the surplus could provide the quantity needed to produce ethanol. However, in the case of oil palm and sugarcane, any surplus would barely meet current food needs.

There is also an interesting opportunity to extend the cultivated area. A total of only 2.32% of uncultivated arable land (0.88% for cassava and 1.44% for oil palm) would be necessary to produce the quantity of biofuel needed to implement an E10/B10 policy.

Besides, other factors that impact the production of biofuels in Ghana, as policies, pricing, land availability and infrastructure, were also analyzed. Authors found out that the downstream sector is competitive and well structured, and gasoline and diesel prices are not subsidized, which would facilitate the introduction of biofuels in the market. The main challenges to produce biofuel in Ghana are the lack of a supportive policy and a complex land tenure system.

Keywords: Biofuel; ethanol; renewable energy; sustainability; oil; Africa; Ghana.

Contents

Introduction, Objectives and Methodology

Much progress has been made in Ghana's energy sector. Indeed, the country should be proud of its achievements in terms of access to electricity and liquefied petroleum gas (LPG), which is among the highest in the region. However, some challenges remain. The availability of affordable energy resources is still limited and the country is highly dependent on imports. This situation jeopardizes the economic and social growth that the Ghanaian population deserves. At the IESE Fuel Freedom Chair for Energy and Social Development, we believe that both the private and public sectors have an important role in tackling these energy gaps and harnessing indigenous resources. We believe that some of the problems hide potential business opportunities, which should be addressed by Ghanaian companies and entrepreneurs, with the indispensable support of and guidance from governments. There should be a business-oriented perspective, but the social impact and public aspects of energy development should always be kept in mind.

In this sense, one of the Fuel Freedom Chair's terms of reference is to research and explore, from an academic but pragmatic perspective, potential opportunities that, if effectively implemented, could help to solve some of the energy challenges identified.

The objective of this study is to assess one specific potential opportunity: the local production of biofuels, ethanol and biodiesel from indigenous crops, and their use as a transportation fuel when blended with gasoline and diesel.

This report examines the following aspects of Ghana's biofuel industry and its challenges:

1. Why a biofuel policy: the problem and what could help to solve it. Benefits to the economy
2. The market size and its evolution
3. Comparison of the international prices of refined oil and biofuels
4. Current policies and the business environment, and how favorable these are
5. Feasibility study: feedstock and land availability—the size of a potential biofuel plant
6. Biofuel plant capacity and feedstock costs for producing biofuels at competitive prices

This analysis is limited as the authors are not addressing some important socioeconomic dimensions such as how a biofuel mandate could affect the price of food and land, investment required and potential return on investment, estimated production cost, impact on job creation, environment and regional development.

Even so, the authors believe this report can provide useful information to Ghana's leaders in the search for the solutions required by the energy sector.

This report complements another Fuel Freedom Chair publication, titled "Transportation Fuels in Ghana: An Overview of the Downstream Oil Sector."

1. Biofuel and biofuels blending

Biofuels are renewable fuels, obtained from crops, that can be used in any conventional vehicle engine by mixing them with regular diesel or gasoline—or pure in adapted engines. They are cleaner than fossil fuels, with lower Sulphur levels, releasing smaller amounts of toxic gases when fired, and their properties can improve ignition and engine´s performance.

- Ethanol is used in gasoline engines. It is an ethyl biofuel, normally produced by the alcoholic fermentation derived from the sugar or starch contained in agriculture crops (as sugarcane, sugar beet, cassava or cereals). Ethanol has as higher octane rate than gasoline (which provides better ignition and greater knock resistance).
- Biodiesel is used in diesel engines. It is produced by transesterification of vegetable oils (palm oil, rapeseed, sunflower, etc.), in a process that separates the two main components of the vegetable oil, fatty acids and glycerine. The fatty acids then bind to alcohol to produce esters. The oil reacts with methanol in the presence of a catalyst to form methyl esters (the fuel) and glycerine (the by-product). By removing glycerin, biodiesel can be used as a fuel. In addition to the low Sulphur levels, it's biodegradable and has a high cetane number, improving engine wear and ignition.

In this study, authors are assessing the feasibility of producing biofuels to blend in a 10% rate with 90% of regular fuels to reduce Ghana's dependence on imported fuels and the associated problems, as well as improve fuel quality and reduce emissions. The mixture of 10% ethanol and 90% gasoline is called E10, and the mixture of 10% biodiesel and 90% regular diesel is called B10.

Why 10%: The E10 blend is used in this report as this is a globally adopted fuel. 10% of ethanol is a commonly accepted limit of ethanol that is compatible with most gasoline cars' engines and the existing infrastructure for the distribution and storage of gasoline. Most diesel engines, however, accept higher blends of biodiesel—up to 20%—with no need to modify the engine. However, to simplify the analysis, the authors have used a 10% blend for both biofuels.

In addition, in order to estimate the amount of ethanol or biodiesel to be blended with the regular fuels, this report assumes that E10 and B10 fuels have the same fuel economy (or energy density) as the gasoline and diesel currently used in Ghana, as explained in **Exhibit 1**.

2. Why a Biofuel Policy: Offsetting the High Dependence on Imports of Gasoline and Diesel and Improving Fuel Quality

Ghana imports most of the gasoline (called "petrol" in Ghana) and diesel (also called "gasoil") consumed in the country, the two main fuels used by its vehicles. In 2017, virtually the whole supply of these fuels was imported: $695 million worth of gasoline and $803 million worth of diesel. The combined total of almost $1.5 billion (free-on-board or FOB prices) represented 2.6% of GDP and 12% of all imports.[1] The proportion of refined fuels being imported has been increasing in the past decade[2].

[1] Import figures from the Bank of Ghana, *Annual Report 2017* (Accra: Bank of Ghana). GDP from the World Bank, "GDP (Current US$)," accessed May 7, 2019, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=GH.

[2] In Section 4 of the author´s study "Transportation Fuels In Ghana: An Overview Of The Downstream Oil Sector", authors provide information on the reasons for the increasing proportion of imports of gasoline and diesel.

There are several drawbacks of an excessive dependence on imported fuels in terms of energy security, exposition to the devaluation of Ghana's cedi currency and to the high volatility of international oil prices, deterioration of the balance of payments and of the country's reserves of foreign currencies.[3]

The domestic demand for gasoline and diesel is also increasing, a trend that is expected to continue.[4] Therefore, the imports are likely to continue to grow too, sharpening the adverse effects of such dependence.

The Ghanaian production of biofuels to blend with gasoline and diesel (whether imported or domestically produced) could reduce Ghana's dependence on imported fuels and the associated adverse effects and bring the country several benefits, as outlined below.

a) Improve energy security in its four dimensions:

- By reducing the dependence on imports of diesel and gasoline.
- By ensuring the fuel supply matches the country's growing demand.
- By reducing the exposure to volatile fossil-fuel prices. The creation of a domestic biofuel industry can mitigate the impact of international oil markets on national fuel prices.
- By reducing the fuel market's exposure to foreign exchange rate.

b) Create positive economic spillovers, such as the following:

- Replacing 10% of diesel and gasoline imports with biofuels produced in Ghana could reduce the import bills by around $98 million to $223 million per year. The amount saved would be injected into the domestic economy, improving GDP by between 0.2% and 0.4%. (These figures are based on simulations of the results from 2013 to 2017. See **Exhibit 6** for more details.)
- It would increase Ghana's international reserves every year. In the five-year period from 2013 to 2017 inclusive, the accumulated value (reduction on imports) would have been $783 million, which would result in a 17.3% increase in international reserves by 2017. (These figures are based on simulations of the results from 2013 to 2017. See **Exhibit 6** for more details.) This would increase foreign currency liquidity and reduce the pressure caused by the foreign exchange rate.
- In the hypothetical case of additional international reserves being used to reduce Ghana's foreign debt, the country could have saved approximately $60 million[5] in interest payments annually. In the following years, additional savings of between $7.5 million and $17 million could be generated.[6]

[3] In Section 4.2 of the author´s study "Transportation Fuels In Ghana: An Overview Of The Downstream Oil Sector", authors discuss the impact of imports of diesel and gasoline on the country´s economy.

[4] See evolution of the demand in the Section 3 of the author´s study "Transportation Fuels In Ghana: An Overview Of The Downstream Oil Sector."

[5] Assuming an annual interest rate of 7.625% applied to the accumulated reduction of $783 million estimated for the period from 2013 to 2018. The interest rate is based on the coupon of the 10-year Eurobond issued by Ghana and maturing in 2029. Source: Ken Ofori-Atta, *The Annual Public Debt Report for the 2018 Financial Year* (Accra: Ministry of Finance, March 29, 2019), 33.

[6] Assuming an annual interest rate of 7.625% applied to the reduction in imports estimated for the years 2016 ($98 million) and 2013 ($223 million).

c) Ghana still faces some problems related to fuel quality. Although Ghana's new standards are in line with AFRI-4 requirements[7] and all imports must comply with these minimum quality and property requirements, Tema Oil Refinery (TOR) has been unable to keep Sulphur levels in domestic diesel production within the limits. Biofuel blending can improve fuel quality and reduce emissions.

Ethanol as an octane enhancer

Another interesting potential use for ethanol in Ghana consists in using it—even in smaller proportions—to boost gasoline's octane rate in the local production of gasoline. Currently, Tema Oil Refiery uses MMT (methylcyclopentadienyl manganese tricarbonyl) as an octane enhancer, limiting the manganese content to 18ppm. MMT usage, although not proven harmful, has been banned or limited in some countries since their metallic components, potentially toxic, are not degraded during fuel use and eventually enter the environment. Worldwide, there are unresolved concerns that manganese emissions produced by MMT could have an impact on humans and the environment. Ethanol could represent an interesting substitute to MMT; it is an excellent octane provider, while being a cleaner and safer burning alternative.

3. Biofuel Policies: Current Situation

From 2002 to 2011, there were several public initiatives and policy developments related to biofuels. Dozens of private companies started projects to produce biodiesel from jatropha plants. For several reasons, the projects collapsed. See **Exhibit 2** for a history of biofuels in Ghana.

Now there is no blending mandate in place in Ghana, and biofuels are neither used nor produced for transportation in the country.

Ghana's current regulatory framework can be summarized as follows:

- The Renewable Energy Act of 2011 (still in force) includes a set of provisions on how to obtain a license to produce biofuels, on the role of the energy ministry in defining the biofuel blend and on the role of the National Petroleum Authority in setting biofuel prices. The act defines biofuel blends as petroleum products, so (as the authors understand this) they will be under the auspices of the National Petroleum Authority.
- The Ghana Standards Authority included in its 2018 catalog[8] the standards for:
  - "Denatured fuel ethanol intended to be blended with unleaded gasoline at 1 to 10 % volume denatured fuel ethanol for use as a spark ignition automotive engine fuel" (GS 946 : 2008).
  - Bioalcohol for "ethanol fuel blend, nominally 75 to 85% volume denatured fuel ethanol and 25 to 15 additional % volume hydrocarbons for use in ground vehicles with automotive spark-ignition engines" (GS 945: 2008).

[7] The African Refiners Association introduced its own specification series: AFRI-1 (10,000 ppm or 1% sulfur) to AFRI-5 (50 ppm or 0.005% sulfur), with the goal of achieving progressively lower sulfur levels, moving from AFRI-1 to AFRI-4 by 2020 and AFRI-5 by 2030.

[8] Ghana Standards Authority. *Catalogue of Ghana Standards 2018.* Accessed April 10, 2019, https://www.gsa.gov.gh/wp-content/uploads/2018/08/2018-Catalogue-of-Ghana-Standards.pdf.

- Biodiesel fuel (B100) "to be used either as automotive fuel for diesel engines at 1005 concentration or biodiesel (B100) Grades S15 and S500 for use as a blend component with middle distillate fuels" (GS 944 : 2008). (See **Exhibit 3** for a comparison of the requirements for diesel, biodiesel, gasoline and ethanol.)

Nevertheless, such provisions have had no real effect or application as a biofuel mandate was never issued and blended fuels were never designated as commercial products.

The *Ghana Renewable Energy Master Plan*[9] (February 2019) brought biofuel production back into government plans, setting a target for the "production of liquid biofuels for blending and export" from 2020 to 2030 (p. 42).

Table 1 compares the master plan's biofuel target with Ghana's current consumption of gasoline and diesel.

Table 1
Biodiesel Targets in the Ghana Renewable Energy Master Plan and Comparison With Current Fuel Consumption

Year	Plan's target (tonnes)	% of 2017 consumption
Reference (2015)	0	0
2020	100	0.004
2025	5,000	0.224
2030	20,000	0.896

The plan is not ambitious, aiming to have less than 1% of biofuels in the overall mix of conventional fuels and biofuels by 2030. There is no mention of goals in terms of blending percentages or the type of biofuel (ethanol or biodiesel).

The master plan recognizes Ghana's biofuel potential, mentioning that "more than 60% of Ghana's agricultural lands are still uncultivated" (p. 41) and saying that several types of multipurpose crop can be used for biofuel production. The plan also says that positive impacts could be obtained, such as a reduced dependence on fossil fuels, new jobs, and a stronger industrial sector (pp. 41–42). There is no explanation about why such limited targets were defined.

The strategies set out in the master plan to promote biofuel are:

- Promote the use of multipurpose crops and trees for biofuel production, e.g. oil palm, sunflower, neem tree, etc.;
- Develop clear procedures and regulations;
- Support relevant institutions to research into second and third generation biofuels;
- Collaborate with relevant institutions (MMDAs, NDPC, MLNR, CSIR [metropolitan, municipal and district assemblies, the National Development Planning Commission, the Ministry of Lands and Natural Resources, and the Council for Scientific and Industrial Research]) to prepare land use plans;

[9] Ministry of Energy et al. Ghana Renewable Energy Master Plan. February, 2019.

- Promote the use of SVOs and PPOs for agricultural machinery; and
- Create market for unrefined biodiesel, which is cost competitive with ordinary diesel, for tractors and other mechanized agricultural equipment. (p. 42; emphasis added.)"

All things considered, the authors' interpretation is that the goal might be, by now, to achieve the production of 20,000 tonnes of unrefined biodiesel in the form of straight vegetable oil (SVO) or pure plant oil (PPO) for use in agricultural vehicles, with no additional targets in terms of refined biodiesel or ethanol. However, this could be a new starting point and a learning experience to revive the biofuel industry in the country and drive higher goals.

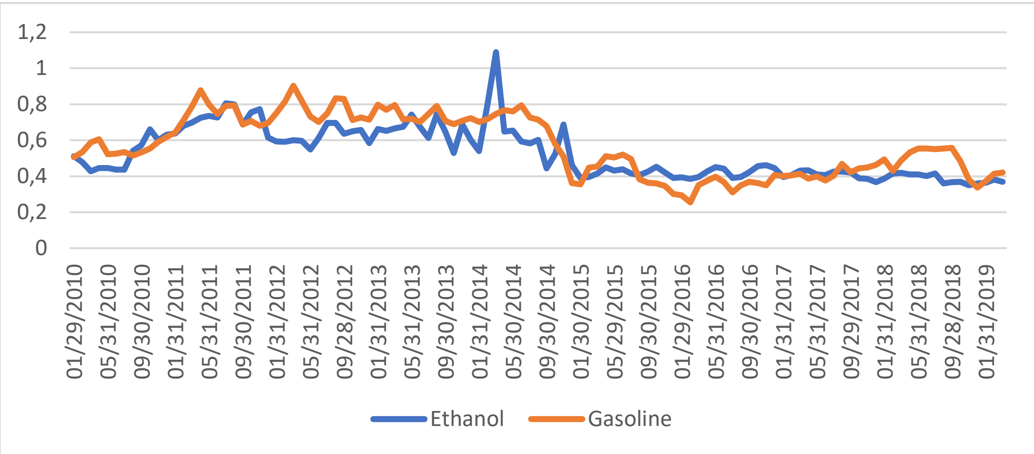
The plan also says that biofuel production should be a private-sector initiative, which would require investment of $90,000 for the first cycle (2020 target) and could create around 50 jobs (p. 54).

4. International Prices: Comparison and Potential Savings for the Economy

Although the main objective of this study is to assess the indigenous production of ethanol, this section analyses de potential saving of substituting 10% of the imports of gasoline for imported ethanol–as an approach to understand if this could be an opportunity to be pursued as well.

Figure 1 shows a comparison of the international prices of ethanol and gasoline.

Figure 1
Ethanol and Gasoline (FOB) Price Comparison, 2012–2019, Dollars per Liter



Source: Prepared by the authors, based on data from Bloomberg Terminal. Ethanol reference: Gulf Coast (code ETHNUSGC). Gasoline reference: Mogas EuroBob FOB Barges.

In a scenario of high oil prices (2011–2014), ethanol was more competitive. Table 2 shows calculations of the potential savings on imports if an E10 policy were in place, based on international prices and on the quantities of fuels consumed in Ghana in 2017, for three time periods: 2013 (high oil prices), 2017 (low oil prices) and 2018 (the most recent series).

Table 2
Hypothetical Savings on Imports With an E10 Policy

	Current 100% gasoline	E10 policy, assuming same energy density 10% ethanol + 90% gasoline	Savings	
			$	%
Total cost ($ prices 2013)	1,166,653,411	1,143,725,945	22,927,466	2.0
Total cost ($ prices 2017)	632,048,596	630,370,623	1,677,973	0.3
Total cost ($ prices 2018)	743,131,196	727,383,510	15,747,686	2.1

Source: Prepared by the authors.

Notes:

1) For the calculations, the following prices per liter were used (averages from data shown in Table 1):

	Gasoline	Ethanol
Average price 2013	$0.774017947	$0.621905333
Average price 2017	$0.419333584	$0.408201049
Average price 2018	$0.493031501	$0.388553243

2) The following quantities measured in liters were used for the calculations:

	100% gasoline	10% ethanol	90% gasoline
Liters (2017)	1,507,269,199	150,726,920	1,356,542,279

As shown, the potential savings when importing ethanol instead of gasoline can vary significantly from year to year. Under the current scenario of low/moderate oil prices, there is little economic incentive to suggest the import of ethanol to replace gasoline.

However, the actual prices of imported ethanol and gasoline are subject to bilateral negotiations between the parties, which in turn are affected by several other factors, such as volume, length of time period, hedging strategies, guarantees, delivery and freight costs, and payment arrangements. Therefore, to the extent that these factors make the final price of imported ethanol deviate from the observed spot market prices, the potential savings could be under–or overestimated.

International biofuel prices should not be used as an approximation for costs or prices of biofuel produced in a particular country. Biofuel prices depend on a series of factors, many of them related to the production costs. These costs in turn can vary significantly from country to country and from season to season, responding to agricultural dynamics and to the prices of biofuel's substitutes, gasoline and diesel.

5. Feasibility Study: Feedstock and Land

The consumption of transportation fuels in Ghana reached 2.8 billion liters of diesel and gasoline in 2017. The production of biofuels under an E10/B10 policy would target 10% of this market. (See Table 3.)

Table 3

Consumption in 2017 and 10% Target of an E10/B10 Policy

2017	Tonnes	Liters	10% (liters)
Gasoline	1,072,000	1,507,269,199	150,726,920
Diesel	1,160,347	1,311,126,554	131,112,655

Source: Prepared by the authors, based on data from the Energy Commission of Ghana. "2018 Energy (Supply and Demand) Outlook for Ghana." April, 2018.

To assess the viability of producing biofuel or the advisability of introducing a biofuel blending policy, several factors must be studied carefully. On the supply and production side, it is necessary to consider aspects such as the availability of suitable feedstock, the sugar content of the local varieties of potential crops, and the land availability. Other important factors to consider are the impact on the food supply, the structure of Ghanaian agriculture (geography, farmers, access to inputs, etc.), the value chain of the crops under consideration and their prices, productivity levels, the water supply, the available infrastructure and the environmental impact. Finally, it is necessary to know how competitive biofuel prices could be compared to the prices of oil-based fuels, under different scenarios.

With regard to demand, beyond a favorable biofuel policy to drive consumption, it is essential to understand the blending levels that vehicles in Ghana can operate with and how biofuel prices will affect retail prices and emission levels. It is also important to assess the macroeconomic and strategic factors already mentioned, such as energy dependency, energy security, the impact on the balance of payments, and job creation. All of these factors must be considered under different scenarios and with a long-term view.

This part of the report focuses on understanding the potential for biofuel production in terms of feedstock and land availability as, in the authors' experience, these are the most relevant initial constraints. While most of the other factors can be shaped, developed and regulated in order to guarantee efficient production of biofuels and so having a positive impact on the economy, environment and population, if there is not enough agricultural land and a surplus of suitable crops, the development of a biofuel industry can scarcely be successful.

To find out whether Ghana has enough land and feedstock resources to encourage biofuel production, the authors selected four crops with the highest potential (maize, cassava, sugarcane and oil palm) and assessed their prospects under five different scenarios.

All the data used for these estimates are available in Exhibit 4. Table 4 shows the biofuel conversion rates.

Table 4
Conversion Rates: Liters of Biofuel per Tonne of Feedstock

Conversion rate	Maize	Cassava	Sugarcane	Oil palm fruit
Liters per tonne of crop	410	150	70	223

Scenarios and Results

Scenario 1. Using 30% of Waste

Under this scenario, the authors have calculated how many liters of biofuel (ethanol and biodiesel) could be produced using 30% of waste crops10 as these quantities should not affect the availability and prices of subsistence crops in Ghana's domestic market. Then the authors calculated how much of the gasoline or diesel could be replaced with these quantities.

Scenario 1
Using 30% Waste

Crop	Biofuel	Biofuel production (liters)	Replaceable gasoline
Maize	Ethanol	22,878,000	1.5%
Cassava	Ethanol	144,000,000	9.6%
Sugarcane	Ethanol	98,000	0.0%
Oil palm	Biodiesel	0	0.0%

As the scenario 1 table shows, 30% of cassava production waste could yield a significant amount of ethanol, enough to replace 9.6% of the gasoline. For the other crops, production under this scenario would not be significant. It is important to mention, however, that a considerable part of the maize produced is used to feed animals—enough to produce 325 million liters of ethanol, equivalent to 21% of the gasoline consumed in 2017. However, this option would require an assessment of the replacement feed options.

[10] Waste may occur in different parts of the supply chain, from the farm fields to the market and even at residential level.

Scenario 2. Share of Crop Production Needed to Achieve E10/B10

Under this scenario, it has been estimated how much of the total production of each crop would be required to produce ethanol or biodiesel to fulfill an E10/B10 blending mandate, thus replacing 10% of the current consumption of gasoline and diesel.

Scenario 2
Share of Crop Production Needed to Achieve E10/B10

Crop	Biofuel	Crop: total production 2017 (kilotonnes)	Crop: amount needed to reach E10/B10 (kilotonnes)	% of total production needed to reach E10/B10
Maize	Ethanol	1,965	368	18.7%
Cassava	Ethanol	18,471	1,005	5.4%
Sugarcane	Ethanol	152	2,153	1,418.8%
Oil palm	Biodiesel	2,470	588	23.8%

Cassava shows the best potential as only 5.4% of its 2017 annual production would have to be used to produce the ethanol necessary to implement an E10 blending policy. Cassava is a staple food, therefore strongly correlated to food security. Therefore, although 5.4% is a small part of production that should not affect food security, any use of this crop for non-food purposes must be assessed with caution.

In addition, the fragmented and not structured production and distribution of cassava over a complex matrix of small-holder landowners poses logistical challenges to gather the crop. It is necessary to assess and optimize the logistic costs, to collect and transport the feedstock to the ethanol distilleries using a cost efficient process.

For the other crops, a significant percentage of their current production would have to be used, which could compromise food security. As shown in **Exhibit 4**, Ghana relies on imports of palm oil to meet domestic demand. Sugarcane production is also low since there are no sugar refineries in the country and all the processed sugar is imported.

Scenario 3. Potential for Better Yields

The yields of maize, sugarcane and palm oil in Ghana are lower than the global average. There is, therefore, an opportunity to increase productivity per hectare and use the surplus to produce biofuels, minimizing the impact on food availability. In this scenario, the authors have estimated the additional production of each crop in the case of productivity reaching the global average levels, using the following yield comparison (See **Table 5.**)

Table 5
Yield Comparison (tonnes/ha)

	Maize	Cassava	Sugarcane	Oil palm fruit
Ghana yield (2016)	2.0	19.0	24.9	7.0
Global average yield (2017)	5.8	11.0	70.9	14.9
Ghana yield as % of global	35%	173%	35%	47%

Source: Food and Agriculture Organization of the United Nations, "Crops", FAOSTAT, accessed June 19, 2019, http://www.fao.org/faostat/en/#data/QC.

Note: Green means Ghana's yield is higher than the global average. Orange means Ghana's yield is smaller.

Scenario 3
Potential for Better Yields

Crop	Biofuel	% of total production needed to reach E10/B10 (from scenario 2)	Additional production with high yield
Maize	Ethanol	18.7%	197.4%
Cassava	Ethanol	5.4%	
Sugarcane	Ethanol	1418.8%	185.3%
Oil palm	Biodiesel	23.8%	112.9%

Source: Prepared by the authors.

Note: Green means the increased yield (to match the global average) would be enough to cover the E10/B10 policy. This does not apply to cassava as Ghana's yield is already higher than the global average.

If the yield (tonnes per hectare) improves to match the global average, the surplus production of maize and oil palm would cover the biofuel needs. In the case of oil palm, though, this surplus would not be enough to replace the current imports of palm oil.

Scenario 4. Using Additional Land to Produce Crops to Achieve E10/B10

According to the Ministry of Food and Agriculture, 42% of Ghana's agricultural land was not under cultivation in 2010. (See **Exhibit 5**.) In this scenario, the authors have calculated how much additional land would be required to produce enough of each kind of crop to fulfill an E10/B10 policy (meaning that all the biofuels needed would come from these areas). The results have been compared with the total available land (the agricultural area not under cultivation).

Scenario 4
Using Additional Land to Produce Crops to Achieve E10/B10

Crop (A)	Biofuel (B)	Land in use (hect.) (C)	Additional land needed to achieve E10/B10 (ha)* (D)	% of agricultural area not under cultivation to be used to achieve E10/B10 (E)
Maize	Ethanol	883,031	165,204	2.86%
Cassava	Ethanol	938,725	51,069	0.88%
Sugarcane	Ethanol	6,422	91,117	1.58%
Oil palm	Biodiesel	349,040	83,092	1.44%

*At 2016 levels of productivity (yield)

A comparison of the land being used (C) and the additional land needed (D) shows that the area used for sugarcane cultivation would have to expanded to more than 14 times the initial level, while the area dedicated to growing maize would have to increase by 18% and the area for oil palm by 23%. However, due to the different yields and conversion rates, after cassava, the crops that would require the smallest area are oil palm and sugarcane. Of the uncultivated agricultural land, a total of only 2.32% (0.88% for cassava and 1.44% for oil palm) would be enough to produce the quantities of biofuels needed to implement an E10/B10 policy.

The main barriers to extend cultivated areas are:

- Land ownership is very fragmented (most of the farms have less than 2 hectares). Land ownership could pose challenges to buy or lease extensive areas.
- Ghana has a very complex land tenure system, where 80% of the land is under customary tenure. Rights over property and use of the land are not always clear and could be claimed by several families over time. In some areas, title is held or vested in traditional stools or skins. In other traditional areas, it could be held by subgroups such as substools, clans and families as well as individuals.

6. Refinery Capacity and Feedstock Prices

To implement a possible E10 blending policy, 150 million liters of ethanol would need to be produced in a year and the amount would increase as the consumption of gasoline increased. This level of output could be met by setting up a medium-sized ethanol plant or several smaller plants. For comparison, Table 6 shows the refinery capacities of Brazil and Thailand, two markets that are global benchmarks for ethanol production.

Table 6
Comparison of Refinery Capacities

	Ghana: annual ethanol production to reach E10	Brazil: smallest plant (sugarcane)	Brazil: biggest plant (sugarcane)	Thailand: average plant (cassava)
Refinery capacity (in liters per year)	150,726,920	36,500,000	547,500,000	74,042,857

Source: Prepared by the authors, based on information from the "Boletim do Ethanol nº 09/2017" Agência Nacional do Petróleo, Gás Natural e Biocombustibles, February, 2017. Accessed April 20, 2019, http://www.anp.gov.br/images/producao-fornecimento-biocombustiveis/etanol/boletim-etanol-fev-2017.pdf.

The authors found no published information about how much investment might be required to set up an ethanol plant in Ghana. In Brazil, the investment could range from $0.54 to $1.28 per liter,[11] including the leasing or acquisition of land. The amount would depend on technology choices, such as the ability to operate with different feedstock or the incorporation of a cogeneration unit to produce electricity. Brazil is a mature and developed ethanol production market, so these estimates should be regarded with caution in the context of Ghana.

Finally, using the following assumptions, the authors have estimated the approximate cost at which Ghana-produced ethanol would be competitive with the current wholesale price of gasoline:

- The maximum ex-factory price of ethanol should be 3.55 cedis per liter, based on the average ex-refinery price of gasoline in Ghana in June 2019.[12] (The ethanol price could vary as oil prices increased or decreased.)
- The cost of the feedstock crops should be limited to 60% of the ex-refinery price of ethanol—that is, 2.13 cedis per liter. The remaining 40% (1.42 cedis per liter) corresponds to other operational costs, depreciation and margins. These costs can vary significantly depending on the scale of the plant, the season, crop prices, the technology used, and whether other outputs (such as sugar or molasses) are also produced for sale.
- The same conversion rates (crop-to-ethanol) set out in **Table 4** were used.

[11] Authors' estimate based on information from Angela Oliveira, Euler J. Geraldo, Juliana Rangel et al. *Investments and costs of operations and maintenance of the Biofuels Sector 2018-2030*. (Rio de Janeiro: Empresa de Pesquisa Energética, 2018) Exchange rate used: $1 = 3.32 reais (December 2017). Conversion rate used (typical for Brazilian sugarcane): 1 tonne of sugarcane = 85 liters of ethanol.

[12] The average indicative ex-refinery price for the period between June 1 and 15, 2019, using information provided by the bulk distribution companies and published on the National Petroleum Authority website: "Indicative Prices From 1st-15th June," accessed July, 15 2019, http://www.npa.gov.gh/indicative-price-year/2019.

Based on these assumptions, the authors have estimated the maximum procurement prices per tonne of maize, cassava and sugarcane, and compared it with the current reference prices. (See Table 7.)

Table 7
Comparison of Crop Prices

Crop	Maximum purchase price (cedis per tonne)	Actual wholesale price: lowest reference (cedis per tonne)*
Maize	874	1,150
Cassava	320	400
Sugarcane	149	—

Source: Prepared by the authors.

* The actual price for February 2019 is from Simone Fugar, "Food Prices in Ghana – February 2019," Esoko, Last modified March 4, 2019, https://esoko.com/food-prices-ghana-february-2019/.

The actual wholesale prices of cassava and maize exceed the hypothetical threshold for purchasing these crops in order to sell ethanol at an ex-factory price that will be competitive with the ex-refinery price of gasoline. However, to get more realistic prices, supply contracts must be negotiated with farmers (at farmgate prices). Given the long-term character and the large volume of these contracts, this could result in lower feedstock prices.

Other options to improve the cost efficiency of ethanol production include:

- An integrated supply chain, where the biofuel producer also cultivates the feedstock. This option has the advantage of reducing crop production costs (due to scalability) and transportation costs (by bringing the plant and feedstock sites closer together). However, it reduces the participation of small farmers in the industry.
- The production of associated products—such as sugar, molasses, gari (cassava flour) and maize flour—to increase revenues and mitigate market risks by diversifying.

7. Conclusions and Summary of Factors to Consider

The introduction of biofuel blending policy could bring Ghana multiple benefits in terms of its trade balance, energy security, the development of the agriculture sector and job creation. Cassava seems to be the best option for producing ethanol in Ghana, given the current level of production. In fact, 30% of the estimated waste from cassava production—or 5.4% of total cassava production—would be sufficient to fulfill an E10 mandate. However, considering cassava's status as a subsistence crop, effective planning would be needed to avoid affecting food security.

The potential of the other crops assessed (oil palm, sugarcane and maize) is limited, at least with the current levels of production. Indeed, the country is a net importer of significant quantities of palm oil and sugar: Ghana imports half of the palm oil and all of the sugar consumed domestically. There is room to improve the yields of these three crops. However, in the case of oil palm and sugarcane, any surplus would barely meet current food needs.

There is an interesting opportunity to extend the cultivated area. A total of only 2.32% of uncultivated arable land (0.88% for cassava and 1.44% for oil palm) would be necessary to produce the quantity of biofuel needed to implement an E10/B10 policy.

So long as Ghana does not have a blending mandate, another interesting opportunity that should be explored is one introduced in the Renewable Energy Master Plan: producing 20,000 tonnes of unrefined diesel in the form of straight vegetable oil or pure plant oil for use in agricultural vehicles. This experience could lay the basis for advocating more ambitious biofuel targets in the future.

By way of a conclusion and recap, Table 8 summarizes the factors considered in this report.

Table 8
Summary of Factors Considered When Assessing Ethanol as a Potential Transportation Fuel for the Ghanaian Market

Opportunity (+)	Challenge (−)
Impact on economy	
• Replacing 10% of diesel and gasoline imports for Ghana-produced biofuels would reduce annual import bills by about $116 million to $223 million, an amount that would be injected into the domestic economy. • Using ethanol would help to maintain foreign currency liquidity and reduce the pressure caused by foreign exchange rate. • If additional international reserves are used to reduce Ghana's foreign debt, this could generate savings of between $7.5 million and $17 million per year, cumulatively.	• Under the current scenario of low/moderate oil prices, there is little economic incentive to suggest the import of ethanol to replace gasoline.
Policy and regulation	
• The Renewable Energy Master Plan introduced biofuel into the national strategy again, although the target was very limited and focused on straight vegetable oil and pure plant oil. Even so, this could be a good new starting point and create momentum to discuss alternatives. • The country already has official standards for ethanol and biodiesel, issued by the Ghana Standards Authority. • The previous draft biofuel policy and the experience with the jatropha projects have given Ghana a critical understanding of the challenges made it better prepared to develop a good biofuel strategy and implementation plan.	• No blending policy is in place. Therefore, there is no immediate opportunity to produce or sell biofuel for the domestic market. • The experience of failed jatropha projects could negatively impact or bias policy-makers and the government's position about biofuels. • Biofuels do not seem to be a priority in the government agenda, which has been focusing on the challenges of the power and natural gas sectors.

<table>
<tr><th>Opportunity (+)</th><th>Challenge (−)</th></tr>
<tr><td colspan="2">Feedstock availability</td></tr>
<tr><td>• There are multi-purpose crops suitable for biofuel production;
• Cassava is the best alternative to produce ethanol. It is massively produced but with high losses during the process. 30% of cassava waste or 5.4% of the total production would be sufficient to meet an E10 policy. Ethanol production could incentivize the reduction of these losses;
• If the yield of maize harvested (tonnes/hectare) improves, the surplus could overcome the quantity needed to produce ethanol.
• If land is available to extend production, all the crops offer potential. Cassava would be the crop demanding less land.</td><td>• Other than Cassava, the potential is limited without increasing the productivity and/or extending the area cultivated.
• Biodiesel from Palm Oil does not seems to be a feasible option. Other oily crops should be studied for biodiesel production;
• Cassava is a staple food, therefore any use of this crop for non-food purposes must be assessed with caution.
• The production and distribution of cassava is fragmented and not organized. It is necessary to assess and optimize the logistic supply chain to collect and transport the feedstock efficiently.</td></tr>
<tr><td colspan="2">Pricing</td></tr>
<tr><td>• The fact that there are no subsidies in the fossil fuel prices and that retail prices are established in the framework of a free and competitive market could ease the introduction of biofuels.
• Other options should be assessed to reduce feedstock costs, as long-term contracts with farmers or integrated supply chain. Producing other associated products could be an option to increase revenues and mitigate risks.</td><td>• Current wholesale prices of feedstock impose a challenge to produce ethanol at a competitive price – considering current petrol prices.</td></tr>
<tr><td colspan="2">Land</td></tr>
<tr><td>• More than 40% of agriculture land is not under cultivation, presenting a good opportunity to expand production areas.</td><td>• Land ownership system could pose challenges to extend cultivated areas or buy or lease extensive areas.</td></tr>
<tr><td colspan="2">Infrastructure</td></tr>
<tr><td>• The volume of ethanol necessary to implement an E10 mandate would require one or more medium-sized ethanol plants.
• The current setup of the fuel sector—in which several private companies already work in different parts of the supply chain—facilitates the trading, storage, transporation and marketing of biofuels.</td><td>• Ghana's refinery has been experiencing financial and operational difficulties, resulting in inconsistent output. It is difficult to assess whether it has the capacity to operate as a blending facility.</td></tr>
<tr><td colspan="2">Other areas affected that have not been assessed in depth in this study include: the environment, food security, agricultural development, employment, and tailpipe and greenhouse-gas emissions.</td></tr>
</table>

Source: Prepared by the authors.

Exhibit 1
Considerations on Biofuels' Energy Density

Ethanol has a lower energy density (calorific value per liter) than gasoline. This means that ethanol may achieve fewer kilometers per liter (volumetric fuel economy).[13] While gasoline contains about 35 megajoules per liter, ethanol has just 23 megajoules per liter.[14] E10 would therefore contain 33.8 megajoules per liter, which could decrease fuel economy by 3.5% compared to a car running on pure gasoline.

However, ethanol fuel has a higher octane rate (which provides greater knock resistance)[15] and greater thermodynamic efficiency compared to gasoline (due to lower combustion temperatures and reduced heat transfer losses). Ethanol properties such as these result in better fuel economy than would be predicted based purely on the calorific value (energy content) of ethanol for all types of blends, especially for E10, where the difference compared to gasoline is almost insignificant.[16] As a result, an E10 fuel could—depending on the characteristics of the final blend—have the same or better fuel economy in relation to the regular gasoline being used. In the case of Ghana, the ethanol used in an E10 blend could replace benzyne as an octane booster, resulting in better fuel economy than what would be expected based solely on its calorific value.

Similar reasoning can be applied to biodiesel. It has 5%–10% less energy density compared to regular diesel, which would represent 0.5%–1% lower fuel economy in a B10 blended fuel. However, in practice, the use of B10 seems to have little impact, if any, on perceived performance.

In order to estimate the amount of ethanol or biodiesel to be produced and blended with regular fuels, this report has made the simplified assumption that E10 and B10 fuels have the same fuel economy (or energy density) as the gasoline and diesel currently used in Ghana.

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[13] Fuel economy is understood to mean the number of kilometers a vehicle travels per liter of fuel.

[14] Cleanleap, "Energy Units and Conversion Factors," https://cleanleap.com/where-are-we-renewable-energy/energy-units-and-conversion-factors.

[15] Bertrand Hauet, Utilisation Rationnelle de l'Énergie dans les Moteurs à Combustion Interne et Environnement. Renault, Conference SIA, March 13, 2007. http://turbo-moteurs.cnam.fr/publications/pdf/conference2_2007.pdf.

[16] Carolyn P. Hubbard, James E. Anderson, and Timothy J. Wallington, "Ethanol and Air Quality: Influence of Fuel Ethanol Content on Emissions and Fuel Economy of Flexible Fuel Vehicles," *Environmental Science and Technology* 48, no. 1 (2014): 861–67. https://web.math.princeton.edu/~sswang/es404041v.pdf.

Exhibit 2
History of the Development of a Biofuel Sector in Ghana

During the first decade of the 21st century, the Ghanaian government was concerned about energy security and the effect of the high cost of oil imports on the balance of payments, in the context of increasing oil prices and growing domestic demand.[17] Influenced by some visionary producers of jatropha, the government included the development of a biofuel industry in its Strategic National Energy Plan. On the policy side, the Energy Commission prepared two comprehensive biofuel policy drafts: one in 2005 (reviewed in 2006) and one in 2010. These aimed to implement a blending mandate through the development of Ghanaian biofuel production. The first policy drafts aimed for biofuel blending of 10% (E10 and B10) in 2015 and 20% in 2020. Because of a lack of refinery capacity, the 2010 biofuel draft[18] postponed the mandate to 2020 for 10% biofuel blending in 2020 and to 2030 for 20% blending. The 2010 draft aimed to transform Ghana into a net exporter of biofuel in the medium to long term.

The government backed the idea of starting jatropha plantations and began the National Jatropha Project, providing seedlings to smallholder farmers. The state agreed to buy the jatropha seeds after harvesting in order to produce biodiesel and use it to run state-owned vehicles.

However, with the sharp decrease in oil prices in 2008, the discovery of significant offshore reserves of crude oil and gas off Ghana's coast and a change in government, the authorities gradually abandoned the plans. Instead, the authorities started focusing on solutions for the power sector, which was facing several challenges. In 2007 and 2008, the National Jatropha Project was in the phase of distributing seedlings to farmers but it was abandoned right after the change in government in 2008. Some nongovernmental organizations (NGOs)—concerned with indiscriminate land acquisitions for jatropha plantations, the negative impact on food production and the lack of engagement with local communities throughout the process—also influenced the government to review and slow down the plans. Consequently, the biofuel policy drafts were never approved or implemented.

The only tangible result in terms of regulation was the inclusion, in the Renewable Energy Act of 2011[19] (still in force), of a set of provisions on how to get a license to produce biofuels, on the role of the energy ministry in defining the biofuel blend and on the role of the National Petroleum Authority in setting biofuel prices. However, these provisions never had any real effect or application.

In addition, the Ghana Standards Authority included in its 2018 catalog (still in force) the specifications of ethanol and biodiesel for fuel blends. (See section 4 of this report.)

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[17] Before 2014, when Ghana produced significant amounts of crude oil for the first time, the country relied on imports of crude oil to supply the state-owned refinery. Ghana still imports gasoline and diesel to complement the refinery's production and to supply the domestic market. The amount produced by the refinery varies a lot every year but, as an example, back in 2000 Ghana was importing half of the diesel and gasoline the country consumed.

[18] Energy Commission. "Bioenergy Policy for Ghana". August, 2010.

[19] Parliament of the Republic of Ghana. Renewable Energy Act, 2011. Act 832. December 31, 2011. http://energycom.gov.gh/files/RENEWABLE%20ENERGY%20ACT%202011%20(ACT%20832).pdf.

Exhibit 2 (continued)

History of Private Investment in Jatropha-to-Biodiesel Projects in Ghana

In the private sector, in parallel, interest in biofuel production in Africa was booming. This could be explained by the peaks in oil prices and the growing demand for biofuels around the world. Foreign investors who were excited about the jatropha potential in Ghana and attracted by the government's plans started investing in jatropha plantations. They acquired land and developed ambitious projects to build biodiesel processing facilities. More than 40 companies were established between 2005 and 2008, with different strategies in terms of vertical integration, products (seeds, raw oil and biofuel) and land acquisition.

As the blending mandates were never implemented, most of these companies switched their focus from the national market to exporting. However, in the following years, it seems most of them[20] either collapsed, cancelled their projects, faced bankruptcy or simply disappeared. This brought an end to the promising cycle of high expectations and large investments in the biofuel sector in Ghana. Despite considerable investments having been made, the companies were never able to effectively produce or export biofuels and just a few ended up producing seeds for a while, always at levels below their initial targets.

Reasons for the Jatropha Failure

The external reasons that contributed to the closure of these companies were:

- The decrease in oil prices and the discovery of oil reserves in Ghana, which improved the country's energy security and its balance of payments
- The change in the government's position on biofuel production and the reversal of its support for the implementation of the policy drafts
- The advent of the 2008 financial crisis, which slowed the flow of capital and led many companies to cancel projects around the world
- The lack of regulations on land acquisition and on engagement with local communities

[20] The authors found contradictory information about companies still operating. Although it is thought that there are no longer any companies producing biodiesel, it is possible that there are still some companies producing and exporting jatropha seeds.

Exhibit 2 (continued)

In addition, several factors linked to the capacities and operations of the companies themselves contributed to their total collapse:

- Unrealistic business plans that reflected a lack of knowledge of jatropha production (the yield per hectare was much lower than expected) and biodiesel refining
- Business plans that were not resilient to the decrease in oil prices
- Lack of experience in the sector and, in particular, poor knowledge about Ghanaian agronomy even though some of the companies were subsidiaries of international biofuel companies
- The lack of a network of private companies to lobby and work with the government
- Poor engagement with local communities in Ghana and unfulfilled promises in terms of the creation of jobs, schools and infrastructure
- The unconstructive involvement of chieftaincy institutions, which were accused of sparking conflict through the "unclear ownership of land, illegal sale of land, unfair sharing of benefits, weak leadership and abuse of authority"[21]
- Opposition from NGOs concerned about food security, land appropriation, and the exploitation of workers and farmers

[21] Ahmed et al. "Biofuel development in Ghana: policies of expansion and drivers of failure in the jatropha sector." *Renewable and Sustainable Energy Reviews*, 2017, 142.

Exhibit 3
Comparison of Basic Requirements of Fuel Standards

Properties	Diesel (TOR)	Diesel (standard)	Biodiesel
Density (kg/m^3 at 15°C), max	—	820–850	860–900
Viscosity at 40°C (mm^2/s)	—	2–4.5	1.9–6
Ignition quality (cetane index), min	—	46	47
Sulfur content (ppm), max	1,000	50	15

Properties	Regular (standard)	Premium (standard)	Ethanol
Density (kg/m^3 at 15°C), max	720–775	720–775	860–900
Lead (Pb) content, mg/liter, max	5	5	0
Research octane number, min	91	95	110
Sulfur content (ppm), max	50	50	30
Benzene (% v/v), max	1	1	0

Source: Prepared by the authors.

Exhibit 4
Data Used in Feasibility Study

Data Used for **Scenario 1** (2013 Data, in Kilotonnes)

Crop/processed food	Maize	Cassava	Sugarcane	Palm oil
Production	1,764	15,990	145	120
Import	6	2		165
Export	4	9	—	60
Stock variation	—	—		1
Domestic supply quantity	1,766	15,983	145	226
Losses	279	4,800	7	
Feed	795	4,020		
Processing			—	
Food	660	5,598	133	81
Other uses	1	1,566	—	145

Source: Food and Agriculture Organization of the United Nations,"Crops", FAOSTAT, accessed June 19, 2019, http://www.fao.org/faostat/en/#data/QC.

Data Used for **Scenario 2** (2017 Data)

Production (in tonnes)	Maize	Cassava	Sugarcane	Oil palm fruit
	1,965,000	18,470,762	151,762	2,469,763

Source: Food and Agriculture Organization of the United Nations, "Crops", FAOSTAT, accessed June 19, 2019, http://www.fao.org/faostat/en/#data/QC.

Data Used for **Scenarios 3** and **4** (2016 Data)

Crop/processed food	Maize	Cassava	Sugarcane	Oil palm fruit
Area harvested (in hectares)	883,031	938,725	6,422	349,040
Yield (in hectograms per hectare)	19,500	189,600	248,489	69,992
Yield (in tonnes per hectare)	2.0	19.0	24.9	7.0
Production (in tonnes)	1,721,910	17,798,217	152,136	2,443,000

Source: Food and Agriculture Organization of the United Nations,"Crops", FAOSTAT, accessed June 19, 2019, http://www.fao.org/faostat/en/#data/QC.

Exhibit 5

Cultivated and Uncultivated Land (2010)

Cultivated land	Hectares	%
1. Total land area	23,853,900	100%
2. Agricultural land area	13,628,179	57%
2.1 Area under cultivation	*7,846,551*	*58%*
2.2 Total area under irrigation	*30,269*	*0%*
2.3 Area not under cultivation	*5,781,628*	*42%*
3. Area under inland waters	1,100,000	5%
4. Others (forest reserves, savannah woodland, etc.)	9,125,721	38%

Source: Ministry of Food and Agriculture. Statistics, Research and Information Directorate. *Agriculture in Ghana. Facts and Figures (2010).* 2011, 2.

Exhibit 6

Balance of Payments and Impact of Gasoline and Diesel Imports

Balance of Payment and Impact of Imports and Exports of Oil and Oil Products (million USD)	2013	%	2014	%	2015	%	2016	%	2017
CURRENT ACCOUNT (A+B)	**-5,704.04**		**-3,694.47**		**-2,823.75**		**-2,840.49**		**-2,004.85**
A. Merchandise Trade Balance	**-3,848.32**		**-1,383.41**		**-3,143.98**		**-1,781.77**		**1,187.67**
Exports (f.o.b.)	13,751.92		13,216.79		10,321.08		11,138.34		13,835.01
of which, Crude Oil:	*3,885.07*	*28%*	*3,724.98*	*28%*	*1,931.28*	*19%*	*1,345.21*	*12%*	3,115.10
Imports (f.o.b.), of which:	- 17,600.24		-14,600.20		-13,465.06		-12,920.11		-12,647.35
Petrol (Premiun)	*1012.32*	*-6%*	*1177.44*	*-8%*	*696.33*	*-5%*	*557.93*	*-4%*	*694.68*
Gas Oil (Diesel)	*1215.13*	*-7%*	*1619.66*	*-11%*	*912.38*	*-7%*	*653.07*	*-5%*	*802.61*
other Oil and Gas products	*1323*	*-8%*	*896.85*	*-6%*	*438.01*	*-3%*	*623.89*	*-5%*	*494.86*
Imports (c.i.f), of which:		-	-	-	-	-	-		-
Petrol (Premiun)	*1036.62*		*1205.7*		*713.04*		*571.32*		*711.35*
Gas Oil (Diesel)	*1244.29*		*1658.53*		*934.28*		*668.75*		*821.88*
B. Balance on Services, Income and Transfers	**-1,855.72**		**-2,311.06**		**320.23**		**-1,058.72**		**-3,192.52**
Services (net)	-2,443.76		-2,602.13		-1,166.60		-1,293.28		-2,875.84
Income (net)	-1,351.39		-1,717.40		-1,110.90		-1,222.07		-2,740.89
Transfers (net)	1,939.44		2,008.47		2,597.73		1,456.62		2,424.21
C. Capital & Financial Account	5,368.16		3,752.80		3,123.24		2,557.86		3,015.72
D. Net Errors & Omissions	-363.34		-144.4		-315.37		530.05		80.57
OVERALL BALANCE (A+B+C+D)	**-699.22**		**-86.07**		**-15.88**		**247.42**		**1,091.44**
E. Change in Reserves and Related Items	699.21		86.07		15.89		-247.43		-1,091.44
Net International Reserves (Million USD)	**3,286.00**		**3,199.00**		**3,094.00**		**3,431.00**		**4,522.50**
% Petrol and Gas Oil on GDP	69%		90%		53%		36%		34%
GDP (Million USD) - Nominal	**63,270.00**		**53,610.00**		**49,182.00**		**55,010.00**		**58,997.00**
% Petrol and Gas Oil on GDP	3.6%		5.3%		3.3%		2.3%		2.6%

Source: Prepared by the authors, based on information from:
Bank of Ghana. *Monthly Statistical Bulletin*. (Editions consulted: March 2018, December 2017, March 2016, March 2015). Accessed May 12, 2019, https://www.bog.gov.gh/publications/statistical-bulletin/
Bank of Ghana. Annual Report 2017. Accessed May 16, 2019, https://www.bog.gov.gh/wp-content/uploads/2019/07/AnnRep-2017.pdf
International Energy Agency. *Statistics – Ghana. Oil production – crude and others products (table).* Accessed March 18, 2019, https://www.iea.org/statistics/?country=GHANA&year=2016&category=Oil&indicator=OilProd&mode=table&dataTable=OIL

Exhibit 7

Hypothetical impact of a 10% Blending policy on Balance of Payments and GDP

Petrol and gas oil consumption **Quantities Consumed for Transportation**	**2013**	**2014**	**2015**	**2016**	**2017**
Petrol - MT	1,081,000	1,102,000	1,163,000	1,069,000	1,072,000
Gas Oil - MT	1,203,000	1,198,000	1,329,000	1,233,000	1,160,000
Decrease on Imports of Petrol by Blending 10% of Locally Produced Ethanol - Million USD	109.83	105.31	68.63	50.17	60.45
Decrease on Imports of Gas Oil by Blending 10% of Locally Produced Biodiesel - Million USD	113.69	103.81	67.96	47.94	56.04
Improvement in the Current Account - million USD	223.53	209.12	136.58	98.11	116.49
Improvement in the Current Account - %	3.9%	5.7%	4.8%	3.5%	5.8%
Improvement in the Overall Balance	32.0%	243.0%	860.1%	39.7%	10.7%
Improvement in the Net International Reserves	6.8%	6.5%	4.4%	2.9%	2.6%
GDP Improvement	0.4%	0.4%	0.3%	0.2%	0.2%

Source: Prepared by the authors.