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Bioenergy potential, its effects on climate change and the economy: A review in the Guyana context

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REVIEW ARTICLE

ABSTRACT

Guyana depends mainly on imported petroleum based products for its energy needs. The use of fossil fuels has been associated with climate change because their combustion releases greenhouse gases at an environmentally harmful rate. This study seeks to strengthen the climate change mitigation efforts in Guyana by reviewing the potential of bioenergy and the effects of its usage on climate change and the country's economy. The available bioenergy sources including rice husk from rice production, residues from the forestry industry, biodiesel from palm oil, cogeneration of bagasse, bioethanol from the molasses and biogas from cattle manure, sewage sludge, urban and suburban waste are quantified. An estimate of the effects of the utilization on country's carbon dioxide, particulates, nitrogen oxides and sulphur dioxide emissions was analysed. In addition, an assessment of the effects of their utilization on the country's fuel expenditure was done. Finally, impediments and opportunities to the utilization of the bioenergy sources are discussed. This study showed that maximizing biofuels will yield at least 31.43% savings annually on the current fuel expenditure. Further, there can be 35.7% carbon dioxide, 32.5% sulphur dioxide, 13.8% carbon monoxide, 9.9% particulates and 4.7% nitrogen oxides eliminated from the environment. This indicates that optimizing bioenergy use can aid in transforming Guyana into a low carbon-based economic model and to the forefront of the fight against climate change while ensuring energy security. Studies to develop strategies for mitigating the challenges for maximizing biofuels use should be pursued.

KEYWORDS
bioenergy; biofuel; climate change; energy; Guyana

1. INTRODUCTION

The use of fossil fuels has accelerated since the beginning of the Industrial Revolution. The use of fossil fuel results in the release of greenhouse gases which is a significant contributor to climate change (Mudri et al., 2005). Greenhouse gases present in the atmosphere absorb solar radiation and prevent the loss of heat to space. This effect is like that of a greenhouse; as these gases act as a "blanket" in keeping the Earth warm making it habitable. The burning of fossil fuels releases large amounts of greenhouse gases, at an accelerated rate into the atmosphere contributing to the effects of climate change. Impacts of climate change includes the rise in temperatures, rise in sea level, change in rainfall patterns and distribution, and increased storm intensity and species extinction rates.

Anthropogenic factors continue to increase atmospheric concentrations of carbon dioxide (CO_2). This increase in CO_2 is associated with the phenomenon of climate change that has resulted in an increase of approximately 0.8 °C in the last century and an average warming rate of about 0.2 °C every ten years (Hansen et al., 2006). Predictions show that Guyana will experience increased temperature by 1°C by the 2030s, 2 °C by the 2060s and 3 °C by the 2090s (Government of Guyana, 2013). Also, it is predicted that there will be a rise in sea level of 0.2-0.5 m by the 2090s, resulting

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in a loss of land ranging from 2000-3000 ha due to flooding and up to 80,000-140,000 ha due to storm surges (Government of Guyana, 2013). In an effort to confront these challenges, the Office of Climate Change of Guyana (OCC) was established as the agency responsible for mobilizing support for climate smart projects. The agency piloted the Low Carbon Development Strategy in 2009 as the overarching policy for Climate Change adaptation and mitigation.

Over the years, energy demand continues to grow in Guyana. Most of the energy is derived from fossils fuels with limited renewable or bioenergy sources. Guyana has great potential for bioenergy generation. The climate, soil and topography are suitable for agriculture; hence utilizing agricultural biomass waste for energy production can be feasible. Rice and sugar cane are the most dominant agricultural crops in Guyana hence utilizing wastes from these two industries could reduce solid waste while producing clean energy. Other sources that can be used to produce bioenergy are animal waste from farms, wood waste from sawmills, feedstock crops and gases from the landfill and sewage systems. These efforts can be perceived as supporting climate adaptation and mitigation measures. Thus, increasing the knowledge and awareness in these areas could lead to suitable actions of climate change mitigation (Strapasson et al., 2017).

This study provides information to enhance climate change mitigation by investigating the use of bioenergy sources as replacement for fossil fuel. The available and potential bioenergy sources in Guyana were identified as rice production, sugar production (molasses and bagasse), forest residue, energy crops, animal excrements, urban waste and sewage. These were quantified to determine the energy potential from these sources then the quantity of fossil fuel replaceable were determined and used to assess the economic impact of their use. Further, the emissions generated from the fossil fuel that could potentially be replaced were calculated and compared with the emissions from bioenergy sources of equivalent energy content to determine the emissions reduction thereby highlighting the environmental effects of bioenergy utilization and the mitigating impact on climate change. Additionally, surveys and interviews were done with agencies related to the bioenergy sources to ascertain the challenges faced regarding their usage.

2. BIO-ENERGY STATUS AND POTENTIAL IN GUYANA

2.1. Bioenergy from rice production

Figure 1. Guyana's rice producing areas

Rice husk collected from the milling of paddy contains about 35% of organic carbon (Shackley et al., 2012). It has a calorific value of about 3000 kcal/kg (Shen et al., 2012) and can be used to generate fuel, heat or electricity through thermal, chemical or biological processes. Rice production occurs along the coastal belt of Guyana (Figure 1), utilizing over 180,000 acres of land (Guyana Rice Development Board, 2015). In 2015 rice production was 683,516 tonnes (Guyana Rice Development Board, 2015) providing average of 368,047 tonnes rice husk as waste. Currently, the country's only rice husk gasification plant located at Exmouth, Essequibo Coast utilizes rice husk from their milling process to power 70% of their internal operations.

Gasification is one of the cleanest, most efficient methods known for the conversion of rice husk biomass to electricity. This process involves incineration at high temperatures in an oxygen controlled environment thereby reducing the amount of carbon dioxide released into the atmosphere. By gasification 220 kg rice husk can produce 93-129 kWh of power (Afzal, 2017), therefore from its annual rice production Guyana can produce approximately 185,696 MW of energy cutting Guyana's annual diesel requirement by 109,813 barrels if all rice wastes are efficiently converted into energy.

2.1.1. Challenges and opportunities

Currently, using open air combustion many mills burn approximately 65% of their rice husk to generate heat for drying of paddy. Approximately 35% of their rice husks together with the char from burning are being dumped in open spaces surrounding the mills as shown in Figure 2. In most cases these pose an environmental threat to surrounding communities. The use of rice husk can provide energy to cater to some of the milling energy demands. Some operators are hesitant to adopt clean energy method due to their lack of awareness on the benefits of using their waste to produce energy and their inability to source the initial high investment. Additionally, some millers have a view that the small scale industries may not be financially stable to invest in a gasification plant. The inability to transfer excess power to the national grid is also a major hurdle that has negatively influenced millers and requires the urgent attention of policy makers. Further, if the by-product of rice husk gasification "char" is not adequately utilized then further solid waste management issues may arise.

Figure 2. Rice husk accumulated at a rice mill

The Guyana Rice Development Board (GRDB) and the Guyana Energy Agency (GEA) play an important role in educating operators on the benefits of using bioenergy. GRDB has informed that more rice mills would soon be able to benefit from gasification plants through a Technical Cooperation between the governments of Guyana and India where the Energy Institute of India (TERI) would provide technical support and Energy Efficient Solutions Limited (EESL) financial support.

2.2. Bioenergy from sugar production

Guyana's sugar industry cultivates about 50,000 hectares of the 1.74 million hectares of land being used for agriculture (Thomas, 2015). Sugar cane is being produced and processed on six estates (Skeldon, Albion, Rose Hall, Blairmont, Enmore and Uitvlugt) along Guyana's coastal region (Figure 3). In 2015, Guyana Sugar Corporation (GUYSUCO) produced 227,727 tonnes of sugar (Ministry of Agriculture, 2015). The four major by-products of the sugarcane industry are cane tops, bagasse, filter muds and molasses (Kumar et al., 2016). The bioenergy potential derived from molasses and bagasse are of interest.

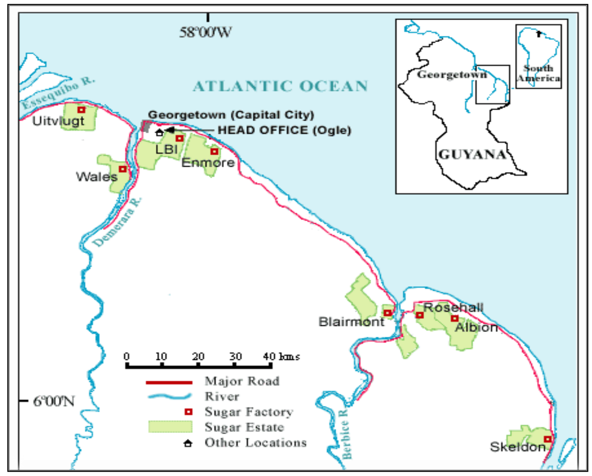

Figure 3. Sugar estates and factories in Guyana

2.2.1. Molasses

Molasses is a dark coloured, viscous liquid remaining after the crystallization of sugarcane juice. It can be used to produce ethanol through the two-stage process of fermentation and distillation. The purity of the ethanol can be enhanced by further dehydration. This process is exemplified at GUYSUCO's Bioethanol Plant located in Albion Sugar Estate, East Berbice-Corentyne. Locally, annual sugar production stood at 227,727 tonnes with approximately 91,090 tonnes of molasses in 2015. The bioethanol plant at Albion produces 1,000 L of ethanol per day at a rate of 250 L per tonne of molasses. Therefore, if all the molasses from annual sugar production is utilized, a total of 143,234 barrels of ethanol can be generated annually. Ethanol has about 2/3 energy of gasoline; this implies that 1.52 gallons of ethanol is needed to replace the energy in one gallon of gasoline (Pimentel and Patzek, 2005). Therefore, maximum ethanol production can eliminate 94,233 barrels of gasoline annually.

2.2.2. Bagasse

Bagasse is the fibrous remains of the cane stalk after crushing and extraction of the juice. Mill-run bagasse contains 48.0% fibre, 50.0% moisture and 2.0% soluble solids (Ramjeawon, 2008). For every 100 tonnes of sugarcane crushed, a sugar factory produces 10 tonnes of sugar and nearly 30 tonnes of bagasse (Birru, 2016).

Some bagasse is burned in a cogeneration process to heat boilers for the generation of steam and power to operate the sugar factory (Bohorquez et al., 2012). It is a carbon-neutral process since its carbon dioxide emission is equal to the carbon the sugar cane would have absorbed during its growth. If gasified the net calorific value of mill-run bagasse is 7,588 kJ/kg (Paturau, 1986). Guyana's annual sugar production of 227,727 tonnes generates approximately 683,181 tonnes of bagasse. This can produce approximately 5,465,448,000 MJ of energy annually. Such plants operate at an average of 77.5% efficiency depending on use (Akay and Jordan, 2011) consequently 4.0147×10^{12} BTU of energy will be harnessed. Hence, producing energy from bagasse can replace approximately 695,787 barrels of diesel.

2.2.3. Challenges and opportunities

Due to a binding agreement between GUYSUCO and a local rum making company, most of the molasses produced is sold to the company and other regional markets. Hence, there are no plans to make ethanol available to consumers. All the ethanol produced at the Albion Bioethanol Plant is used within GUYSUCO labs for sanitation purposes and in gasoline blends for Ministry of Agriculture vehicles. With moves being made to diversify the sugar industry, GUYSUCO plans to continue operating three estates and ethanol production is not the commodity of focus.

The bioethanol demonstration plant only serves to prove the applicability of this technology in Guyana. There are ongoing collaborations with neighbouring Brazil to obtain ethanol powered engines for Ministry of Agriculture vehicles. Upon the agreement of all stakeholders, ethanol production can be boosted at the demonstration plant and be used to power GUYSUCO's vehicles with 100% ethanol. With the sugar industry being diversified to include aquaculture, there is expectation that ethanol would be used to power the production cycle. Using GUYSUCO's lands for the cultivation of energy crops is also an option. There are long term research studies in progress to experiment on energy canes which are low in sugar, high in biomass and fast growing. These studies are vital to develop alternative uses for bagasse.

2.3. Bioenergy from forestry residues

Sawmills spread across Guyana (Figure 4). Wood waste (Figure 5) includes sawmill rejects, edgings, trimmings, veneer rejects, bark and saw dust from the logging industry (James et al., 2012). Over the years many mills regarded wood waste as a troublesome by-product of the sawmilling operation, resulting in incineration or disposal in the landfill. There is currently a 40% recovery rate of timber in Guyana coupled with a build-up of sawmill waste which poses a solid waste concern (Guyana Forestry Commission, 2012). In the year 2014, the forestry sector produced 406,433 m^3 of logs, 24,666 m^3 of round wood, 67,147 m3 of sawn wood and 41,372 m^3 of combined plywood and veneer (Guyana Forestry Commission, 2014). This resulted in approximately 273,248 m^3 or an equivalent of 81,974.4 tonnes residues being produced based on the conversions done according to the Waste Authority of Australia (2014). This has the potential to produce 631,202,880,000 BTU energy; equivalent of 109,393.87 barrels of diesel.

Figure 4. Sawmills in Guyana

Figure 5. Sawmill waste

2.3.1. Challenges and opportunities

Currently, some sawmill waste end up at the landfill and dump sites across the country. One major challenge faced by operators in utilization of their waste to produce energy is the high investment needed to implement a gasification system. An operator of a larger sawmill was interviewed, he indicated their attempt to privately source a gasification system was abandoned because of the high cost and long payback period (12 years). A smaller sawmill operator noted that the scale of his operation doesn't make the venture financially viable. Operators of both large and small sawmills indicated that it will not be possible for them to separate waste according to type since their wastes are commingled and is collected after a few days of operation.

It was noted that sawmills in Guyana utilize old equipment which results in lower efficiencies levels, hence producing more waste. Additionally, sawmilling operations are dispersed geographically with some logistical challenge making it impossible to consolidate waste from many sawmills. Also, the supply of waste is not reliable since some sawmills do not operate on a regular schedule. Finally, it is difficult to persuade operators to participate in such projects because of their resistance to change. Operators of wood processing facilities are encouraged by the Guyana Forestry Commission through their code of practice to recycle sawdust and wood shavings for animal bedding, waste as fuel to generate heat/power, to produce fuel briquettes and manufacture of charcoal. The final disposal of waste should be through a controlled incineration if all beneficial uses prove unsuccessful. Accumulation of waste in a dump or landfill is not acceptable.

2.4. Bioenergy using fuel crops

Guyana's climate, soil types and topography are suitable for cultivation, hence there is great potential for the cultivation of energy crops and the subsequent bioenergy production. The crops can be cultivated on marginal agriculture land so as to prevent competition with food production. Giant king grass (GKG), palm oil, hemp, cassava and jatropha are among the most common energy crops. When cultivated in tropical areas, the giant king grass can yield approximately 167 tons per acre per year and has an energy content of 18.4 MJ/kg (Davies, 2013). Hemp has an energy content of 16.98 MJ/kg (Komlajeva et al., 2012), non-food parts of cassava has an energy content of 16.2 MJ/kg (Zhu et al, 2015) while jatropha has an energy value of 38.2 MJ/kg (Pramanik, 2003).

2.4.1. Palm oil

Currently there is a palm oil estate in Barima -Waini Administrative district of Guyana that processes palm oil to produce biodiesel. This plant has the capacity to produce 300-600 barrels of biodiesel per month which is equal to the same quantity of fossil fuel-based diesel since they have the similar energy content.

Figure 6. Giant king grass

2.4.2. Giant king grass (GKG)

In Guyana, 2,980,836 ha of land is categorized as poor agricultural lands with fertilization potential due to the transportation cost of fertilizer to these areas (Government of Guyana, 2013). GKG (Figure 6) can be cultivated on these 2,980,836 ha of marginal lands unsuitable for food crops. This would eliminate the issue of competition for agricultural lands that could be used for planting food crops. It would also cut the cost of transporting fertilizer to these lands since this specie does not require fertilizer. GKG is a semi-annual crop, hence harvesting could be done twice per year. If cultivated on these marginal lands, 294,506,596.8 tons dry weight of GKG can be harvested annually, producing the equivalent of 806,447,594 barrels of diesel annually.

2.4.3. Challenges and opportunities

To avoid using agricultural land for energy crops instead of food, the focus is on utilizing marginal and poor agricultural lands for energy crops. Some of these lands are difficult to access and develop a cropping system because of their topography. It is anticipated that with continued infrastructural developments more of these lands would be accessible. Additionally, it is noted that GKG and Palm Oil attract better prices as raw materials, and producers are more inclined to take the most economical route.

The Caribbean Community Climate Change Centre (CCCCC) is currently conducting a pilot study to use the GKG and other species to produce propane and biogas. If the necessary funding and infrastructure are provided for the cultivation of fuel crops, Guyana could be able to produce bioenergy crops on a much larger scale.

2.5. Bioenergy (biogas) from cattle manure

Using an anaerobic digester, farm manure can be converted to biogas. Biogas is a mixture of colourless, flammable gases obtained by the anaerobic digestion of plant-based organic waste materials (Onwuliri et al., 2013). In the digester, bacteria decompose organic materials in the absence of air producing approximately 60% methane and 40% carbon dioxide (Kumar et al.,2014). Local examples of biodigester utilization are at the Guyana School of Agriculture, Mon Repos East Coast Demerara and the Flavour Shore Farmers group in Upper Demerara Administrative Region.

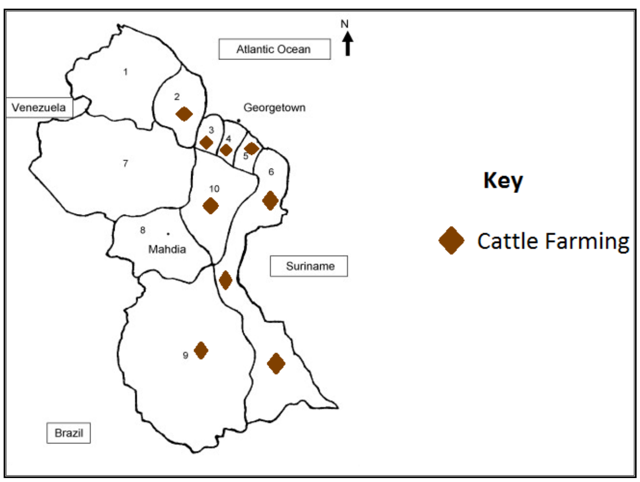

Figure 7. Administrative regions where cattle farming occurs

In Guyana there are approximately 220,000 – 250,000 heads of cattle being reared in seven (Figure 7) Administrative Regions (Milla and Ramirez, 2012). One such animal is estimated to produce on average of 23,200 BTU per day (Cuellar and Webber, 2008). Therefore, it is estimated that the total quantity of biogas that can be produced annually is 1.99×10^{12} BTU; the equivalent of 518,766 barrels Liquefied Petroleum Gas (LPG).

2.5.1. Challenges and opportunities

There are mixed views on the use of cow manure to produce biogas for cooking purposes. There is the assumption by farmers that there would be hygiene concerns while using digested manure for cooking. Cattle farmers were found to utilize a semi-intensive and an extensive farming system in such a way that there is not much accumulation of cow manure to the extent that it became a solid waste challenge.

A few decades ago, bio digesters were common among livestock farms however there has been a shift from this activity since the farm layout was labour intensive, the construction of the facility was expensive and the storage of the gas was problematic. Farmers are hesitant to adopt bio-digesting technology since there are no extension programs to assist in resolving these and any technical difficulties that would arise. Biodigestion are among the sustainable methods farmers are encouraged to adopt to manage waste. Recently, the Guyana Energy Agency has pledged its commitment to monitor and support the installation of bio-digesters for farmers as such this provides a unique opportunity for farmers to gain all the technical advice needed for bio-digester implementation.

2.6. Bioenergy (biogas) from urban and sub-urban wastes

In Guyana, total solid waste load is estimated as 545.66 tonnes per day from the most densely populated Administrative Region of the country (Demerara-Mahaica) with 405,225 persons (Ministry of Communities, 2016). Vegetables and putrescible materials account for 50.1% of the waste produced in Guyana (Ministry of Communities, 2016). Themelis and Uloa (2007) indicated that 50 Nm^3 of methane can be generated per ton of MSW landfilled and 5800 Nm^3 of such gas is equivalent to 27.4 MW. The total waste per year (199,165.9 tons) has the potential to produce an average of 9,958,295 m^3 of methane per year, an equivalent of 1.6×10^{11} BTU replacing an average of 41,846 barrels of LPG annually.

Majority of animal manure waste end up at the landfill where anaerobic bacteria decompose organic waste to produce biogas (carbon dioxide and methane) which are the major contributors of climate change. Methane is 25 times more detrimental in its influence on climate change than carbon dioxide. Once captured, the biogas can be treated and sold, or used to generate electricity. Re-directing this waste to bio-gas production would reduce the burden on landfills while

Table 1. Summary of the challenges and opportunities in the utilization of bioenergy sources in Guyana

Sources	Challenges	Opportunities
Sugar	✓ Small capacity of ethanol plant ✓ Small percentage of molasses used to produce ethanol ✓ Diversification of the sugar industry ✓ Greater profitability of molasses than ethanol	✓ Research being done on fuel cane ✓ Research being done on alternative uses of bagasse ✓ Sourcing of vehicles that run on 100% ethanol ✓ Prospects of using ethanol to power aquaculture operations
Rice	✓ 35% of rice husk being dumped ✓ High initial investment ✓ Char being dumped	✓ Collaboration with TERI and EESL to support and fund bioenergy projects ✓ Theopower introduced to Guyana
Forestry Residues	✓ High investment cost ✓ Old equipment resulting in low efficiency levels	✓ Baseline data is available ✓ GFC collaborating with logging companies to power Bartica using wood waste ✓ Operators are willing to transport waste to a point of collection
Crops as Feedstock	✓ Lack of investment ✓ Agricultural land being used to produce fuel crops ✓ Feedstock attract better price as raw material	✓ Caribbean Community Centre for Climate Change is conducting a pilot study to use giant king grass to produce propane and biogas
Cattle Manure	✓ Farmers have a negative perception on using manure to produce biogas ✓ Biogas digesters have high initial cost and it is labour intensive	✓ Currently under consideration
Urban and Sub-Urban Waste	✓ Small volume of waste will produce small volume of gas. ✓ Landfill is not equipped to capture gas. ✓ Waste is being landfilled in a commingled form.	✓ A study is being conducted to determine the feasibility of capturing biogas from the Haags Bosch landfill.
Sewage	✓ There is no treatment facility for sewage in Guyana. ✓ Limited sewage network coverage ✓ Lack of political will to invest in the sector	✓ Plans to construct a treatment facility within the next five years ✓ There are plans to develop sewage networks in Bartica and new housing schemes across Guyana ✓ GWI is partnering with CReW and IDB to treat waste then produce biogas
Summary - Bioenergy	✓ Cost of implementation is high ✓ Challenging to implement rather than solar energy ✓ Lack of funding ✓ Political interference ✓ Lack of public-private partnerships ✓ Lack of systems to accept power onto the national grid	✓ Collaborations with TERI and EESL will benefit the bioenergy sector ✓ The energy policy points to using mined-out lands for fuel crop production ✓ GUSUCO has the option of cultivating fuel crops as part of their diversification ✓ There is hope that revenue from oil extraction can be channelled to developing bioenergy and the renewable energy sector as a whole

providing environmentally friendly energy solutions.

2.6.1. Challenges and opportunities

Guyana's waste collection system does not require citizens to sort waste by metals, biodegradables and plastics. As it is, waste is collected and landfilled in a commingled form. Before biogas can be captured from landfills there needs to be a system where waste is separated by type. Currently, there is no facility in place to capture landfill gas. The feasibility of capturing landfill gas is being studied at one site. If implemented it can be a starting point for the country to obtain the most out of urban and sub urban waste.

2.7. Bioenergy (biogas) from sewage system

In rural parts of Guyana, there is no connection to the main urban sewage system. Residents, schools and other institutions commonly utilize a septic-tank system to manage their sewage. A septic tank is a holding reservoir where the faecal waste is flushed into via an inlet and stored. Settled solids are digested anaerobically while excess liquid, usually in a clear state is drained via an outlet into a drain field. Gases produced (biogas) escape through a vent attached to the tank.

Conservative estimate states that 125 g of sludge is produced per person per day (Gudulas et al., 2007). The urban population that utilizes the main sewage system (118,363) as stated in the 2012 National Census produces approximately 14.8 tonnes of sludge daily. 1 tonne of sludge produces approximately 270 m^3 of biogas (Qian et al., 2016) and 1 m^3 of biogas generates 1.25 kW of power (Vaid and Garg, 2013). Therefore 1,458,084.21 m^3 of biogas can being produced annually replacing 1622 barrels of LPG.

2.7.1. Challenges and opportunities

Sewage sludge is generated after the treatment of sewage therefore the lack of a treatment facility is the major impediment to the utilization of biogas from sewage. There is also a lack of sewage networks in the entire urban area, currently only 5% of its population has access to the network. It is anticipated that the populace would be skeptical in supporting such a development since there may be a fee collected from the residents which they may not be willing to pay to use the system. The initial task would be convincing the residents why it is beneficial to use it instead of septic tanks. Other challenges to the utilization of sewage sludge would be the setting up of sewerage networks in places other than the urban area, funding and sourcing skilled personnel to carry out such projects.

There are plans to develop sewerage networks in the entire city, the town of Bartica and in the new housing schemes. Considerations are being made to build a treatment facility to service the sewage network and another where local septic tank sludge collectors can treat their waste. After these facilities are up and running, sludge would then be available to be used to produce biogas.

3. COUNTRY OVERVIEW OF BIOENERGY POTENTIAL

Table 1 provides a summary of the challenges and opportunities that exist regarding the use of bioenergy from various sources. Although bioenergy is considered valuable and within the mix of sources to aid the country in achieving its renewable energy goals, it is not given priority in terms of funding and implementation. Additionally, levelling out local issues must be addressed before these technologies are implemented. For example, before selling excess power to the grid proper arrangements should be considered between the private sector and GPL (Guyana Power and Light Inc.), for the private investors to add power to the grid. Firstly GPL needs to be an equipped hybrid power generation company in order to accept power onto the grid (Gardner et al., 2014).

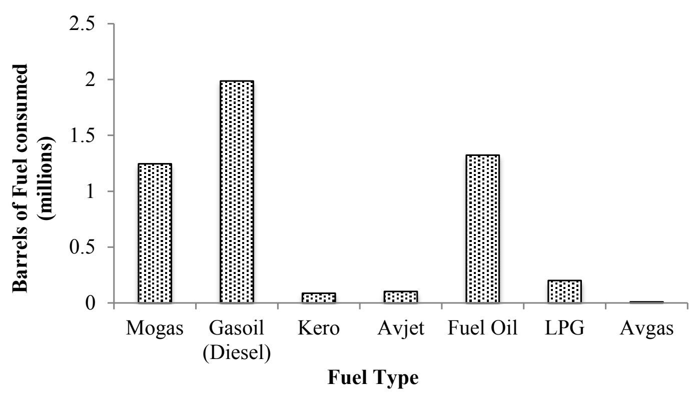

Figure 8. Guyana's fuel consumption 2015 (Guyana Energy Agency, 2015)

4. ECONOMIC IMPACT

Guyana imports 100% of its fossil fuel as illustrated in figure 8. The total cost of fuel importation for 2015 was pegged at US$355,201,732, with the average cost per barrel being US$71.02. While avgas, kero, avjet and fuel oil would not be replaced, mogas (gasoline), diesel and liquefied petroleum gas can be supplemented with bio fuels. Table 2 summarizes the potential

Table 2. Economic effect of using bioenergy

Fossil Fuel	Replaceable source	Replacement potential (BBRL)	Financial savings (US$)
Mogas	Ethanol Sugar production	94,233	6,692,428
LPG	Biogas Cow manure Landfill Sewage sludge	562,234	39,929,859
Diesel	Gasification Rice husk Bagasse Forestry residues Palm oil	915,444	65,014,823

savings from the usage of bioenergy. With bioenergy replacement there could be financial saving of US$ 111,637,110 which represents 31.43% of the current fuel expenditure. There could be a 46% replacement for diesel, 8% replacement of gasoline and a surplus of 360, 780 barrels of LPG equivalent.

Guyana has the potential to replace all of its annual energy demand of 4.6 x 10^{15} BTU estimated at US $57.2 billion with the gasification of the GKG. However, the form of the energy produced from GKG would not be compatible with all forms of use (liquid and gaseous). Therefore Guyana can trade GKG pellets produced to obtain the required energy forms.

5. ENVIRONMENTAL IMPACT

Climate change accelerants include water vapour, methane, nitrous oxide, sulphur dioxide, carbon dioxide and carbon monoxide. Sources of these accelerants include emissions from vehicles, manufacturing industries, power generation, burning of garbage, chlorofluorocarbons, charcoal production, deforestation and decomposition. In Guyana, the energy sector accounts for 53.94% of all emissions, agriculture 43.31% and waste disposal 2.75% (UNFCCC, 2004). Guyana imported 4,955,013 barrels of petroleum-based products in 2015 with an average of 13,575 barrels per day (Guyana Energy Agency, 2015). The utilization of bioenergy sources will not only allow zero net release of carbon dioxide but also eliminate the production of sulphur dioxide, nitrous oxides and particulates. The carbon in biomass (biogenic carbon) is the part of natural biosphere where the same amount of carbon would be released if the organic matter were left to decompose naturally in the environment. Carbon dioxide released during its combustion is offset by reabsorption from the plants it was produced.

Most cars in Guyana can operate on blends of gasoline/ethanol up to E10 (mixture of 10% ethanol and 90% gasoline). This would reduce emissions from the combustion of gasoline and specifically reduces carbon dioxide emissions by approximately 44,289.51 tons. Carbon dioxide emitted from the combustion of ethanol is sequestered by the sugarcane plants, hence there is no net release (de Oliveira et al., 2005).

Biodiesel (blended or pure) produces less emission and eliminates sulphur emissions entirely. Utilizing energy produced from gasification to supplement the diesel used for power generation can offset a substantial amount of GHG. Replacing the 915,470 barrels of diesel can reduce carbon dioxide emissions by 430,258.68 tonnes. While combustion releases carbon dioxide into the atmosphere, gasification is a cleaner method of conversion. Gasification systems use high temperatures in an oxygen-controlled environment to convert woody biomass into a gas (a mixture of hydrogen, carbon monoxide, and methane). The gas produced from this method is called synthesis gas and it is considered an environmentally safe alternative.

Applying comparative analysis as utilized by Kaltschmitt et al. (1997) and Prasad and Dhanya (2011), if bioenergy in the form of ethanol, biogas and synthesis gas is used to replace fossil fuel sources 35.7% carbon dioxide, 32.5% sulphur dioxide, 13.8% carbon monoxide, 9.9% particulates and 4.7% nitrogen oxides can be eliminated from the environment (Figure 9).

In the case of utilizing giant king grass, all the carbon dioxide currently dissipated into the atmosphere

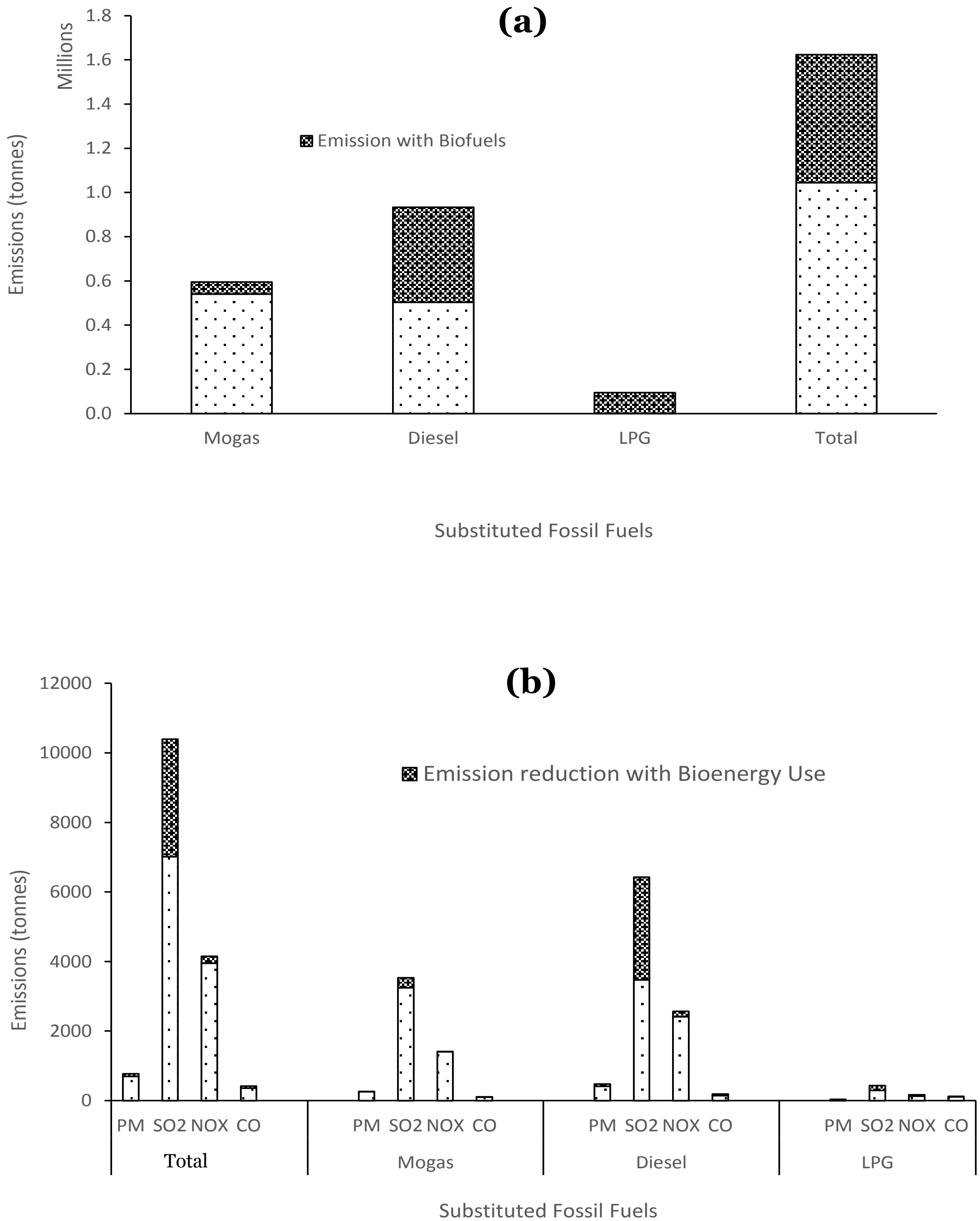

Figure 9. Comparison of emissions (a) carbon dioxide and (b) other common emissions from the substitution of selected bioenergy sources (US Energy Information Administration, 2016 and 2019; Kaltschmitt et al.,1997; Prasad and Dhanya, 2011)

could be eliminated and the surplus of 376,701,513 tons could be traded for carbon credits. Similarly, there will be reductions in release of particulate matter, sulphur dioxide but increases in nitrogen oxides and carbon monoxide.

6. CONCLUSIONS

This study assessed the possible effects of maximizing the use of bioenergy sources in Guyana. It sought to determine and quantify the bioenergy sources. Further, a comparative approach was used to investigate the use of bioenergy sources as a replacement for fossil fuel considering both economic and environmental effects. Impediments to their utilization were also identified through the relevant agencies. With these analyses, an assessment was made of the mitigating impact of bioenergy utilization on climate change in Guyana.

Bioenergy sources in Guyana include rice husk from rice production, residues from the forestry industry, biodiesel from palm oil, cogeneration of bagasse, bioethanol from the molasses, biogas from cattle manure, Georgetown's sewage sludge, and urban and suburban waste. However the bioenergy sector is faced with some general challenges of funding, lack of investment, farmer's unwillingness to adopt new technologies and profitability of some source materials. In the year 2015, Guyana imported 4,955,013 barrels of petroleum based products at a cost of US$355,201,732. The country can benefit from a saving of 31.43% of the current fuel expenditure should the aforementioned bioenergy sources be utilized to their maximum. While some fuel types cannot be replaced or supplemented, gasoline can be supplemented with ethanol, diesel with biodiesel and energy from cogeneration and liquefied petroleum fuel can be replaced by biogas.

Guyana is extremely vulnerable to the effects of climate change. Utilizing bioenergy sources to supplement petroleum based products can slow the process of climate change by lowering the net release of carbon dioxide and other greenhouse gases into the atmosphere. Cultivating energy crops on marginal lands can provide a plausible solution to the twin challenges of energy security and climate change mitigation. Future research should be conducted on the life cycle analysis of each bioenergy source in Guyana to provide detailed comparison on current quantity of emissions.

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