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The Bioenergy Potential of Guyana's Sugarcane Yield: An Alternative Use of the Sugarcane Harvest for GuySuCo

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Abstract
Guyana is undertaking a green energy transition, in which renewable energy sources will replace fossil fuels. Therefore, bioenergy conversion can play a significant role in providing an alternative source of clean energy. Although GuySuCo is currently facing challenges, there is renewed interest in resuscitating it as Guyana's largest sugarcane cultivator and producer. This paper examines the potential of using the sugarcane yield of GuySuco to produce bioenergy. The researcher does not recommend abandoning sugar production, which GuySuCo has a long history of, but rather transitioning to bioenergy products. First, 25% of the sugarcane harvest can be dedicated to the production of ethanol from the sucrose and maltose of sugarcane juice, and 25% of sugarcane bagasse can be used to generate energy via direct combustion. The cellulose, hemicellulose and lignin in the bagasse, once combusted, provide more energy than the ethanol from 25% of the sugarcane yield. This paper will focus on the 2017 and 2022 harvests, in which GuySuCo produced 1,859,037 tonnes and 700,149 tonnes of sugarcane, respectively, as these are the maximum and minimum yields for the 2017 – 2022 period. The Ethanol that GuySoCo can produce based on these years is 2.6143×10^4 tonnes in 2017 and 9.8458×10^3 tonnes in 2022, using only 25% of the sugarcane harvest. The bagasse from the 2017 harvests would be 1.5105×10^5 tonnes from 4.6476×10^5 tonnes of sugarcane producing 5.1084×10^8MWh of energy. For 25% of the 2022 harvest would correspond to 1.7504×10^5 tonnes of sugarcane leaving 5.6887×10^4 tonnes of bagasse, the direct combustion of this bagasse would produce 1.9239×10^8MWh of energy.

Keywords- Bioenergy, Biofuel, Direct combustion, Energy conversion, Ethanol, GuySuCo, MATLAB, Methane, Sugarcane & Sugarcane juice.

1. Introduction and Problem Definition

1.1 Sugarcane Engineering

Solar irradiation, carbohydrate production, and the uptake of water contribute to the growth of the sugarcane stalk. The biorefinery production cycle has an exergy efficiency for sugarcane at 4.99%. From the exergy, we can generate $17.866\ \mathrm{kWh/m^2}$. The exergy efficiency of solar panels is 31.6% with an electrical energy production of $255.84\ \mathrm{kWh/m^2}$. Consequently, photovoltaic models can be used with sugarcane to decrease Brazil's dependence on fossil fuels. This progressive view of Brazil can be applied to many other countries globally (Righetto and Mady, 2024).

Microorganisms play a vital role in the degradation of sugarcane leaves for conversion into nutrients. Bacteria are involved in material transformation, especially in the subtropical soil of Southern China. The degraded leaf can be used as an alternative to fertiliser. The bacterial communities that do the degradation are diverse, but bacterial networks are present everywhere in nature, on Earth. The bacterial communities consist of *Acidobacteria*, *Actinobacteria* and *Bacteroidetes* and are found across all treatments of the sugarcane leaf return. The bacterial networks are correlated to the potassium (K) and nitrogen (N) matter in the soil. Increasing the complexity of the soil bacteria will benefit the sugarcane plant production and the health of the soil from the degradation of the sugarcane leaf (Liu et al., 2024b).

The world population and electricity demands are increasing. Urbanisation and industrialisation pose environmental concerns as fossil fuels remain the major source of energy. Alternative energy resources, such as biofuel, will have increased importance as fossil fuels become scarce. There is a large potential for feedstock in biofuels. Sugar and fibre content are favourable to energy production. The fermentation of sugar to ethanol is a source for future biofuels. The use of crops for bioethanol requires an industrial procedure that can meet the demand for foodstuffs as well as an energy resource. This requires a scientific intervention that will build bridges between science and industry for investigation and research, leading to an industry that can deal with the new technologies of bioenergy (Thorat et al., 2024a).

Table 1. Different generations of biofuel production (Thorat et al., 2024a).

Generations of biofuel	Description
1 G	Food from crops, hydrolysis and the fermentation process.
2 G	Having non-food crops, lignocellulosic agriculture and animal biomass for thermochemical methods.
3 G	Energy from algae and other microbial processes. Having fast-growing feedstock and other sources. Biothermal processes and methods via dewatering.
4 G	Using genetically engineered algae with alterations of cellular metabolism will lead to high production rates and CO_2 capture, with bio-thermochemical processes and methods for dewatering.

Table 1 shows the generations of biofuel development. The Sustainable Development Goals (SDGs) of the United Nations prioritise clean energy solutions to mitigate climate change. The Bangladesh agricultural sector produces a significant amount of biomass that can be utilised for renewable energy as an alternative to fossil fuels. The physical properties of biomass were studied, and the volatile matter and components of sugarcane and rice straw were examined. Advanced technologies in bioenergy would be required for the transition from fossil fuels (Kamruzzaman et al., 2024). There has been an increasing demand for food, fodder and fuel for the population. Sugarcane has the potential to be the needed feedstock for biofuel to be productive. Sugarcane can be a driver and a sweetener in this global transition for biofuels. It has a biomass capacity of carbohydrates, sugar and fibre that is favourable to energy production. Sugarcane can absorb CO_2 emissions as a carbon sink (Thorat et al., 2024b).

The evaluation of cultivation methods for the efficiency of sugarcane crop growth can be configured so that the solar radiation is effectively converted into biomass. The sugarcane varieties can be cultivated in single spacing or other combined spacing. The biometric and solarmetric measurements can be evaluated for the canopy on a coefficient for radiation specified for how much energy can be stored in the dry matter, and then converted to useful energy (Ferreira Jr. et al., 2015).

First-generation biorefineries can be fashioned to produce polyethene terephthalate or its monomers (Louw et al., 2024). Dark co-generation can produce biohydrogen from agricultural waste and is a promising technology for sustainable energy. Sugar substrates, especially vinasse and bagasse, can be hydrolysed and acidified to produce conditions of biohydrogen production (Rashidi et al., 2024). The diversification of sugarcane mills is becoming essential for the sustainable development of the sugarcane industry. It is economically feasible to have biorefineries and sugarcane mill simulations and analysis to produce citric acid from sugarcane feedstock (Gouws et al., 2024).

Biorefinery scenarios can simulate the techno-economics of sorbitol co-produced with fructose from molasses (van Heerden et al., 2024). Residue from the poultry supply chain can be used in aerobic digestion for the co-digestion process. Sugarcane juice can be used in the production of energy from anaerobic co-digestion with the chicken slaughter residue, to improve production (Restrepo et al., 2022). Soda pretreatment of sugarcane bagasse can be up-scaled by introducing a redox mediator such as 2-hydroxynaphthalene-1,4-dione, which can be obtained by renewable energy sources and does not affect hydrolysis or fermentation. A fed-batch method was used to load the solid, which increased the loading ability by 10% to 15%. This maximised the sugar concentration by 142 g/L after 72 hrs of hydrolysis. The sugarcane-rich hydroxylate maximises the ethanol production of 61.3 g/L and after fermentation, the energy produced was 21.11 MJ with a 1G biorefinery. A 2G biorefinery would enhance the ethanol potential and improve the efficiency (da Silva Barreto et al., 2025).

There are microorganisms found in sugarcane juice; the genome of the main strain can be sequenced, as it accounts for *Leuconostoc mesenteroides* accounting for 39.89% (Su et al., 2024). Toxic heavy metal-contaminated soils pose a challenge for productive agricultural systems. In contrast, agricultural waste can exhibit a promising potential for removing toxic heavy metals, as bagasse can absorb toxic heavy metals better when in aquatic systems (Liu et al., 2024a). Efficient irrigation is essential for marginal profits for sugarcane crops. Weather forecasting is essential for agricultural decisions; studies must be incorporated to optimise irrigation management. To generate the forecast and ensemble irrigation indices can be produced from numerical weather prediction conditions (Schepen et al., 2024). Genetic engineering can reduce sugarcane cell walls and reduce the lignocellulose recalcitrance CRISPR/Cas9 technique. The genetic engineering of sugarcane can be a feature to enhance energy production for biorefineries (Laksana et al., 2024).

1.2 Sugarcane to Bioenergy

The disposal of sugarcane bagasse is often done through dumping, which is environmental pollution. The implementation of technologies that are deployable, for instance, in recycling technologies, the production of bio-oil can be undertaken, which has significant value. Utilising the sugarcane bagasse to create bio-oils is an alternative to pollution. Sugarcane bagasse is a functionally and economically viable alternative energy source, and it is environmentally friendly (Hidayana et al., 2024).

The mitigation of agro-industrial waste is crucial to lowering pollution. Sugarcane bagasse is a sustainable biomass that can be used to generate energy. It is derived from the sugarcane industry after the extraction of the sugarcane juice. Some mills use bagasse as a fuel, but a significant portion of it is just incinerated on site, as it is highly flammable and poses a significant safety risk. The conversion of agricultural waste into biochar is an efficient means of harnessing energy. There is interest in trying to form biomass into a high-value product like biochar, biogas and biofuel (Zafeer et al., 2024).

Sugarcane to ethanol conversion occurs in a series of processes, from an energy-intensive extraction process to concentration and finally to the fermentation of the sugarcane juice. Solid-state fermentation occurs in the absence of free water and has the potential for higher product concentration, reducing the water required and the liquid effluent of the process (van Dyk et al., 2025). Bioenergy production from sugarcane can contribute to biogas-derived electricity and biomethane production. Nevertheless, biomethane is a greenhouse gas. The State of São Paulo in Brazil holds 45% of the ethanol-producing plants, which meet the consumption demand of 6.5 million inhabitants. Biomethane production can potentially replace the need for diesel in the state, which stands at 26%. Utilising biogas is necessary to prevent the emission of greenhouse gases such as methane when produced in controlled conditions (de Melo et al., 2024).

CRISPR-Ca9 technology can be used to enhance the genetic traits of sugarcane to produce biofuel. Genetic engineering can transform the role of sugarcane as a bioenergy crop. Sugarcane is a good source of biomass for renewable energy and is valued as a sustainable source of second-generation biofuel. Enhancing the traits of sugarcane to improve critical biomass yields and biofuel production is a pertinent application of biotechnology. It can effectively raise biomass output for the manufacture of bioethanol. When sugarcane production is feasible, it can become a reliable source for biofuels, increasing the efficiency of the biofuel industry and making its impact scalable to meet market demands. It would be economically and environmentally sustainable with the development of a superior sugarcane variety for use as a bioenergy crop (Ahmad et al., 2024).

1.3 Brief History of GuySuCo

The Government of Guyana nationalised the sugar industry, which was operated by Booker Sugar Estates Limited and Jessels Holdings, and merged them to form the Guyana Sugar Corporation on May 21, 1976. The company would later become Guyana Sugar Corporation Inc. with the enactment of the Companies Act of 1991 (Guyana Sugar Corporation, 2023a).

Figure 1. Train used in the harvesting of sugarcane (Guyana Sugar Corporation, 2023a).

Figure 1 shows a train being used in harvesting. By 1967, there were 18 estates with 11 factories; 9 of the factories were owned or managed by Booker McConnell Limited. The other 2 factories were owned by the Demerara Company. The total acreage was 113,474 acres (Guyana Sugar Corporation, 2023a). In 1975 Demerara Company was nationalised and formed DEMSUCO, and acquired Booker Sugar Estates on May 21, 1976. The new acquisitions were added to the Demerara Sugar Corporation and amalgamated into the Guyana Sugar Corporation – GuySuCo (Guyana Sugar Corporation, 2023a).

With the collapse of the EU preferential market in the early 2000s, Guyana has faced many challenges to remain competitive in the world's sugar market. During 2015 – 2019, the estates of Enmore, Rose Hall, Wales and Skeldon were decommissioned by the A Partnership for National Unity + Alliance For Change (APNU+AFC) government, which only left Blairmont, Uitvlugt and Albion as estates in the corporation. Nonetheless, in 2020, with the re-election of the People's Progressive Party/Civic (PPP/C), financial resources were injected into the sugar industry, and the Rose Hall estate was resuscitated in 2023, with the Enmore and Skeldon Estates to be resuscitated in the future (Guyana Sugar Corporation, 2023a).

1.4 Research Objectives

The objectives of the research are to be able to determine the bioenergy potential of Guyana, particularly the sugarcane sector, using data on the harvest of GuySuCo. The research will utilise sugarcane juice to produce bioethanol and biomethane, and determine how much electrical energy can be obtained from their conversion. The bagasse or waste from the sugarcane harvest can be used to produce energy using direct combustion. The conversion of sucrose and maltose can be done to form bioethanol or biomethane. The inspiration for this research is the Bioenergy I and Bioenergy II courses at the University of the West Indies, in which the researcher first began computing bioenergy products for a biodigester with MATLAB.

The framework for the conversion of bioethanol and biomethane will be researched, along with the chemical equations for the combustion of bagasse. The researcher will also use ChatGPT and Copilot, which are artificial intelligence tools to assist in focusing the research and brainstorming ideas. The research is primarily computational, with the MATLAB environment being used to build the Graphical User Interface (GUI) apps, which would be programmed to perform the calculations. The computation will be done for 25%, 50%, 75% and 100% of sugarcane yield. The bagasse will be computed for the same percentages of sugarcane yield and then converted into energy via direct combustion. The yearly production for 6 years, 2017 – 2022, for GuySuCo will be used to compute bioethanol, biomethane potential and energy that can be extracted from sugarcane juice conversion, the bagasse that is leftover and its direct combustion into energy.

2. Literature Review

2.1 Sugarcane to Energy

Bioethanol is a fuel that can potentially fill the need for gasoline, as it has similar but superior properties. It can help to decrease emissions. It can be produced effectively from sugarcane. The market is flooded with sugarcane; consequently, bioethanol can be feasibly produced from sugarcane. There is a global concern about greenhouse gases that are accelerating the warming of the planet. Bioethanol has the potential to replace fossil fuels and aid mankind in meeting our environmental goals. The world experienced its first oil crisis in the 1970s, which highlighted fossil fuel dependence. Price-taking nations began to look for an alternative energy resource to decrease their dependence on fossil fuels (Kabeyi et al., 2022).

In Mexico, during the harvest time in 2021 – 2022, 54.6 million tonnes of raw-milled sugarcane were made. This makes Mexico the sixth-largest producer of sugarcane in the world. Sugarcane can be used to co-produce energy, which includes generation from bagasse. The process that is involved in the generation of energy involves combustion, with nearly 25% of the weight being converted to greenhouse gases. Producing so much greenhouse gas will pose a problem for environmentalists. Combustion of sugarcane for generation needs to align with the sustainable goals, and the valorisation should be promoted for diversification of the electricity supply (Contreras et al., 2023).

Biofuels will become an essential part of the energy transition as the times change, but they will have an impact on land use. Policies to reduce the carbon footprint and metal analysis of sugarcane crops are needed for the management of the fields. Converting the native vegetation of sugarcane into useful energy and the conversion of the annual crop yield into energy with pastures of sugarcane over 20 years need to be studied. The interaction of soil texture regarding the straw and fibres of the sugarcane will dictate the feedstock for any fermentation process or milling needed. Public policy will initiate future life cycle assessment modelling for sugarcane biofuel production (Junior et al., 2024). In Louisiana, 11.7 million Mg of millable sugarcane, 1.47 million Mg of raw sugar and 3.5 million Mg of bagasse; therefore, the conversion of sugar to energy would be necessary for all that vast amount of material (Webber III et al., 2018).

Sugarcane is one of the oldest crops that has been cultivated by humans. The burning of sugarcane poses environmental concerns, especially when farmers do it to facilitate harvesting. The leaves can be managed, and sugarcane management can be turned into a business model. Using the leaves, convert them into biomass for power plants, so farmers can grow their crops and produce biomass. An economic analysis was done, and it was seen that a payback period of 1.72 years, plus an even longer payback period of 2.06 years, was required for a strategic enhancement of biomass to waste for the mitigation of pollution (Borisoot et al., 2024).

2.2 Bagasse to Energy

Biorefineries can operate on sugarcane bagasse to produce energy and heat. Brazilian sugarcane has been studied for its biomass potential, chemical and physical properties, which influence energy conversion (Moreira et al, 2017). The techniques are being improved for the development of clean energy. Bioethanol is an important renewable fuel. The life cycle of bioethanol can be explored from the sugarcane to bagasse and the final conversion to energy. Bagasse can be fermented for the conversion process or burned. Bioethanol can be used as an alternative to diesel fuel, and the process of production can make nitrates that can be used as fertiliser. Fossil fuels contribute to air pollution and acid rain that can damage forests and harm wildlife. Bioethanol from sugarcane bagasse requires a lot of feedstock to produce the energy.

There is a cost-efficient way to treat bagasse and turn it into biogas. Sugarcane can be grown abundantly in tropical countries, but there are structural hindrances for developing countries to produce biogas. There are different pretreatment methods; broadly, there are physical pretreatment, chemical pretreatment, physicochemical pretreatment and biological pretreatment methods for sugarcane conversion to bioenergy. Successful pretreatment can enhance the efficiency of the biogas produced from sugarcane. The structure of the lignocellulose in sugarcane must be broken down. A designed biodigester cannot handle the fibres of the bagasse without pretreatment, or there is a risk of clogging the biodigester. For maximum pretreatment, there needs to be delignification to produce maximum biogas, which can be achieved by loading 1% sodium hydroxide (NaOH) to enhance biogas production (Sethi et al., 2024).

2.3 Other Uses of Sugarcane

Utilising the extract of sugarcane has a growing interest in academic circles as the extracts have valuable nutrition. Animals can be fed the extracts, as immune supplements, made from sugarcane, which can boost the immune system. Supplements from sugarcane have a promising future as they positively influence the animals' lives. It can be used for swine and aquaculture to boost immunity and growth performance (Edirisinghe et al., 2024).

Sugarcane is a good source of biomass, which in turn can be used to produce energy, but the potential has repercussions that will have to be mitigated. The sugarcane will produce waste that can be pre-treated and burnt to produce energy. One challenge to the sugarcane industry is the cost of irrigation, which affects small-scale grower, yet they can supplement their income through energy generation from biowaste. The burning of sugarcane waste is a common practice, which allows for a high energy potential that can fill the need in the energy market. Other methods of converting sugarcane to energy can save on the emissions to the atmosphere that burning would create. The estimated energy for 330 small-scale farmers in South Africa, with a 50% recovery efficiency and a 36% energy conversion, is 150,323.3 MWh (Chipfupa and Tagwi, 2024).

Acrylic acid can be obtained directly from the microbial conversion of sugar. It has environmental and economic benefits as it is done biologically. For a large implementation of direct microbial conversion, the selling pitch must be the greenhouse gases associated with the conversion. Typically, sugarcane is milled for fermentation, but this process of microbial conversion has 97.5% less greenhouse gases. The energy produced by this system would be less than the fossil fuel prices. It is desirable to have fermentation, but the feedstock needs to be continually fed, where the microbes in the fermenter can produce acrylic acid (Sikazwe et al., 2025).

Sugarcane molasses is rich in sucrose, fructose and glucose; hence, it can be used as a carbon source for industrial fermentation at a low cost (Kim et al., 2024). A cross Holstein and zebra steer was fed a diet containing sugarcane with two levels of concentrate 30% and 70%. The steer was reported to have a high dry matter for its faeces of 25% to 60% higher compared to a diet without sugarcane. There was an average daily weight gain for the steer that had a diet of sugarcane concentrate (Vieira et al., 2017).

2.4 Other Uses of Bagasse

In sugarcane cultivation, several factors impair growth, including nutrient depletion due to monocropping, salinity stress, water stress and temperature stress. The biomass conversion is a thermochemical process. Sugarcane can also be grown using biochar to amend soil fertility. Biochar can help with water stress by increasing the mass of the root system. The sugarcane root grows differently at different stages in its development. The sugarcane crop can overcome the stresses of its development by using biochar (Iwuozor et al., 2024).

China is one of the largest sugarcane-producing countries globally. This leaves a lot of waste from bagasse, abundant in the industry. The inclination is to landfill the bagasse, but there is a current call to utilise it comprehensively. The use of biologically activated carbon, via the pre-carbonisation of potassium hydroxide (KOH), in the activation process. This will make electrodes for rechargeable zinc-air batteries. When considering long-term battery usage, rechargeable batteries are optimum with a life cycle that can last 250 hrs. Hence, the carbon electrode can be derived from sugarcane, as it is a potential carbon source for zinc-air batteries (Deng et al., 2024).

Bagasse is fibrous after the removal of sucrose and other impurities. Sugarcane bagasse can be used to produce power. It is profitable to use thermal conversion processes from the bagasse and produce sugarcane ash as a result. The sugarcane ash can then be used in commercial greenhouses to aid in the fertility of the soil and spur increased plant growth of seedlings. Sugarcane bagasse ash can impact the pH of the soil and its organic matter. Increased use of sugarcane bagasse ash has been seen to enhance the growth of Chinese kale seedlings. It can be used as an additive growth medium to increase harvests. The harvest has peaked with 25% sugarcane bagasse ash, and increasing the bagasse ash after that percentage does not markedly increase growth. It is not costly to produce sugarcane bagasse ash as materials are gained directly from the sugarcane industry. Increasing the sugarcane bagasse ash to 50% is not recommended (Webber III et al., 2017).

3. Data and Method

3.1 Data Collection

The data that is needed for this research is the sugarcane production tonnage from GuySuCo. This information can be obtained from annual reports from GuySuCo, so there is no need to physically request data from GuySuCo, as the annual reports are already online on the website of GuySuCo. Contrastingly, in the later years after 2017 – 2022, specifically 2023 and 2024, the annual reports are not available on the GuySuCo company website. There, in contrast, are articles written in the local newspapers that have been written with production figures on GuySuCo, in which they state the production figures, but no article states the sugarcane yield in tonnes. The sucrose content maltose content of sugarcane will be researched. The tonnage of bagasse from sugarcane production will be computed from the percentage of bagasse in the average sugarcane crop globally.

3.2 MATLAB App Sugarcane Juice (Ethanol, Methane and Energy)

GuySuCo uses sugarcane to produce sugar; the end of preferential prices in the European Union means that GuySuCo is not profitable as an industry, which prompted the closure of many estates under the APNU+AFC government. This research suggests alternative uses of sugarcane in Guyana to make bioethanol and biomethane, plus to obtain energy. A GUI app will be created in MATLAB to compute the bioethanol potential, biomethane potential and energy potential in MWh from sugarcane contents such as sucrose and protein. The researcher recognises that not all the sugar may be converted away from sugarcane production by GuySuCo, so computations for the conversion of 25%, 50%, 75% and 100% will be done. The years the computation will be done for are 2017 – 2022. This was chosen since it is a six-year interval. A longer period of study can be a calculation for work in the future. For this research, there is no consideration for cogeneration with other crops. Those can be a source of research for future work.

3.3 MATLAB App Bagasse (Combustion to Energy)

There is a lot of waste bagasse from the extraction of sugarcane juice from sugarcane. These fibres are, in some cases, burned or landfilled in various countries. This wastes the biomass energy potential. If they must be burnt to dispose of them, direct combustion should be used to generate electricity. For this research, the researcher will not explore the means of converting the heat energy from direct combustion into electricity, but will compute the energy that is stored in bagasse that can be used for generation. To convert the bagasse to energy, the researcher will have to first compute the bagasse from the tonnage of sugarcane produced by GuySuCo. This computation can be based on a percentage of bagasse normally found in sugarcane from scientific articles. Once the amount of bagasse is obtained, it can be combusted to produce energy. The researcher will do the estimation for 25%, 50%, 75%, and 100% combustion of the bagasse. Artificial intelligence will be referred to in the research mainly to aid the researcher in brainstorming ideas.

4. Results

4.1 Data Collection and Formula

The essential data and formula that were needed for the conduct of this study were gathered from GuySuCo production figures on sugarcane yield from the working estates. The components of sugarcane and bagasse, in addition to the necessary formula critical for computation, were obtained from research and the use of artificial intelligence.

Table 2. GuySuCo sugarcane yield (tonnes).

Year	Sugarcane yield (tonnes)
2017	1,859,037 (Guyana Sugar Corporation Inc., 2023b)
2018	1,214,495 (Guyana Sugar Corporation Inc., 2023c)
2019	1,119,149 (Guyana Sugar Corporation Inc., 2023d)
2020	1,217,154 (Guyana Sugar Corporation Inc., 2023e)
2021	830,526 (Guyana Sugar Corporation Inc., 2024a)
2022	700,149 (Guyana Sugar Corporation Inc., 2024b)

Table 2 depicts the tonnage of the yield of GuySuCo sugarcane harvest in tonnes. From the available data on the years 2017 – 2022, 2017 had the largest harvest. This is before the closure of 3 of 6 estates of GuySuCo. Therefore, the 2018 sugarcane harvest reflects a lower tonnage, being a harvest from just 3 estates. One of the remaining 3 estates was again closed in 2020, and the 2021 sugarcane harvest is lower still. The lowest harvest experience was in 2022; this reflects the harvest from only 2 estates. The reason for the closure of the estates was the lack of profitability of sugarcane cultivation in Guyana. GuySuCo has been a battleground of the main political parties in Guyana, with the APNU+AFC government closing many estates and the PPP/C government reopening Rose Hall Estate with plans to reopen the others. To make Sugarcane viable, the research suggests growing sugarcane as an alternative product to sugar as bioethanol, biomethane and energy to foster the transitions to renewable energy, particularly bioenergy.

Table 3. Components of sugarcane used in computation.

Molecule	Estimated percentage of sugarcane
Sucrose ($C_{12}H_{22}O_{11}$)	12.5%
Maltose ($C_6H_{10}O_5$)	5%
Bagasse	32.5%

Table 3 outlines the estimated percentages for the components of sugarcane that are the focus of this research. For this research, sucrose and maltose were converted to ethanol or methane. The ethanol or the methane was then, in turn, converted to energy. The sucrose and maltose were used in the Sugarcane Juice Conversion App. Bagasse was derived from sugarcane tonnage by the Bagasse Conversion App and then converted into energy by direct combustion. The components of sugarcane used in this research are given in the above table as a percentage of sugarcane.

Table 4. Components of bagasse used in computation.

Molecule	Estimated percentage of bagasse
Cellulose ($C_6H_{10}O_5(n)$)	45%
Hemicellulose – Xylose (Pentose) ($C_5H_{10}O_5$)	25%
Lignin ($C_9H_{10}O_3$)	25%

Table 4 gives the percentages of the components of bagasse. In the Bagasse Conversion App, the bagasse was derived from sugarcane tonnage. The bagasse in tonnes was converted into cellulose, hemicellulose and lignin. The hemicellulose in sugarcane is xylose, which is a pentose. The percentage estimates of bagasse's components used in this research are shown above.

Anaerobic Digestion

$$C_{12}H_{22}O_{11}(\text{Sucrose}) + H_2O \rightarrow 6CH_4(\text{Methane}) + 6CO_2 \quad (1)$$

(i) the conversion of sucrose into methane.

Enzyme

$$C_6H_{10}O_5(\text{Maltose}) + H_2O \rightarrow 3CH_4(\text{Methane}) + 3CO_2 \quad (2)$$

(ii) the conversion of maltose into methane is given by the above chemical formula.

Yeast

$$C_{12}H_{22}O_{11}(\text{Sucrose}) + H_2O \rightarrow 4C_2H_5OH(\text{Ethanol}) + 4CO_2 \quad (3)$$

(iii) shows that yeast is required for the conversion of sucrose into ethanol. The above chemical formula reflects that relationship.

Yeast

$$C_6H_{12}O_5(\text{Maltose}) + H_2O \rightarrow 2C_2H_5OH(\text{Ethanol}) + 2CO_2 \quad (4)$$

(iv) shows that yeast is required to convert maltose into ethanol. The above chemical formula reflects that conversion.

Ethanol Combustion

$$C_2H_5OH(\text{Ethanol}) + 3O_2 \rightarrow 2CO_2 + H_2O + 1{,}367\ \text{kJ/mol} \quad (5)$$

(v) the ethanol produced from the sucrose and maltose can be converted into energy by combustion. This formula reflects the production of energy from the combustion of ethanol.

Methane Combustion

$$CH_4(\text{Methane}) + 2O_2 \rightarrow CO_2 + 2H_2O + 890\ \text{kJ/mol} \quad (6)$$

(vi) the methane was also produced from maltose and sucrose. The methane can be combusted to produce energy. This formula reflects that combustion.

Cellulose Combustion

$$C_6H_{10}O_5(n)(\text{Cellulose}) + 6O_2 \rightarrow 6CO_2 + 5H_2O + 2{,}934.6\ \text{MJ/mol} \quad (7)$$

(vii) the cellulose is a component of bagasse; to compute the energy released from bagasse, the energy produced from its components is needed. This formula reflects the combustion of cellulose.

Hemicellulose Combustion

$$C_5H_{10}O_5\ (\text{Hemicellulose} - \text{Xylose (Pentose)}) + 5O_2 \rightarrow 5CO_2 + 5H_2O + 2{,}400\ \text{MJ/mol} \quad (8)$$

(viii) the energy derived from the combustion of hemicellulose was also computed and added to that of the other components of bagasse, to give the total energy released from bagasse. The hemicellulose for sugarcanes is xylose, which is a pentose.

Lignin Combustion

$$C_9H_{10}O_3\ (\text{Lignin}) + 10O_2 \rightarrow 9CO_2 + 5H_2O + 15.6\ \text{MJ/mol} \quad (9)$$

(ix) the last component of interest in bagasse was lignin. The energy released from the lignin was calculated and added to the other components of bagasse. This allowed the derivation of the total energy produced from the direct combustion of bagasse.

Conversion between MJ and MWh

$$\text{Energy (MWh)} = \text{Energy (MJ)} \times \frac{1\ \text{MWh}}{3{,}600\ \text{MJ}} \quad (10)$$

(x) shows how that energy was computed in MJ and then converted to MWh, as this unit of energy is used in power engineering for energy produced.

Conversion between kJ/mol and MJ/mol

$$1\,\frac{\text{kJ}}{\text{mol}} = \frac{1}{1{,}000}\,\frac{\text{MJ}}{\text{mol}} \quad (11)$$

(xi) shows how the energy per mol is converted in the research.

Conversion between MJ and MJ/mol

$$\text{Energy (MJ)} = \text{Number of Moles (mol)} \times \text{Energy}\left(\frac{\text{MJ}}{\text{mol}}\right) \quad (12)$$

(xii) shows the conversion needed to derive the energy in MJ.

4.2 Sugarcane Juice Conversion App Results

The results displayed in the following reflect the computed output of the Sugarcane Juice Conversion App. The app takes as input the sugarcane tonnage of the studied year 2017 – 2022 of GuySuCo. The sugarcane tonnage was computed as either 25%, 50%, 75% or 100% of the sugarcane yield. From the sugarcane tonnage, the tonnage of either ethanol or methane was calculated. Lastly, the ethanol and methane tonnage were converted to energy production.

Table 5. Estimated ethanol, methane and energy yield from 25% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Ethanol (tonnes)	Methane (tonnes)	Energy from ethanol (MWh)	Energy from methane (MWh)
2017	4.6475×10^5	2.6143×10^4	1.7428×10^4	2.1580×10^5	2.6929×10^5
2018	3.0362×10^5	1.7079×10^4	1.1386×10^4	1.4098×10^5	1.7593×10^5
2019	2.7979×10^5	1.5738×10^4	1.0492×10^4	1.2991×10^5	1.6212×10^5
2020	3.0429×10^5	1.7116×10^4	1.1411×10^4	1.4129×10^5	1.7631×10^5
2021	2.0763×10^5	1.1679×10^4	7.7862×10^3	9.6410×10^5	1.2031×10^5
2022	1.7504×10^5	9.8458×10^3	6.5639×10^3	8.1276×10^4	1.0142×10^5

Table 5 shows the tonnage of ethanol and methane using 25% of the sugarcane yield, plus the energy produced when they are combusted. When 25% of the sugarcane was converted into ethanol or methane. The ethanol and methane were converted into energy each year. The methane converts into more energy overall. The ethanol, nevertheless, could have alternative usage as biofuels for vehicles.

Table 6. Estimated ethanol, methane and energy yield from 50% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Ethanol (tonnes)	Methane (tonnes)	Energy from ethanol (MWh)	Energy from methane (MWh)
2017	9.2952×10^5	5.2285×10^4	3.4857×10^4	4.3161×10^5	5.3859×10^5
2018	6.0725×10^5	3.4158×10^4	2.2772×10^4	2.8197×10^5	3.5186×10^5
2019	5.5957×10^5	3.1476×10^4	2.09884×10^4	2.5983×10^5	3.2423×10^5
2020	608,577	3.4232×10^4	2.2822×10^4	2.8258×10^5	3.5263×10^5
2021	415,263	2.3359×10^4	1.5572×10^4	1.9282×10^5	2.4061×10^5
2022	3.5007×10^5	1.9692×10^4	1.3128×10^4	1.6255×10^5	2.0284×10^5

Table 6 shows the tonnage of ethanol and methane using 50% of the sugarcane yield, plus the energy produced when they are combusted. Converting the sugarcane juice to ethanol and methane provides a substitute sugarcane market for Guyana. The Guyanese economy was focused on sugarcane agriculture before the new oil and gas industry. The anticipation for the oil and gas economy led the country to attempt to shutter the sugarcane industry under the APNU+AFC government. This was the result of the unprofitability of sugar. Ethanol can provide a new market for biofuels.

Table 7. Estimated ethanol, methane and energy yield from 75% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Ethanol (tonnes)	Methane (tonnes)	Energy from ethanol (MWh)	Energy from methane (MWh)
2017	1.3943×10^6	7.8428×10^4	5.2285×10^4	6.4741×10^5	8.0788×10^5
2018	9.1087×10^5	5.1237×10^4	3.4158×10^4	4.2295×10^5	5.2778×10^5
2019	8.3936×10^5	4.7214×10^4	3.1476×10^4	3.8974×10^5	4.8635×10^5
2020	9.1287×10^5	5.1349×10^4	3.4132×10^4	4.2387×10^5	5.2894×10^5
2021	6.2289×10^5	3.5038×10^4	2.3359×10^4	2.8923×10^5	3.6092×10^5
2022	5.2511×10^5	2.9538×10^4	1.9692×10^4	2.4383×10^5	3.0426×10^5

Table 7 shows the tonnage of ethanol and methane using 75% of the sugarcane yield, plus the energy produced when they are combusted. The table above represents the conversion of 75% of the sugarcane into ethanol or methane. The 2017 figures were competitive for ethanol and methane tonnage. They both would have produced a lot of energy that year. The ethanol market is being tapped by Brazil, which has converted its grid to renewable energy using hydropower and bioenergy. Assessing Brazil's development of ethanol from sugarcane can be a case study that would lead to a strategy for how Guyana can better develop its bioenergy potential from sugarcane.

Table 8. Estimated ethanol, methane and energy yield from 100% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Ethanol (tonnes)	Methane (tonnes)	Energy from Ethanol (MWh)	Energy from Methane (MWh)
2017	1,859,037	1.0457×10^5	6.9714×10^4	8.6321×10^5	1.0772×10^6
2018	1,214,495	6.8315×10^4	4.5544×10^4	5.6393×10^5	7.0371×10^5
2019	1,119,149	6.2952×10^4	4.1968×10^4	5.1966×10^5	6.4847×10^5
2020	1,217,154	6.8465×10^4	4.5643×10^4	5.6517×10^5	7.0525×10^5
2021	830,526	4.6717×10^4	3.1145×10^4	3.8564×10^5	4.8123×10^5
2022	700,149	3.9383×10^4	2.6256×10^4	3.2510×10^5	4.0569×10^5

Table 8 shows the tonnage of ethanol and methane using 100% of the sugarcane yield, plus the energy produced when they are combusted. It may prove costly to convert all of Guyana's sugarcane to ethanol or methane. Therefore, the 100% conversion is not the sought-after solution. Also, there would be queries in

growing all of 2017 is 1,859,037 tonnes of sugarcane and converting it all into energy, when the land can be used for foodstuffs. Nonetheless, a staple food in Guyana is rice, which is grown by rice farmers. Guyana also exports rice, and its population is relatively small at about 800,000 persons. The 2017 sugarcane crop represents all 6 estates, and it can provide 1.0457×10^5 tonnes of ethanol. Alternatively, it can provide 6.9714×10^4 tonnes of methane. When these are converted into energy, it gives 8.6321×10^5 MWh from ethanol and 1.0772×10^6 MWh from methane.

4.3 Bagasse Conversion App Results

The following results reflect the output of the Bagasse Conversion App. The app takes as inputs the sugarcane tonnage produced by GuySuCo for 2017 – 2022. The app uses 25%, 50%, 75% and 100% of the sugarcane tonnage to estimate the bagasse tonnage left over as waste. The app then performs a computation of the energy that can be obtained from the direct combustion of bagasse.

Table 9. Estimated bagasse and energy yield from 25% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Bagasse (tonnes)	Energy (MWh)
2017	4.6476×10^5	1.5105×10^5	5.1084×10^8
2018	3.0362×10^5	9.8678×10^4	3.3373×10^8
2019	2.7979×10^5	9.0931×10^4	3.0753×10^8
2020	3.0429×10^5	9.8894×10^4	3.3446×10^8
2021	2.0763×10^5	6.7480×10^4	2.2822×10^8
2022	1.7504×10^5	5.6887×10^4	1.9239×10^8

Table 9 depicts the tonnage of bagasse when 25% of the sugarcane yield and the energy is produced from the direct combustion of the bagasse. The amount of bagasse that is left over from the sugarcane was first derived. That bagasse would have the components cellulose, hemicellulose as xylose, a pentose, and lignin. To estimate the energy released from the direct combustion of bagasse, the combustion of the individual components was performed, and the total energy released was summed.

Table 10. Estimated bagasse and energy yield from 50% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Bagasse (tonnes)	Energy (MWh)
2017	9.2952×10^5	3.0209×10^5	1.0217×10^9
2018	6.0725×10^5	1.9736×10^5	6.6745×10^8
2019	5.5957×10^5	1.8186×10^5	6.1505×10^8
2020	608,577	1.9779×10^5	6.6892×10^8
2021	415,263	1.3496×10^5	4.5643×10^8
2022	3.5007×10^5	1.1377×10^5	3.8478×10^8

Table 10 depicts the tonnage of bagasse when 50% of the sugarcane yield and the energy is produced from the direct combustion of the bagasse. The conversion of bagasse derived more energy than either ethanol or methane. Hence, sugarcane can be grown for sugar and ethanol in Guyana, and the bagasse can be used to generate electricity by the thermal process of combustion.

Table 11. Estimated bagasse and energy yield from 75% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Bagasse (tonnes)	Energy (MWh)
2017	1.3943×10^6	4.5314×10^5	1.5325×10^9
2018	9.1087×10^5	2.9603×10^5	1.0012×10^9
2019	8.3936×10^5	2.7279×10^5	9.2258×10^8
2020	9.1287×10^5	2.9668×10^5	1.0034×10^9
2021	6.2289×10^5	2.0244×10^5	6.8465×10^8
2022	5.2511×10^5	1.7066×10^5	5.7717×10^8

Table 11 depicts the tonnage of bagasse when 75% of the sugarcane yield and the energy is produced from the direct combustion of the bagasse. With 75% of bagasse converted into energy, it is a better use of the bagasse than landfilling or burning without conversion into energy.

Table 12. Estimated bagasse and energy yield from 100% sugarcane conversion (2017 – 2022).

Year	Sugarcane (tonnes)	Bagasse (tonnes)	Energy (MWh)
2017	1,859,037	6.0419×10^5	2.0434×10^9
2018	1,214,495	3.9471×10^5	1.3349×10^9
2019	1,119,149	3.6372×10^5	1.2301×10^9
2020	1,217,154	3.9558×10^5	1.3378×10^9
2021	830,526	2.6992×10^5	9.1287×10^8
2022	700,149	2.2755×10^5	7.6957×10^8

Table 12 depicts the tonnage of bagasse when 100% of the sugarcane yield and the energy is produced from the direct combustion of the bagasse. The highest year of sugarcane production is 2017, which is the focus of this research. The bagasse for 2017 was computed to be 6.0419×10^5 tonnes. The direct combustion of this bagasse would produce 2.0434×10^9 MWh of energy that can be fed into the grid. This would require the reopening of the shuttered estates and the upgrade of the GuySuCo so that it can generate electricity from biomass and plant waste.

Table 13. Sensitivity analysis using 100% of sugarcane yield for the trial.

Trial	Sugarcane (tonnes)	Ethanol (tonnes)	Methane (tonnes)	Energy from ethanol (MWh)	Energy from methane (MWh)
1	1	0.0563	0.0375	0.4643	0.5794
2	10	0.5625	0.3750	4.6433	5.7943
3	100	5.6250	3.7500	46.4334	57.9427
4	1,000	56.2500	37.5000	464.3342	579.4271
5	10,000	562.500	375	4.6433×10^3	5.7943×10^3
6	100,000	5,625	3,750	4.6433×10^4	5.7943×10^4
7	1,000,000	56,250	37,500	4.6433×10^5	5.7943×10^5

Table 13 shows the sensitivity analysis for the Sugarcane Juice Conversion App that the researcher built using MATLAB. The researcher utilised semantic scholar API, but could not find any papers that gave this comparison of tonnes of sugarcane to tonnes of ethanol/methane produced, **(i)**, **(ii)**, **(iii)**, and **(iv)** were the basis of the computation. The paper did not give indications as here as to the energy in MWh that can be produced from the conversion of ethanol/ methane, but **(v)** and **(vi)** were used to determine the energy, and **(x)**, **(xi)** and **(xii)** were used to convert MJ/mol convert it into MWh.

Figure 2 shows the app. The user must first click the Initialise button, then enter the sugarcane data into the first table. The first table features a horizontal scroll to facilitate data entry into each field. The radio button should be selected for the percentage of sugarcane tonnage that will be used in the computation. After that, the Start button is pressed to run the programme. The results table displays the Year, Sugarcane (tonnes), Ethanol (tonnes), Methane (tonnes), Energy from Ethanol (MWh) and Energy from Methane (MWh).

Table 14 shows the sensitivity analysis for the Bagasse Conversion App. The direct conversions were not found in research papers, but bagasse accounted for 40 – 45% (Bisanal et al., 2020). While the direct combustion of bagasse to energy in MWh was not directly given. Note that **(vii)**, **(viii)** and **(ix)**, which were the basis of computing the energy. The energy was converted to MWh using **(x)**.

Figure 3 shows the Bagasse Conversion App. First, Initialise must be pressed to see the cells of the tables. The sugarcane data in tonnes are entered in the first table; the horizontal scroll needs to be used to fill the table. The radio button is used to select the percentage of sugarcane to be used in the computation. Next, Start is pressed to run the app and perform the calculation. The results table shows the Sugarcane (tonnes), Bagasse (tonnes) and the Energy (MWh) from the direct combustion of bagasse.

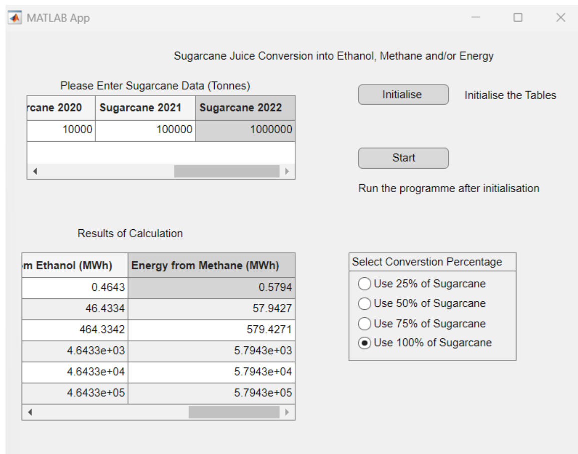

Figure 2. Trial of sugarcane juice conversion app.

Table 14. Sensitivity analysis using 100% of bagasse waste for the trial.

Trial	Sugarcane (tonnes)	Bagasse (tonnes)	Energy (MWh)
1	1	0.3250	1.0991×10^3
2	10	3.2500	1.0991×10^4
3	100	32.5000	1.0991×10^5
4	1,000	325	1.0991×10^6
5	10,000	3,250	1.0991×10^7
6	100,000	32,500	1.0991×10^8
7	1,000,000	325,000	1.0991×10^9

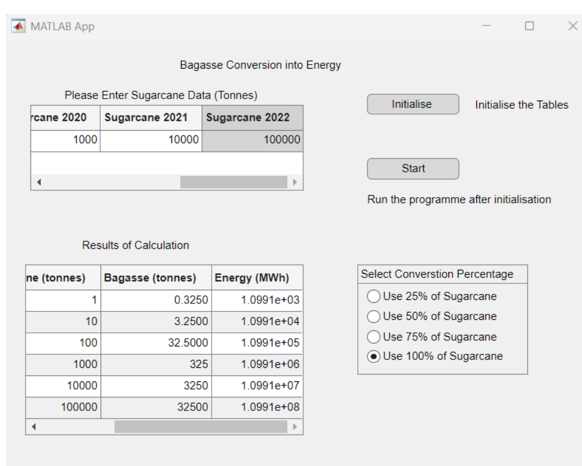

Figure 3. Trial of bagasse conversion app.

5. Discussion

5.1 Models of the Programs

The flow charts of the Sugarcane Juice Conversion App and the Bagasse Conversion App were used to calculate the results for this bioenergy potential investigation of GuySuCo. MATLAB was the primary software for building the model. Modelling the energy potential shows a viable alternative for sugarcane in Guyana.

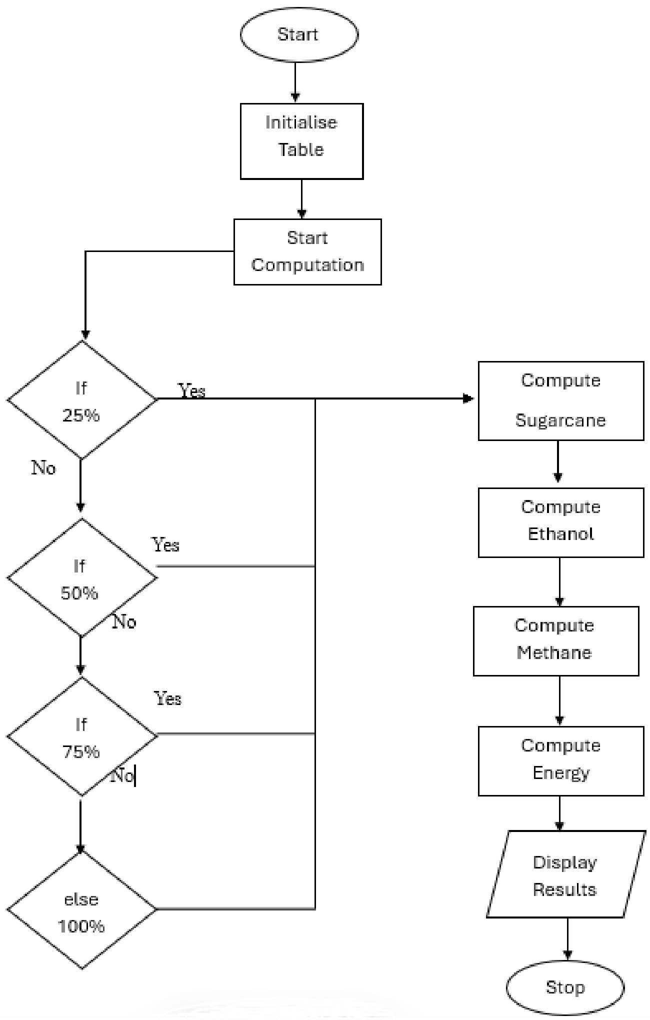

Figure 4. Sugarcane juice conversion app model.

Figure 4 shows the general flowchart of the Sugarcane Juice Conversion App. The graphical user interface (GUI) was built with MATLAB. When the program is opened, it must first be initialised. After initialisation, the data can be entered. The percentage of sugarcane that will be converted for the computation has to be selected from several radio buttons. In the program, the calculation starts with a click of the start button. Once the computation is started, the programme checks what percentage of the sugarcane will be converted.

It computed sucrose and maltose from the sugarcane intended for the analysis. It then computes ethanol if the sucrose and maltose are all converted to ethanol. Computes methane in the case where all the sucrose and maltose were converted to methane.

The software further goes on to compute the energy that would be derived from the combustion of ethanol or the combustion of methane. The resulting information is then displayed, which was calculated. The program can be run more times for additional computation. MATLAB allows the building of the app in an easy programming language. The MATLAB environment is flexible with matrices and operations that are involved in MATLAB, allowing for the separation of pre-programmed code needed for the app and code for the operation that is being performed.

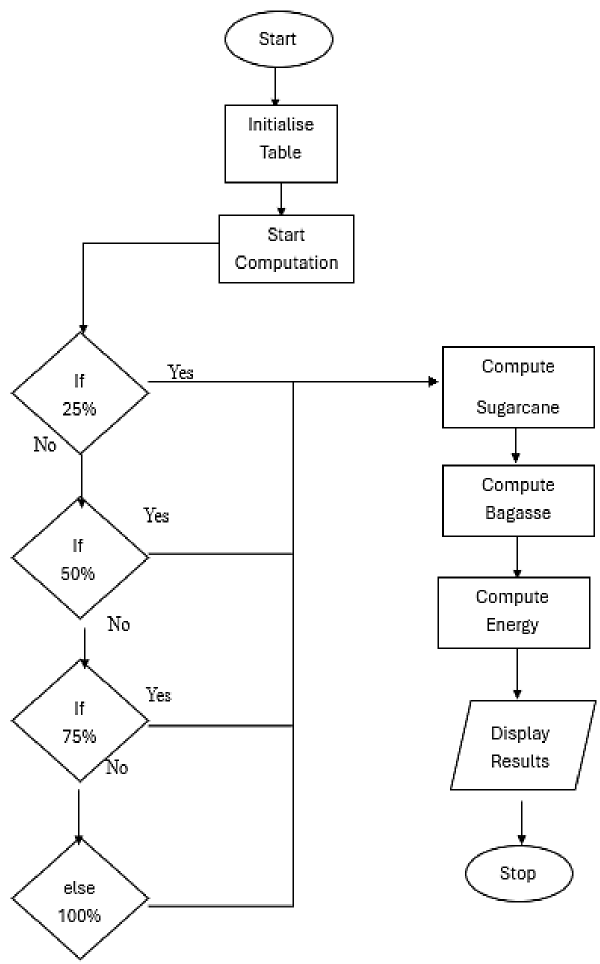

Figure 5. Bagasse conversion app model.

Figure 5 shows the general flowchart of the Bagasse Conversion App. The graphical user interface (GUI) was built with MATLAB, which allows for complex computation in an easy-to-use environment. When the app starts, the first thing is to initialise the tables. This tells the software to give the tables a condition that can be editable by the user of the app. The percentage of sugarcane must be selected after the value of the sugarcane harvest in tonnes is input into the editable table.

Once the Start push button is pressed, the software checks which percentage of the sugarcane harvest is being used to produce the bagasse. The bagasse was computed from the sugarcane harvest, and the energy from all the components of bagasse was derived from the combustion of said components, cellulose, hemicellulose and lignin. The information derived from the computation was then displayed to the app. The computation can be repeated for other percentages of sugarcane.

5.2 Sugarcane Juice Conversion App

The GuySuCo sugarcane harvest was used as input to the Sugarcane Juice Conversion app. The highest harvest was in 2017 with a harvest of 1,859,037 tonnes. The lowest sugarcane yield was in 2022, having a harvest of 700,149 tonnes. Several factors account for the disparity in production. In contrast, the main reason is the closure of estates. The harvest for 2017 accounts for the output of all 6 of the GuySuCo estates before the closure, but the 2022 yield was the production of only 2 estates. It would be interesting to see the production of 2023 and 2024, as the PPP/C government has reopened the Rose Hall Estate with expectations of reopening the others.

What prompted the closure of the estate by the APNU+AFC government was the fact that the sugar industry was running at a loss, but the estates were needed to retain employment in the regions. The reasoning for the closure would have looked at the losses that the industry is making and deemed it more expedient to shutter the industry and divide the land for alternative uses. Hence, when the change of government occurred, the PPP/C reopened the estate, intending to make sugar a productive and income-generating source. The paper will examine the potential of utilising the sugarcane crop as a bioenergy resource. Sucrose in the sugarcane crop is estimated at 12.5% of the sugarcane content, with maltose being 5%.

Sucrose can be anaerobically digested into methane, while maltose is turned into methane in the presence of an enzyme. Yeast converts sucrose and maltose into ethanol. So, sugarcane has two avenues for conversion, either into methane or into ethanol. Combinations in production were not investigated in this paper. Both ethanol and methane can be combusted to release energy. Ethanol produces $1{,}367\ \mathrm{kJ/mol}$ while methane produces $890\ \mathrm{kJ/mol}$ when combusted.

In examining the bioenergy potential, the research computed the potential for various percentages of sugarcane tonnage. These were 25%, 59%, 75% and 100% use of sugarcane yield for conversion. These are represented in the result, but the researcher will take time to mention that converting 25% of the sugarcane crop is the best strategy for the overall gradual conversion of the industry. The two years the research will focus on are 2017 and 2022 in the analysis. The 2017 crop at the recommended 25% conversion was 4.6476×10^5 tonnes of sugarcane would yield 2.6143×10^4 tonnes of ethanal or 1.7428×10^4 tonnes of methane. In terms of energy generation 2.1580×10^5 MWh would be produced from ethanol, and 2.6929×10^5 MWh produced from the conversion of methane. In 2022 the 1.7504×10^5tonnes of sugarcane would yield 9.8458×10^3 tonnes of ethanol could be produced from that year's crop or 6.5639×10^3 tonnes of methane. The energy that can be generated is 8.1276×10^4 MWh from ethanol and 1.0142×10^5 MWh from the combustion of methane. Concerting initially just 25% of the sugarcane crop will allow the gradual takeover of bioenergy as the main product from the sugarcane in Guyana.

5.3 Bagasse Conversion App

For the Bagasse Conversion App, 2017 was the highest input of sugarcane harvest, and 2022 was the lowest. The tonnage of the 2017 harvest was 1,859,037 tonnes of sugarcane, while the 2022 harvest was 700,149 tonnes of sugarcane. These two years will primarily feature as the years for analysis. The Bagasse

Conversion App differs from the Sugarcane Juice Conversion App in that bagasse is the primary material for conversion. Bagasse makes up approximately 32.5% of sugarcane. Bagasse comprises 45% cellulose, 25% hemicellulose called xylose, which is a pentose, and 25% lignin. These cannot be broken down in a biodigester. Consequently, direct combustion is the best way to convert these organic materials into energy.

The combustion of cellulose releases $2{,}934.6\ \mathrm{MJ/mol}$ of energy, while the combustion of the hemicellulose called xylose, which is a pentose, will release $2{,}400\ \mathrm{MJ/mol}$. The combustion of lignin releases $15.6\ \mathrm{MJ/mol}$ of energy. The energy released from all the components of bagasse was then summed up. Using only 25% of the bagasse for the year 2017 was 1.5105×10^5 tonnes of bagasse from 4.6476×10^5 tonnes of sugarcane. The direct combustion of the 2017 bagasse would produce 5.1084×10^8MWh of energy. On the other hand, 25% of the 2022 sugarcane yield of 1.7504×10^5 tonnes would leave 5.6887×10^4 tonnes of bagasse as waste. This bagasse could have produced 1.9239×10^8MWh of energy. Then, it is better to use bagasse for combustion into energy and produce ethanol or methane from sugarcane juice.

6. Conclusion

The Sugarcane Juice Conversion App was built with MATLAB, and it required as inputs the sugarcane yield in tonnes for the years 2017 – 2022. The user also defined the percentage of the sugarcane that will be used in the calculation to compute ethanol tonnage, methane tonnage, energy derived from ethanol and the energy derived from methane. For this app, the sucrose and maltose content were converted to ethanol and methane tonnage. The ethanol or methane was then combusted, and the computation of the energy derived was computed.

The Bagasse Conversion App was also a graphical user interface made in the MATLAB environment. The sugarcane harvest in tonnes for 2017 – 2022 was required, and the percentage of the harvest used in the conversion was selected. The bagasse for that percentage of sugarcane used was first calculated, and the components of bagasse were individually combusted to give the overall energy that would be released from the combustion of bagasse. The components of interest were cellulose, hemicellulose called xylose, which is a pentose and lignin.

For the Sugarcane Juice Conversion App, the year with the most harvest was 2017, with 1,859,037 tonnes of sugarcane. The year with the least harvest was 2022, with 700,149 tonnes of sugarcane harvests. It is important to note that in 2017 GuySuCo had 6 estates, and by 2022 it had just 2 working estates. The percentage of sugarcane recommended for conversion for this paper is 25% as GuySuCo previously only made sugar from its sugarcane crop. Then, Guyana should aim at converting a lower percentage of its crop to ethanol, methane or energy, and once systems are in place, the conversion of the entire yield can be a future source of revenue. The 2017 crop at the recommended 25% conversion was 4.6476×10^5 tonnes of sugarcane, which would yield 2.6143×10^4 tonnes of ethanol or 1.7428×10^4 tonnes of methane. In terms of energy generation, 2.1580×10^5 MWh would be produced from ethanol or 2.6929×10^5 MWh produced from the conversion of methane. The 2022 crop, at 25% converted, would mean 1.7504×10^5 tonnes of sugarcane, which yields an estimated 9.8458×10^3tonnes of ethanol from that year's crop or 6.5639×10^3 tonnes of methane. The energy that can be generated is 8.1276×10^4 MWh from ethanol or 1.0142×10^5 MWh from the combustion of methane. Consequently, the researcher recommends producing ethanol with 25% of the sugarcane tonnage.

The Bagasse Conversion App used 2017 tonnage as 1,859,037 tonnes as the highest sugarcane yield, with the lowest harvest being 2022 with 700,149 tonnes. In this app, the bagasse had to be computed first and then converted into energy by the combustion of cellulose, a hemicellulose called xylose, which is a pentose and lignin. Direct combustion was the best option for bagasse, as it cannot be broken down in a biodigester. Using only 25% of the bagasse for the year 2017 was 1.5105×10^5 tonnes of bagasse from 4.6476×10^5 tonnes of sugarcane. The direct combustion of 2017's bagasse would have produced $5.1084 \times 10^8 MWh$ of energy. While 25% of the 2022 sugarcane harvest is 1.7504×10^5 tonnes would leave 5.6887×10^4 tonnes of bagasse. This bagasse could have produced 1.9239×10^8 MWh of energy. Hence, it is better to use bagasse for combustion and conversion into energy and produce ethanol from sugarcane juice.

The process to obtain energy is direct combustion. It will release carbon dioxide into the atmosphere; this situation can be mitigated using carbon capture technology and sequestration to remove the carbon from the air. The project highlights that ethanol and biodiesel utilisation will have to be studied. The processing of sugar into ethanol will require a complete change of direction for GuySuCo, and the feasibility of that change will have to be investigated. The use of syngas for the manufacture of biodiesel should be studied. Bioenergy potential for another crop, such as rice, should be studied, particularly the direct combustion of rice husk. Waste from cows should be studied, and biological waste from human beings to be made into bioenergy via the use of biodigesters. Lastly, future studies should be undertaken to evaluate the economic feasibility of integrating the production of bioenergy into the operation of GuySuCo. These studies can explore different hybrid models by combining sugar and bioenergy production.

Conflict of Interest

The author of this paper had no conflict of interest in the writing of this paper.

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AI Disclosure

During the preparation of this work, the author used generative AI in order to improve the language of the article. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Appendix

```
function tMethane = Methane(app, tSugarcane)% Convert sucrose and maltose to methane

   tSucrose = 0.125*tSugarcane; %deriving sucrose content from tonnes of sugarcane
   tMethaneS = tSucrose*(1/6); %deriving the tonnes of methane derived from sucrose


   tMaltose = 0.05*tSugarcane; %deriving the maltose content from tonnes of sugarcane
   tMethaneM = tMaltose*(1/3); %deriving the tonnes of methane derived from maltose

   tMethane = tMethaneM + tMethaneS; %deriving the total tonnage of methane from maltose and sucrose

end

function tEthanol = Ethanol(app, tSugarcane) % Convert sucrose and maltose to ethanol

    tSucrose = 0.125*tSugarcane; %deriving sucrose content from tonnes of sugarcane
   tEthanolS = tSucrose*(1/4); %deriving the tonnes of ethanol derived from sucrose


   tMaltose = 0.05*tSugarcane; %deriving the maltose content from tonnes of sugarcane
   tEthanolM = tMaltose*(1/2); %deriving the tonnes of ethanol derived from maltose

   tEthanol = tEthanolM + tEthanolS; %deriving the total tonnage of ethanol from maltose and sucrose

end
```

Figure 6. Methane and ethanol (tonnes).

Figure 6 shows the functions for calculating methane and ethanol tonnes.

```
function MWhEnergy = Ethanol2Energy(app, tEthanol) % Converting ethanol to energy
   MolarMassEthanol = 2*12+6*1+1*16; %Calculating the molar mass of ethanol

   kgEthanol = tEthanol*(1000/1); % calculating the amount of ethanol in kg
   kmolEthanol = kgEthanol*(1/MolarMassEthanol); % calculating kmol of ethanol
   MWhEnergy= kmolEthanol*(1367/1)*(1/3600); % calculating Energy in MWh from Ethanol

end

function MWhEnergy = Methane2Energy(app, tMethane) % Converting methane to energy
   MolarMassMethane = 1*12+4*1; %Calculating the molar mass of methane

   kgMethane = tMethane*(1000/1); % calculating the amount of methane in kg
   kmolMethane = kgMethane*(1/MolarMassMethane); % calculating kmol of Methane
   MWhEnergy= kmolMethane*(890/1)*(1/3600); % calculating Energy in MWh from Methane

end
```

Figure 7. Methane and ethanol conversion to energy (MWh).

Figure 7 shows the conversion of methane and ethanol to energy (MWh).

```
function MWhEnergy = Bagasse2Energy(app,tBagasse) %converting bagasse to energy

        MolarMassCellulose = 6*12 + 10*1 + 5*16;% determining the molar mass of cellulose
        tCellulose = 0.45*tBagasse; % determining the amount of cellulose in tonnes
        kmolCellulose = tCellulose*(1000/1)*(1/MolarMassCellulose);% determing the amount of cellulose in kmol
        MWhEnergyCellulose = kmolCellulose*(2934.6*1000)*(1/3600); %determing the amount of energy derived from the combustion of cellulose

        MolarMassHemicellulose = 5*12 + 10*1 + 5*16;% determining the molar mass of hemicellulose
        tHemicellulose = 0.25*tBagasse; % determining the amount of hemicellulose in tonnes
        kmolHemicellulose = tHemicellulose*(1000/1)*(1/MolarMassHemicellulose);% determing the amount of hemicellulose in kmol
        MWhEnergyHemicellulose = kmolHemicellulose*(2400*1000)*(1/3600); %determing the amount of energy derived from the combustion of hemicellulose

        MolarMassLignin = 9*12 + 10*1 + 3*16;% determining the molar mass of lignin
        tLignin = 0.25*tBagasse; % determining the amount of lignin in tonnes
        kmolLignin = tLignin*(1000/1)*(1/MolarMassLignin);% determing the amount of lignin in kmol
        MWhEnergyLignin = kmolLignin*(15.6*1000)*(1/3600); %determing the amount of energy derived from the combustion of Lignin

        MWhEnergy = MWhEnergyLignin + MWhEnergyHemicellulose + MWhEnergyCellulose; %determining the total energy derived from the combustion of bagasse
end
```

Figure 8. Conversion of bagasse (tonnes) to energy (MWh).

Figure 8 shows the function that converts bagasse tonnage into cellulose, hemicellulose and lignin, then converts the same to energy in MWh.

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