GBEP Working Group on Capacity Building for Sustainable Bioenergy

ACTIVITY GROUP 2

"Raising awareness and sharing of data and experiences from the implementation of the GBEP indicators"

Template for the Compilation of GBEP Indicators Experiences

OVERVIEW

- Country: ***JAMAICA***
- Scale at which the GBEP indicators were measured: **LOCAL**
- Year(s) during which the GBEP indicators were measured: **2012 – 2014**
- Organization(s) commissioning/overseeing the measurement of the GBEP indicators: **The project was implemented by the Organization of American States under the Trilateral MOU for Biofuels Development between US/Brazil/Jamaica for the Ministry of Science, Technology, Energy and Mining.**
- Organization(s) carrying out the measurement of the GBEP indicators: **Center for Life Cycle Assessment and Sustainable Design (CADIS)**
- Source(s) of funding: **United States Department of State**
- Funding size: ☒ **< 500k USD**; ☐ 500k - 1,000k USD; ☐ > 1,000k USD
- Existing bioenergy pathways (e.g. feedstocks, processing technologies, fuels and end-uses) in the country: **Sugarcane-based ethanol and bagasse-based cogeneration.**
- Bioenergy feedstocks assessed through the GBEP indicators: **Sugarcane (including molasses and bagasse) were the bioenergy feedstocks considered.**
- Liquid, solid and gaseous fuels assessed through the GBEP indicators and respective end-uses (e.g. heating and cooking, power generation and transport) and end-use sectors (e.g. residential, commercial, industry): **The main fuels end-use and end-sectors considered were: sugarcane-based ethanol from molasses for the transportation sector and bagasse-based electricity generation for own consumption as well as for the national grid.**
- GBEP indicators measured (disaggregated by bioenergy feedstock, fuel, end-use and end-use sector considered, as necessary): The GBEP indicators measured are as follows:
  Environmental Pillar: 1. Life-cycle GHG emissions for new bioenergy production; 4. Emissions of non-GHG air pollutants, including air toxins; 5. Water use and efficiency; 6. Water quality.

  Social Pillar: 9. Allocation and tenure of land; 11. Change in income; 12. Jobs in the bioenergy sector; 13. Change in unpaid time spent by women and children collecting biomass; 15. Change in mortality and burden of disease attributable to indoor smoke; 16. Incidence of occupational injury, illness and fatalities.

Economic Pillar: 17. Productivity; 19. Gross value added; 20. Change in consumption of fossil fuels and traditional use of biomass; and 22. Energy diversity. The GBEP indicators tested were based on the availability of data from the participating entities.

- Approach/methodology used for attribution of impacts to bioenergy: **A multi-functional approach utilizing the principle of the life cycle assessment (LCA) methodology defined in the international standard ISO 14040, as the compilation and evaluation of inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040) was used. The experts who carried out the measurement used the software *SimaPro 8*, a calculator that returned the values in a form that differs from the standard GBEP methodology. Outcomes of the measurement were subsequently adapted to adhere more closely, but with inevitable differences, to the methodological approach of the GBEP Indicators. For the LCC the cost allocation is based on a market value criterion, costs are allocated in proportion to the estimated value of the products at the point of production or sale, assuming that higher selling prices indicate higher costs. For bagasse cogeneration and bioethanol production, mass- balance allocation was used.**

- Year when the next measurement of the GBEP indicators is planned: **UNKNOWN**

KEY RESULTS

- **Overview** (max. 1 page):

The sugarcane industry is the largest agricultural sector in Jamaica, and the second largest single employer of labour, employing approximately 38,000 persons in the crop season and 28,000 persons out of crop; and contributing USD74.5 million to GDP in 2010. Approximately 5% of the land is dedicated to growing sugarcane and the waste, bagasse from sugar mills contributes to the energy generation. Sugarcane production has been declining for the last three decades and has only started to recover, only to be interrupted by the national drought of 2015. The industry is dependent upon the international price of sugar (main product) and the price of alternative products including ethanol and rum.

Jamaica has an E-10 mandate that was designed to support local production of ethanol from sugarcane (stimulate the local market for ethanol) and also to replace MTBE from local transport fuel (mainly environmental reason and as an oxygenating agent in the fuel). This in turn would create a market for locally produced ethanol and to support the diversification of the sugarcane industry into a multi-product industry and contributing to the National Energy Policy 2009-2030 goals of energy security, energy diversification, production of clean energy and the creation of green jobs. To date, this has not be forthcoming, since the sugarcane industry has been faced with several issues; namely, low production, high usage of fossil fuel, energy inefficiency and the lack of financing for the modernization of the plants. Jamaica currently imports corn ethanol from the United States to meet the demand for anhydrous ethanol, due in part to the lack of readiness of the local sugarcane industry to meet this demand, based on the challenges that are faced by the sector.

The project was developed to address risk management and assist with creating a sustainable pathway for the sector. The project examined the production of anhydrous bioethanol derived from molasses at Everglades Farms and electricity cogeneration from sugarcane-based bagasse at Golden Grove; comparing current situation of generation bagasse-derived electricity in the sugar mills, and the alternative scenario which updates the existing cogeneration system to that of improved technology.

The goals of are as follows:

- Perform a Life Cycle Sustainability Assessment (LCSA) and obtain the Global

Bioenergy Partnership (GBEP) Indicators of two bioenergy products, anhydrous ethanol produced by and Everglades Farms in Trelawny and bioelectricity generated by Golden Grove in St. Thomas;

- Discuss results and findings of LCSA in business decision making; identify key needs, challenges for a successful production of biofuels; identify success and failure factors; and provide guidance on using LCSA results and findings for further policy development in the Caribbean; and

- Highlight to users (Government of Jamaica and other local stakeholders) the importance of LCSA in the process of promoting sustainable production of bioenergy production in Jamaica.

Everglades is located in Trelawny parish which is historically sugar-dependant and has relatively high levels of poverty and poor social infrastructure, including poor access to potable water, educational and health services as well as poor quality roads and energy supplies. Everglades is the only remaining sugar estate in Trelawny (merging of Long Pond and Hampden), and is well-known sugar (including rum) industry. Everglades has a total of 2,700 ha land available for cane cultivation, the target for 2015 is approximately 175,000 tonne cane based on an average yield of 65 tc/ha and with further 30 % contribution from private cane farmers. Approximately 68,486 tonnes of cane is milled annually at Evergaldes, with annual sugar production of 5,590 tonnes and 2,677 tonnes of molasses. Some manufacturing, a declining fishing sector and a growing tourism industry, providing an increasing number of low paid jobs in the service sector are the current economic activities of Trelawny. Rural to urban migration from Trelawny has slowed in the last decade and social indicators have been gradually improving. The Government's focus, via the Sugar Transformation Unit (STU), is to improve the social infrastructure to better serve local communities and the sugar industry and reducing outward migration of young people to the cities. In Trelawny, housing relocation has almost been completed and some investments have been made in repairing schools and health centres.

Golden Grove is located in St Thomas parish which has high poverty levels relative to the rest of Jamaica and particularly poor social indicators e.g. highest teenage pregnancy and lowest male literacy rates. Social infrastructure (access to education, healthcare, energy, roads) is poor. There are few employment options other than the sugar industry (other agricultural products such as bananas have been severely affected by natural phenomena, particularly hurricanes). Rural to urban migration has been historically high. The government's focus, via the Sugar Transformation Unit (STU), is to improve the social infrastructure to better serve local communities and the sugar industry, reducing outward migration of young people to the cities. However, in St. Thomas, housing relocation has been more costly than anticipated, reducing the availability of funds for social infrastructure. Golden Grove uses a bagasse cogeneration system to generate and meet part of its energy demand that is complemented with the external power grid. The current system has outdated and inefficient technology. The new (proposed) scenario introduces an updated and more efficient bio-cogeneration system that would meet all energy demand of the sugar mill. A cogeneration plan uses heat engine or power station to simultaneously generate electricity and heat. The bio-cogeneration system uses biomasses, such as bagasse, as energy source.

The project as outlined above was initially designed to examine Life Cycle Sustainability Assessment (LCSA), after which the results were harmonized to obtain the GBEP indicators whereby specific indicators were assessed based on the availability of data. The LCSA is recognised as the best tool for assessing biofuel/bioenergy sustainability; because it allows us to understand the different implications of production and consumption in different scenarios modelling. However, further full assessment and testing of the GBEP indicators should be undertaken in Jamaica, and assistance is required for the collection of data in accordance with the GBEP's methodology.

For the Everglades assessment, two (2) scenarios were tested. The first or baseline scenario examined the use of E10 by using anhydrous bioethanol from Brazil and gasoline from Trinidad and Tobago. In this scenario, the agricultural and industrial stages for Brazilian conditions are considered. In the use stage, transportation of gasoline and anhydrous bioethanol, and the combustion of the mixture in an average car are taken into account. The baseline scenario uses the same quantity of anhydrous bioethanol for blending with gasoline as Scenario 1. The second scenario/scenario 1 examined the use of E10 by using anhydrous bioethanol from Everglades and gasoline from Trinidad and Tobago. In this scenario, the Jamaican conditions for the agricultural and industrial stages are considered. The functional unit normalizes the results of the analysis to 66.7 million kilometres driven with an average vehicle in Jamaica fuelled by E10, an ethanol-gasoline blend of 10 % volume anhydrous bioethanol and 90 % gasoline. The functional unit was defined according to the annual production capacity of Everglades having a capacity of approximately 800,000 litres of anhydrous bioethanol per year. It is assumed that the average vehicle with a performance of 0.12 litres E10/km will have total fuel consumption for driving 66.7 million kilometres is 7.33 million litres of gasoline and 800,000 litres of anhydrous bioethanol. The use stage includes the transporting of gasoline and the combustion of the mixture in an average car. In undertaking the study, several assumptions were made and include the following: for the production of 1 t of cane sugar per day in the chosen mill it is necessary to produce 12.5 t of sugar cane that requires an area of 0.017 ha; the use of filter cake substitutes synthetic fertilizers according to the concentration of phosphorus, potassium and nitrogen. Diesel fuel is used for land preparation, crop maintenance, e.g., irrigation and fertilizer/herbicide application, and harvesting in sugar cane farming; a major part of the anhydrous bioethanol plant’s energy demand is derived from diesel combustion; the average E10 consumption was 0.12 l/km; for the anhydrous bioethanol production it is considered that 85 % of molasses is imported; for E10 blend in baseline conditions the anhydrous bioethanol is imported from Brazil and gasoline from Trinidad Tobago; in Scenario 1 all E10 consumed is produced by anhydrous bioethanol from Everglades; the supplier of molasses imported for anhydrous bioethanol production in Everglades is from Mexico and Dominica; the average distance was included in this study; the production process was modelled according to Brazil conditions; and the inventory for different kinds of energy was modelled according to Ecoinvent processes and adapted to Jamaica. Additionally, limitations were considered and include the following: there were no available data for combustion of E10 in Jamaica and it was necessary to use data from literature report; the distance between port and refinery where E10 is produced is not considered in the study; the distance between refinery and service station for E10 distribution are not considered; and some implicit modelling assumptions of ReCiPe are representative for world and not for the region of the study.

The baseline scenario or reference scenario for Golden Grove consists of the current installed cogeneration technology, which is 2.2 MW plant for producing electricity from bagasse, imports from the grid is used to meet shortfalls. This scenario considers an agricultural stage for a production of 63,697.74 t /annual of sugar cane using data supplied by Golden Grove. In the bagasse production stage the sugar cane is milled to extract the juice and bagasse. A mass-based allocation method was applied for the products (bagasse and mixed juice) obtained in this stage. This distribution was used in order to assess the real impact of bagasse. According to this principle, bagasse represents about 27% of the total mass of the products and mixed juice about 73%. Scenario 1 considers the agricultural stage and bagasse production stage with the same characteristics as that of the baseline scenario, but with different quantity due to major efficiency in cogeneration process. In this scenario, the cogeneration technology is changed to 5.0 MW of power facility for generating steam and electricity from bagasse, that is, additional electricity will be generated with the objective of meeting their on-site needs as well as to export the surplus to the national grid. Assumptions for the bagasse cogeneration include the following: for the production of 1 t of cane sugar in the chosen mill it is necessary to produce 12 t of sugar cane that requires an area of 0. 1579 ha; diesel fuel is used for land preparation, crop maintenance, e.g., irrigation and fertilizer/herbicide application, and harvesting in sugar cane farming; the inventory for different kinds of energy was modelled according Ecoinvent and adapted to Jamaica; all pesticides used in the agricultural stage in Golden Grove that are not included in the database of the SimaPro software are modelled as unspecified pesticides; the air pollution control technologies in the process of steam generation are not considered in this analysis because it is not common practice in Jamaican sugar mills. Limitations are as follows: in the baseline scenario there is not data about the use of agricultural wastes, ashes produced from burning bagasse and the excess of bagasse; some implicit modelling assumptions of Recipe are representative for world and not for the region of the study.

- Environmental pillar (max. 1 page):

Bagasse Cogeneration

For bagasse cogeneration it is observed that the agricultural stage for the baseline scenario present the major contribution to two categories. It contributes the most to agricultural land occupation and fresh water eutrophication and is due to the area of soil used for plantation involving the use, production and transport of fertilizers and herbicides. The cogeneration stage contributes most in the rest of the categories except: natural land transformation, urban land occupation and metal depletion were the bagasse extraction stage shows the major effect, due to the transportation of sugar cane from plantation to the sugar mill mainly. The effect of the cogeneration stage is associated to the use of electricity from the grid and the cogeneration with bagasse process without equipment for controlling the particulate material and gases emissions. The agricultural stage evaluation for the baseline scenario considers the sugar cane necessary for the bagasse production according with the allocation considered in the extraction stage. The most impacting processes are pesticides production and use, the emissions to air, water and natural resources use and diesel consumption. It is appreciated that the pesticides production and use contribute the most to potential impact in eight of the eighteen categories analyzed. The major contribution is to metal depletion, terrestrial ecotoxicity, human toxicity, water depletion, urban and natural land occupation, fresh water and marine ecotoxicity. The emissions to air and water for the use of nitrogen and phosphorous fertilizers and natural resources use in the agricultural activities have high impact on the following seven categories: agricultural land occupation, marine eutrophication, fresh water eutrophication, photochemical oxidant formation, climatic change, particulate material formation and terrestrial acidification. On the other hand, diesel consumption generates impact on several categories as ionizing radiation, fossil depletion, and ozone depletion. For the bagasse production stage for the baseline scenario it is appreciated that the transport has the predominant impact to all categories due to the consumption of fuel and its associated impacts; it is a logical result attending to activities of this stage where only, the sugar cane is transported from plantation to de sugar mill and then it is milled with the addition of water. For the electricity cogeneration stage it shows that the use of electricity from the grid generates the greatest potential impact on nine of eighteen categories analyzed due to the consumption of electricity from fuel. While the cogeneration with bagasse process present the major impact to the photochemical oxidant formation, marine eutrophication, particulate material formation, terrestrial acidification and climatic change caused by the bagasse combustion, which generates significant amounts of particulate material. Besides, there are other potential impacts on metal depletion, ionizing radiation and ozone depletion caused for the water softening process by ion exchange for the steam generation. It shows that agricultural stage for scenario 1 contributes the most in seven of the categories analyzed. The bagasse extraction stage shows the major dangerous effect for the urban land occupation, natural land transformation and metal depletion, similar to baseline scenario. The behaviour of the electricity cogeneration stage is different to baseline scenario because of the use of electricity from the grid is eliminated in the scenario 1. The major contribution of the process is on the categories: photochemical oxidant formation, particulate material formation, terrestrial acidification, marine eutrophication and climatic change, due to the bagasse combustion process fundamentally.

Ethanol Production

Sugar cane is a multi-year crop; two to five harvests can be achieved from one new planting. Land preparation, planting, crop maintenance (fertilization, weed control, irrigation) and harvesting are major farm activities. The industrial stage considered two subsystems: molasses production and anhydrous bioethanol conversion. For the Baseline Scenario, it is observed that the use stage contributes the most to majority of impact categories except marine eutrophication, terrestrial ecotoxicity and agricultural land occupation, where the raw material stage shows the major effect. The potential impact of the fifteen categories mentioned is due to the raw materials and emissions of the processes for obtaining gasoline from crude oil mainly. The combustion of E10 in the average car in Jamaica during the use stage causes the greatest impact in the categories climatic change, followed by the transport of anhydrous bioethanol from sugar cane from Brazil and gasoline from Trinidad Tobago. The potential impacts in raw stage are associated to the emissions of nitrates and ammonium due to the high consumption fertilizer, the crop residues and the emission of heavy metals and organic compound in the case of terrestrial ecotoxicity. The highest impact in agricultural land occupation depends of acreage of soil used for crop. The stage for obtaining anhydrous bioethanol production in Brazil has the least impact. The process involves the

use of by-product and cogeneration of electricity and heat with good environmental conditions. For Scenario 1, the relative contribution of life cycle stages to impact categories is different to that of the Baseline Scenario. It is observed that the raw material stage (sugar cane in Everglades) does not contribute most to impact categories; however, it is important to the contributions of production process in some impact categories, only the contribution of raw material to agricultural land occupation is relevant with respect the production and use stage contrary to performance in Baseline Scenario. The major contribution of anhydrous bioethanol production is to freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity and natural land transformation. The use of imported molasses represents the largest contribution to these impact categories, due to the emissions associated with the agricultural stage for its production. Others factors that contribute to this result are the emission of a high volume of vinasses to the watercourses with high content of chemical oxygen demand (COD), nitrogen, and phosphorus and the emission associated to diesel combustion for generate electricity and heat for the anhydrous bioethanol conversion process. The potential impact in use stage is like in Baseline Scenario associated mainly to production of gasoline from crude oil and the combustion of E10 in the average car in Jamaica during the use stage. The comparison of scenarios showed that the baseline scenario is better than scenario 1 in thirteen of eighteen impact categories). Only in human toxicity, terrestrial ecotoxicity, photochemical oxidant formation, urban land occupation and water depletion the scenario 1 shows the best result. Several factors contribute to this result: The sugar cane from Everglades has lower yield than sugar cane from Brazil; The use of imported molasses for anhydrous bioethanol production in Everglades represents the 85 percent of total consumed and it is necessary to use transport by sea;
The cogeneration process in Everglades does not satisfy the electricity consumption of the process and it is necessary to generate electricity from diesel and buy from the national grid; The national grid in Jamaica is based in oil consumption; During the production process for molasses production bunker oil is used for generating electricity in the boilers; It is considered that sugar mill and anhydrous bioethanol plant emit the wastewater to superficial bodies; Only the use of filter cake as fertilizer is considered, the rest of wastes are not used; The cogeneration process in Everglades doesn't include the use of systems for controlling the gases emissions; With respect to water depletion, the use of electricity from hydropower in Brazil and the major consumption of water for irrigation of sugar cane are the processes that have major contributions in the Baseline Scenario; The best results in human toxicity are associated to emissions to soil during the fertilization in sugar cane from Brazil. This process has major consumption or fertilizer and pesticides than the sugar cane from Everglades (raw material in scenario 1); and The use of major quantity of pesticides in the Baseline Scenario with respect Scenario 1 contributes most to the photochemical oxidant formation category and terrestrial ecotoxicity due to emissions to soil of pesticides.

- <u>Social pillar</u> (max. 1 page):

The study drew on two (2) sources of inventory indicators: the Methodological Sheets for Impact Categories and Indicators by Stakeholder Group, issued by UNEP/SETAC Life Cycle Initiative (UNEP, 2013), and the Global Bioenergy Partnership's (GBEP) list of eight (8) social sustainability indicators for bioenergy (GBEP, 2011). Within the system boundaries of the S-LCA study, both Worker and Local Community Stakeholder categories were identified as appropriate for assessment of potential social impacts of the proposed changes on both sites, although different geographical aspects were identified. In the case of Everglades, Worker and Local Community Stakeholders in Brazil could experience social impacts caused by elimination of exports of E10, while Worker and Local Community Stakeholders in Trelawny, Jamaica could experience social impacts caused by elimination of sugar production in the Everglades factory. In the case of Golden Grove, Worker and Community Stakeholders in St. Thomas, Jamaica could experience social impacts from the introduction of upgraded equipment to the Golden Grove factory. This study found insufficient generic social data available about rural Jamaica to be able to do more than provide a general context within which to assess potential social impacts of change in the sugar cane industry, on workers and local communities. Additionally, recognizing that most social impacts bear little relation to processes themselves (such as sugar production, bio-ethanol/co-generation of electricity), and more to the conduct of the companies performing the processes. The decision was taken for this S-LCA study to focus on the conduct of Everglades and Golden Grove companies, collecting site-specific data relating to the conduct of the company, using a site visit to each company to attain up-to-date information with reasonable accuracy. Considering the above, the study was developed to maximize spread of information (to explore as many potential social impacts as possible) and maximize accuracy through cross-checking and triangulating information. However, it was understood that much information gathered would be qualitative and would need narrative explanation rather than production of quantitative or semi-quantitative data. For each case study, information was sought through use of primary sources (semi-structured interviews and group meetings) and compared with secondary sources (documents and statistics) where available. This process of eliciting primary information and verifying or 'cross-checking' with secondary information, was conducted across three (3) types of information source: Company; Worker; and Local Government. In order to improve the quality of the site-specific information, triangulation of information across sources was used. Triangulation is an accepted technique for qualitative research to assess the reliability of information and data gathered. Information collected for each indicator was Social Life Cycle Assessment and GBEP indicators of biofuels in Jamaica subsequently compared with or 'triangulated' across these three (3) information sources.

- Economic pillar (max. 1 page):

For the LCC for Golden Grove, the first scenario assesses the current condition where the cogeneration technology is outdated and inefficient, and the second scenario is a proposal, where Golden Grove invests in a new and more efficient cogeneration system, using bagasse as the main energy source. The current energy capacity at Golden Grove is 2.2MW and a harvest season of 2,941 hours, power generation is approximately 6,470 Mwh/year with an energy performance of 3.27 TB/MWh. It is assumed that with an investment in a new 5.0 MW bio-cogeneration system, it would generate 14,704MWh and have a surplus of approximately 6,176.48 MWh/year. This new system will yield an equivalent to 1.44TB/MWh. The assessment found that a new and more efficient 5.0 MW bio-cogeneration system is capable of fulfilling the energy demand of Golden Grove and to sell 2.1 MW to the external grid, along with other valued- added products increasing the diversification of the sugar cane industry, reduce dependence in fossil fuel usage, contribute to the energy security and the overall social and economic development of the country. The cash-flow generated from the sale of the surplus electricity to the external grid would pay back the investment. The reduction in the energy bill will increase market competiveness. For the GBEP indicators, when the productivity indicators for both scenarios are compared, it is observed that scenario 1 has the best productivity performance, because it represents the introduction of a new and more efficient cogeneration technology. The advantage of scenario 1 against the baseline scenario is shown in the production cost per unit of bioenergy equal to J$9,609.04/MWh, decreasing 53% from the production cost of baseline scenario. Additionally, the annual saving from reduced purchases of fossil fuel would be approximately J$44 million when the sector uses all the bagasse-derived power generation potential.

ETHANOL PRODUCTION

From an economic perspective, it is recommended that before introducing the use of domestic anhydrous bioethanol in the E10 blend, it is necessary to take some actions that help to improve the sugar cane industry infrastructure and the sugar cane production performance in Jamaica. Additionally, a mix structure in anhydrous bioethanol industry using both molasses and cane-juice to produce anhydrous bioethanol could be an option to improve the industrial productivity. Finally, it is recommended to carry out another lifecycle costing analysis for different blends of ethanol gasoline. From a cost perspective, gasoline continues to be by far, the main element of E10. For the GBEP indicators, it is seen that the overall productivity is greater in the Baseline Scenario in regard to technology and feedstock, processing efficiencies; however, the production cost is greater in Scenario 1. No change was observed in change in consumption of fossil fuel and traditional use of biomass and in energy diversity. There is also less value added in Scenario 1.

KEY LESSONS LEARNT AND RECOMMENDATIONS ON THE RELEVANCE, PRACTICALITY AND SCIENTIFIC BASIS OF THE INDICATORS

- Overview / cross-cutting, e.g. stakeholder engagement (max. 1 page):

The results of the study showed that the operational conditions of Brazil and Jamaica are different and hence environmental, social and economic results are different. The new generating capacity at Golden Grove has significant environmental and economic gains for the sugar factory and the workers. Additionally, the production of ethanol at Everglades, although has increased environmental impacts, the social conditions are better than those experienced in Brazil. In general, due to the lack of the relevant data necessary to complete a thorough SLCA and to test all of the GBEP indicators render the results of the study limiting. Considering that currently the Jamaica sugar cane industry is in limbo, having experienced a severe drought leading into this crop season, and the continued decline in global sugar prices. It is now critical for a holistic approach be taken by the industry and to utilize the necessary methodology etc. for risk management, since the industry is a major earner of foreign exchange and local job creation.

- Environmental pillar (max. 1 page):

The stage of electricity cogeneration with bagasse contributes more in thirteen of the eighteen impact categories analyzed for the baseline scenario. In four of these, the process of electricity from the grid in Jamaica has the greatest impact due to the carbon dioxide fossil emissions in the process and vanadium consumption. Whereas, for the scenario 1, the stage of electricity cogeneration with bagasse is the most impacting stage only in five categories (photochemical oxidant formation, particulate material formation, terrestrial acidification, marine eutrophication and climatic change) due to the nitrogen oxides and other particulate material emissions in the process of cogeneration with bagasse. Although, the impact is reduced for this scenario 1, there is an impact due to the emissions associated to the bagasse combustion. For the baseline scenario, the agricultural stage, sugar cane cultivation at Golden Grove presents the major impact in two categories due to the emissions from sugar cane production and the processes of diesel and pesticides production mainly. For the scenario 1, the agricultural stage, sugar cane Golden Grove, present the major impact in nine categories for the same reasons. These results show that the reduction of impact in the scenario 1 is due to the stage of electricity cogeneration with bagasse mainly, because of the energy from the grid saved, the emissions and use of natural resources associated to it. The results indicate that the baseline process generates the greatest potential impact on all categories analyzed. It demonstrated the feasibility of upgrading the cogeneration process in order to increase the electricity generation contributing to avoid the use of fossil fuel in the process and to export electricity to the grid. For the GBEP indicators it is observed that the scenario 1 has the best results in all indicators. In baseline scenario it is necessary to consume electricity from the grid contrary to scenario 1, where it is possible to satisfy the demand of electricity and to export to the grid. Besides scenario 1 achieves major efficiency in electricity cogeneration. It is strongly recommended that the implementation of modern biomass power plant (5.0 MW of power installed) in order to upgrade the cogeneration technology into the Golden Grove enterprise and the implementation of an appropriate waste gas treatment to reduce the impact of the cogeneration stage in the process.

The baseline scenario for this study considered the use of anhydrous bioethanol from Brazil and gasoline from Trinidad Tobago to form the E10 blend and use it as fuel for passenger vehicles in Jamaica. Three life cycle stages are considered, agricultural (sugar cane cultivation in Brazil), industrial (production of molasses and anhydrous bioethanol in Brazil) and the use stage, which includes the transportation of anhydrous bioethanol and gasoline and the combustion of E10. It can be concluded that fir the Baseline Scenario, the combustion of gasoline contributes to most of the potential environmental impacts assessed, and thus the use stage is the most significant in terms of these impacts. The greatest potential environmental impacts can be observed in the use stage due to the combustion of gasoline, which represents 90% of the volume of the blend. The combustion of the mixture presents a significant contribution to climate change; the impacts on agricultural stage are mainly due to the use of fertilizers and pesticides, resulting in emissions that their application generates. The production stage has no significant impacts; the processes for obtaining molasses and anhydrous bioethanol consider a proper use of by-products avoiding impacts to the evaluated categories. In Scenario 1, the anhydrous bioethanol imported from Brazil was replaced by its production in Everglades. The same three life cycle stages as of the baseline have been considered, in the case of the obtaining of anhydrous bioethanol, the local conditions were modelled. Like the Baseline Scenario, the use stage contributes the most to the potential impacts assessed, but in this case production stage is also relevant. For this *Scenario* the main impacts from the agricultural stage are associated with the use of pesticides and fertilizers, and the use of diesel. The crop yields are lower than those reported for Brazil. The impact on the production stage for obtaining anhydrous bioethanol relies heavily on the imported molasses, which represents 85% of total consumption. The sugar factory is not self sufficient in consumption of electricity from bagasse, for this reason the molasses production in Everglades presents major impacts associated with the processes of energy generation from diesel and bunker oil. The comparison of the scenarios showed that under the conditions evaluated in the study to obtain anhydrous bioethanol from Everglades presents less favourable conditions in terms of the potential environmental impacts. This is evident since Scenario 1 is higher in twelve of the eighteen environmental impact categories evaluated. The sensitivity analysis showed that the project presents low sensitive to parameters evaluated. The potential impact in some categories can be diminished, but in the majority of these is not achieved a considerable decline below those obtained in the baseline scenario, due to several effects related with the relations between agricultural and industrial stages for obtaining anhydrous bioethanol in Jamaica. It is highly recommended that the factory finds greater use of by-products and increases bagasse cogeneration considering gas cleaning systems. It is recommended that, the system for obtaining bioethanol in Jamaica will be modelled considering the technology installed in Brazil and similar consumption of molasses per tonne of anhydrous bioethanol.

- Social pillar (max. 1 page):

Most of the positive social impacts are derived from changing production of anhydrous bioethanol from Brazil to Jamaica, due to the fact that Jamaican workers in the sugar industry enjoy better conditions than their Brazilian counterparts, including no child labour or forced labour, better guarantees for freedom of association and more regulated working hours. An anticipated negative impact on the local community is the loss of a number of unskilled low wage permanent Jobs. For the Golden Grove scenarios, the positive social impact for workers is an increase in average income, due to a number of new, well-paid middle management jobs required to manage the new cogeneration machinery. The positive social impact for the local community is an expected increase in a number of unskilled, temporary jobs required to renovate the facility and install the new cogeneration equipment.

- Economic pillar (max. 1 page):

The current context of importing bioethanol for E10 blend in Jamaica offers the lowest life cycle cost, and this is due mainly to the competiveness of the imported bioethanol and the technology gap in the sugar/ethanol and sugarcane industries between Jamaica and Brazil.
This is versus domestic produced bioethanol for the E10 blend, which is less competitive. Whereby, bioethanol production in Brazil is characterized by a higher industrial productivity as compared that of production in Jamaica. However, the competiveness of Jamaica's bioethanol production could be significantly improved with a mix structure in the bioethanol industry, where, sugar molasses and cane juice can be used for ethanol production. It is being recommended from an economic perspective for the installation of a new 5.0 MW bio-cogeneration system capable of selling 2.1 MW to the external grid. This would bring economic benefits (co-benefits) to the sugar mill, reducing the energy bill and the introduction of value-added products. The production cost of sugar cane should be monitored because of its significance to the life cycle cost of the sugar-ethanol mill.