Journal of Agricultural Studies
ISSN 2166-0379
2013, Vol. 1, No. 2

# Environmental Bio Economic Impact in Nicaragua

Blanco Orozco, Napoleón Vicente

Doctoral Program in Natural Sciences for Development, Ph.D student

Technological Institute of Costa Rica, National Engineering University of Nicaragua

Faculty of Electrical Engineering and Computing, Nicaragua

Tel: 505-2278-5220 E-mail: napoleon.blanco@usr.uni.edu.ni, blanconapoleon@yahoo.com

Zúniga González, Carlos Alberto

National Autonomous University of Nicaragua, León

Technology and Sciences Faculty, Agroecology Department

Researching Centre for Agrarian Sciences and Applied Economic

Tel: 505-2311-5013 E-mail: czuniga@ct.unanleon.edu.ni, czunigagonzales@gmail.com

Received: May 29, 2013 Accepted: June 12, 2013

doi:10.5296/10.5296/jas.v1i2.4033 URL: http://dx.doi.org/10.5296/jas.v1i2.4033

**Abstract**

In this article the Bio economy of power plants connected to the national interconnected system of Nicaragua is analyzed, through the study of environmental effects of greenhouse gases emissions from the use of solid biomass from sugarcane bagasse and oil to generate electricity. In addition, an analysis of Cost - Benefit of investments to the electricity generation using fossil fuel and bagasse is done. The Methodology EX-Ante Carbon-balance Tool (EX-ACT) was used; this methodology was proposed by the United Nations Organization for Food and Agriculture (FAO) to determine the overall greenhouse gases (GHG) emission balance. Additionally, the WinDASI program, also developed by FAO, was used for the Cost - Benefit Analysis of investment in power plants. Furthermore, we performed marginal costing GHG reduction. The results show, that all plants are sources of GHG emissions, however the impact of sugar mills is partially positive by reforestation components and annual crops. However, the component inputs had negative environmental and socially impact. In the case of thermal power generation plants based on petroleum connected to the national grid, they were found to be sources of greenhouse gases. The analysis of the Benefit Cost in their investment indicates that there is a positive financially impact except in ALBANISA power plant and sugar Mills power plants.

**Keywords**: WinDASI program, Biomass, Bio Economy, Oil fuel, Energy

**JEL Classification**: L:23, L:65, Q:16, Q :43, Q :51

## 1. Introduction

The greenhouse gases emissions (GHG) in Nicaragua increased by an annual average of 3.24% between the year 1990 to year 2009 (CEPAL, 2013). In this sense, the annual net emissions of carbon dioxide ($CO_2$) from the energy sector increased by 32.5% in the year 2000 and the second largest source of GHG emissions at the national level is made up of the agriculture and energy sectors with 19.4% of the total $CO_2$ equivalent. In the case of the electrical industry, the emissions come mainly from the consumption of petroleum in the process of power generation (MARENA, 2008).

Most of the electricity generated in Nicaragua still comes from thermal plants operating based on petroleum accounting for 60% of installed capacity, the hydroelectric 11%, geothermal 4.1%, wind 7.12%, biomass 11.79 % and isolated systems 1.2% (INE, 2012). Furthermore, it is predicted an average annual growth of 4.5% of the power demand and 4.8% for energy demand from the years 2003 to and 2018 (National Energy Commission, 2005). Therefore, if there is no change in the energy matrix using a greater proportion of renewable energy sources, the greenhouse gases emissions will continue contaminating the atmosphere in the process of generating electricity using petroleum.

Moreover, electricity generation using thermal power plants based on fossil fuels cause negative environmental impacts through heat emissions and greenhouse gases resulting from the combustion of petroleum. So, due to the combustion of fossil fuels pollutants are emitted to the environment such as: nitrogen oxides (NOx), sulfur dioxide (SO2), carbon monoxide (CO), carbon dioxide (CO2), unburned hydrocarbons (HC), dust particulate matter, heavy metals and organic compounds (National Commission for the Efficient Use of Energy of Mexico, 2009; Laguna, 2007).

Alternatively, renewable energy can be used to meet the growing demand for renewable energy and to reduce the emissions of greenhouse gases. Udomsri et al. (2010) observed that the use of such solid waste, incinerated in a controlled way to produce energy, reduce environmental impacts and recovers energy with low emissions production; they also claimed that the combination of hybrid systems and biogas is very attractive in terms of further reducing organic waste, since the system reduces the $CO_2$ levels by 4% compared to existing thermal plants based on petroleum and gas plants.

In this context, the Government of Nicaragua has made efforts to transform the energy matrix and for this purpose a strategy was designed to change it in terms of using generation from renewable electricity. From the year 2007 to 2011 there have been installed 135 MW of power from renewable energy, of which, 63 MW are wind energy, 36 MW of geothermal energy, and other small hydroelectric plants. In 2012 there were installed 36 MW of the San Jacinto Tizate geothermal plant, 40 MW of the Blue Power wind plant and 44 MW of Eolo wind plant, which are expected to begin operations in the year 2013; besides, two hydroelectric power plants are under construction: Larreynaga of 17 MW and Hidropantasma of 12 MW (Ministry of Energy and Mines of Nicaragua, 2012).

On the other hand, from the point of view of energy security and the availability of power, biomass has great potential to be used as fuel from renewable energy sources (Moon et al., 2011). Also, biomass can be used on the generation of electricity in cogeneration systems. In this sense, cogeneration, or the combination of heat and power (CHP) has been recognized as a more efficient alternative to generate energy through large power plants. The cogeneration can reduce $CO_2$ emissions and reduce the energy required to be transferred in the transmission and distribution lines (Siler et al., 2006).

So that, a change arises towards the concept of moving economies based on petroleum and its derivatives to the Bio Economy based on biofuels and sustainable energy sources and environment friendly products. However, for the foreseeable future, renewable energy and biotechnology will have to coexist with hybrid technologies in a gradual process of change of current energy-intensive technologies to energy-efficient alternatives, with an increase in productivity and, at the same time, generating benefits in terms of natural resource management (Trigo, 2011).

In this article, the impact of Greenhouse Gases mitigation was analyzed taking as a source the uses of solid biomass from sugarcane bagasse and thermal generation plants that use petroleum. For the analysis, a tool proposed by the United Nations Organization for Food and Agriculture called Carbon-balance Tool (EX-ACT) was used, which is a methodological tool to study different components of a project in order to determine an overall assessment of the greenhouse gases emission. Furthermore, the WinDASI program was used for Cost - Benefit analysis of investment on power plants with power purchase agreements contracts and connected to the national grid. WinDASI was also used for the financial analysis of the mitigation options for climate change profitable to run and to obtain the cost-effectiveness in terms of USD / t CO2e for each mitigation action.

Therefore, the purpose of this article is to determine the environmental effects as greenhouse gases emissions caused by the power generation using fossil fuels and to compare the effect of the use of renewable energy resources such as biomass from sugarcane bagasse and energy crops to generate electricity in San Antonio and Monte Rosa sugar mills. The aforementioned mills generate energy through cogeneration systems; that is to say, they produce energy as heat for the industrial production process and also take advantage of the steam to generate electricity for domestic consumption and to sell electric energy and power to the national grid of Nicaragua.

This article is divided into five sections: the first section is a literature review related to the environmental impact assessment of energy projects; the second is a description of the methodology used to study the Bioeconomy in Nicaragua based on EX-ACT Tool and Cost - Benefit Analysis of electricity generation projects investment, in the third section the data used in the analysis are detailed, the fourth section is a description of the results of the application of the EX-ACT tool and Cost - Benefit Analysis of investment projects in power plants and the in the final section the final conclusions are presented.

*1.1 Production Flow of the Cogeneration System in Sugar Mills*

San Antonio and Monte Rosa Sugar mills are connected to the National Interconnected System (NIS) and generate energy for auto consumption and to sale to national and Central American market by developing a complementary production process of food and energy. The sugar cane is grown, harvested and then heads for milling where bagasse, molasses and cane juice is obtained. From the sugar cane juice, the sugar destined for national market and to export is obtained; of molasses, liquor is obtained which is also sold nationally and internationally and ethanol that is sold exclusively to international markets (see figure 1).

Besides, the bagasse is destined to the cogeneration process for the simultaneous production of steam used in the production process of sugar, molasses, cane juice, and electric power generation. Outside harvest, the use of energy crops, especially the Eucalyptus species, is implemented to generate the steam cogeneration system mentioned above.

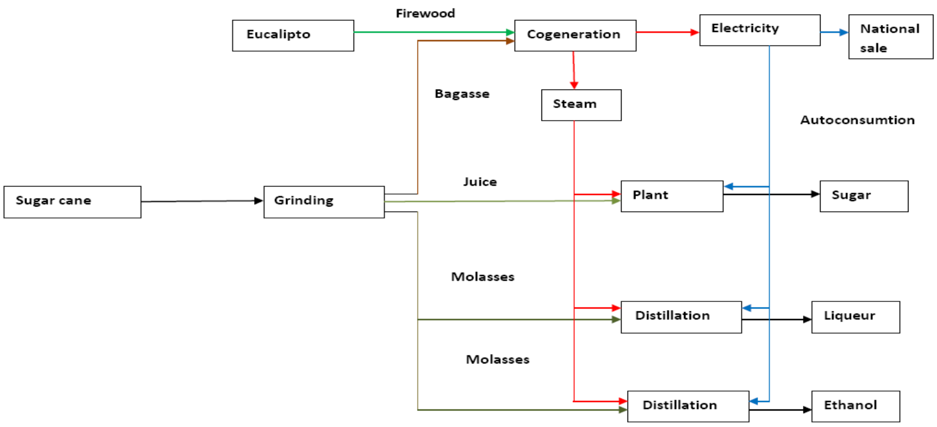


Figure # 1: Production flow of sugar mills connected to the National interconnected system of Nicaragua

## 2. Literature Review

The literature review focuses on the application of EXACT tool to determine the climate change impact of electricity generation using renewable resources such as biomass and non-renewable resources such as petroleum products, through the calculation of carbon dioxide emissions. Furthermore, it is included the WinDASI application for Cost - Benefit analysis of investment in generation of electricity projects.

EX-ACT Carbon-balance Tool (carbon balance tool) is a tool developed by the United Nations Organization for Food and Agriculture (FAO) that provides estimates of the reduction of the environmental impact of agricultural and forest projects, calculate balance of greenhouse gas (GHG) emissions and carbon sequestration using IPCC guidelines for National Inventories of greenhouse gases (Bernoux, Tinlot, Bockel, Branca, and Gentien, 2011). Additionally, EX-ACT is an accounting system that analyzes various project components as deforestation, forest degradation, changes in land use, emissions of greenhouse effect gases and calculates the equivalent emissions in tons of $CH_4$, $N_2O$ and $CO_2$ (in $tCO_2$-eq/ha per year) and provides as output a balance of greenhouse gases emissions. Even more, EXACT has the potential to select the activities of a project with greater benefits in both economic and climate change mitigation and the results of the application of EXACT could be used in the financial and economic analysis (FAO, 2011).

EX-ACT is a tool to estimate GHG emissions and carbon sequestration projects. So that, when the effects of GHG through a carbon balance are shown, this process can be selected as of a potential project mitigation indicator (Bockel, 2011). In addition, the environmental service of carbon sequestration provided by a project and estimated through the balance of greenhouse gases using EX-ACT, can be priced and incorporated into the economic analysis of the project.

Also, the financial evaluation of a project, using discounted measures of project value, such as net present value or internal rate of return, can change if the benefits of carbon sequestration are considered. Furthermore, the assessment of the environmental benefit of avoiding emissions of greenhouse gases has the potential to complement the economic analysis and provide useful information on the efficiency of the project in environmental services (FAO, 2011). Moreover, the impact of development projects on greenhouse gases emissions and carbon sequestration, can serve as an indicator of the mitigation potential of a project for its selection among a specific sector program (Sutter, 2012). The defaults values for mitigation options in the agricultural sector are based on Smith et al. (2007). Similarly, other GHG emission coefficients of agricultural operations, supplies, transportation and application of irrigation systems are based on Lal (2004).

EX-ACT tool logic is based on the fact that if you develop an ex- ante analysis you should have an idea of what would happen without carrying out a specific project; that is, the approach without project, which is a scenario often called the baseline. So, the final balance is the comparison between the greenhouse gases associated with the project implemented and the baseline without the project, that is to say comparing two scenarios: without project and with project(Jönsson, 2012).

The methodology of implementation of EXACT can be reduced to three stages in order to consider each project activity: estimation of the affected area by the change in land use and its management, characterization of the technologies and practices used in the situation with and without project, and quantification of the mitigation potential of the project activities with EX-ACT (Branca, Carro, and Medeiros, 2009). In this sense, comparing the evaluation results of carbon balance with EXACT and the clean development mechanisms methodology (CDM) was determined that EXACT provides estimates of GHG in a short time and exposes the benefits of the implementation of project activities; proving the relevance of EXACT tool to determine GHG emissions (FAO, 2013).

Moreover, the program developed by the FAO called WinDASI allows financial, economic analysis, and project cost benefits. The WinDASI project model begins by defining the basic elements of the project (inputs and outputs) later, this elements are combined to create more complex project elements (project activities), which can be mixed to construct more detailed elements such as components project, project geographical areas, target groups, etc. (Bellù, 2005).

The NPV calculation is done using the FAO WinDASI Program. The equation that follows shows how to estimate the NPV of a project:

$$VPN = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_o \qquad Equation\ \#\ 1$$

Ct = cash flow the investor receives each year

C0 = the initial investment

r = the discount rate

t = project duration

In a case study of crop intensification and coffee plantations in Thailand, Bellù (2005) stated that when applying WinDASI the information should be organized starting with the identification of all project inputs and determining its financial and economic price. Subsequently, the project activities are identified and then all production units in study are defined as plans. The need to identify specific areas of study is expressed; so the project study area should be zoned to differentiate the results depending on the different physical characteristics of these sub-areas, to determine the economic and financial feasibility of the project, and the impact in each area. Finally, the costs and benefits and other financial indicators such as net present value, internal rate of return and benefit-cost ratio are calculate to analyze the profitability of productive activities of coffee plantation in the different areas of study.

In addition, in the financial analysis of projects is necessary to employ an appropriate discount rate, which may be a private discount rate, to reflect the cost of capital, as a weighted average private cost of capital and representing the cost of a loan, that is to say, the income forgone from an investment alternative or transaction costs. Also, you can use the social discount rate that provides an estimate of the speed at which the society evaluate the future and the present; that is, the preference of society over time. However, sometimes the mitigation projects are not developed by governments, but by a large number of private and public investors with different perspectives compared to social planners who pay taxes and are subsidized (European Bank for Reconstruction and Development, 2010). It is for the above reason, that a type of hybrid discount rate can be used, as suggested by the Committee on Climate Change (The Committee on Climate Change, 2008) in which the social discount rate also includes capital costs.

Moreover, agro activities have mitigation potential if appropriate production techniques are used. In addition, environmentally friendly agro production practices are generally relatively inexpensive options and can generate significant benefits in improving agricultural production systems, ecosystem resilience and other environmental services (Bockel, Sutter, Touchemoulin, and Jönsson, 2012).

In the same sense, there are a variety of technical solutions for GIE mitigation, but not all options are economically more efficient. Therefore, there are methodologies that can be used to try to determine the efficiency of production techniques in GIE mitigation and one of them is the use of marginal abatement costs, which compare the cost-effectiveness of mitigation options between different sectors (eg, agriculture, energy, transport, industry and domestic energy consumption). Similarly, the methodology of marginal abatement costs can be used combined with the EXACT tool support, as is confirmed by Bockel and Tinlot (2012) when they claimed that EXACT can estimate the mitigation potential of rural development projects generated by changes in farming systems and land use, demonstrating the possibility of using this method together with the analysis of GHG emission balances.

As detailed by Bockel, Sutter, Touchemoulin, and Jönsson (2012) to implement the marginal cost calculation tool of reducing greenhouse gases first, the measures and mitigation options are identified and selected. Then, the maximum technical potential mitigation of greenhouse gases of the measures in terms of land use constraints are quantified. Finally, the costs and benefits of mitigation action are estimated and the marginal cost approach relating to reduction mitigation potential and costs of mitigation projects is used.

In relation to costs, the analysis focuses on the direct costs of the proposed mitigation technique, implementation costs, capital and production costs. The costs and benefits to consider are additional costs due to project revenues, compared to a reference situation when nothing is done. The marginal cost is calculated as the ratio of NPV of the project and the greenhouse gases emissions of the mitigation project; by dividing the NPV by the amount of greenhouse gases avoided and the duration of the project, you get the annual average cost of reduction or increase in GHG emissions, in USD / t CO2e/year.

So, the evaluation of the cost-effectiveness of the mitigation option of GHG selected is a process in which the relationship is quantified in terms of US $ / t CO2e for each mitigation action. First, the costs and benefits should be quantified, allowing calculating the Net Present Value (NPV). The NPV is used to analyze the profitability of an investment and represents the difference between the present value of future cash flows of an investment and the amount of investment. The present value of expected cash flows is calculated using the required discount rate of return; a positive NPV means that the project is profitable; while a negative NPV means that the costs outweigh the benefits and are therefore the project is not profitable.

## 3. Methodology

In this section, we present the application of the methodology EXACT as a tool for estimating the carbon balance and WinDASI for Cost-Benefit Analysis. Below is presented the description of the methodology to examine the data necessary for the analysis of $CO_2$ emissions and financial analysis of electricity generation using biomass from sugar cane and oil derivatives.

### *3.1 Using Exact*

To calculate the balance of greenhouse gases (GHG) and estimate the environmental impact of sugar mills that use biomass from the sugar cane bagasse and energy crops to generate electricity, and thermal plants that generate electricity based on petroleum products, EX-ACT carbon-balance tool (carbon balance tool developed by the United Nations Organization for Food and Agriculture, FAO) was used. This tool calculates balance of greenhouse gases and carbon sequestration using the IPCC Guidelines for National Inventories of GHG.

The $CO_2$ balance calculation is performed by a method that can be applied in a manner very similar to any of the types of land use, that is to say is a generic method. As part of the methodology an analysis of biomass on the ground, below ground biomass, soil, dead wood and litter is considered. EXACT tool for the treatment of biomass in land surface considers appropriate default values provided by IPCC related to the tons of dry matter (DM) per hectare, and the calculations of biomass and ground biomass are done using a ratio of below-ground and the biomass of aboveground biomass in tones.

The calculation of GHG emissions is achieved by a balance between greenhouse gases associated with the project and the baseline without the project. On the other hand, the structure of the EX-ACT tool is a set of Microsoft Excel sheets linked, in which the project design parameters are inserted as basic data on land use and management practices under the project activities. EXACT adopts a modular approach, each module describes the specific use of the land and follows a three-step logical framework: project Overview (geographical features, climate and soil, the duration of the project); identification of land use changes and technologies provided by the components of the project with specific modules (deforestation, forest degradation, afforestation / reforestation, annual / perennial crop, rice cultivation, pasture, organic soils, livestock, supplies, other investments) and carbon balance calculation with and without the project using the IPCC default values.

Data for each power plant under study were inserted in the component description of the Excel sheets. In the case of the sugar mills data components of annual deforestation and agricultural practices were inserted; to determine greenhouse gases associated with net electricity generation for power plants that use petroleum, during the study period of 2000 through 2011, the component other investments was used. Finally, the EXACT program results determined which power generation plants are sources and which are sinks of greenhouse gases emissions.

On the other hand, continuing the methodological process, activities with agro mitigation potential of offsetting GHG emissions from thermal plants were proposed. First, we selected agro production practices that are environmentally friendly according to criteria related to environmental externalities, economic and social externalities. After choosing the options to take, carbon balance EXACT tool was used considering the difference between the CO2 ton of carbons emitted and stored by a proposed option as compared to a baseline scenario or reference; that is, scenarios with project and without project were considered and we quantified the maximum technical potential for GHG mitigation using EXACT.

Subsequently, we determined the efficiency of the use of these production practices in mitigating GHG. So, we began on estimating the costs and benefits of mitigation actions and then calculated the marginal abatement costs in order to compare the cost-effectiveness of mitigation options. Similarly, the costs and benefits were updated using the concept of NPV to analyze the profitability of each mitigation action. Then, the marginal cost of reduction or mitigation was the result of to dividing the NPV by the amount of greenhouse gases avoided expressed in t CO2e/year in U.S. $ / t CO2e.

*3.2 Using Windasi*

For the NPV calculation, WinDASI developed by FAO, was used. WinDASI program is designed to perform most of the calculations required in project analysis like to determine goods produced and consumed in a given period, to determine flows of costs and benefits, and to determine present value and net present values using a specific internal rate of return. In the end, using WinDASI is possible to calculated financial indexes as the net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (Bellù, 2005).

For each power plant the inputs (commodities) that correspond to the fuel used in power generation and electrical energy generated as output of each plant were specified, grouping the commodities in the business of power generation. In addition, the investment for each power plant calculated according to what has been amortized as recognition of the product of average power cost in the study period was specified. In the component of plan, all power plants in study were identified; the power plants were divided in western zone and central zone of the pacific area of Nicaragua, where power plants under study are concentrated. Finally, the cost-benefit study of the electric power generation plants in analysis was assigned as project.

Additionally, with the information on the mitigation potential (t of CO2e reduced) and the average cost of each mitigation measure (USD / t CO2e/year) an analysis was performed and the most feasible mitigation options was chosen. The cost of implementing a specific mitigation action was compared to the price of a ton in the carbon market, in this way, the actions that can be funded by the carbon market were identified.

## 4. Data

*4.1 In the Case of the Use of Exact*

4.1.1 Coverage

In the present study we considered the following power plants: ALBANISA, GECSA, GESARSA, CENSA, EMPRESA ENERGETICA CORINTO, TIPITAPA POWER COMPANY, GEOSA, CHINANDEGA (GEOSA) y LAS BRISAS (GECSA). Also MONTE ROSA and SAN ANTONIO sugar mills.

4.1.2 Period of Study

For each power plant the period was among the year 2000 to 2011.

4.1.3 Overview

For the analysis of power generation plants a description of the project area, including the location of the project, the description of basic physical parameters such as the prevailing weather and the dominant type of soil was provided. Also, the limits of the project to confine the risk of land use and changes in land use outside the project boundaries were fixed. Therefore, in the evaluation the direct and indirect impacts of the project within its boundaries were considered; that is, an area where the activities are related to electric power generation project was considered.

Moreover, EX-ACT consists of different modules that can be used to simulate the impact of project activities on the carbon balance; but in this specific case there were only used the modules that are relevant to electricity generation project using biomass and petroleum. It should be mentioned that, we considered the situation without project or baseline scenario as a non-existence of the power generation plant in the area under study. The situation with project is the largest in reasoning analysis, and project activities in operation. That is, all land uses and direct and indirect land use changes are integrated by the EX-ACT tool in assessing the carbon balance

4.1.4 In the Case of San Antonio Sugar Mill:

It was considered an implementation time of 3 years

Capitalization time of 10 years

For a total of 13 years of planning horizon

4.1.5 In the Case of Monte Rosa Sugar Mill

It was considered am implementation of 3 years

Capitalization time of 14

For a total of 14 years of planning horizon

4.1.6 In the Deforestation and Reforestation Module

An average consumption of metric tons of wood was used and the total annual reforestation acres per metric ton (MT) of wood were estimated using a factor of 150 MT / ha

4.1.7 In the Analysis of Agricultural Practices in the Annual Module

The consumption of tons of bagasse ($10^3$ t) was used as data and from this data it was possible to determine how many acres should be planted with a factor of 17 ha /t (Ramirez, 2008, p.11).

4.1.8 In the Input Module

It was considered that sugarcane requires about 1 kg of nitrogen (N) for each tone produced, in terms of phosphorus (P), it takes about 0.7 kg per ton produced and the potassium (K) needs of sugarcane are approximately 2.3 kg per ton produced (Perez, 2012). Also, it was considered that sugarcane needs 200 kg / ha of urea (Segura and Martinez, 1973). The fuel consumption corresponding to the sugar cane harvest index was considered as 0.322 liters consumption per ton of cane harvested (Rodriguez y Valencia, 2012). Likewise, in the case of the use of eucalyptus wood energy an index of consumption of 10 liters per ton of processed wood was considered (Paul et al, 2003).

4.1.9 In the Case of Power Generation Plants Based on Petroleum

In the other investments module : data of Electricity next generation of each plant were used, namely own consumption plus total electricity generated throughout the study period in Option 1, while in the Option 2 the annual average generation was used.

*4.2 Data Used in the Cost - Benefit Analysis of Investment of Power Plants*

4.2.1 Coverage

In the present study we consider the following power plants: ALBANISA, GECSA, CENSA, EMPRESA ENERGETICA CORINTO, TIPITAPA POWER COMPANY, GEOSA, Also MONTE ROSA and SAN ANTONIO sugar mills.

*4.3 Period of Study: for Each Power Plant the Period was from 2007 to 2011.*

*4.4 Commodities Identification*

In power plants based on fossil fuel, the input used was the cost in dollars of fuel used for the generation of electricity from each plant annually. Revenues were estimated based on an annual variable cost recognized to each plant per MW-HR generated. In the case of the sugar mills the input is the fuel in form as bagasse at a cost of U.S. $ 5 per ton (Sanchez et al., 2007) and revenues are estimated based on variable cost recognized each mill generated per MW-HR annually.

*4.5 Activities Identification*

For each plant studied the activity considered was the generation of energy, expressed like the difference in fuel costs in dollars and income from power generation also in dollars.

*4.6 Plans Identification*

In this component each power generation plant described in the coverage of the study is identified.

*4.7 Zones Identification*

The zones correspond to areas of plant location divided into northern and central Pacific of Nicaragua. In the central zone are the power plants: EMPRESA ENERGÉTICA CORINTO, CENSA, GEOSA, INGENIO SAN ANTONIO, INGENIO MONTE ROSA. In the north zones are the power plants: ALBANISA, TIPITAPA POWER y GECSA

*4.8 Identifying Components of the Project*

This component corresponds to the cost-benefit analysis of the power generation plant under study

*4.9 For the Study of Each Power Plant a Discount Rate of 15%, was Considered Representing the Minimum Attractive Rate of return Investors.*

The calculation of marginal cost of GHG mitigation practices as a compensatory measure of $CO_2$ emission from thermal power plants was based on the emission data for the estimation of areas of perennial crops per hectare needed to mitigate potential ton of $CO_2$e/year determined with the EXACT. The costs adopted of implementing the technological mitigation options were the reported by FAO (2009). The cost of planting perennial crops associated agroforestry are US $ 125/ha and the maintenance cost of forest farming are between U.S. $ 183 / ha per year (Moreno and Hernando, 2005) and US$ 256 /ha per year (Gomez y Reiche, 1994); but it was considered to be US $ 183 / ha.

Moreover, for each GHG mitigation practice, a discount rate of 20% was established and a planning and financial time of evaluation that depends on the size of each project was estimated ranging between 10 and 15 years. For the calculation of income, a sale price of tons of carbon sequestered of $ 20 / t CO2e was considered (FAO, 2009). In the case of fuel consumption for planting, harvesting and processing of eucalyptus an index of 10 L/t was considered (Paul et al, 2003).

## 5. Results and Discussion

In our study we aimed to analyze the environmental effects of the greenhouse gases emitted and the Cost - Benefit Analysis of investment in power generation plants that use solid biomass from sugar cane bagasse and power plants that use petroleum.

### *5.1 Environmental Impact*

In San Antonio sugar mill the areas deforested for planting biomass (eucalyptus wood) are replanted to maintain the resource resulting in a zero balance tons of GHG emissions tCO2. In the reforestation module was shown that annually are sequestered -74,819 tCO2. In the annual module, since the sugar mill presents improvement in farm management such as: improved agronomic practices using precision agriculture to reduce economic and environmental costs, biological pest control, nutrient management using biosolids, proper waste management, proper management of water resources, and the use of low impact chemicals, is shown that the sugar mill has a mitigation potential of -15,372,448 tCO2.

Certainly, the San Antonio sugar mill generates energy that is sold to the national grid and for auto consumption from biomass in the form of bagasse (Bio Economy) which is residue of sugar cane used to manufacture other products such as sugar and ethanol. If bagasse is not used it, it would decompose and generate greenhouse gases. In addition, In San Antonio Sugar Mill energy crops are used and considered in GHG balance; these energy crops are constantly renewed and converted into energy through cogeneration.

The biomass in the form of bagasse does not provide GHG. Since from the harvested biomass is obtained the energy for auto consumption, there are not emissions generated by the activity of power generation. The combustion of biomass has an environmental advantage by not increasing atmospheric carbon concentration, because only returns to the atmosphere the carbon fixed by sugarcane during its growth, that is, it is not released more $CO_2$ than the plant absorbed during its growth cycle (Jawit et al. 2006; Grillo, Silva, Escobar, Venturini, Buchgeister y Almazan, 2011). This was demonstrated in the gross flow without project where San Antonio sugar mill is a GHG sink of -12,005,436 tCO2 due to their annual crops and improved agricultural practices evaluated in the module reforestation, afforestation and annual crops. The approach of considering that the energy produced by biomass and used by the sugar mills and injected into the national grid saves emissions coincides with the point of view of Bockel (2011).

However, if you consider the environmental impact of the use of inputs in planting and harvesting sugar cane with the use of urea, nitrogen, phosphorus and potassium, in addition to the above, if you consider the fuel used in the cultivation and harvesting sugarcane and eucalyptus, the effect of the industrial and irrigation, San Antonio sugar mill proves to be a source of GHG balance 3, 896, 475,439 tCO2.

In the case of Monte Rosa sugar mill like San Antonio sugar mill the areas deforested to obtain biomass (eucalyptus wood) are replanted to maintain the resource, resulting in a balance of zero emission tones $tCO_2$ GHG. In reforestation module is shown that Monte Rosa sugar mill sequestered 708 tCO2 annually. Similarly, in the annual module, it is considered that the sugar mill presents improvement practices in farm management so it has a mitigation potential of -9, 768,221 tCO2.

Likewise, the Monte Rosa sugar mills generates the energy that is sold to the national grid and the energy that is used in auto consumption from biomass in the form of sugar cane bagasse; If bagasse is not used it, it would decompose and generate greenhouse gases, therefore no pollution from the process of the production of sugar cane, rum and ethanol, should be associated to bagasse which is an industrial waste. As well, in Monte Rosa sugar mill energy crops are used and considered in GHG balance; these energy crops are constantly renewed and converted into energy through cogeneration. In the gross flow without project Monte Rosa sugar mill is a GHG sink of -7, 066,279 tCO2 due to their annual crops and improved agricultural practices evaluated in the module reforestation, afforestation and annual crops.

However, when considering the environmental impact of the use of inputs in planting and harvesting sugar cane with the use of urea, nitrogen, phosphorus and potassium; and if you consider the fuel used in the cultivation and harvesting of sugarcane and eucalyptus, the effect of the industrial area by watering, Monte Rosa is a source of GHG with a balance of 2, 158, 545,829 $tCO_2$.

In the case of power generation plants based on petroleum oil, the EXACT tool is used to determinate the GIE emitted in the process of electricity generation. GHG emissions were calculated in the case of plants with EXACT, considering the net electricity generation in the number one choice. Additionally, the calculation of tons of $CO_2$ emitted is based on the total amount of electricity generated expressed in MWh; whereas, in the option number two the average electricity generated by the plant in the study period of 2000 through 2007 was considered.

As an example the "ENERGY COMPANY CORINTO" power plant as a product of its net electricity generation emitted an amount of 7, 966, 282 tons of CO2 to the environment in the study period between 2000 to 2011 t, being evidently a source of greenhouse gases.

The following table summarizes the results of the use of EXACT in calculating emissions balance GIE thermal power plants that generate electricity based on petroleum.

Table 1. Results of calculation of GHG emissions from thermal power plants based on petroleum.

| # | Power Plant | Total de tCO2 emitted | Type of source |
|---|---|---|---|
| 1 | ALBANISA | 2,418,676 | It is a source of GHG emission |
| 2 | GECSA | 2,960,046 | It is a source of GHG emission |
| 3 | GESARSA | 46,651 | It is a source of GHG emission |
| 3 | CENSA | 3,622,103 | It is a source of GHG emission |
| 5 | EMPRESA ENERGÉTICA CORINTO | 7,966,282 | It is a source of GHG emission |
| 6 | TIPITAPA POWER | 5,974,087 | It is a source of GHG emission |
| 7 | GEOSA | 7,641,299 | It is a source of GHG emission |
| 8 | Chinandega (GEOSA) | 12,253 | It is a source of GHG emission |
| 9 | Las Brisas | 2,545,192 | It is a source of GHG emission |
| | Total | 33,186,589 | It is a source of GHG emission |

Below is a summary table comparing the results obtained with the EXACT tool applied to the sugar mills and power plants based on fossil fuels.

Table 2. Comparative results GHG emissions of power plants based on fuel oil and sugar mills using biomass in electricity generation. Gross results.

| Power Plant | GGH emitted ton CO2 eq reforestation component | GGH emitted ton CO2 eq Annual Crops | GGH emitted ton CO2 eq Inputs component | GGH emitted ton CO2 eq Other investments Component | Final Balance GGH ton CO2 eq | Results Per hectare | Type of source |
|---|---|---|---|---|---|---|---|
| Ingenio San Antonio | -74,819 | -3,367,012 | 3,899,821,924 | 95346 | 3,896,475,439 | 14,499.4 | It is a source of GHG emission |
| Ingenio Monte Rosa | -708 | -9,768,221 | 2,168,248,129 | 66,629 | 21,585,455,829 | 10,765.4 | It is a source of GHG emission |
| ALBANISA | | | | 2,418,676 | 2,418,676 | | It is a source of GHG emission |
| GECSA | | | | 2,960,046 | 2,960,046 | | It is a source of GHG emission |
| GESARSA | | | | 46,651 | 46,651 | | It is a source of GHG emission |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CENSA | | | | 3,622,103 | 3,622,103 | | It is a source of GHG emission |
| EMPRESA ENERGÉTICA CORINTO | | | | 7,966,282 | 7,966,282 | | It is a source of GHG emission |
| TIPITAPA POWER | | | | 5,974,087 | 5,974,087 | | It is a source of GHG emission |
| GEOSA | | | | 7,641,299 | 7,641,299 | | It is a source of GHG emission |
| Chinandega (GEOSA) | | | | 12,253 | 12,253 | | It is a source of GHG emission |
| Las Brisas | | | | 2,545,192 | 2,545,192 | | It is a source of GHG emission |
| Note: Negative values represent sink effect (not emitting GHG) positive values GHG source | | | | | | | |

### *5.2 Financial Impact, Cost Benefit Analysis*

Our analysis is based on the previous section results that all power plants are sources of GHG emissions, with the variant of sugar mills where the Bio-Economy based on Eucalyptus and bagasse biomass represents GHG mitigation in reforestation and annual crops components. By using WinDASI we obtained that power plants based on fuel oil are financially profitable in the proposed study period, since they have a net present value greater than zero; proving that power plants are able to cover their operating costs and investment and pay the internal rate of return required by the investor. Similarly, all generating plants studied have an internal rate of return greater than the minimum attractive rate of return on investment (MARR) of 15%, confirming the financial profitability of the operation of such plants.

Thus, electric power generation based on fuel oil, bagasse and energy crops is considered a productive activity profitable from the financial point of view. However, in terms of cost benefit ratio the plants: SAN ANTONIO, MONTE ROSA AND ALBANISA have a ratio less than unity because they are recent plants in operation and their investment needs a longer period than the considered of five years to show a better performance in the current benefits of power plants. Table # 3 summarizes the financial indicators.

Table 3. Financial indicators of power plants based on WinDASI results

| # | Power Plant | Net present value | Internal rate of return | B/C rate |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | ALBANISA | 430,444,032.00 | > 100 | 0.68 |
| 2 | GECSA | 123,391,672.00 | > 100 | 1.56 |
| 3 | CENSA | 135702640.00 | > 100 | 1.24 |
| 3 | EMPRESA ENERGÉTICA CORINTO | 123,740,880.00 | > 100 | 2.79 |
| 5 | TIPITAPA POWER COMPANY | 76,095,608 | > 100 | 2.10 |
| 6 | GEOSA | 310,234,688 | > 100 | 3.31 |
| 7 | INGENIO SAN ANTONIO | 54,961,332 | > 100 | 0.37 |
| 8 | INGENIO MONTE ROSA | 38,183,484 | > 100 | 0.38 |

Moreover, the financial analysis by zones of location of the power plants showed that, as a whole, the central zone is financially profitable with a Net present value of 143,521,616 greater than zero, with an internal rate of return higher than the minimum rate of return and with a benefit-cost ratio of 1.57; proving financial profitability of power generation activity in this area using fossil fuel and using bagasse of sugar mills. Also, the north zone resulted with Net present value of 340, 890.688 greater than zero and with an internal rate of return greater than the rate of return considered attractive by the investor of 15% and a benefit-cost ratio of 2.79. So, the north zone also shows a financial profitability of the operation of power generation plants that use fuel oil.

In conclusion, the cost-benefit analysis using WinDASI in the north and central areas of study where power plants are located resulted with a Net present value greater than zero of 326, 224 576, an internal rate of return greater than the minimum rate attractive to investor and a cost benefit ratio of 1.54; confirming the financial profitability of the business of electric power generation in the power plants studied that use fossil fuels and biomass in the form of sugar cane bagasse and energy crops ( San Antonio and Monte Rosa mills).

*5.3 Marginal Cost Analysis*

As mitigation Greenhouse Gas action we proposed to establish agro-forestry practices of perennial crop that produces a positive impact, because they provide higher yields of adjacent crops, reduce erosion in the medium and long term, allows better rainwater management and make a revegetation that supports improving crop yielding or adjacent pastures due to wind reduction, soil erosion in deforested areas of western Nicaragua (FAO, 2009).

Other possible actions include agricultural land management through improved agronomic practices to generate more carbon sequestration and increase of water availability in the area through water management, increasing biomass production and improving the concentration of organic carbon soil (Follett and Reed, 2010). Also, you can implement the restoration of degraded land using the carbon storage practices that claims soil productivity for example, re-vegetation, the application of nutrients and organic substrates such as manure, biosolids and compost, reducing tillage and residue retention and water conservation (Lal, 2004). However, from the practical point of view agroforestry practices of perennials are more feasible to implement.

Continuing the development of the financial impact assessment we estimated the marginal cost reduction and as illustrated example of calculation we have ALBANISA power plant. To neutralize the GHG contribution of ALBANISA needs a perennial crop area (teca) and replant 250,000 ha according to the results of the EXACT tool simulation, which has a mitigation potential of -2, 887,500 tons of CO2-eq. Considering the costs of adoption of technological mitigation options reported by FAO (2009), the cost associated agroforestry planting perennial crops is US $ 125/ha and the cost of maintaining forest farming is between US $ 183 / ha per year (Moreno and Hernando, 2005) and US$ 256 /ha per year (Gomez and Reiche, 1994) we considered US $183/ha annually. The income from the project would be to the possibility of tons of carbon sales sequestered to $ 20 / t CO2e (FAO, 2009).

Therefore, for a period of 15 years of the project and considering that the average interest rate in the banking system is 12.79% (Central Bank of Nicaragua, 2012) and the Nicaraguan social rate of discount is 8.10% (Ministry of Finance and Public Credit of Nicaragua, 2010) this calculation assumes a composite rate of 20%, using WinDASI the net present value (NPV) resulted positive, so this project is profitable. The resulting NPV is US $ 207, 777,968. The marginal cost of reduction or mitigation is calculated dividing the NPV by the number of avoided greenhouse gases which is 2, 541,000 t CO2e/year and for this case the result was 81.70 USD / t CO2e/year.

Considering the perennial plant of teca, the cost associated of agroforestry planting for perennial crops of US $ 125/ha, the cost of maintaining forest farming of US $ 183 / ha, a discount rate of 20% and a period 20 years analysis we obtained the following results:

Table 4. Details of calculation of marginal abatement cost of GHG mitigation for thermal power plant projects with WinDASI simulation

| **Power plant** | **GHG emissions t CO2e/year** | **Cultivation area required Ha** | **Mitigation Potential t CO2e/año** | **Discount rate** | **NPV** | **Marginal cost reduction or mitigation USD / t CO2e/year** | **Remark** |
|---|---|---|---|---|---|---|---|
| ALBANISA | 2,418,676 | 110,000 | -2,541,000 | 20% a 15 years | 207,777,968 | 81.70 | Profitable |
| GECSA | 2,960,046 | 129,000 | -2,979,900 | 20% a 15 years | 243,666,912 | 81.7 | Profitable |
| GESARSA | 46,651 | 2,020 | -46,662 | 20% a 10 years | 3,434,985.75 | 73.6 | Profitable |
| CENSA | 3,622,103 | 160,000 | -3,696,000 | 20% a 15 years | 302,222,496 | 81.70 | Profitable |
| EMPRESA ENERGÉTICA CORINTO | 7,966,282 | 345,000 | -7,969,500 | 20% a 15 years | 652,366,976 | 81.8 | Profitable |
| TIPITAPA POWER | 5,974,087 | 259,000 | -5,982,900 | 20% a 15 years | 481,456,256 | 80.47 | Profitable |
| GEOSA | 7,641,299 | 333,000 | -7,692,300 | 20% a 15 years | 629,000,512 | 81.7 | Profitable |
| Chinandega (GEOSA) | 12,253 | 550 | -12,705 | 20% a 10 years | 939,041 | 73.911 | Profitable |
| Las Brisas | 2,545,192 | 112,000 | -2,587,200 | 20% a 10 years | 189,700,960 | 73.32 | Profitable |
| Total | 33,186,589 | 1,450,570 | 33,508,167 | | | | Profitable |

Therefore, to mitigate 33, 186,589 t CO2e/yr emitted by power plants using fuel oil for electricity generation 1,450,570 of species of perennial crops such as teca are needed according tool results EXACT. The areas for cultivation of teca for carbon sequestration need a convenient location in order to not compete with productive land; on the contrary, you should prefer the rehabilitation of deforested areas.

**Social Impact**

It is important to assess the social impact from the point of view of the benefit that electrical energy users perceive by the power plants studied. In this regard, we appreciate that since 2007 in Nicaragua the blackouts were finished, and a transformation of the energy matrix has begun. The Bio economy of power plants has a positive mitigation impact in terms of the components of reforestation and annual crops; on the contrary, a different situation is presented in the components inputs because they generate or are GHG sources. In terms of Bioeconomy based on biomass its use is perceived as an alternative to generate jobs and mitigation of environment impact; however is not an overcrowded investment or economy of scale.

## 6. Conclusion

In this paper we analyzed the impact on the emission of greenhouse gases due to the production of electricity in power generation plants in Nicaragua and for this purpose we used the EX-ACT tool to estimate the carbon balance in the power plants under study. All estimations using EX-ACT are supported by the IPCC methodology; EX-ACT Tool provides data of the affectation of electricity production utilities to climate change by calculating greenhouse gases. Additionally, the carbon balance can guide the decision-making process for the development and financing of electricity generation with greater environmental benefits.

In the case of the San Antonio sugar mill the reforestation component shows that -74,819 tCO2 are sequester annually and the annual component shows that 15, 372,448 tCO2 are sequesters annually. However, if the environmental impact of the use of inputs in planting and harvesting sugar cane you is considered San Antonio sugar mill is a source of GHG with a balance of 3, 896, 475,439 tCO2.

The Monte Rosa sugar mill in the reforestation component sequesters 708 tCO2 annually and in the annual component sequesters, 9 768,221 tCO2. But, when considering the use of inputs in planting and harvesting sugar cane, the mill is a source of GHG with a balance of 2, 158, 545.829 tCO2.

It should be noted here, that the use of biomass from sugar cane has environmental impacts due to land use change, the use of fossil fuel for farming and for transportation of materials, the use of fertilizers and necessary pesticides applied for industrial production of derived from sugarcane as sugar, rum and ethanol. However, the cultivation of sugar cane absorbs carbon dioxide during the photosynthesis process; therefore, it has a positive impact on global warming by absorbing carbon dioxide (Grillo, Silva, Escobar, Venturini, Buchgeister y Almazan, 2011).

Furthermore, the production of sugar from sugar cane causes $CO_2$ emissions during the combustion of bagasse in cogeneration systems by incomplete combustion and depends on biomass composition. This can be overcome by controlling emissions, avoiding incomplete combustion, controlling the stoichiometry and biomass humidity with a controlled management of ash generated and its proper handling. It should be noted here, that the amount of carbon dioxide emitted by burning biomass was sequestered earlier by the plants during their growth. Thus, $CO_2$ emissions from biomass sugarcane are part of a natural circulation flow between the atmosphere and vegetation, so there is not an increase in emissions, on the contrary, the use of biomass helps reduce $CO_2$ emissions to the atmosphere, provided that biomass replace fossil fuels ( National Energy Commission, 2007).

Also, Reyes (2003) shows that the combustion of biomass has an environmental advantage by not increasing atmospheric carbon concentration, because it only returns to the atmosphere the carbon fixed by the sugarcane during its growth. Therefore, bagasse from sugar cane is a renewable fuel that does not contribute to the greenhouse effect and releases no more $CO_2$ than the plant absorbed during its growth cycle, this coincides with the results of Jawit et al. (2006) who stated that $CO_2$ emissions from biomass combustion can usually be excluded from inventories of greenhouse gases since carbon is derived from biomass that has previously sequestered $CO_2$ through photosynthesis. In this sense, Follett and Reed (2010) concluded that biomass brings environmental benefits recognized such as carbon sequestration and compensation of atmospheric CO2 by long term storage.

On the other hand, in power plants using petroleum the EXACT tool was used to obtain the amount of greenhouse gases emitted to the environment as a consequence of net electricity generation for a total of 33,186,589 tCO2 discharged to the environment during the study period between the years 2000 until the year 2011. It should be noted here that all thermal power plants that use fuel oil for electricity generation are sources of emissions of greenhouse gases and they do not has the ability to sequester carbon, as the sugar mills can, producing electricity using biomass derived from sugar cane.

In the cost-benefit analysis of the following power generation plants : ENERGY COMPANY CORINTO, CENSA, GEOSA, SAN ANTONIO SUGARMILL, MONTE ROSA SUGAR MILL, ALBANISA, TIPITAPA POWER and GECSA was confirmed the financial profitability of electricity generation activity using fossil fuels, biomass in the form of sugar cane bagasse and energy crops used by the sugar mills San Antonio and Monte Rosa.

Moreover, by applying the calculation tool of marginal cost reduction of greenhouse gas, the mitigation options were identified and then this tool yielded cost-effectiveness in terms of USD / t CO2e for each mitigation action.

To mitigate the greenhouse gases emission produced by the generation of electricity in generating plants that use fuel oil, it is recommended to establish agroforestry practices of perennial crop that produces a positive impact on the environment. It is necessary an area of perennial crops and revegetation of 1, 450,570 ha with a mitigation potential of 33, 508,167 tons of CO2-eq to neutralize the emissions of GHG of power plants based on petroleum. When considering the costs and benefits of mitigation projects its implementation was found to be feasible through the financial profitability; this was demonstrated by obtaining a positive NPV using WinDASI and an acceptable marginal cost of reducing greenhouse gases expressed in terms of USD / t CO2e/year, representing the relationship between costs and benefits of mitigation measures. In the same way, the results show that the proposal is feasible for funding in the international carbon market.

Furthermore, Branca et al. (2009) studied the case of Rio de Janeiro using the EXACT tool performing a methodological process very similar to the one developed in this article. First, they collected data on the components to investigate without project and with project, and then estimated Carbon balance using EX-ACT. They also described the effects of the components of the selected projects in the emissions of greenhouse gases and carbon sequestration. Additionally, they determined the overall potential impact mitigation component of the selected projects that were considered relevant in environmental analysis and selected activities with potential impact on the carbon balance through the implementation of various agricultural practices.

In the economic analysis of the case study conducted in Rio de Janeiro Branca et al. (2009) reached the conclusion that the average mitigation potential of the project was equal to 0.19 tCO2e/ha per year, and it was valued using a price of US $ 3 / tCO2e, as bond average price in retail level in the voluntary market in 2008, this value is very low and lower than the value used in this article of US $ 20 / tCO2e . Therefore, the averaged value of reduction potential calculated by Branca et al. (2009) was US $ 0.57 / TCO2e (per hectare per year) and since this value is below the level of transaction costs for the public execution of 4 US $ / tCO2e dollars, is considered that the project would have no feasible option to be funded by the carbon credit sector falling into "Type 1". On the Contrary, with the assumptions considered in this work, the GHG mitigation projects of thermal power generating plants have higher marginal abatement costs than the transaction costs or the public execution of 4 US $ / tCO2e dollars considered in the Rio de Janeiro case ; therefore, these project can be financed through the carbon market and listed as projects "Type 3".

Likewise, in a study involving four projects in Mali, India, Ethiopia and Moldova were analyzed respectively to compare the results obtained by EX-ACT first and then to assess the additional benefits of using EX-ACT compared with the use of CDM methodology. It was confirmed the relevance of EX-ACT as a tool to determine project GHG emissions. Additionally, it was found that EX-ACT provides very similar results, which show that could be easily used in the evaluation of CDM projects. Additionally, it was verified that EXACT tool provides information about the benefits of reducing carbon emissions indicating CO2, CH4, N20, but also the carbon sequestered in biomass and soils. As well, it was found that using EX-ACT could help further analyze the costs and benefits of carbon sequestration, taking into account other indirect activities and externalities provided by the project (value chain approach, consumption of natural resources , avoided deforestation) that could impact climate change mitigation and that have not yet been recorded in the CDM methodology(FAO, 2013).

Adding to this, Bockel and Tinlot (2012) state that the EX-ACT tool can estimate the mitigation potential of rural development projects generated by changes in farming systems and land use, coinciding with the results of determining an overall assessment of the greenhouse emission using EXACT of power plant in Nicaragua studied in this article.

Meanwhile, Bockel (2011) carried out an assessment of carbon balance in LCASP project in Vietnam with the EX-ACT tool in order to reduce air, water and soil pollution, implementing climate-smart agricultural practices of waste management for the treatment of livestock waste through widespread use of biogas and bio- technologies sludge treatment. The results of Bockel work showed the mitigation potential of the project, which avoids the emission of almost 25 Mt of CO2 over a period of 20 years and notes that while the anaerobic digestion of manure in biogas plants contributes about 15% to mitigation, the main benefits come from the conversion to more sustainable agricultural practices. In this sense, in this article we agree with Bockel that EXACT is a tool used to estimate the impacts of productive activities, in our case, the estimation of greenhouse gases emissions and carbon sequestration of electricity generation from bagasse as by-product of the sugar manufacturing process; likewise, this is consistent with reasoning that the energy produced by biomass and employed by the mills and injected into the national grid should be counted as emissions savings or emissions sink.

Similarly, Jönsson (2012) conducted a study to quantitatively estimate greenhouse gases emissions avoided by the intervention of a conservation project and the adoption of climate-smart practices and technologies that reduce emissions of greenhouse gases among small farmers with agricultural mitigation program (mitigation of Climate Change in Agriculture MICCA) in Tanzania. The author Jönsson considered mitigation practices to sequester carbon, as we did in our investigation reported in this article, proposing the teca perennial crops to mitigate GHG emissions from power plants using petroleum. The practice of carbon sequestration by perennial crops were considered in the calculation of t CO2e/year mitigation potential and in the calculation of marginal abatement cost of GHG mitigation projects as compensation measures of externalities derived of using Petroleum products in power generation.

Also, Pehnelt and Vietze (2012) conducted an analysis of environmental flows associated with the processing of the palm to produce biodiesel using the life cycle methodology in Southeast Asia. In particular, they found that a 52% saving in GHG emissions is achieved by using waste from the palm oil manufacturing process as raw material for electricity generation. The research results of Vietze and Pehnelt harmonize with the conclusions we made in this article arguing that the use of bagasse, a waste of the conversion of sugarcane into finished products such as sugar, rum and ethanol and that is used to generate electricity, saves GHG emissions.

Therefore, when comparing the results of this paper with those of the authors discussed before the relevance of the application of the EX Carbon-balance Tool (EX-ACT) methodology can be supported to determine the environmental effects of the emission of greenhouse gases caused by power generation using fossil fuels and compare the GHG mitigation effect of the use of renewable energy resources such as biomass from sugarcane bagasse to generate electricity in San Antonio and Monte Rosa sugar mills (Blanco, 2013; Zúniga, 2013).

**Acknowledgement**

This research was conducted with support from Carlos Zúniga Gonzalez, Ph.D. Director and Researcher of the Centre for Agrarian Sciences and Applied Economics, UNAN Leon, Nicaragua. The authors do a tribute to the reviewers for their contributions to improving the

scientific article.

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## Glossary

TM= metric ton
Mt = Millions of tons
Ha= hectare
t= ton
GHG = Greenhouse gases
Kg = kilogram
L= liter
Mw – hr = energy unit mega watts per hour

Co2eq = CO2 equivalent: CO2 equivalent unit, it explains the radioactive forcing (climate change impact) of a substance, usually GHG compared to CO2, for a period of time. It is calculated based on Global Warming Potential (GWP). IPCC official values for PCG are: 21 for methane (i.e.: 1 kg of CH4 has the same impact radioactive CO2 21 kg) and 310 for nitrous oxide (N2O), for a time scale of one hundred years (Colom et al., 2012).

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