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Eco-innovation in the Brazilian sugar-ethanol industry: a case study

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Abstract

This research analyzes the eco-innovation performance of a sugar-ethanol plant located in São Paulo State, Brazil. The focus is on constructs related to the generation of innovation, environmental performance and social aspects. The analysis of the capacity to generate eco-innovations was based on investments in fixed assets. As of the environmental performance dimension, the company's improvements lie in a reduction in greenhouse gas emissions (GHG), and an increase in water reuse and energy efficiency. In social construct, improvements in absenteeism and turnover were observed; however, work accident rates increased.

Keywords: Eco-innovation; Sustainability; Sugar-Ethanol Industry

Background

The growing interest of the developed countries in eco-innovation lies in their commitments to the United Nations (UN) regarding greenhouse gas emissions during the meetings in Kyoto and Marrakesh (Hellström, 2007; Zapata & Nieuwenhuis, 2009; United Nations, 1998).

The literature has focused on the understanding of this society movement. Therefore, several authors have adopted different names to refer to environmental impact reduction-related innovations in business activities. Some examples are as follows: Environmental Innovation, Eco-innovation (Andersen, 2006; Hellström, 2007), Clean Innovation (Veugelers, 2012), Green Innovation (Chang, 2011; Dangelico & Pujari, 2010), Sustainable Innovation (Barbieri et al. 2010), Ecotechnology or Green Technology (Kobayashi et al. 2011; Sarkar, 2013). In this article, the term adopted was "eco-innovation", as it has been largely adopted the in literature and technical reports. This term succeeds to cover the entire scope provided by the other terms (Schiederig et al. 2012).

Energy and fuel production-associated economic sectors are crucial to the efforts for global sustainability, due to their environmental impact and their Greenhouse Gas (GHG) emissions caused by their activities. Therefore, the sugar-ethanol industry has become importance due to their power and fuel generation potential from renewable sources.

In Brazil, the traditional benchmark has been the agricultural sector since its colonial period. Indeed, the country has been the top sugar producer and exporter in the world for a long time. In addition, the technology ownership of large-scale biofuel production (ethanol) and electricity generation (biomass) resulted in US$ 48 billion for the 2013 GDP, accounting for 1.2 million direct jobs (Zapata & Nieuwenhuis, 2009; Gouvea & Kassicieh, 2012; Neves & Trombin, 2014).

As the best renewable alternative to oil, the Brazilian sugarcane-derived ethanol has gained scope with the capacity to produce co-generate energy (electrical and thermal) in the same factory by processing sugarcane straw and bagasse (sugar and ethanol by products) (Santos et al. 2010; Chandel et al. 2010; Lima et al. 2012; Hall et al. 2012).

Sugar, ethanol and electricity production consist of two macroactivities: agriculture and industry. The processes of which demand natural resources, such as water and soil, and material and energy resources. Also, labor conditions are often unhealthy and dangerous, and they generate a great amount of inert and hazardous waste. Therefore, even if the energy balance favors the sugar-ethanol industry, there are still several opportunities to enhance the companies' economic, environmental and social sustainability.

All things considered, this research aims to analyze the eco-innovation performance of a sugar-ethanol company located in São Paulo, Brazil, as its characteristics represent the technological stage of the Brazilian sugar-ethanol sector as a whole. For this purpose, an empirical approach was not adopted. Instead, a theoretical model was chosen for the analysis, in order to assess whether the variables mentioned in the literature were taken into account by the company management, and also to foster discussions for more extensive researches that would compare the companies and eventually build a historical series.

Apart from its introduction, this article was organized as follows: the theoretical foundation that supports the model adopted for the case study analysis, as well as the technological stage, the boundaries of research, and innovation-related issues of the Brazilian sugar-ethanol industry. After that, the methodological procedures and conditions that shaped this research are described. The research outcomes are introduced and discussed in the following section; then, the conclusions and new opportunities for research are analyzed.

Conceptual background

The terminology "eco-innovation" was proposed in the mid-1990s, and it was first defined by Fussler & James (Fussler & James, 1996; Schiederig et al. 2012). Eco-innovation refers to a new product and/or process that adds value to an organization and simultaneously has lower environmental impact (Hellström, 2007; Schiederig et al. 2012; Sarkar, 2013). According to Jansson (2011), eco-innovation is the creation of goods, processes, systems, services and procedures that can meet the human needs and improve the quality of life of the population with minimal use of natural resources and emissions of toxic substances.

Eco-innovation is "eco-efficient" innovation, as its adoption or development in technology minimizes the "environmental footprint". Therefore, eco-innovation efforts should take the life cycle of products into account, from the primary source of raw material to the final place of destination (Hellström, 2007; Jansson, 2011). The eco-innovation theoretical framework is still an ongoing process. In particular, the measurement and evaluation process through indicators is still incipient (Rennings & Wiggering, 1997; Blum-Kusterer & Hussain, 2001).

It is highlighted as a management practice of eco-innovation Eco-innovation Observatory - EIO, the European Union, which monitors regional and national levels of efforts and results in eco-innovation. However, the indicators adopted by this organization are too broad, ideal for macroeconomic variables, but not for companies, as they provide several indicators, without defined patterns or typologies.

The need to associate eco-innovative results and business performance is important to meet the sustainability dimensions proposed by Elkington (1998). Indeed, management models and systems for presentation of results such as the Global Reporting Initiative (GRI) aim to guide the companies in order to promote their actions towards their employees, the society and the natural environment.

Brazil has failed to produce company-level quantitative aggregated data regarding eco-innovation. Quantitative research in the country have used data from the Social Report - IBASE, environmental certification or data taken by case studies (Ceretta et al. 2009; Bufoni, 2009; Alberton and Costa 2007; Oliveira et al. 2012) and the variables used are many and the environmental and social outcomes as they relate to business performance is controversial results (Bufoni, 2009).

Because of this theory-practice gap, (Basso et al. 2013) have suggested the model shown in Figure 1 as a measurement tool to provide a co-innovation index for the Brazillian companies. The authors report the difficulty in proposing and formulation of variables for the index as well as in obtaining the data.

This model introduces three latent dimensions (entrepreneur, environmental and social) to represent the eco-innovative results. It is similar to what has been suggested by Blum-Kusterer & Hussain (2001) and Chang (2011). However, the construction of the variables adopted by the authors differ.

The variables suggested by (Basso et al. 2013) have the advantage to collect quantitative results from the companies that adopt the GRI model in their reports, and need to report their actions and results for GHG emission, wastewater emission, solid waste, material consumption, energy consumption, work accidents, absenteeism and staff turnover (Global Reporting Initiative - GRI, 2013).

In the business dimension, the performance achieved through eco-innovation effort is theoretically supported in the studies by (Santos et al. 2014), Ngo & O'Cass (2013) and (Bowen et al. 2010). Nevertheless, for economic analysis purposes, profitability and market share-related variables may be obtained from the companies' standard financial statements.

The eco-innovation capacity, similarly to innovation, is a latent variable involving human capital, internal capital and relational capital. They refer to the variables associated with the number of technicians, graduates and postgraduates employees, internal R&D investment, training, machinery, marketing, management systems, R&D and external knowledge (Santos et al. 2014).

All things considered, the exploration model suggested here is based on empirical studies, and is aligned with the corporate sustainability dimensions. However, these suggested variables require a qualitative research that verify their capacity to support eco-business innovation, and to provide data for the development of a historical series or cross-section info for the sectors.

The creation of models for the analysis of eco-innovation efforts and results in companies is aligned with several researches on innovation in different countries. These

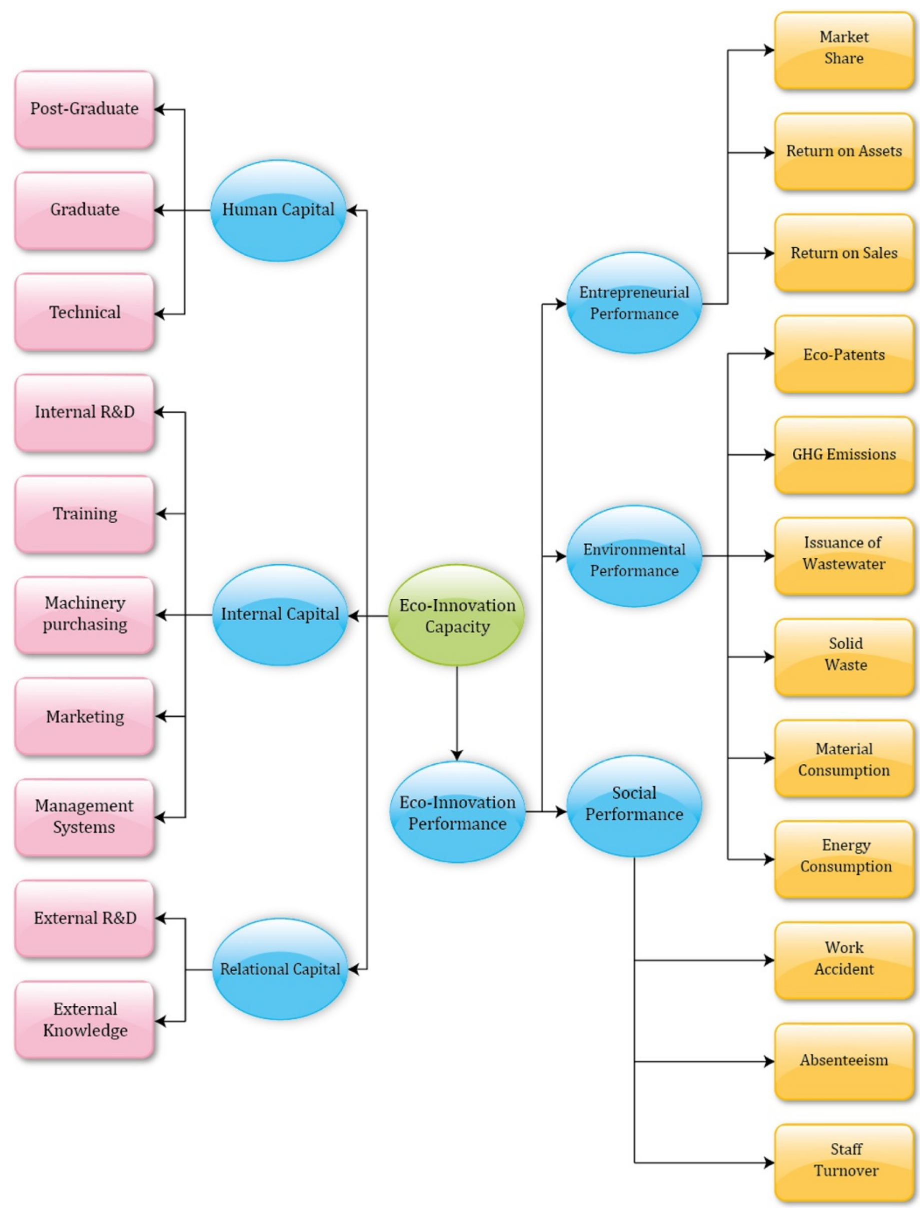

Figure 1 Concept Model of the Brazilian eco-innovation Index. Source: Adapted from (Basso et al. 2013, p. 12).

models succeeds to provide a better understanding of the current stage of the adopted strategies and the opportunities to be developed.

The Brazilian industry moves toward the commitment of more environmentally "clean" and "balance" processes (Hall et al. 2012). The Research on Technological Innovation (PINTEC/IBGE) has brought qualitative issues that commonly result in categorical data, e.g. distributed items such as "high", "average", "low" and "not relevant", as for the environmental impacts of innovation (IBGE, 2010). Figure 2 highlights the average evolution of the indicators published in the survey's last three editions, considering the sectors rated as "high" regarding the impact of their

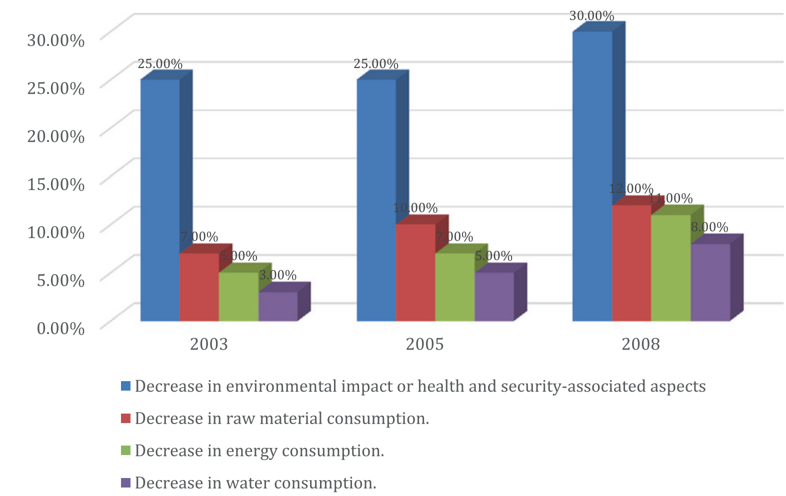

Figure 2 Evolution of the environmental impacts of innovations in Brazil. Source: Based on data taken from the PINTEC/IBGE.

innovations in that period. The Figure 2 also shows that the environmental impact of innovations in Brazil increased, the most significant being safety, environment and health-related items.

This scenario is no different in the sugar-ethanol industry, as sugarcane is the one of the most traditional cultivations in Brazil. Indeed, it began with Brazil's first settlers, and today is part of the economy of 21 Brazilian states, the country being the largest sugar producer and exporter in the world. The 2012/2013 harvest is expected to reach about 779.862.000 50 kg bags (Higman, 2000; Informa Economics, 2013).

The efforts for sustainability-oriented innovation in the sugar-ethanol industry has been growing, involving different areas of knowledge in Brazil and other countries (Higman, 2000; Shukla et al. 2004; Banerjee, 2005; Carvalho & Barbieri, 2010; Chandel et al. 2010; Ortiz et al. 2013; Hall et al. 2012). (Furtado et al. 2011) point out that the prominence of the Brazilian industry in the international markets is not due to its natural resources, but rather a consolidated innovation system that began in 1930 and was boosted in the 1970s and 1980 because of the Proálcool Program (Banerjee, 2005; Zapata & Nieuwenhuis, 2009; Leopold, 2010).

The sugarcane chain has gained scale and scope. From its primary product, sugarcane, ethanol and electricity is generated. Nowadays, chemical and pharmaceutical companies have already developed projects and plans for biorefining. As a consequence, sugarcane-derived products have been replacing oil and natural gas-derived products (Banerjee, 2005; Santos et al. 2010; Chandel et al. 2010).

Due to the growing need to increase agricultural and industrial productivity, the companies need to develop and implement technologies to enhance the reutilization of waste, to reduce water, energy and material consumption, to reduce CO_2 emission and, at the same time, to preserve the biodiversity surrounding the facilities and cultivated areas, as well as to ensure safe, healthy working conditions (Pires, 2008; Cirani et al. 2010; Santos et al. 2010; Leopold, 2010; Chandel et al. 2010; Gomiero et al. 2010; Spetic et al. 2012).

Figure 3 shows the emerging issues related to the sugar-ethanol industry, highlighted in a research proposed by (Spetic et al. 2012), which corroborate the remarks already mentioned.

It is important to highlight that some sugar-ethanol companies are focusing their strategies on organic sugar production and, therefore, have adapted or are implementing processes, practices and lifecycle control that are more appropriate to sustainability (Carvalho & Barbieri, 2010; Hall et al. 2012). The development of the sugar-ethanol industry and its inherent technological and institutional apparatus have turned it into one of the most prominent sectors in the Brazilian economy. On the other hand, such statues requires the companies to develop technology and management methodologies aiming at the market competition (Banerjee, 2005; Shikida et al. 2010; Gouvea & Kassicieh, 2012).

Based on this scenario, this study focus on a topic that has gained scale among all layers of society. The industry studied here has the potential to meet the energy demands through renewable sources, and the potential to boost new business through innovative products that might be applied in several different industries.

Methods

This study adopted a qualitative, exploratory and descriptive methodology, and a case study was used as the research method. A case study was chosen for this survey due to the following factors: i) the theme's topicality; ii) the need for more knowledge in business practices; and iii) an opportunity to analyze this phenomenon where it happens. Such factors are supported by Eisenhardt (1989) and Yin (2003).

Eco-innovation is not yet a clearly defined, consolidated theoretical field. Proposals for analysis are suggested, but the results are often heterogeneous, especially regarding

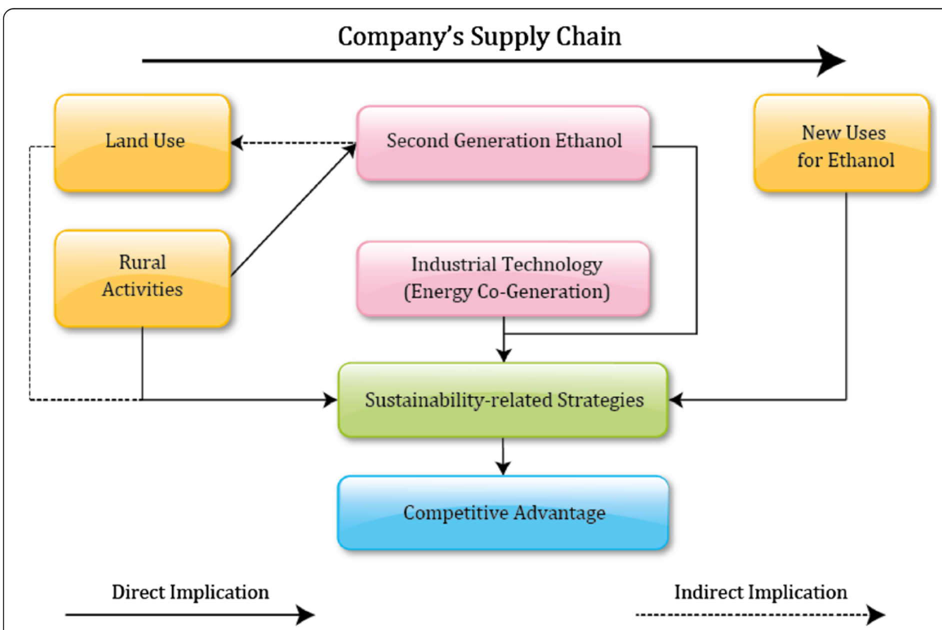

Figure 3 Emerging themes in the sugarcane industry sustainability. Source: Adapted from (Spetic et al. 2012, p. 378).

the sugar-ethanol industry; in Brazil, the researches on which are still primarily theoretical studies or case studies.

This study, based on the theoretical model proposed by (Basso et al. 2013), searched for a common agent that would lead to an understanding of a particular organization's reality and, in the future, provide a cohesive basis for more significant analysis. Such research opportunity is supported by Eisenhardt (1989), who states that researchers with a better understanding of reality are able to collect more information for broader qualitative research – such as *"multi-case"* and *"grounded theory"* – or even for quantitative analysis – through a representative sample of a population.

This research adopted the following instruments: i) a written article with the analysis variables set by (Basso et al. 2013), as well as empirical work from the Proquest, Ebsco and SCIELO databases. Those papers were mostly qualitative studies focused on the Brazilian scenario, even those published in foreign journals. Such aspect indicates that the Brazilian sugar-ethanol companies play an important role in the international scenario (Furtado et al. 2011).

Nevertheless, the study found out that the main eco-innovations analyzed are related to ethanol as automotive fuel and electric energy based on sugarcane bagasse and straw burning. The literature survey also pointed to studies on new opportunities for products made of sugarcane or industrial waste (Pierro, 2013).

Given the lack of studies and a consolidated theory, a case study was adopted towards a greater understanding and knowledge about the eco-innovation phenomenon in the sugar-ethanol industry. The guidelines required that: a) the case be located in the State of São Paulo, which provides the best environment for industry innovation; b) the case's industrial plant produce sugar, ethanol and energy, which are the three major sugar-ethanol industry products; and c) the case's socio-environmental report be published according to the Global Reporting Initiative's (GRI) standards, and its financial statements be available for analysis.

The last requirement has some important characteristics for this study: GRI-formatted dissemination of information requires an internal organization able to provide structured data of the three information categories, as the model proposed by (Basso et al. 2013) has a similar structure to the GRI indicators.

All considered, four companies out of the twenty largest sugarcane mills were contacted by telephone. Then, one was selected for its availability. It was agreed, however, that the company's name would be omitted due to reliability issues and competitive strategies. Thus, this study does not provide the names of the companies that met the criteria, so they cannot be identified from the outcomes presented here.

The research in the mill facilities was conducted from September to December/2013. Meanwhile, two interviews were done with the industrial coordination staff, and a guided tour was held in order to observe the industrial process and practices of the company. It is worth noting, however, that the eco-innovation analysis took place from 2010 to 2012; during that period, the company published its 2010–2011 sustainability reports. Reports for the 2012 were taken from the company's website, internal newsletters and interviews with employees.

This case study's instruments for data collection included: document analysis (reports, documents and Internet domains), semi-structured interviews (two 120-minute interviews) and one onsite industrial process observation that lasted 240 minutes. The period in which the analysis was conducted included the harvest season in South-Central Brazil; because of that, it was difficult to find professionals available for the research and the monitoring of related activities. The visitation and interview techniques and report analysis combined were important for high result reliability. Also significant was the researchers' analysis process, as a researcher with experience in industrial plants held the interviews and visitations. All collected evidence was discussed among all authors via electronic media. A preliminary reading of the documents provided a better understanding of the sugar-ethanol industry and maximized the efficiency of the interviews and field observations.

Based on the conceptual model proposed to guide the analysis, the survey results were organized in three subsections: company overview, capacity for innovation and eco-innovative performance. The overview subsection contextualizes the company and the researchers' assessment on the eco-innovation actions taken by the company. The capacity for innovation subsection searched for information or indicators for human capital, internal capital and relational capital constructs. Similarly, the eco-innovative performance subsection aimed to identify business, environmental and social performance-related information. It is worth noting, however, that this case study has some limitations inherent to its methodology guidelines: impossibility of generalization and repetition; time extrapolation; and the lack of relatedness between the researchers and the phenomenon (Eisenhardt, 1989).

Results and discussion

Overview

Two of the company's industrial mills located in the State of São Paulo had their results analyzed. The company was established over 50 years ago, and has produced sugar and ethanol for 20 years. The organization has 10 years' experience in generating power to utility servers, and currently employs over 4,000 workers in the two above mentioned facilities, including rural workers.

The company's social object lies in the sugarcane plantations, the production and trading of sugar, ethanol and by-products, as well as the cogeneration of electricity. The company also invests in other sugar-ethanol companies, which allows an assessment of its operational performance and its best agricultural, industrial and administrative-related practices.

Regarding the last harvest (2011/2012) prior to this survey, the company processed more than 4 million tons of sugarcane, produced over 300 thousand cubic meters of ethanol, and generated approximately 300 MWh of electricity for the Brazilian system.

The company's management policies found in the analyzed documents focus on investments in technology to promote environment-friendly sugar, ethanol and energy production. Such policies can be verified in the introduction of its Sustainability Report, in which some commitments are stated, such as to improve mechanical harvesting without sugarcane burning, to reduce straw burning and freshwater consumption in the industrial process, and to hold training and relocation programs for the rural workers.

Socio-environmental responsibility is listed as one of the company's values. Indeed, the term "sustainability" is stated in the organization's mission. Industrial engineers constantly mentioned such company management standard in the interviews, which also appeared in plaques and banners within the company's industrial area.

The company's financial report does not mention any social or environmental-oriented investments, neither do the notes and account breakdowns. Nevertheless, the company's overview and some notes do show tentative actions for industrial and agricultural productivity, as well as administrative and commercial cost reduction.

When the above mentioned topics were brought up in the interviews, it was agreed that both plant and agriculture field productivity were the company's investment vectors, due to the falling price of sugar in the international market and the petrol price under Brazilian government control. As a result, both environmental and social concerns were in accordance with the company's commitments with regulatory and control agencies (CETESTB, ANA - National Water Agency, ANP - National Agency of Petroleum, Natural Gas and Biofuels, DAEE - Department of Water and Electricity, ISO 22000 - Food Safety Management System and the Sugar-ethanol Industry Agro-Environmental Protocol), as well as the ordinary environment, civil and labor regulations.

The company's liability reports showed no environmental liabilities in the analysis period, and a marginal reduction in labor liabilities by 37.6% from 2010 to 2012. It is presumed, therefore, that the company aims to perform their actions based on the legal and market requirements.

Capacity for innovation

As for the human capital construct, no data related to the company staff size, distribution or profile (technicians, graduates and postgraduates) were identified. No quantitative documents were found, either. Respondents were not able to provide any information on the Ph.D employees; they were aware of "some" master's holders, and they confirmed that the company has encouraged and hired more higher education professionals, especially agronomists, mechanical engineers and biofuel technologists. The Human Resources Department reported that the company had no such information available at time of research.

No records were found regarding the number of people trained by the company during the analyzed period. The interviews indicated that the company holds a training program focusing on operational performance improvement and on the industrial safety field. The sustainability report lists some training programs focusing on the empowerment of rural workers for technical activities, such as welders, painters, drivers, among others. However, there is no information on the number of trained or reclassified workers, not even the amount of training hours.

Machinery and equipment purchase is the only variable with available qualitative and quantitative explanations. The company invested a total of R$200 million in machinery, equipment and facilities for the period. As a result, the CAPEX (Capital Expenditure) was higher than 1.3, meaning that the company has replaced assets and added new ones. The main assets shown in the reports and interviews were: new harvesters, conveyor improvements, raw material transport and handling equipment, high-precision technology for agriculture, wastewater station and power transmission units.

There is no information regarding the abovementioned assets' return on investment or financial gain. The only linked data shows that the mechanization increase in agriculture resulted in less 13 thousand tons of CO_2 equivalent, and a reduction in the number of work accidents with days lost. The latter consequence cannot be attributed only to the improved facilities/equipment, as there were also improvements in training and working conditions. The company's documents showed no reports on the introduction of technological innovations. Indeed, the company's coordinators were not aware of any projects under development on biorefining products, second-generation ethanol and organic products, nor even actions for a better use of process waste, such as yeast and vinasse. The collected data shows that the company's revenues are distributed as follows: Sugar - 31%; Ethanol - 61%, Electricity - 8%.

Thus, the three products, as the company's commodities, do not need further marketing efforts, as sugar is marketed through trading companies, ethanol is sold to distributors, and electricity is sold to regional power utility servers.

The company does not hold any social or environmental certification, such as the ISO 14001, the SA 8000, the OHSAS 18001 or the statement that follows the ISO 26000 (the latter is not certified). However, the company has committed to using the GRI as a guideline model for its management and reporting standards, within the principles of sustainability (environmental, social and economic). Also, the company holds the title of *"Committed Company"*, awarded to plants that meet the requirements of the *"National Commitment to Improve Working Conditions in the Sugarcane Industry"*, and the company has voluntarily adhered to the Sugar-ethanol Industry Green Protocol.

Besides the lack of a consistent internal R&D, the company's organizational structure does not have one department to promote and manage external R&D, or even external knowledge. The analyzed documents show no information as to the existence of innovation or eco-innovation development practices outside the company. This was confirmed by the interviewees, who were also unaware of any database for projects, researchers, etc. According to the interviews, the company is open to projects, mainly from universities and research institutes, especially projects on agricultural and industrial productivity improvements. However, the respondents did not know the company's *"rationale"* behind its technology needs.

As for the company's investments, the interviewees said that the company follows the technologies which are developed and consolidated by other groups, but does not *"promote"* new actions. The concern lies in an environment-friendly approach by meeting the legal requirements, but focusing on efficient productivity. In the sugar industry, for instance, such effort can be seen primarily in adequate plantation practices for mechanized harvesting, and the use of more than 95% of installed capacity.

Eco-innovative performance

Given the lack of information that might link investments in eco-innovative capacity to financial results, the analysis of profitability indicators and of the market share, as proposed by (Basso et al. 2013), was considered unnecessary, as the characteristics of the context into which this study is inserted make any discussion on the subject impossible. As for the environmental construct, the company did not provide quantitative information on the volume of solid waste and Eco-Patent. The documents did not show any information on this subject, and the respondents do not know of the company's patent applications for the period. They were also not allowed to estimate the amount of solid waste (generated and treated). With this in mind, Table 1 shows the marginal results of

Table 1 Environmental dimension: eco-innovative performance indicators

	GHG emission	Waste water emission	Solid waste	Material consumption	Energy consumption	Sugarcane milling process
General evolution	+9.30%	−1.36%	n.d.	+65.59%	−0.95%	+4.07%
Evolution by capacity	−12.08%	−8.78%	n.d.	+104.65%		

the indicators defined by (Basso et al. 2013) on the environmental dimension in the analyzed period.

The total GHG emissions consist of emission produced by all company activities (direct) added up to third parties (indirect), especially transport. A real increase in GHG emissions was observed in the period, even surpassing the total volume of milled cane. Such difference has a nominal value of approximately 12,380 tons of GHG. However, the company claims that that increase in GHG emissions was caused by an increase in the plantation area, which required more machinery movement.

According to the data provided by the company, the emission amount per hectare (ha) actually decreased 12.08% due to an increase of 24.39% in planted area. It is worth noting that, in the last year of the analyzed period, the company managed to reduce more than 13,000 tons of CO_2 equivalent through actions aiming at the elimination of agricultural burning practices and at an average reduction of 25% in fertilizers and herbicides.

The company did not have separate emission data on the agricultural board and the industrial board, so as to provide this study with more accurate results from each area. Also, the total result does not include the company's total "carbon stock", which reached over 400 thousand tons of CO_2 equivalent, acquired from actions for the protection and recovery of areas affected in the process.

The implementation of a unit dedicated to treat the water used in the process, as well as internal efforts to reduce water consumption, helped the company to increase the recirculation of water in more than 1 million m^3/year, resulting in an increase of 1,36% in water reuse. In addition, the company reduced 8,78% of water use per ton of processed sugarcane. The latter indicator is not included in this study's conceptual model; however, it is significant for the industry (m^3/Ton of milled sugarcane).

Regarding material consumption, there has been an increasing need for materials for accrued revenue, as proposed by (Basso et al. 2013), and for an increase in production capacity. Company purchases raised more than 130% during the analyzed period. The documents did not show any specific information about the latter; however, the report shows that one of the mill facilities is currently being adjusted for agricultural, industrial and administrative purposes. In addition, this mill was not in its full effective capacity, which negatively affects the index due to its high fixed costs.

Moreover, the company's inventory is valued according to the market price of sugar; consequently, the market price volatility of this commodity affects the related indicators, regardless of more or less material consumption. Nevertheless, the reduction in the price of sugar and the gasoline price "control" established by the Brazilian Government in the analyzed period resulted in a decrease in the company's revenue by more than 20%, despite the growth in plantation area and the sugarcane milling process.

The energy efficiency rates of the two mills analyzed showed higher values than the ones set by the UNICA for the industry (9.3 - GJ/GJ - Gigaloules) (Neves & Trombin, 2014).

The variation in the period was small, but points to an average increase of 0.95% in the mills' energy efficiency, despite the fact that one of the two facilities has potential to improve its diesel fuel replacement rates in the transport of process waste, which is not reused (especially vinasse).

It should be highlighted that, in the analyzed period, the company received national awards for industrial efficiency, agricultural productivity, soil analysis and lab conditions.

Social performance

From the study's conceptual model, three indicators were assessed for the social dimension: work accidents, absenteeism and turnover. The results are shown in Table 2:

There was a significant increase in the work accident rates. The company presented some programs for accident prevention, as well as occupational health awareness actions (corporate fitness, lab check-up and support of the regulatory actions such as the CIPA and the SISPAT). This study states that, despite the increase in accidents, there was a decline in accidents with working days lost, that is, those with greater severity. On the other hand, it was not possible to verify the quantitative results, as separate information on the characteristics of each accident was not available (with and without days lost, commuting accident, and death). Nevertheless, the information provided by the company partly corroborates the reduction in staff absenteeism rates. As for the days lost, those resulted from accidents are also accounted for, in addition to other reasons for health-related absenteeism.

Finally, a reduction of 8.16% in the company's turnover was observed. The industry's traditional structure has always caused high staff turnover rates, especially in the agricultural area (sugarcane cutters). The ongoing mechanization in sugarcane fields has reduced the number of workers in the last ten years (average reduction of over 9%/year) (Baccarin et al. 2013). Some social movements have demanded that the companies and representative agencies promote qualification programs so that the laid off workers be relocated within the sugar-ethanol sector or in other sectors. The studied company seems to promote various qualification courses: during the onsite visitation, it was possible to meet two "reclassified" employees of the industrial area. However, there was no quantitative information or data on the number or percentage of skilled and reclassified employees.

In fact, the variables suggested in the model reflect the company's internal social dimension, as they target its staff. Initiatives focusing on local development or improvements in the living conditions of the communities that surround the industrial plants might become a new variable to this model. In the case studied, two related actions were identified: The participation in the "Melhor Caminho" state program, through which the company makes investments to improve rural roads; and two municipal tree planting programs involving public kindergarten and elementary schools. However, the study lacks quantitative data, such as the total length of rebuilt roads, the number of planted trees and the number of people involved, or even the amount spent on these actions.

Table 2 Social dimension: eco-innovative performance indicators

	Work accidents	Absenteeism	*Turnover*
Evolution	14.25%	−61.81%	−8.16%

Conclusions

Regarding the conceptual model adopted here, the variables proposed by (Basso et al. 2013) succeeded to guide the analysis of the general eco-innovation performance of the company studied. However, it was not possible to cross the proposed variables to assess the sustainability of the company studied, due to a lack of objective information on the proposed indices.

However, the variables were best understood when associated to the company's activity level. Therefore, the index, as postulated, can be applied according to the characteristics of the activity sectors. In addition, the triangulation of the surveyed sources led to a better understanding of the activities undertaken by the company, what enabled the analisys of the overall eco-innovation results. That would not have been possible if the analysis was to be based only on published data.

On the other hand, the detailed analysis of the company's efforts to eco-innovative capacity was not possible, due to the lack of information on the variables and, eventually, Their relationship to the results. The company was not comfortable to provide such information, and it lacked organization and control during the data collection process. Innovation in biomass electricity generation was considered the main consolidated innovation in that sector. The literature has shown new paths for innovation, especially in biorefining, ethanol by-products and process waste, such as vinasse, yeast and CO_2.

Despite these new opportunities for innovation, the company adopted a strategically reactive approach, as its organizational structure and decision-making process lack the innovation management that has been adopted in the sector. This study found out that the company's concern lies in conducting its operations in accordance with the requirements set by the several regulatory agencies (quite a few, as a matter of fact) and its investment prerogative focuses on productivity gains.

As for the environmental performance scope, the company introduced improvements in three of the four indicators analyzed. The material consumption indicator was negatively affected by monetary variations; as a result, it was not possible to estimate the actual amount of demanded input. In addition, the lack of quantitative data and further information on the company's solid waste type, management and disposal practices negatively affected the sustainability report.

Regarding the social performance, the actions undertaken by the company improved in two of the three indicators analyzed. The company's efforts to improve working conditions, as well as industrial safety reports and training, were significant. However, the company should work on its stratified quantitative data on accidents for a better analysis result, including the proposed conceptual model. The agricultural work characteristics in the plantation fields, as well as the technology evolution process, demand that companies minimize negative turnover effects. The company showed different actions related to this issue.

A significant aspect not covered by the proposed conceptual model were actions for the biodiversity protection and restoration undertaken by the company, including its accumulated carbon credits. Therefore, the inclusion of such variable in the conceptual model is hereby proposed.

It was observed that the social variables lead the focus of the analysis to the company. In this case, the extrapolation of the evaluation of actions towards the society is necessary, as they could be associated with the GRI External Initiatives indicators. All Considered the sugarcane mills' Favorable energy balance does not exempt the companies from investments and actions to minimize social and environmental impacts Caused by Their actions. Further research and new technologies should be developed aiming at a better use of process waste, as well as the exploration of new second-generation ethanol-based products. These evidences are this research's main contributions, and corroborate other studies and bring opportunities to discuss Brazilian eco-innovation-associated measures. The limitations of this research must be taken into account, as its results cannot be applied to other realities without proper contextualization, especially regarding the period and the authors' idiosyncrasy.

Abbreviations

CAPEX: Capital Expenditure; CIPA: Internal Commission for Accident Prevention; CO_2: Carbon Dioxide; EIO: Eco-innovation Observatory; GDP: Gross Domestic Product; GEE: Greenhouse Effect Gases; GHG: Greenhouse gas; GJ: Gigajoules; GRI: Global Reporting Initiative; ISO: International Organization for Standardization; MWh: Mega Watts per Hour; PINTEC: Technology Innovation Research; R&D: Research and Development; SISPAT: Internal Week for Safety and Working Accident Prevention; TCM: Tons of Milled Sugar Cane.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

DFLS, LFCB and HK participated in the development of the research. The first author conducted the study at the plant and the results were discussed initially with LFCB and HK. Following the three authors developed the initial version of the manuscript. Then, VAS revised and improvement in the paper and its graphical content. Finally, all authors read and approved the final manuscript.

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