The second-generation ethanol in the state of São Paulo – Brazil: understanding the stakeholders' point of view

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Abstract: This article aims at conducting a study on the productive sector of ethanol in Brazil, specifically regarding second-generation ethanol. To map the industry the technique of stakeholder analysis was used. The primary data were collected through semi structured interviews and questionnaires with ten experts from different stakeholder groups in the industry. The results showed that the ethanol plants, research funding agencies, technology centres and central government are the main stakeholders in the industry. The trends with greater impact on the future of the industry are investments in the development of second-generation ethanol, the high biomass production potential in Brazil and the process of industry concentration of ethanol plants, through mergers and acquisitions. The main uncertainties are the results of technology development of second-generation ethanol, the creation or not of subsidies for this technology and the possible commoditisation of the ethanol market.

Keywords: stakeholder analysis; second-generation ethanol; bioenergy sector; Brazil.

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1 Introduction

The environmental studies that investigate details of the variables of an economic sector have gained importance in the daily life of organisations. Such studies have, in the theory of stakeholders, a solid foundation on how to identify and analyse the behaviour of agents in a social system. The fundamental idea of the stakeholder theory is that influential agents in the organisational environment form groups who act according to their interests.

In strategic management, recent studies show that stakeholders analysis techniques are increasingly being employed in the search for an analytical view of all social actors and their interests. Noteworthy examples are the studies Gonçalves et al. (2008) on stakeholders in the hospital sector in São Paulo as well as Martins et al. (2012) who develop scenarios for the sector of road haulage in Brazil. Both make use of stakeholder analysis for their evaluations.

The energy sector has traditionally been subject to environmental and strategic studies, and due to being a key economic sector that deals with long-term investments, studies of stakeholders evaluation have proven to be of utmost importance. Stakeholders with diverse interests, affected by environmental, ethical, political and economic problems, are a recurrent predicament in the exploration of energy and need to be acknowledged and respected.

In the case of bioenergy production (specifically ethanol), researchers and managers today are faced with the possibility of applying new production technologies. The conversion of cellulose (bagasse) into liquid fuel (ethanol), the so-called second-generation ethanol, has significantly increased the efficiency of the current production.

Brazil, the state of São Paulo, in particular, decided to develop a renewable bioenergy programme for producing ethanol to replace gasoline vehicles. The programme has grown and currently has over 400 operating plants. And, though the plants are the central actor in the production of ethanol, this study shows that, indeed, a web of different types of organisations is needed to operate a renewable energy matrix.

Considering the importance of the sector, this paper aims at conducting a study on the productive sector of ethanol in Brazil, specifically regarding the development of second-generation ethanol (cellulosic), from the perspective of stakeholders. To map the sector studied the technique of stakeholder analysis was used. As a result, this mapping provides managers with essential information on environmental variables and stakeholders with a view to strategic management in the bioenergy sector.

Although the old macro-environmental analysis already possessed well-established methods, inherent to the process of environmental analysis, the stakeholder analysis method proves to be more complex because it deals with environmental variables dynamically. While in the traditional techniques of environmental analysis the analyst raises questions regarding static descriptions, in stakeholder analysis dynamic arrays

between variables are taken into account. There is the intention to understand the multifaceted aspects as the behaviour of several agents, interrelations, agendas, influences and resources that these could add to or aggregate from the understanding of the environment (Brugha and Varvasovsky 2000; Carroll and Buchholtz, 2000).

2 Background

The use of renewable energy dates back to the *Homo ergaster* full control of fire in the Middle Pleistocene. The dendro energy (wood) was the first storable energy source used by human kind. Later, vegetable oils and alcohol were discovered and used by various cultures for more than 50 centuries. The renewable energy sources generate light and heat, baked foods, and served as the basis for metallurgical activities and pre-industrial production processes for thousands of years. However, their use has largely been replaced in the 18th century industrial civilisations by fossil energy sources. This was more prominent after the invention of the combustion engine. In later centuries, the consumption of fossil energy increased exponentially and currently, fossil fuels are the most widely used by our civilisation (Leite, 2007).

However, in the last 30 years, the use of fossil fuels began to be questioned by the scientific community for being linked to problems of scarcity, plus environmental and geopolitical problems. In this context, renewable fuels have gained a new dimension of utility, and it moved again to consider its adoption, this time as an energy source in industrial societies (Sachs, 2006).

This rereading of renewable fuels as an energy source for large scale for use in industrialised societies has a notorious example, observed in the Brazilian case. In the 70s and 80s, Brazil suffered with two oil crises, in that barrel prices rose significantly. Brazil was a strong importer of oil, and this increase caused a hole in the national balance of payments. Given the geographical conditions being favourable for producing sugarcane, the primary ingredient of the national production of ethanol, the Brazilian Government, compared to oil shocks, saw the possibility of producing ethanol, mainly in São Paulo, to replace alcohol gasoline as fuel carrier (Josef, 2007).

The Brazilian Government launched a bold programme of multilateral activities, investing in plants, research centres, plant breeding and adaptation of gasoline-powered motor vehicles, so that they could also be fuelled by ethanol. The historical process of the creation of the Brazilian bioenergy programme for the production of ethanol as vehicle fuel, the pro-alcohol, was described by Zapata and Nieuwenhuis (2008).

This Brazilian bioenergy programme became the largest renewable energy programme in the world (in joules of energy produced). The achievement of this magnitude in the use of renewable energy was the result of Brazilian leadership in the technology of first-generation ethanol production technology (traditional fermentation of the sugarcane juice) (Goldenberg, 2007). With technological development and the creation of a consumer market for ethanol, over 25 years, the learning curve of ethanol production has made it competitive with gasoline price (Goldemberg et al., 2004).

However, with the advancement of science, second-generation technology in ethanol production began to be regarded as a future possibility to further expand production. In the production of second-generation ethanol, the simple sugars contained in the sugarcane juice are not fermented, but the wood (cellulose) of the plant is turned into simple sugars

for subsequent fermentation and ethanol production. Enzymatic hydrolysis of cellulose is one of technologies for producing second-generation ethanol. Hydrolysing the cellulose means breaking the molecular structure of the crushed sugarcane into simple sugars, in other words, become 'the wood of the plant' in soluble sugars and liable to turn into ethanol by the action of microorganisms, using more photosynthesised efficient energy for the plant. With the first-generation technology becomes ethanol only the 'juice' of the sugarcane; with the second-generation, the bagasse of sugar cane is converted into ethanol.

3 Theoretical framework

3.1 Stakeholder theory

Stakeholder theory is employed in various fields of literature: corporate planning, systems theory, corporate social responsibility and organisational theory. Freeman (1984) note that these various fields of literature support the area of strategic management. The most widely accepted definition of stakeholder currently is "a group or individual who is affected or may affect the pursuit of goals of an organization" [Freeman, (1984), p.46]. Freeman and Miles (2006) posit that this definition is the broadest of all definitions made so far and complete its order including the principles of legitimacy and loyalty. Legitimacy, since an organisation must be run in the interest of its stakeholders. Loyalty, because company directors should have an ethical relationship towards the company and its stakeholders.

Donaldson and Preston (1995) explain that the stakeholder theory is subdivided into three aspects: descriptive, instrumental and normative. More specifically, it can be noted that the technique of stakeholder analysis is a component of strategic management related to the descriptive aspect of the theory of stakeholders.

The central argument of stakeholder theory is that organisational performance depends on how organisations operate in relationships with other organisations in their operational environment (customers, suppliers, communities, investors and others) that influence these organisations in achieving their goals (Freeman and Phillips, 2002). Clarkson (1995) classifies an organisation as part of a system of key stakeholders, where interest groups are related, thus, different rights, objectives, expectations and responsibilities are established. An inability to respond to these concerns and have their own interests responded to, leads the company to compromising not only its own success and survival, but also the whole system of stakeholders linked to this organisation.

An aspect to be considered is raised by Savage et al. (1991). It lies in the fact that the literature on stakeholders is often unable to satisfactorily classify the categories and types of organisations to design strategies for management. The authors highlight that the significance of stakeholders is linked to the situation and questions raised during the environmental review. Managers therefore must pay special attention to the methods to map, at first, and to negotiate, in a second phase with different stakeholders. They, thus, describe two fundamental aspects to consider: the potential threat of each stakeholder to the organisation and the potential to collaborate with it. It is from this tension that opportunities for strategic advantage sought by organisations arise. In this sense, the study of the competitive environment through a stakeholder analysis, is a corporate tool for environmental assessment, especially when, besides the economy, the politics,

technology and society, the ecological dimension that affects the industry in question, is inserted in the analysis. The discussion whether the environment (ecological) is a stakeholder or not, has been presented by Haigh and Griffi (2009) and discussed by González-Benito and González-Benito (2010). It is not the aim of this article to delve into the theoretical discussion of this problem. It is rather, to emphasise that the analysis presented here, the ecological environment was considered an instance of the macro-stakeholder environment and proved – empirically – useful for unveiling the strategic variables of the bioenergy sector.

3.2 Stakeholder analysis

The primary purpose of a stakeholder analysis is to provide decision makers with strategic information, and despite having its origins in the field of management, the stakeholder analysis has been employed in various fields of study.

There is a consensus among different authors about the concept of stakeholder. Stakeholder is defined as groups or individuals that may influence or may be influenced by mutual interactions, given the policies and practices of an organisation (Freeman, 1984; Frooman, 1999; Goodpaster, 1991; Weiss, 1998). Therefore, stakeholders are actors in a social system that interferes with their behaviour. The influence of stakeholders in the social system can be identified in the variables that influence these stakeholders with its performance and the pursuit of interests.

In addition to defining the concept of stakeholder, some authors have proposed methods to analyse the major stakeholders. Carroll and Buchholtz (2000), Freeman (1984), Svendsen (1998) and Wood (1990), are notable examples of such proposals. They all have developed methodologies for stakeholder analysis. In general, methods of stakeholder analysis followed a protocol of environmental research in the strategic sense of the term. What vary are the sources of information for recognition of the environment and the way in which these sources generate reliable data. A stakeholder analysis can rely on documentary research, interviews with experts, participant observation, among others. The key is that, at the end of the process, it is possible to map the environment, their agents and variables.

Mitroff and Emshoff (1979, p.6) have developed a traditional method of stakeholder analysis, widely used for dealing with environmental variables accurately, a method used by Boaventura and Fischmann (2007), Gonçalves et al. (2008), and Martins et al. (2009, 2012). The research method of Mitroff and Enshoff describe that the analysis technique essentially consists of asking individuals (experts) about stakeholder components of a productive sector, with the starting point of a central organisation as an object of study. In this study, however, there was an adjustment. Because it is the exploration of variables related to second-generation ethanol, instead of taking as a starting point a central organisation, in view of the nature of the problem studied, it was assumed that the starting point was an economic sector, i.e., the productive sector of ethane in the state of Sao Paulo. Only thus became possible to lift the variables needed to conduct the study.

Mitroff (1983) attempts to characterise the stakeholders according to their peculiarities. For example, motivational aspects of each stakeholder, their purposes and motivations, their interests and the tangible (material) or intangible (abstract) resources that they have. As well as that, their legal commitments, distinctive knowledge, relationships with other organisations regarding various attributes such as power, rights, authority, duties and credibility. This is an intuitive and exploratory characterisation with

the aim to discover key aspects in stakeholders that may influence the decisions of the organisation or sector, besides the identification of value in relations between the components of the social organisations. The author also shows that the characteristics of stakeholders may be intrinsic (if they do not depend on other stakeholders) or extrinsic (if there is any dependency). For this reason, it is necessary to identify the variables that are part of the performance of each stakeholder.

3.3 Macro-environment analysis

Although the identification of stakeholders and their conditioning variables are fundamental to the analysis of the industry, they do not present a sufficient condition for such a task. This is because there are other instances that influence industry beyond the stakeholders. The macro-environment in which stakeholders are inserted into, have, especially in the case of the energy sector, a considerable weight in influencing the possible environmental consequences.

The macro-environment is the instance of the forces that act in the broader social system studied, such as political issues at the state level and its macroeconomics. Long-term prospects for technological, cultural, social and ecological development may also be part of the macro-environment.

Stoner and Freeman (1999) deal with the micro environmental aspects in detail. According to the authors, the theory of stakeholders is the result of the application of systems theory in management. The organisational environment can be further divided to Stoner and Freeman (1999) in three instances of stakeholders: internal, external and indirect stakeholders. The internal stakeholders are those who act within the organisation, such as the board. The external stakeholders are those that interact directly with the organisation, such as customers and suppliers. The indirect stakeholders in turn, are linked to the climate in which the organisation is embedded, such as social or political. The authors describe four indirect instances in the macro-environment: social, political, economic and technological.

On the other hand, some authors even consider the macro-environment itself as a stakeholder. To Carroll and Buchholtz (2000, p.336) and Svendsen (1998, p.36), the macro-environmental forces (social, political, etc.) are, in fact, effects of several sets of stakeholders that constitute society. Thus, in view of the possibility of the complexity of the analysis being unlimited, one concludes that the definition of which variables should be considered is the most significant factor in the study.

The elements of the macro-environment (according to their ratings criteria in addressing Social, Economic, Political and Technological – SEPT) proposed by Wilson (1998) are the most commonly used. However, other instances may be added depending on the needs of the study.

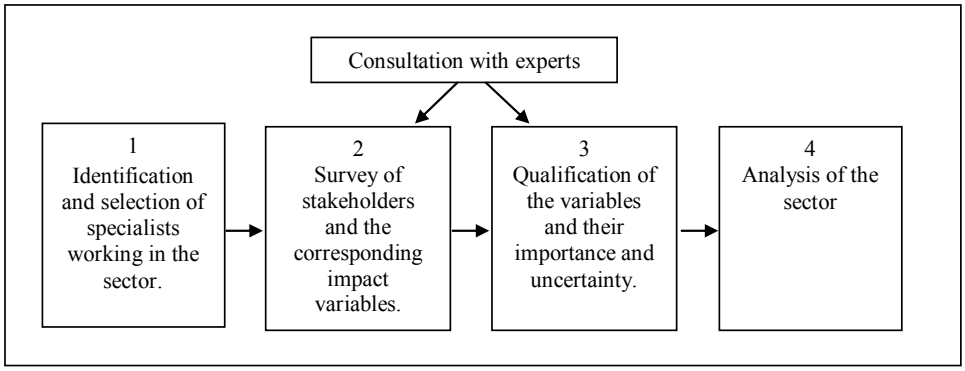
4 Methodology

Methodologically, this study is characterised as predominantly qualitative, although it uses quantitative scales and matrices for organisation and presentation of data collected. The object of the study corresponds to the ethanol production industry, especially regarding the development of the production of second-generation ethanol. Four

methodological steps were taken to meet the goal of mapping and prospecting the future impact of variables in the bioenergy sector through a stakeholder analysis technique.

Figure 1 graphically represents the methodology employed.

Figure 1 Graphic representation of the methodology employed



Source: Authors

4.1 Identification and selection of experts working in the sector

The concept of expert employed is based on the idea of key informant of Fetterman (1998) who describes as an informant that an individual capable of enlightening to the investigator historical, sociological and cultural aspects of the environment upon which one intends to generate knowledge. Moreover, it is advisable to interview experts from different stakeholder groups so that they capture a wide view of the variables involved, as recommended by Boaventura and Fischmann (2008).

4.2 Survey of stakeholders and the corresponding impact variables

The purpose of this step was to identify the stakeholders and their impact variables in the sector for the next ten years.

We applied semi-structured interviews with selected experts. The application of the interviews sought to assess the main characteristics of each stakeholder, such as purpose, interest, commitment, knowledge, intentions, power and other features deemed interesting for the expert to talk about.

The guidelines were based on the relationship of stakeholders proposed by Mason and Mitroff (1979) which embodies typical industry stakeholders, such as those contained in the analytical models of industry by Porter (1980) or the net value of Brandenburger and Nalebuff (1995, 1996). Additionally, guidelines were based on proposals of Wilson (1998) for the analysis of macro-environmental variables. Apart from the political, economic, technological, and social aspects addressed by these authors, the instance 'ecological' is added, i.e., the influence of the natural environment in the model proposed.

The data were analysed and categorised with a view to making the third step.

4.3 Qualification of the variables and their importance and uncertainty

Once the variables for each stakeholder, are identified Mitroff and Emshoff (1979, p.9) propose classifying these variables by their importance and uncertainty. The qualification was operationalised through the application of a structured questionnaire, consisting of a scale of –5 to 5 for each variable. These scales are presented below and correspond to the importance of the variable in the studied environment, and the nature of the variable being a trend or uncertainty. For the latter, it was established that a negative value represents a larger degree of certainty and a positive value to a higher degree of uncertainty.

Importance of the variable in the environment studied.

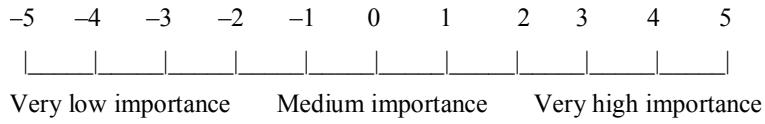
(–5) variable of very low importance in the environment

(–4) … (–1) intermediate variables

(0) variable of medium importance in the environment

(1) … (4) intermediate variables

(5) variable of very high importance in the environment.



Degree of uncertainty of the variables (classified later as 'trend' or 'uncertainty'):

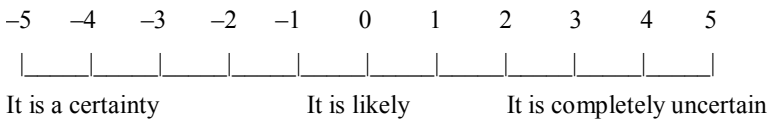
(–5) the variable is likely

(–4) … (–1) intermediate variables

(0) the variable is likely

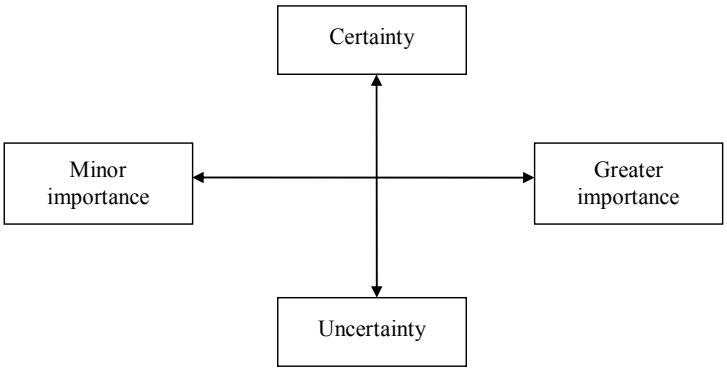
(1) … (4) intermediate variables

(5) variable is entirely uncertain.



The median score of importance and uncertainty pointed out by experts for each variable is plotted on a matrix, where the horizontal axis shows the gradation of importance and the vertical axis shows the gradient of uncertainty, as illustrated by the authors in Figure 2:

Figure 2 Matrix of importance and uncertainty



Source: Mitroff and Emshoff (1979, p.9)

The variables located in the upper right variables are more realistic, i.e., they are highly important variables, and there is a high degree of certainty as to their behaviour. Those located at the bottom right of the matrix show a level of uncertainty and should be taken as variables on which the stakeholders may have less predictable behaviour. They are the most complex variables in the system of and Mason and Mitroff (1979).

4.4 Analysis of the sector

Based on the classification of variables, the fourth and last stage of the research is held, consisting in the development of a qualitative analysis of the sector.

5 Results and discussion

This session aims to present the results obtained in four phases methodology proposed in this study.

5.1 Identification and selection of experts working in the sector

We selected ten experts from different stakeholder groups to gather data. Table 1 describes the profile of each expert chosen for the study.

Table 1 Experts and respective profile

	Experts/profile
E1	Director of financial advisory firm
E2	Professor and researcher working with a public university
E3	Technical manager at an ethanol research centre
E4	President of industry that manufactures consumables
E5	Consultant of organisations in the sugar cane industry
E6	Production manager of ethanol plant

Source: Research data

Table 1 Experts and respective profile (continued)

	Experts/profile
E7	Advisor to the ethanol programme of the government in the State of São Paulo
E8	Technical manager of equipment manufacturing company
E9	Technology editor of specialised journal
E10	Director of national bioenergy programme for research funding agency

Source: Research data

5.2 Identification of stakeholders and the corresponding impact variables

In the task of understanding the stakeholders and their corresponding variables, we applied the proposed methodology. Table 2 presents the stakeholders cited by experts interviewed for the studied sector.

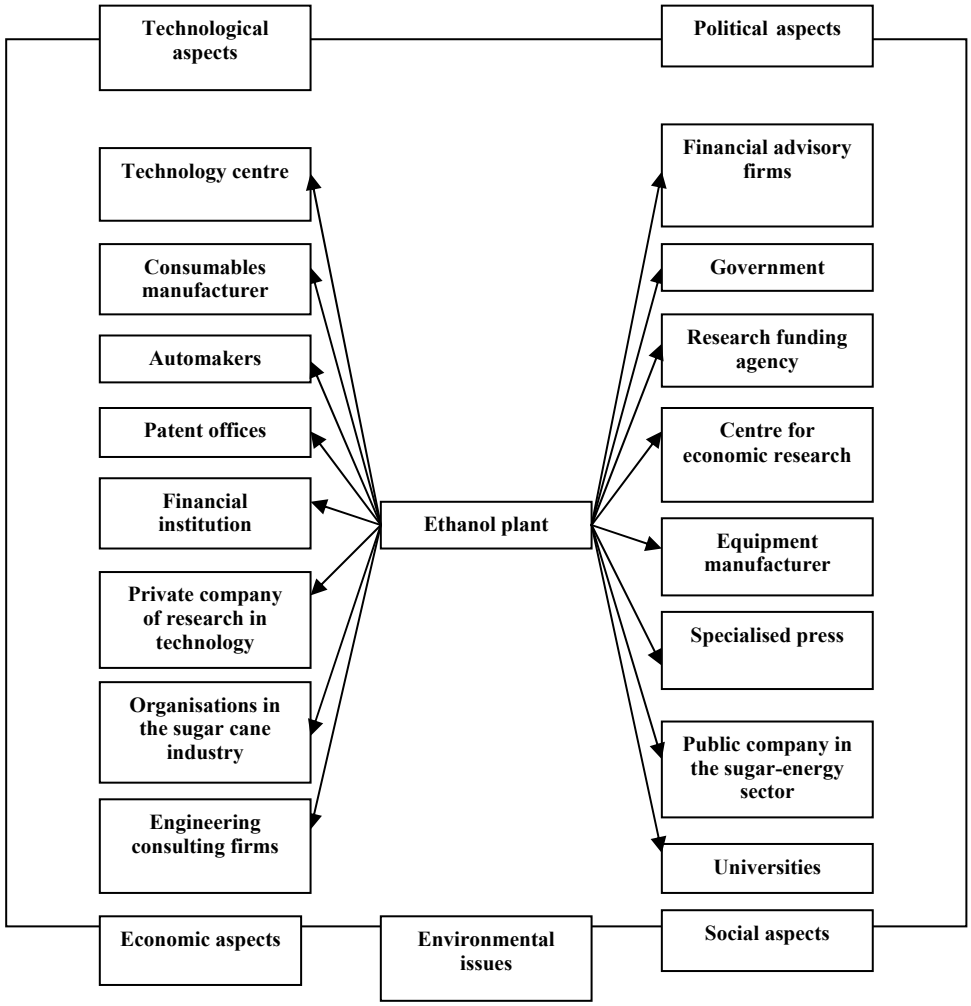
Table 2 Stakeholders identified by expert

Stakeholders	*Expert*									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Technology centre		x	x	x	x	x		x	x	x
Universities		x	x	x	x			x	x	x
Research funding agency			x	x					x	x
Ethanol plant		x	x	x		x		x	x	x
Organisations in the sugar industry		x	x	x	x	x	x	x	x	x
Manufacturer of consumables	x	x	x		x	x	x	x	x	x
Government	x	x			x	x		x		x
Manufacturer of equipment	x									
Specialised press	x								x	
Financial advisory firm	x				x					
Engineering consulting firm	x									
Centre for economic research	x	x			x	x		x		
Financial institution	x		x	x	x	x	x		x	x
Public company from the sugar-energy sector		x	x		x			x	x	x
Patent offices								x	x	
Automakers			x						x	
Private company of research in technology				x					x	

Source: Research data

Figure 3 is a graphic synthesis of the stakeholders shown in Table 2 along with the macro-environmental instances suggested for the analysis.

Figure 3 Stakeholders and macro-environment



Source: Research data

For those stakeholders shown in the survey, respondents identified their main impact variables. It is worth considering that in the consolidation of data, the stakeholders 'Technical consulting firm' and 'Financial consulting firm' were unified in stakeholder 'Consulting companies in finance and engineering'. Stakeholders 'Financial institutions' and 'Centre of economic research' generated identical variables to stakeholder 'Financial advisory firm', so the first two were suppressed.

The number of variables generated was 87. Similar parameters were unified in a new nomenclature that encompassed them to simplify the model and make the next operational phase of the study. We, then, obtained 59 different operating variables that condition the system studied. Table 3 shows the survey of stakeholders mentioned by experts and their variables:

Table 3 Variables identified by stakeholder

	Technology centre		*Private company of research in technology*
1	Forces development of more efficient microorganisms	1	Forces development of genetically modified sugarcane to increase production in the agricultural phase
2	Forces the development of more efficient enzyme cocktails		
3	Forces the development of more efficient methods of treatment of bagasse		
4	Forces the development of simulators for ethanol plants of the second-generation		
			Organisation to the sugar industry
		1	Forces the opening of national and international markets for Brazilian ethanol
		2	Aligns the strategies of the research according to the needs of the industry
	Universities		*Ethanol plant*
1	Forces the creation of research centres	1	Forces the agricultural mechanisation
2	Forces the creation of human resources	2	Forces the integration between the 1st generation and second-generation technology
		3	Electrification and automation of current production
		4	Competition between the bagasse-based ethanol and second-generation bioelectricity
	Manufacturer of consumables		
1	Forces the reduction in the cost of production of enzymes by increasing the productive scale		
	Specialised press		*Research funding agency*
1	Shapes as favourable or unfavourable public opinion on the second-generation ethanol	1	Funds research in the technical bottlenecks to the consolidation of second-generation ethanol
		2	Physiological and genetic changes in sugarcane to pre-hydrolyse the bagasse in the agricultural phase
	Engineering and financial advisory firm		*Patent offices*
1	Facilitates the technical and economic development of the sector	1	Guarantee rights to technological innovation
		2	Source of information for acquisition of technology

Source: Research data

Table 3 Variables identified by stakeholder (continued)

	Automakers		
1	Forces development of heavy and light engines that run on ethanol		
2	Forces the internationalisation of *Flex-fuel* technology		
3	Forces the dissemination of the electric car		
			Manufacturer of equipment
		1	Develops and supplies equipment for treatment of bagasse and enzyme production
		2	Forces the development of bioreactors for large scale production
	Government		
1	Forces the construction of second-generation ethanol plants in the pre-industrial scale		
2	Forces balance between supply and demand of domestic ethanol		
3	Forces the construction of ethanol pipelines and the use of petrochemical infrastructure		
			Public company from the agro-energy sector
		1	Forces development of equipment for the agricultural phase
	Technological aspects		*Economic aspects*
1	Production of biodegradable plastic made from ethanol	1	Price of sugar
2	Simultaneous production of second-generation ethanol, sugar, bioelectricity and by-products	2	Price of oil
3	Feasibility of hydrolysing agricultural waste	3	Relative value of foreign currencies
4	Use of post-hydrolysis bagasse for the production of animal feed	4	Discovery of oil deposits
5	Brazilian research in biofuels is internationalised and world-class	5	Brazilian logistics favourable for use of biomass (bagasse)
		6	Low electricity prices
		7	Trend of mergers and acquisitions in the sector
		8	Forces lower interest rates to finance second-generation technology
		9	Ethanol price
		10	High productive potential of biomass in Brazil

Source: Research data

Table 3 Variables identified by stakeholder (continued)

	Social aspects		
1	Adherence of industry to labour standards		
2	End of burning and manual harvesting of sugarcane		
3	Replacement motivated by the mechanisation of fields		
4	Competition with food for land use		
	Ecological aspects		*Political aspects*
1	Reduction in the environmental impact by promoting second-generation ethanol	1	Commodisation of ethanol
2	Further climate change	2	Creation of subsidies for the consolidation of second-generation ethanol
3	Sustainable water use	3	Absence of US tariffs on sugar produced in the Brazilian Northeast
4	Biosafety of GMOs	4	Strategic aspect of the energy matrix
5	International setting of targets for CO_2 emissions	5	Foreign protectionism
6	Adherence to AE zoning		

Source: Research data

5.3 Qualification of the variables regarding their importance and uncertainty

The third phase of data collection aimed to qualify the 59 variables listed in Table 2. As described in the methodology, the qualification was implemented by applying a structured questionnaire, consisting of a scale from –5 to 5. The variables were qualified according to their importance and uncertainty.

5.3.1 Qualification regarding the importance

The ten experts were consulted for all the variables. The average total points assigned to a scale of importance (–5) to (5) was 2.52, and despite the frequency assignments of three important degrees (3, 4 and 5) being superior to other frequencies, the median point of answers was around 2.5.

The standard deviation of the importance medians achieved the value of 1.33. The first quartile showed 1.9, the second quartile 2.7 and the third quartile 3.3. Since the majority of responses focused on the highest values of the scale, it can be said that there was more agreement among experts on those variables that can be attributed to the high scores.

5.3.2 Qualification regarding the uncertainty

Considering that a negative value would represent a higher degree of certainty and a positive value, a greater degree of uncertainty, the following result is observed:

- The median of uncertainty of variables was negative, pointing to (–0.5), showing a slight tendency for the aspect of ‘certainty’ of the variables.

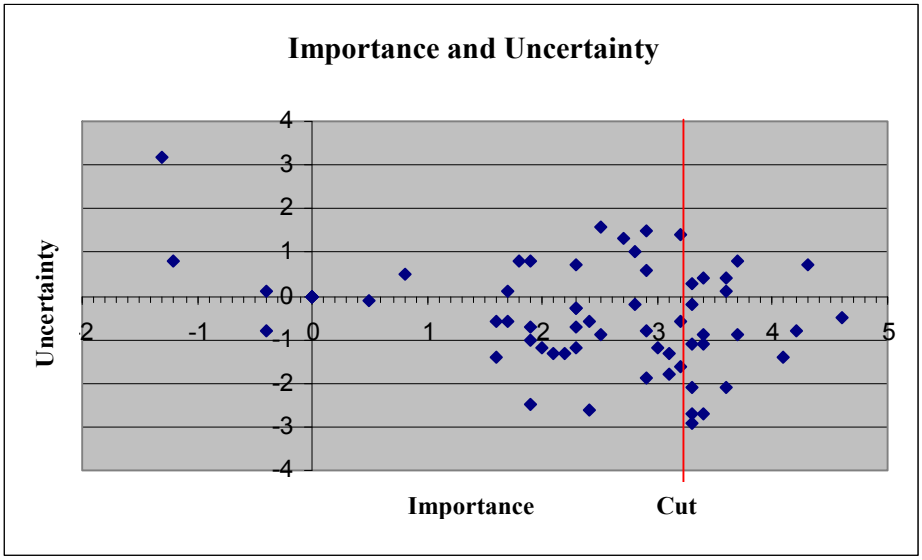
The first quartile showed (0.35), the second quartile (–0.6) and the third quartile (–1.2). The standard deviation showed the value (1.19).

- The attribution of uncertainty or certainty of the variables was made through the scale itself, i.e., variables with uncertainty values greater than zero were considered as variables of 'uncertainty'. On the other hand, variables with negative uncertainty were considered as 'trend' variables.

5.3.3 Matrix of importance and uncertainty

Having established the importance and uncertainty of variables, data were combined in the form of a matrix, as shown in Figure 4. The value of the horizontal axis corresponds to the importance of the variable and the vertical axis to the degree of uncertainty. It is noteworthy that in the adaptation of the matrix of importance and uncertainty for this work we chose to standardise the positive values of the vertical axis corresponding to an increasing degree of uncertainty, i.e., the upper half of the vertical axis represented a high degree of uncertainty.

Figure 4 Matrix of importance and uncertainty (see online version for colours)



Source: Research data

Of the 59 variables studied, the 21 most important were selected to analyse the productive sector of ethanol. Namely, the selection was made by cutting the right of the third quartile (3.3) in the horizontal axis (scale). Besides the election of nineteen variables which were located in the third quartile, two variables were included because they are critical to the technological development of second-generation ethanol: the variable 'Plants 3 – competition between the bagasse between ethanol and second-generation bioelectricity' and 'Research funding agencies 2 – physiological and genetic changes in sugarcane bagasse to pre-hydrolyse in the agricultural phase'.

In the case of variable 'Plants 3 – competition between second-generation ethanol and bioelectricity for the bagasse pulp' experts linked to first-generation ethanol plants awarded maximum score for the importance of this variable regarding the future of second-generation ethanol, mainly because the decision about future investment in second-generation technology competes directly with the investment in technology to generate electricity by burning the bagasse in sugarcane mills.

The variable 'Research funding agencies 2 – physiological and genetic changes in sugarcane bagasse to pre-hydrolyse in the agricultural phase' was selected for the next phase for two reasons. First, it was awarded a top mark regarding its importance, by experts linked to the promotion of technological research for the second-generation ethanol. Also, because it is a new variable, one whose importance, some other experts in economics and politics were unaware of. Therefore, it was decided that such variables should be included in the analysis of the research.

Out of the 21 selected variables, 12 belong to the macro-environment and nine to stakeholders. The fact that the majority of variables belong to the macro-environment is bound to the complex and long-term development of second-generation ethanol. Because it is a development concerning the change of the energy source of a country, many factors of comprehensive influence are part of the problem.

Table 4 shows the variables selected for analysis in the industry. These are the variables that affect the productive sector of ethanol, considering the next ten years of the issue of second-generation ethanol. The table also presents the classification of variables in the categories of trend or uncertainty:

Table 4 Variables classified according to their importance and uncertainty

Variable	*Stakeholder – variable number*	*Category*
Adherence of industry to labour standards	Social Aspects – 1	Trend
Further climate change	Ecological aspects – 2	Trend
High productive potential of biomass in Brazil	Economic aspects – 10	Trend
Strategic aspect of the diversification of the energy matrix	Political aspects – 4	Uncertainty
Commodisation of ethanol	Political aspects – 1	Uncertainty
Competition between the bagasse between second-generation ethanol and bioeletrecity	Plants – 3	Trend
Creation of subsidies for the consolidation of second-generation ethanol	Political aspects – 2	Uncertainty
Funds research in the technical bottlenecks to the consolidation of second-generation ethanol	Research funding agencies – 1	Trend
Forces HR training	Universities – 2	Trend
Forces the integration between 1st generation and second-generation technology	Plants – 2	Trend
Forces the agricultural mechanisation	Plants – 1	Trend
Forces the opening of national and international markets for Brazilian ethanol	Organisations – 1	Trend
Forces the development of more efficient enzyme cocktails	Technology centre – 2	Uncertainty
Brazilian logistics favourable for use of biomass (bagasse)	Economic aspects – 5	Trend

Source: Research data

Table 4 Variables classified according to their importance and uncertainty (continued)

Variable	*Stakeholder – variable number*	*Category*
Physiological and genetic changes in sugarcane to pre-hydrolyse bagasse in the agricultural phase	Research funding agencies – 2	Trend
Brazilian research in biofuels is internationalised and world-class	Technological aspects – 5	Trend
Price of ethanol	Economic aspects – 9	Trend
Price of oil	Economic aspects – 2	Uncertainty
Tendency of mergers and acquisitions in the sector	Economic aspects – 7	Trend
End of burning and manual harvesting of sugarcane	Social aspects – 2	Trend
Feasibility in hydrolysing agricultural waste	Technological aspects – 3	Uncertainty

Source: Research data

Table 5 presents the values of average importance and uncertainty assigned to variables by experts:

Table 5 Mean and standard deviation of the importance and uncertainty of variables

Data – second phase of the study	*Median*		*Standard deviation*	
Variables	*Importance*	*Uncertainty*	*Importance*	*Uncertainty*
Adherence of industry to labour standards	3.3	–0.2	2.45	2.82
Further climate change	3.3	–1.1	2.11	2.38
High productive potential of biomass in Brazil	3.6	–2.1	1.35	3.87
Strategic aspect in the diversification of the energy matrix	3.6	0.4	1.07	2.76
Commoditisation of ethanol	3.4	0.4	1.51	3.27
Competition between the bagasse-based ethanol and second-generation bioeletrectricity	3.2	–0.6	1.87	2.37
Creation of subsidies for consolidation of second-generation ethanol	3.3	0.3	2.67	2
Funds research in the technical obstacles to the consolidation of second-generation ethanol	3.3	–2.1	2.83	2.38
Forces the training of HR	4.2	–0.8	0.79	3.01
Forces the integration between 1st generation and second-generation technology	4.1	–1.4	0.88	3.13
Forces the agricultural mechanisation	3.4	–2.7	2.55	3.16
Forces the opening of national and international markets for Brazilian ethanol	3.4	–0.9	2.37	2.69

Source: Research data

Table 5 Mean and standard deviation of the importance and uncertainty of variables (continued)

Data – second phase of the study	*Median*		*Standard deviation*	
Variables	*Importance*	*Uncertainty*	*Importance*	*Uncertainty*
Forces development of more efficient enzyme cocktails	3.6	0.1	1.5	3.0
Favourable Brazilian logistics for use of the biomass (bagasse pulp)	3.3	–2.9	1.06	3.31
Physiological and genetic changes in sugarcane to pre-hydrolyse the bagasse in the agricultural phase	2.3	–0.3	2.58	2.41
Brazilian research in biofuels is internationalised and world-class	3.7	–0.9	1.06	2.96
Price of ethanol	4.6	–0.5	0.7	3.14
Price of oil	4.3	0.7	1.06	4.14
Tendency of mergers and acquisitions in the sector	3.3	–2.7	1.42	2.71
End of burning and manual harvesting of sugarcane	3.4	–1.1	2.41	2.6
Feasibility in hydrolysing agricultural waste	3.7	0.8	1.49	3.61

Source: Research data

5.4 Analysis of the industry sector

For the synthesis of the sector, we chose to make a brief description of the stakeholders and the macro-environmental aspects whose variables were selected for the second stage of the study, i.e., stakeholders or environmental factors whose median of importance is equal to or greater than 3.3 points on the axis of the matrix importance-uncertainty already mentioned.

5.4.1 Technology centres

The research centres are the 'bridge' between industry needs and technological development. Basic research is often concentrated in scientific institutes that are purely academic, being up to the technology centres to mediate the migration of basic science (academic) to technological application (industry). Technical issues investigated by these centres are directly linked to the challenges of the industry. During the interviews, a topic that stood out was the importance of research in the technical bottlenecks to increase efficiency in the production of second-generation ethanol, in particular the development of more efficient enzyme cocktails for ethanol production from bagasse. The aspect of this variable, however, has appeared as of high uncertainty.

5.4.2 Universities

The universities, noted as a trend, have the pivotal role of educating highly specialised human resources for the techno-economic development of the productive sector of ethanol.

5.4.3 Research funding agencies

The agencies that foster scientific research are autonomous institutions funded primarily with federal or state public funds. They play a decisive role as a funding mechanism for research at universities and technology centres. The main variables of that stakeholder showed some critical technical issues that can be understood as technological bottlenecks for the development of technology. Genetic research has also proven to be a powerful variable for the future of second-generation ethanol. Both variables appeared as trends.

5.4.4 Ethanol plants

According to experts, there are no ethanol plants producing second-generation ethanol on a commercial scale in Brazil (2010); however, there is a positive expectation on the implementation of this technology, since this would make production more flexible and potentially reduce the risk of the operation. This flexibility is the hope of the industry to turn plants into biorefineries. There was also emphasis on the question of the use of bagasse to generate electricity by burning in it boilers as a factor for future competition with the second-generation ethanol from biomass through the use of biomass in the plant and the tendency of agricultural mechanisation in the field, which would increase the availability of biomass in power plants.

5.4.5 Class entities organisations in the sugarcane industry

The organisations that represent the sugarcane industry proved to have a fundamental role in the political sector. First, as catalysts in opening up new markets for Brazilian first-generation ethanol and, consequently, the opening of the market for future production of second-generation ethanol.

5.4.6 Technological macro-environment

The technological macro-environment that encompasses the issues of second-generation ethanol is diverse and complex. Many variables are multidependent on exogenous factors and influence each other. The comparative analysis of these variables shows that the flexibility of the techno-productive plants is a decisive factor for the sector. Genetic engineering, increasing the efficiency of microorganisms in enzyme production and in the fermentation process is relevant factors. Genetic improvement of sugar cane as well as the possibility of expressing a gene that pre-hydrolyses the plant in the agricultural phase is seen as important, but uncertain in terms of technical and ecological perspectives.

5.4.7 Social macro-environment

The social aspect in the ethanol production chain is heterogeneous. Since Brazil has agriculture to produce the most sophisticated energy in the world – in large agribusiness enterprises – smaller and peripheral producers still carry traces of the old Brazilian old agricultural mentality. According to some experts the social scenario among small and medium sized producers is critical, and initiatives are insufficient to improve the conditions of rural workers.

5.4.8 Economic macro-environment

The economic macro-environment aspects define, above all, the speed with which the second-generation ethanol will be incorporated into the productive sector. If the technological feasibility is defined, economic aspects set the pace and urgency of this change. It is worth mentioning that the market prices of energy are crucial for investment decisions, especially in the bid to a new technology.

The variable on the price of ethanol was classified as a trend, i.e., opposite to the oil price, which received a rating of high uncertainty. This shows an advantage in the use of renewable energy that is not exploited, but produced. The fact that energy is produced rather than exploited, seems to give more stability to its supply.

The trend of mergers and acquisitions in the sector is another factor that encourages innovation, because it oxygenates the sector with new businesses positioning, which are, in general, more prone to risk taking.

The favourable logistics also stood out among experts, since it increases the energy-efficiency of the chain as a whole – in the case of sugar cane bagasse, it is already available at the plant, which does not happen with other types of agricultural hydrolysable waste. Naturally, by not transporting pulp to produce second-generation ethanol, the efficiency of the process is increased since it eliminates the use of fossil fuels for transportation of the pulp from field to mill. This gives a competitive advantage to cellulosic ethanol from sugarcane compared to cellulosic ethanol from corn, for example. However, the industry sees as a potential competitor in the production of second-generation ethanol (cellulosic) not only other agricultural waste, which will be capable of conversion into ethanol (as tailings of processed corn and soy), but the generation of bioelectricity itself, with the burning of the sugarcane. The co-generation of electricity can, indeed, be a source of future competition for production of second-generation ethanol.

5.4.9 Political macro-environment

The macro-environment that interferes with the issue of second-generation ethanol has an agenda of few and crucial decisions. The commoditisation of ethanol is a vital step to consolidate a global market for ethanol and force the end of international protectionism. The creation of tax subsidies for all stages of the production of second-generation ethanol is key to ensuring benefits to Brazil. The issue of diversification of energy sources is essential to national security, and it is evident that not depending on a single and unstable source such as oil represents a major strategic advantage. It is worth noting that all the variables in this topic were classified as uncertain. This demonstrates that there is no recognition of long-term stability over political decisions with regard to the productive sector of Brazilian ethanol in view of the second-generation ethanol.

5.4.10 Ecological macro-environment

The eco-environmental aspects should be highlighted in the analysis of the production of a renewable fuel. Firstly, the production of second-generation ethanol could increase the energy efficiency of the production process of ethanol, further decreasing the environmental impact of fuel compared to petroleum-based ones (in cumulative CO_2 per energy unit). The main environmental variable is linked to global warming and is considered a trend.

Because of having an agricultural phase, the use of water is another critical environmental issue in ethanol production. The agricultural phase was also involved with regard to ending the burning of sugar cane for harvesting. The ecological and social aspects of this practice, together with the waste of energy from burning the fields to facilitate the harvesting seems to disquiet the experts. All technology developed to reuse the straw burned in the field should come into the equation of the energy efficiency of ethanol production in the coming years.

And finally, when dealing with genetically modified organisms (GMOs) the second-generation ethanol depends on an austere regulation aimed at minimising the environmental risks of such manipulation.

6 Conclusions

This paper aimed at conducting a study on the productive sector of ethanol in Brazil, specifically regarding the development of second-generation ethanol (cellulosic), a renewable energy source, from the perspective of stakeholders. The stakeholder analysis technique was used to map and prospect variables of future impact in the bioenergy sector.

The results showed that the ethanol plants, research funding agencies, technology centres and central government are the main stakeholders in the industry. The trends with greater impact on the future of the industry, according to the study, are investments in the development of second-generation ethanol, the high biomass production potential in Brazil and the process of industry concentration of ethanol plants, through mergers and acquisitions. The main uncertainties that drive the future of the industry highlighted by the study correspond to the development of technology for second-generation ethanol, the creation or not of subsidies to this technology and possible commoditisation of the ethanol market.

The second-generation ethanol is an important promise for many countries wishing to develop this technology in order to convert various types of biomass into ethanol. This study shows that the generation of technology and market development for renewable fuel involves a complex web of organisations and a vast myriad of variables. These variables, revealed here, are useful to support the development of strategies for bioenergy production in the Brazilian context and, with some limitations, in other countries.

Although there is a vast literature covering the ethanol industry, this study contributes pointing out the variables that can lead to the future of this sector in Brazil, through a perspective of stakeholders of this sector. It also contributes presenting a teaching mode, using the technique of stakeholders analysis for a study of the industry.

The initial purpose of this study was to map the ethanol production sector with a view to the future of production technology, the second-generation ethanol. The mapping was done successfully, and indeed, environmental variables that will drive technological development and possible political, economic and social unfolding were identified. One can clearly find out the main variables that influence the potential technological leap in the industry. The variables found and qualified in this study grant for the planning activity of managers who work in this sector, which receives both incentives and pressures for development towards a greener economy.

A final note should mention that investing, in order to master the production of cellulosic ethanol on a commercial scale is a particularly welcome green alternative,

instead of exploiting fossil energy sources. Thus, the article closes with the hope that this discussion, the use of second-generation ethanol, may contribute to a greener economy.

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