Systems Analysis Framework for Selecting Sustainability Assessment Models: A Proposal to Support the Sugarcane Ethanol Case in the State of São Paulo

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ABSTRACT

In Brazil, the sugarcane ethanol has presented extent prominence as biofuel. Then, postulating sustainability for this activity is an essential, difficult but important challenge. With the options range of assessment tools available, this research focused on how these complex issues are considered in the selection of valuation models process as well as how these models are chosen and proposed. For the search was conducted a contextual analysis, identified intervention points for the sugarcane ethanol system, identified critical issues involved in the sustainability concept and its assessment, and was ranked attributes for systemic criteria. The research concluded that there hasn´t been an adequate linkage between the analysis models and their selection, harming the operational sustainability and evaluation. So, the analytical and systemic framework proposed for model selection of sustainability assessment, can contribute to the decision-making process and the formulation and / or evaluation of public policies aimed for the sector's sustainability.

Keywords: Sustainability Evaluation; Bioethanol; System Approach; Energy.

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Providing for human needs has always been subject to the supply of energy sources. With the evolution of technology and new scientific discoveries aimed at developing and enhancing energy sources, the energy system has become more efficient in its capacity to produce energy, especially regarding sources based on fossil fuels.

The increase of fossil-based energy alternatives, both in quantity and variety, has been accompanied by a growth in production. As a result, there has been a significant leap in the impact of human activities on the environment, increasing the use of natural resources, gas emissions and waste production and affecting the balance of ecosystems, climate and population health. As of the 1960s, awareness of these social-environmental impacts has created a paradox in the concept of development and a state of uncertainty regarding the benefits and harms of this transformation and of development based primarily on production growth geared towards economic growth.

Alternative sources of energy have been claimed to generate more positive externalities. The supply of energy from renewables are generally seen less polluting, as well as reduces the external dependence on non-renewable fuel reserves in the future (Pina et al. 2017). That was the mainly incentives to acquire expertise about other forms of energy.

In Brazil, among the various new energy sources such as wind, solar and biomass, biofuels have stood out as an alternative with great potential for compliance with the precepts of sustainable development, especially regarding the following aspects: low polluting potential compared to fossil fuels, high agricultural yield and expertise in sugarcane crops thanks to the country's long history of sugar-alcohol production. In addition, new technological and production capacity and competitive costs reduce dependence on oil producing countries, considered unstable in international trade due to their political regimes. Another positive aspect of biofuels is the reduction of greenhouse gas emissions, with the ensuing mitigation of negative impacts associated with the global climate system (Mussatto et al. 2010; Pereira et al. 2012, Pina et al. 2017).

Within this setting, the leading biofuel in Brazil is ethanol, obtained from the fermentation of sugarcane biomass. On the one hand, its production is considered beneficial for being renewable and contributing to reduce pollution. On the other, widespread monoculture and large-scale production cause inevitable environmental degradation. In addition, the industry has a history of continuous risk of labor instability, low salaries and unhealthy working conditions.

Considering the advantages and disadvantages, the sustainability of ethanol production is still a major challenge that depends on local conditions such as climate, agricultural suitability, economics, etc.

Likewise, it implies considering the existence of political and technical agents and consumers involved in the debate. Such determining factors and agents may directly and/or indirectly influence the future of sugarcane in Brazil, from product manufacturing systems to consumption decision, including means to manage and solve the sector's negative impacts. The interaction among these various elements makes for a complex reality in the sector and heightens the various concerns about its evolution.

Such complexity relates to planning and deciding on the sector's production growth and solving the negative impacts of such growth, considering moreover that the viewpoints, interests and knowledge of stakeholders are many and often different. Therefore, the notion of sustainability as an essential feature of the industry has proved to be a difficult but important challenge, whose foundations are yet to be established considering its various dimensions. One of the important variables of this process is sustainability assessment, given its strategic role in the context of bioenergy policy, which has sustainability as one of its distinctive features.

However, different views generate different proposals and, consequently, a wide range of sustainability assessment models and tools applied to planning and management. The quantity and types of analysis resources, based on different areas of knowledge and often on fragmented views of reality, coupled with the lack of transparency on choice criteria, undermine the assessment process. Furthermore, although there are many assessment tools, most of them have limitations regarding a systems approach to sustainability criteria, often focusing on one or other dimension, leading to fragmentation. In addition, as shown in the literature, the professionals responsible for selecting a particular tool are often influenced by interests and values that are not aligned with sustainability goals, but sometimes represent the very worldview that created states of unsustainability (Meadows 1999; Ridder et al. 2007; Gasparatos 2010; Mangoyana et al. 2013; Gough et al. 1998; Gasparatos et al. 2008).

Although authors such as Eisenack et al. (2006), Wiek et al. (2006), Gasparatos (2010), Grace and Pope (2011) and Olde et al. (2017) have proposed models and tools to assess sustainable development levels, seeking to understand the theoretical and practical features of existing resources, most of the criticism of sustainability assessment relates to inadequate knowledge of the theoretical and practical features of such tools. For Sala et al. (2015) sustainability assessment transcends a purely technical/scientific evaluation. It is a systematisation of knowledge, for specific applications and decision contexts. Tayra (2006) explains that many of these tools actually follow an inadequate sustainability approach guided by a technocentric view, represented by the environmental economics trend, which considers that, in the long run, natural resources (sources of input and/or capacity to absorb impacts) do not represent an unrestricted limitation to economic expansion (Romeiro 2001),

since total substitution between different types of capital is possible (Solow 1974; 1986; 1993 apud Gasparatos 2010). Romeiro (2001) states that this view follows the neoclassical economics approach that disregards nature in the economic function of production. According to this reasoning, nothing results from nothing since nothing is returned to nothing, that is, the inputs, outputs and their relations to the state of the environment are disregarded, which is not observed in real life systems or even in the economy itself (Binswanger 1999).

The same criticism applies to sustainability assessment models and tools, since they are not value-free. That means that such analysis resources incorporate theories and values of the worldview of those who devise or decide to use them. However, there is no guarantee as to the most suitable form of choice when deciding on a method. Users (researchers, policy managers, stakeholders, among others) rarely define adequately the reasons for choosing one method over others (Gasparatos & Scolobig 2012). Knowledge of and affinity with a certain approach seem to be the main reasons for choosing a specific procedure (Meadows 2009; Cinelli et al. 2014), especially when mathematical and computational formulations exceed the skills of users and creators to understand and explain them (Hanneman 1998). Alternatively, certain models or approaches simply enjoy greater acceptability in given contexts, for example, a particular certification demand that a country or region may establish as a criterion for importing biofuels.

In addition, the modes of assessing sustainability have often been decided and employed by analysts who adjust the situation to their values and areas of expertise. In this case the choice is not always aligned with the values of those affected and of stakeholders, so there are ethical and practical consequences in a process without transparency and pertinent criteria. In choosing how to assess sustainability the analyst imposes a worldview, and it is likely that he will not be directly affected by the situation under assessment. The attributes considered by the chosen mode of assessment affect the results, for the value concepts pertaining to the assessment will be viewed as the most important (Gasparatos 2010). Ridder et al. (2007) add that choice is sometimes based on the availability of data, time, budget and access to the assessment resource rather than a theoretical basis or the needs of the context under assessment.

In practical terms this implies the acceptance or rejection of stakeholders, since they did not take part in the process, or rather, their values were not used as guiding principles in choosing. Therefore, in the long run these users may not benefit from the assessment result for not accepting it (Meadows 2009, Gasparatos 2010).

Thus, the challenges posed to sustainability assessment, considering its various dimensions in a systems approach, include the development of an integrated model that corresponds to its philosophical conception of integrated world, going beyond mere economic rationality, based on inter- and trans-disciplinary principles and involving efforts of broad participation of stakeholders without losing sight of the worldview intrinsic in the paradigm introduced by the concept of strong sustainability (Fernandes & Sampaio 2008; Fernandes 2010).

This paper, through the elaboration of systems procedures and criteria, proposes an analysis framework for the selection of sustainability assessment models and/or tools capable of indicating the best alternatives for assessment and, therefore, mitigating the difficulties involved in the operationalization of sustainable principles and goals.

Its results expand the discussion on the sustainability of ethanol production and consumption through the development of a conceptual framework and enable a broader analysis of the issue related to the concept of sustainability and the complexity of ethanol. The proposed framework aims to be a tool to support decision-makers, policy makers, millers, consumers and stakeholders in the sugar-energy sector regarding the transparency and understanding of reality for the parties involved. At the same time as it aims to assist in decisions taken in the context of sugarcane ethanol, it provides input for the decision-making process and the design and/or assessment of public policy for the sector. This proposal was developed with a focus on the state of São Paulo given its representativeness in Brazilian production.

METHODS

In order to highlight the complexity of the context under analysis, conjunctural analysis methodology was used. The conjuncture is analyzed by means of forces and problems implied in the facts and events (Chart 01).

The context analysis relates the macroscale (international and national scope) and mesoscale (state scope) considering geographic, cultural, economic and social features. The time span under analysis ranges from the 1970s to 2014. The initial date marks the beginning of the Brazilian National Alcohol Program (Proálcool), considered the first economic and political event relevant to the sector in the country, since it encouraged alcohol production through incentives to expand existing mills and set up new production units (Pereira et al. 2012; Stattman et al. 2013)

Chart 01. Typical posture when serendipity is acting.

CONJUNCTURAL ANALYSIS CATEGORIES USED IN THE STUDY		HOW THE CATEGORY WAS APPLIED
Events	Events have a special meaning in the context according to their importance.	The most important facts and events in the literature and press were researched and their positive and negative consequences were discussed, focusing on sugarcane ethanol sustainability.
Actors	Actors are people who play a role in a chain of events, a network of relationships.	The complexity of the actors involved in the subject of sugarcane ethanol was represented by the creation of a network of actors.
Relationships	The relationships among actors and their links are in permanent change.	The study presents the relationships among the actors based on common interests and goals, not in order to understand their intensity, but rather to ascertain how systemic and complex such relationships are.

Source: Based on Souza (2009).

In the context analysis, (i) the main stakeholders in the system were determined and (ii) their links and relationships were observed, aiming to understand the complexity of the subject from the analysis of the social and technical network of ethanol in the state of São Paulo. To this end the study carried out a mapping based on a focal actor chosen for its importance in the cross section analyzed. The mapping started out from the focal actor's website and proceeded through the hyperlinks it contained. Thus it was possible to chart the field of investigation, the various actors and those with whom they relate. Two methods were used: GEPHI software, a platform that tracks hyperlinks in the internet and broadly maps the network, and the Snowball method, also known as nonprobability sampling, used to gain access to populations that are hard to reach and/or concealed (Fávero et al. 2009). In this method, the network is built from a focal actor and its connections with other actors. The actors who have relations with those initially considered are also part of the network, and the process proceeds until no new actors are identified or the researcher decides to interrupt it, either for reasons related to the research objective or because the new actors are too marginal to the study group (Hanneman and Riddle 2005). In this case, all actors tracked by GEPHI were considered, but only those with at least a third-degree link with the focal actor where highlighted as a way of limiting and establishing a cross section to describe the actors. Therefore, first-, second- and third-degree actors were obtained.

Applying the Snowball method allowed zooming in on a network of actors closer to the focal actor and thus understand its most influential links. This network was established based on a criterion: mapping those actors with missions and/or projects focused on sustainability and directly linked to the focal actor under analysis (no links depending on a mediating actor). This entire analysis was conducted in the Websphere environment.

The analysis strategy explored more specifically the institutional and relational contexts associated with the actors and with the facts and events occurring since the 1970s (due to Proálcool) related to the subject of sugarcane ethanol sustainability. Therefore, it can be stated that the research carried out a Policy Network Analysis (PNA) or, more specifically, a Policy Websphere Analysis (PWA).

This stage enabled the definition of the subsystems that make up the broader ethanol system, with the network of actors and the current discourse on ethanol sustainability. The main contribution of this stage is the identification of intervention points, variables considered to be the most relevant for assessing the system and which supported the design of the analysis framework to guide the selection of sustainability assessment models and tools.

In the next step the study sought to analyze in greater depth the limitations of the concept and of operationalizing sustainability, as well as its influence on the process of sustainability assessment. This investigation was important to define the analysis criteria, since it introduces the principles of general systems theory, which are at the core of the systems analysis framework. Bibliometric methods were used to outline the current sustainability discourse for sugarcane ethanol, understand the weaknesses of sustainability assessment models and comprehend concepts and principles that govern systems theory. The bibliometric analyses were carried out in two phases: the first in 2012-2013 and the second in 2014-2015.

In the first phase, a search was conducted on Web of Science[4] for papers related to the period 2000-2012. The keywords used were sustainability, ethanol and public policy. In the abstracts, however, the search was for themes and discussions focused on the following topics: (i) economic sustainability, (ii) environmental sustainability, (iii) ecological sustainability, (iv) social impacts, (v) environmental impacts, vi) ecological impacts, vii) local impacts, (viii) regional impacts, (ix) sustainability assessment models, (x) energy policy, (xi) social policy and (xii) agricultural policy. Next the selected articles were analyzed by analytical indexes using the bibliometric software HistCite, which enabled the identification of the key literature on the subject, as well as the most cited authors and the journals with the greater number of publications, besides presenting the descriptive statistics for groups and subgroups (average and median citation rates of papers, number of authors per paper, etc.), among others. Analysis of the most cited papers was based on the GCS or TGCS index.

[4] Thomson Reuters database (scientific journals)

By applying the stages it was possible to establish grounds for critical appreciation and thus design the desired analysis framework: a systems analysis framework with criteria that help select/indicate sustainability assessment models and tools in the context of sugarcane ethanol [5].

THE COMPLEXITY OF REALITY

Understanding sustainability-related issues required understanding the types of interconnections inherent in its organization and considering that changes to the parts that make up the problem affect the behavior and trigger changes to the system as a whole. Starting out from the complexity involving the subject of ethanol and the systemic nature of sustainability, the general theory of systems constitutes an alternative for the analysis of complex problems, due to the limitations of fragmented approaches. In order to design a guiding framework for the selection of sustainability assessment models based on systems analysis concepts and inspired by the sugarcane ethanol context in the state of São Paulo, it was possible and essential to identify its underlying features/attributes, to wit:

THE DIFFERENT VIEWS AND WAYS OF THINKING IN ANALYZING REALITY.

There are several scientific approaches to thinking and analysis, the so-called epistemologies, stemming from different paradigms of science. The list of epistemologies includes positivism, pragmatism, functionalism, structuralism, phenomenology and historical materialism (Faria 2012), and complexity can be added as a seventh item (Morin 2010).

According to Faria (2012), each epistemology entails a worldview, an outlook of knowledge production, a method and ensuing techniques. Without going into details of each epistemology, one can affirm that the main tension is between the reductionism and fragmentation of some (positivism, pragmatism, functionalism and structuralism) and the non-reductionist view of others (phenomenology, materialism and complexity). Traditional science adopts three assumptions: simplicity (separating the complex into simpler parts to understand the whole), stability (the world is stable, consequently predictable (determination) and controllable (reversibility)) and objectivity (it is possible to know the world as it is).

These assumptions follow approaches such as: reductionist (centered on the isolation of elements), mechanistic (observation of parts to conclude on the whole) and linear causality (the causes act together linearly to result in an event). Analytical forms deriving from classical science and others inherent in traditional or modern science seek to control variables by means of laws that indicate

[5] The preliminary results of the model testing were presented and discussed at the 5th Urbenviron Seminar Brasilia 2012 (Gomes et al. 2012).

regularities and make it possible to predict events (Brandão & Crema 1991; Vasconcellos 2003). Postmodern science or emergent new paradigmatic science, in turn, advocates epistemological change, a revision of the hitherto dominant paradigm, with assumptions related to complexity (simplification obscures interrelations, hence the need for contextualization); the assumption of instability (the world is constantly changing and therefore many phenomena become indeterminate or unpredictable); and lastly intersubjectivity (there is no reality independent of the observer and there are therefore multiple versions of reality) (Vasconcellos 2003).

The paradigm shift of science is justified, firstly by the insufficiency of the reductionist approach, a fragmented mode of thinking and analysis. Something is always lost with fragmentation since there are functions that emerge from the interrelation of the components of the analyzed system. Systemic thinking is opposed to linear, causal and reductionist thinking, given that systems are susceptible to occurrences that are unpredictable, non-linear, non-reducible and difficult to control. When one considers the limitations of mechanistic and reductionist thinking, it is evident that the socio-environmental planning process should not be dependent on the "precision" of predictions, but rather consider the unpredictable and issues related to the complex in order to better deal with the uncertainties of the future.

Systemic methods make it possible to understand the complexity of a problem, as they help to observe the "structures," "patterns" and "events" behind complex situations that are part of the characteristics of a system. The importance of systemic thinking lies in its broad approach to analysis, considering what other methods are unable to analyze. Thus, adopting an appropriate interpretative and analytical approach to a complex of elements is essential to avoid unclear or mistaken conceptions in problem solving.

By referring to the different goals and purposes of the "ethanol system," the latter can be considered a soft system, mainly due to the existence of a network of organizations and individuals that influence behavior in the entire system through their interpretations and decisions about existing problems. Likewise, the system is accepted as open, since there is exchange of material, energy or information with the outside environment. Open systems, such as social, economic and socio-environmental systems, differ from closed systems, among other aspects, by their level of entropy. Entropy can be understood as a degree of disorder of a system (Solé & Goodwin 2000; Bertalanffy 1950) due to changes in energy, temperature, and/or organization and functions of its components.

In open systems, entropy may decrease as long as the entropy of the outside environment increases (Bertalanffy 1950). This indicates that for systems involving human production activities, environmental degradation (outside environment) is inevitable in order to reduce the system's entropy.

More clearly, the "ethanol system" is considered to be complex because it consists of a large number of parts that interact in a non-simple way (Simon 1962), generating an emergent behavior resulting from such interaction (Bossel 2002; Meadows 1999; Meadows 2009), a behavior that is increasingly understood as more information becomes available (Hanneman 1998).

It is seen then that the complexity of the ethanol network context and the way people view reality may be manifold, which interferes in the design of models and tools, as well as in their choice, such choices being the representation of different and often fragmented understandings.

THE COMPLEXITY OF THE CONCEPT OF SUSTAINABILITY AND OF ITS ASSESSMENT

In the analysis of the subject of sustainability assessment it was noticed that it involves many experiences and options of analysis, that is, there are several sustainability assessment models and tools. There were signs that fragmented views and distinct ways of thinking have influenced and influence the concept and assessment of sustainability.

It was noted that the first discussions on sustainability were linked to environmental issues and that over time they incorporated considerations of the close relationships between the environmental, social, economic and policy themes, among others relevant to development agendas.

According to authors in the field of economics, for example, development ensures that the per capita income of future generations does not fall below that of the present generation. In sociology, sustainable development is that which preserves the community, that is, maintains the proximity of social relationships in communities. And lastly, ecology views sustainable development as the conservation of the diversity of biological species, essential ecosystems and ecological processes. That shows that sustainability is often seen in a simplified, unilateral way. In other cases, it is a highly complex subject for being multidimensional. In addition, other issues enhance the difficulty of operationalizing sustainability, such as the following (Chart 02).

Through historical analysis it was observed that the debates concerning sustainability are many, as are the worldviews in society. Therefore, several means of analysis and forms of understanding surround the notion of sustainability, hindering the concept's operationalization (practice) as well as its assessment process. In addition, it was found that one of the most relevant issues related to assessing sustainability is the lack of clear criteria for the selection of models and tools.

The main reasons for choosing a specific method seem to be the knowledge or affinity of the analysts who choose it.

Chart 02. Difficulties in operationalizing sustainability.

DIFFICULTIES	DEFINITIONS
Consumerist lifestyle.	The causes of unsustainable human activities are intrinsically linked to people's lifestyle, choices and patterns of consumption, besides production activities. The provision of sustainable goods and services must meet people's needs rather than desires, requiring the use of fewer natural resources and considering waste assimilation services.
Limited access to quality of life.	Sustainable communities and support for infrastructure (including transport) are needed for people to develop a sense of citizenship, autonomy to live and work well.
Misrepresentation of human values.	For a growing number of citizens, ethical reassessment is also a necessary condition for sustainability.
Poor social-environmental governance.	Socioeconomic systems dominated by market principles need to be replaced by more participatory political systems.
Depreciation of social capital	The concept of community and collective values must be fostered alongside increased investment in social capital in order to offset the loss of trust in society and the declining standards of reciprocity and cooperation networks.
Lack of ethical awareness and standards.	There is a need for a code of ethics that addresses the role and rights of people alive today in relation to the survival of the environmental system and also recognizes the well-being of future generations of human beings and nonhuman species.
Absence of theme integration.	The measurement of progress in terms of sustainability has been fragmented.
Disregard for intergenerational equality.	Sustainability requires that the capital stock does not fall over time in order to meet the criterion of intergenerational equality, that is, preserving or increasing the conditions that will enable future generations to live in a sustainable way

Source: Based on Turner (2006).

One of the consequences is having assessment processes, such as the choice of analysis resources, which do not systemically consider the issues that undermine sustainability assessment or take into account the complexity of reality. In addition, participants and stakeholders may not benefit from the assessment result for not accepting it.

RESULTS AND DISCUSSION

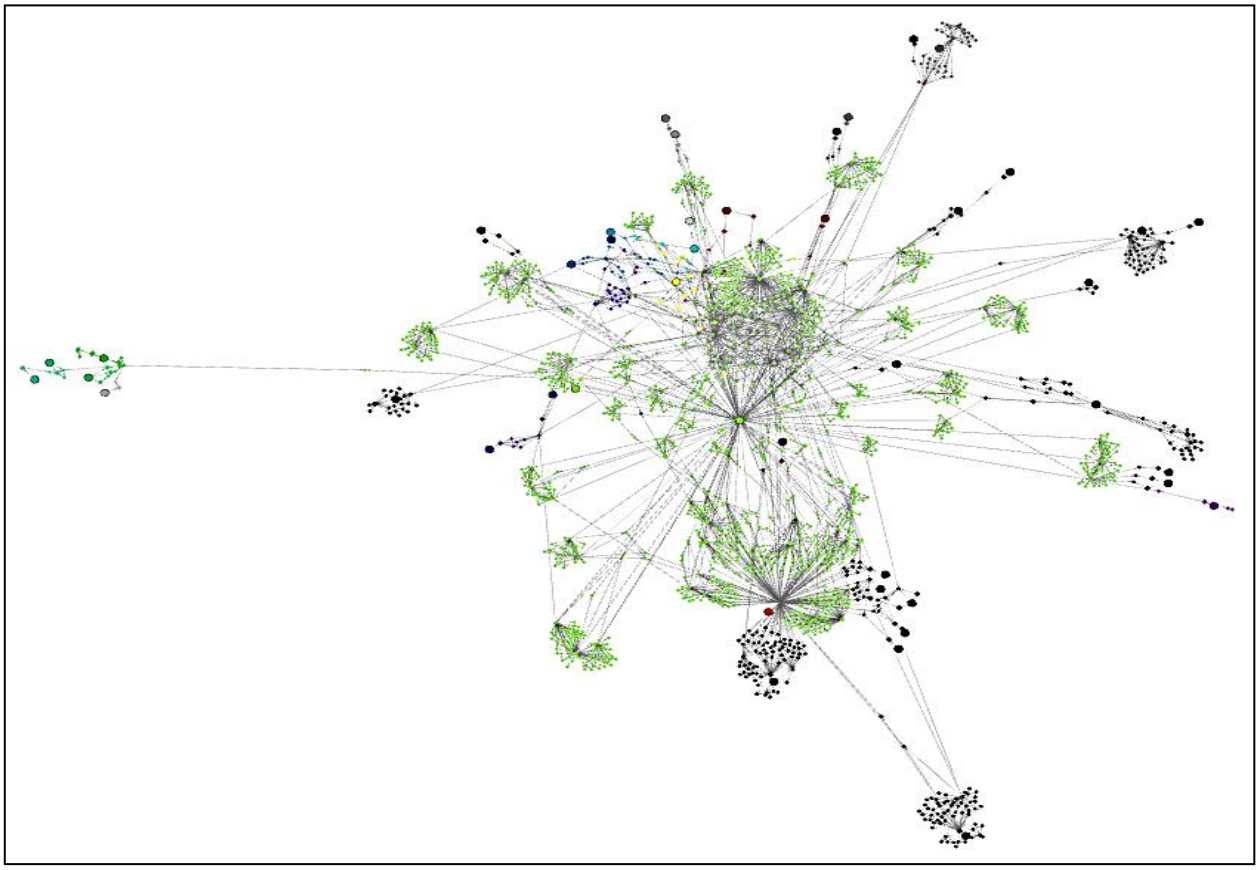
THE CONTEXT OF SUGARCANE ETHANOL IN SÃO PAULO-BRAZIL

Context analysis made it possible to describe subsystems within the larger ethanol system: economic subsystem (production and trade of ethanol in Brazil and worldwide), environmental subsystem (the social and environmental consequences of ethanol production and consumption) and policy subsystem (public policy and the sugar-energy context.) Based on such description the study

sought to discuss the influences, the complexity and the problems implied in the facts. The analysis indicated that the main issues to be discussed regarding ethanol sustainability are related to:

i) the existence of a network with a diversity of actors: politicians, technicians, scientists, producers and consumers, all involved in the discussion and decision-making process on social, economic, policy and environmental issues. Such actors influence, directly and/or indirectly, the social and political scenario of sugarcane, due to the pressures they exert as players in the decision-making context of ethanol production, commercialization and consumption. The identification of the actors' actions and missions revealed a governance arrangement, highlighting actors and presenting a thematic policy network (Figure 01).

Figure 01. Overall configuration of the UNICA network designed with GEPHI software.



Source: Authors.

Following the overall mapping of the various actors that made up the network, the focus was on highlighting the actors more directly linked to the focal actor, UNICA (Brazilian Sugarcane Industry Association). UNICA was chosen as focal actor for being the largest representative organization of the

sugar and bioethanol sector in Brazil. The association comprises 146 companies which account for over 50% of ethanol produced in Brazil.

Therefore it was possible to identify the actors with closest links with the association and thus understand the most frequent actions and discussions occurring in the network. The reason is that the proximity of an actor to other actors in a network shows to what extent this actor can be influential in communicating information (Adamic & Adar 2005) compared to others.

Analyzing the goals, missions and/or projects on websites related to the actors closest to UNICA, indications were found of actions aimed at the discussion or assessment of sustainability directly or indirectly linked to the production and consumption of sugarcane ethanol. The identification of the actors' actions and missions evidenced a governance arrangement, highlighting the actors and thus presenting a thematic policy network[6], in this case, that of sugarcane ethanol. Such networks reveal an absence of consensus and the presence of conflicts, since interaction is based on negotiation or bargaining, an unequal power relationship in which many participants may have few resources, little access and even no alternative whatsoever (Rhodes 2009).

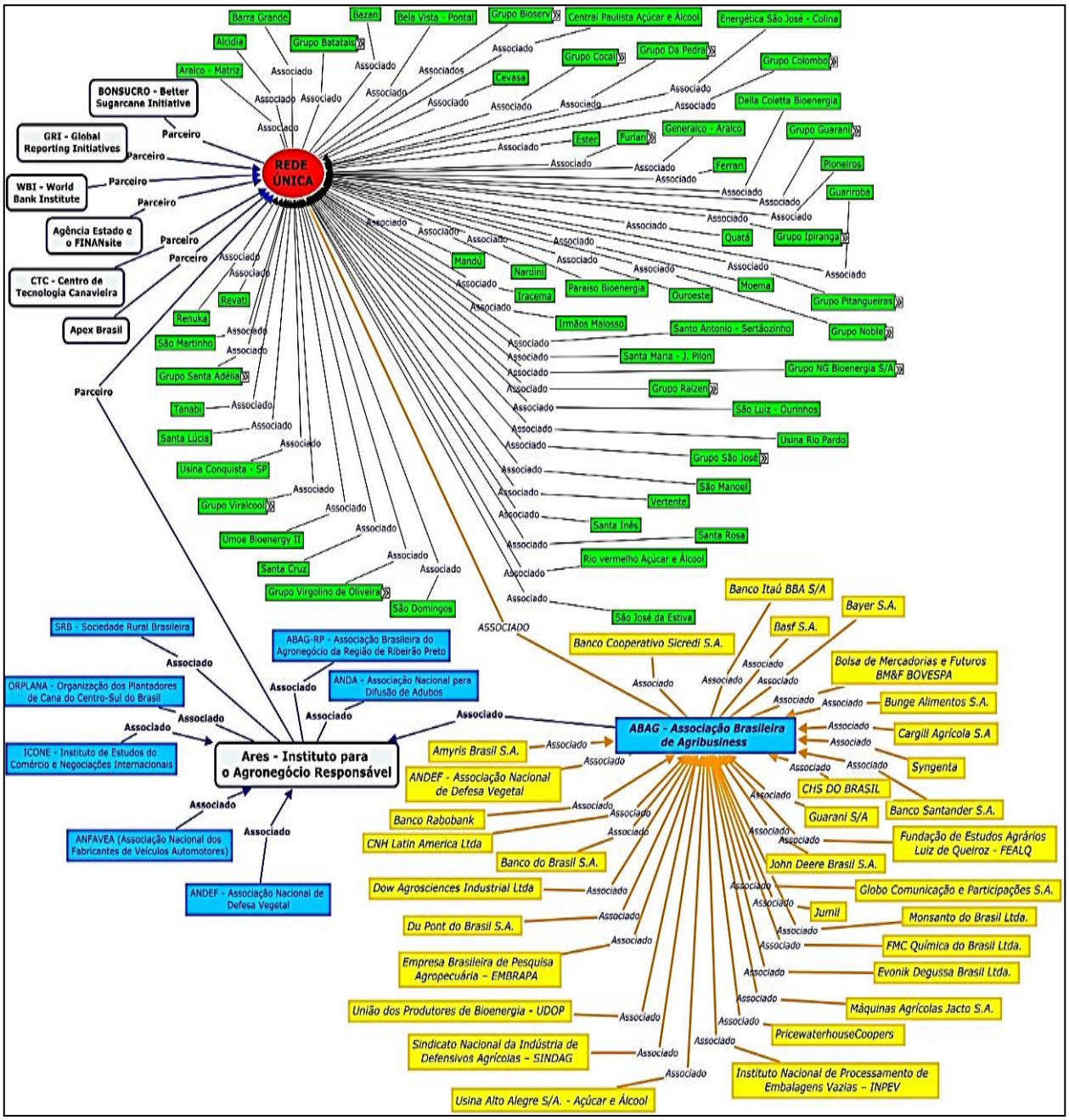
This cross section evidenced that the actors closest to the organization (Figure 02), and due to their proximity to UNICA, are considered the most influential in the discussions related to ethanol sustainability among the actors mapped in the network.

Among the various actors included in the sugarcane ethanol network the study sought to map a second network with a scientific profile whose focal actor is FAPESP (São Paulo Research Foundation), the most important research support agency of the state of São Paulo, and thus acquire an understanding of the organization and complexity of this type of network (Figure 03). This decision was made for two reasons: this is an important network as Brazil has broad scientific and technological knowledge in the sector due to its history of experience and investment in the sector, and also because the networks can influence each other in their decisions.

Regarding the area of ethanol research the study identified BIOEN, a program launched in 2008 focused on bioenergy research which "aims to stimulate and coordinate research and development activities using academic and industrial laboratories to promote the advance of knowledge and its application in areas related to the production of bioenergy in Brazil" (FAPESP 2013). Thus, the projects (interests and actions) directly involved with this program were investigated.

[6] Thematic networks can be understood as communications networks featuring many participants (government officials, legislators, businessmen, lobbyists and even academics, journalists, among others.) who have an interest in policy in a specific area and constantly impart criticism on such policy or generate ideas for new initiatives (Rhodes 2009).

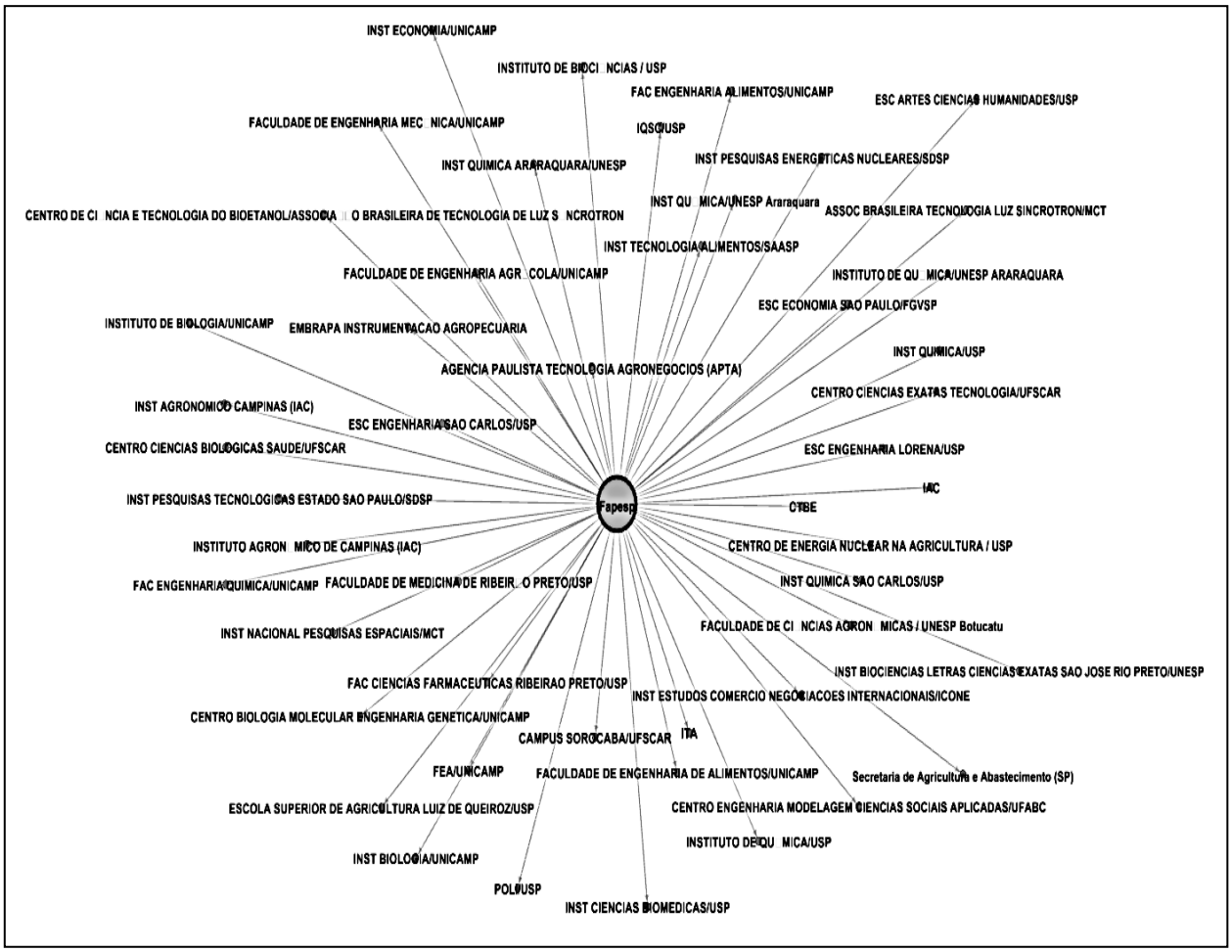
Figure 02. UNICA Core Network (most influential actors).



Source: Authors.

Considering the five research divisions within BIOEN, more than 1,300 linked research projects were found, at scientific initiation, master's, PhD and postdoctoral levels. The various projects are related to the following divisions: a) Bioenergy Biomass (focused on sugarcane); b) Biofuels Manufacturing; c) Biorefineries and Alcohol Chemistry; d) Ethanol Applications for Automotive Engines: internal combustion engines and fuel cells; e) Research on socioeconomic, environmental and land use impacts (FAPESP 2013).

Figure 03. FAPESP Focal Network.



Source: Authors.

It was noticed that despite being an academic research program, there are partnerships with technological institutes and private companies in several projects, as well as with other federal and state agencies (FAPESP 2013). This shows that the FAPESP network has a heterogeneous profile, which implies that even greater consideration should be given to these actors and their views when proposing the discussion about the future of the activity and an effective approach to sustainability.

On the other hand, in the attempt to map a government-related network (government agencies) the choice of a focal actor was not an easy task. The political scenario related to the context of sugarcane ethanol is very broad, ranging from the Presidency of Brazil to ministries, state departments, state governments and even municipal administrations.

First of all, policy actors are those involved in the direct administration of the executive power, the main persons responsible for formulating, implementing and monitoring public policy.

Ministers and secretaries are the head of government's subordinates and auxiliaries, appointed at any moment by the President of Brazil.

The choice may be based on political or technical criteria. Among the various functions of a minister are guiding, coordinating and supervising the bodies and institutions within the sphere of his or her ministry. Ministers additionally endorse acts signed by the president, being also accountable for them. Moreover, they are charged with creating regulation and monitoring and evaluating federal programs. Ministries are created to compose the foundation of government. Secretariats, in turn, are usually born from social demands. The government has special secretariats in strategic areas such as institutional security and human rights. The general secretariat advises the federal government and the president of Brazil, directly aiding in the relationship and interaction with social movements and providing channels of popular participation in the definition the country's agenda of priorities. In this the general secretariat is assisted by the other secretariats, each in its specific area.

Federal secretariats are related to the principle of social participation and, therefore, to the affirmation of democracy. They are mediators between government and society, since they build spaces that allow the interests of the various sectors of society to be incorporated in the formulation of public policy (Portal Brasil 2013). Also within this sphere are the public policy management boards, responsible for creating guidelines, making policy-related decisions or monitoring the management of programs. The boards may be composed of representatives of diverse segments besides representatives of the public administration, i.e., their members may come from both government bodies and civil society.

Regulatory agencies, in turn, were created to supervise the provision of public services by the private sector. They establish rules for their corresponding sectors and, depending on the sector, supervise their activities. Therefore, it is within this public administration structure that public policy is designed and implemented and the network's policy actors inserted. Thus, the very definition of a policy network of government agents attests to its complexity.

When carrying out a Policy Network Analysis, it should be said that the cohesion of the actors and the development of the network, as a whole, derive from common actions and interests within the network. In this sense, (Rhodes 2009) affirms that the institutionalization of common values is inevitable. Once these values are in harmony with the values and interests of society the network tends to gain legitimacy, transcending the regulatory power of government and bestowing authority on its

actors (Latour 2011). In any case, the government is indispensable to delineate relationships within the network, despite being one of its actors.

Since this governance environment is seen as a bottom-up system based on widely distributed power of information, the network as a whole is self-regulated and thus has the features of a "complex adaptive system" (Atkinson 2003). Complex adaptive systems are constantly adaptable due to the mechanisms of real-time information capture and dissemination, enabled by the internet.

In such systems the actors interact to determine and achieve results by continually adapting to what the others are doing. Thus, these complex adaptive systems comprise autonomous and decentralized decision-making agents, with no one directly in charge (Atkinson 2003). However, the network's relationships are not totally informal, since the government is well represented by its institutions as actors in the network, helping it acquire a more efficient structure and greater formal regulation (e.g. legislation) besides the rules and behaviors informally institutionalized by the network's actors, which guarantees a minimum of trust and credibility among the generated relations (Rhodes 2009).

In addition, the analysis made it possible to verify a variety of areas of interest and organizations related to the private, public, third and research sectors. Focusing on a core actor results in a larger number of representatives belonging to that sector, as in the case of the network which has UNICA as the core actor. The most prominent group in terms of numbers is represented by the private sector. Likewise, the FAPESP network with the largest group represented by research centers and the government agencies network. These sectors (private, research and government) are not closed subsystems since they are structured and overlap due to interfaces with other subsystems of other policy networks and in different spheres, both nationally and internationally. This again shows the complexity of the relationships of the actors of policy networks, whatever their nature.

ii) sustainability discourses of the activity: the historical facts and events of the ethanol context show different dimensions compared to the activity's current discourse of sustainability. These dimensions are considered subsystems and are related to planning and decision making concerning sugarcane ethanol. These subsystems are economic, policy and social-environmental. Regarding the economic subsystem, the sugar and alcohol activity is very important in Brazil due to the national production capacity and its relevance in the energy scenario worldwide. It should be noted that Brazil is

currently considered the second largest producer of ethanol in the world and the first of ethanol made from sugarcane.

Due to economic incentives to stimulate alcohol production, expansion in the production of flexible fuel vehicles and the consequent increase in the demand for ethanol fuel, the Brazilian domestic sugarcane market experienced strong expansion. The historical contextual analysis, however, shows relative economic instability due to cyclical crises related to overproduction, price depreciation with rising sugar prices in the international market, international economic crises, unfavorable climatic conditions (droughts and high temperatures), government economic policy and absence of price regulation reducing competitiveness.

Among the environmental problems of ethanol production and consumption raised in the literature review, the most discussed are related to the production model based on the intensive use of soil and natural resources with the expansion of monoculture.

In the social dimension, attention is focused on the expansion of the sugarcane crop area, which has consequently reduced food production in certain regions and caused the withdrawal of small farmers. This situation is aggravated by mechanization which requires skilled labor and fewer workers compared to manual harvesting. Although working conditions in manual harvesting are considered inadequate, the negative consequences of job losses cannot be ignored. In order to mitigate these negative social impacts, a few professional training projects and programs have been implemented.

Lastly, the policy subsystem in the sugar-energy context was investigated. It was observed that there are various policies related to the biofuels theme with environmental, energy and agricultural goals, forming a policy network. This network has focused largely on managing the expansion of monoculture. One of the most severe criticisms refers to the absence of public policies focused on ethanol exports and social-environmental aspects, such as mitigating social exclusion generated by market inequalities and/or generating employment and income for family farmers.

Environmental policies which have been specially institutionalized stem from national and international discussions on ethanol sustainability. Noteworthy among them are credit lines offered to producers able to present proof of sustainable practice, such as certifications.

1. *ETHANOL SYSTEM*

Because it is a holistic and integrated complex, that is, a system, the dimensions or subsystems pertaining to the sugarcane ethanol theme are interrelated and overlap, so to a certain extent it is meaningless to explain them separately. The reason is that there are many factors involved in the

planning and decision-making activities of a productive sector, especially when it is economically relevant for a country or the whole world. A clearer understanding of the interrelationships and overlapping of the subsystems is obtained by analyzing the influence of the policy sector on the economic sector.

Policies may influence, for example: (i) ways of stimulating a sector, discouraging or controlling when or how to increase or withdraw investment actions, ii) other activities, other organizations, other governments, (iii) ways of selling a product due to marketing and advertising, (iv) operational decision making (fund raising, choice of production technology) (v) and even the internal management of an organization (recruitment, wages and other personnel policies). In short, policies influence the economic dimension (microeconomics in this case) (Allen 2001).

That means that the organizational actors, particularly those in the private sector, must be able to identify the policy factors that have affected or could affect business. The literature itself shows several cyclical moments of crisis in the history of ethanol in Brazil, obviously considering a large amount of influential variables behind them. In any case it is understood that policy changes or indecisions hinder the sector's development as they lead to lack of investment and the undermining of business.

In this sense, it is necessary that the organizations, using policy risk assessment tools, regularly carry out analyses of the policy context in which they are inserted due to the changes that occur from one government to another. To this end, these organizations must also demand that the government generate data to enable such analyses. Thus, the policy factors that can influence the sector will be evidenced and new strategies can be devised.

In the same way, policy analysis must take into account not only the government of the country in question, but the influence of other organizations on the sector (Allen 2001). For example, economic blocks or regional and/or global groups such as the European Union (EU), Mercosur, North American Free Trade Area (NAFTA), World Trade Organization (WTO), Organization for Economic Co-operation and Development (OECD), among others.

These organizations are as influential as any other relevant actor in the Brazilian sugarcane ethanol policy network. This is due to the relationships of interests, conflicts and alliances among the actors. Therefore the government must act through economic and regulatory instruments and contractual mechanisms, performing a role of public mediation of such interests. So, one can affirm that policies may economically influence the way of doing business in the productive sector.

From another perspective, the economy influences policy. Among many aspects, the economy can influence mainly: (i) inflation rate, (ii) tax rates, (iii) interest and exchange rates, (iv) stock price changes due to stock market volatility, (v) employment and wage rates, (vi) national and local market growth rates, (vii) the effects of trade barriers and tariffs. For these reasons some government control is necessary as it would afford a balance between the needs of society and companies, guaranteeing necessary services such as transportation and education, infrastructure, while ensuring that organizations operate in a fair, legal and competitive way (Allen 2001). By intervening in the economy through economic policy to stimulate a given activity or protectionist strategies, the government necessarily influences the market economy, which can reduce competitiveness or even undermine business efficiency.

Another example of systemism is between the economic and social dimensions. The economy affects consumer preferences in purchasing products and services. If the economy is heated consumers spend more, but the opposite is true when the economy is in recession. In the latter case consumers avoid purchasing and that affects the organizations that depend on the sales of their products and services. People's behavior and choices may have important effects for an industry. A specific case in point related to ethanol in Brazil is the number of flexible fuel cars acquired in recent years, much higher than any other type of vehicle. People have been looking for alternating technology, that is, the flexible fuel car allows someone to decide which fuel product to buy and ethanol is often the most economically viable option when compared to gasoline or other fuels such as natural gas. These issues, for example, condition choices, which in turn condition products and services offered in the market.

Nonetheless, these choices are not merely focused on consumer awareness. Most times these choices are mainly related to economic factors, but may also be a combination of public policy, social values and economic factors. Once again integration between the dimensions, that is, between the subsystems, is perceptible.

It is important to mention that some factors may lead people to change their values, such as increased environmental awareness, and these must also be considered. A product viewed as polluting, or manufactured with slave labor or with a reputation for bad quality will not be favorably assessed by the public. These are issues that economically influence the production of ethanol. In this case one clearly observes several dimensions in focus: social and environmental issues affecting the economy. These factors may even create restrictions to the expansion of a crop. An example is the issue of food security, seen as threatened by the production of sugarcane monoculture. Likewise, even if not

threating food production, a crop expansion might invade or degrade important ecological areas such as the Cerrado, Pantanal and Amazon biomes, causing environmental impact.

Other social issues concerning the production of ethanol are working conditions. Once manual, harvesting nowadays is basically mechanical. Both have consequences, since the former is considered degrading for workers due to the intense physical effort and low pay. On the other hand, mechanization requires a higher level of skills and a smaller workforce compared to manual harvesting, increasing unemployment. Again the problem involves more than one analysis dimension.

Another very important topic, intrinsically associated with policies, economics and all the other dimensions making up a system, is legislation. All organizations and their sectors are subject to laws, since laws and regulations cover a wide range of subjects, from the operational procedures of a company to the control of quality and product and the pollution generated in its production, use and disposal. It is no different in the sugar-energy sector.

It is important to mention that in addition to the laws and regulations directly imposed by legislation, there are also voluntary agreements stemming from the attitudes and pressures of society.

Last but not least is the environmental dimension and its interrelation with the other subsystems. Environmental awareness has grown considerably in recent years and so have society's demands for a better preserved environment, more pollution control and more sustainable attitudes. In this context, ethanol fuel has gained prominence as a potential substitute for fossil fuels – highly polluting and non-renewable sources of energy that contribute to global warming.

However, consumer awareness, despite exerting strong pressure for a more sustainable scenario, has little strength on its own. Effective changes require incentive from the government and financial institutions. One ally in this sense is technology. New technologies can affect and even revolutionize certain industries by affording competitive advantage through innovation, but may also have the opposite effect, the impossibility of competing due to lack of technological innovation. In the case of the sugar-energy industry, innovation can be a more efficient production model and/or new ways of managing problems (such as environmental impacts), and/or the discovery of new products and new ways of providing services.

Once again there is evidence of the relationship and involvement among the various parties. In line with the unquestionable importance of the environmental and economic issues and all other subjects herein mentioned to the discussion of sustainability, it should be remembered that, for this

study, the network of actors is considered as a component of these subsystems. Therefore, its characteristics and relationships are essential to a systems analysis of sustainability.

Since the network's configuration and the relationship of forces among the actors undergo permanent change, an attempt was made to present an example to demonstrate how complex and important it is in the context of sugarcane ethanol-related issues, such as those of a policy, social, economic, technological and environmental nature.

Although it is hard to delineate the concept of network (Bott 1976), one can say that a network is defined by the common or controversial interests and objectives existing among the various parties involved in a specific issue or topic. Its importance is in the bonds between the actors, who may be individuals or entities and organizations. Such ties build and establish structures of relational influence in procurement, exchange and loss of material goods, information and power (Scott 2000; Freeman 2002). It is no different with policy. The relationships and positions (relational structures) may coerce choices, afford distinct access to goods and instruments of power, form specific alliances or conflicts and thus influence policy outcomes due to the behavior of interest groups (Marques 2006).

The reasons behind the strategic positioning of the actors may range from protection of ideological and/or economic interests to increase of forces due to the cohesion of groups, among others. Regardless of such reasons, their relevance is key in discussing public policies and their objectives aimed at a sector with actors involved in power games and interests. Therefore they should be considered by the public policy related to the sector.

It is therefore concluded that taking networks into account may greatly contribute to the design and assessment of public policy, since it makes it possible to discuss the effects of the complex interactions among actors, understand the structure of the bonds and examine the patterns of behavior and effects of the relationships, thus assisting in strategic policy action.

2. *INTERVENTION POINTS OF THE SYSTEM*

The context analysis afforded an understanding of the breadth of the problem, its complexity and integration in order to exemplify the variables and relationships that must be considered in a systems sustainability assessment. Therefore, the first requirement when performing a systems sustainability assessment is grasping the complexity of the system and highlighting the most important points (that influence the system state), called intervention points of the ethanol system. Branco (1999) defines intervention point as an element that, if modified, changes the whole completely. Meadows (1999) calls them leverage points and defines them as "...places within a complex system (a corporation,

an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything."

These points allow us to understand the system. In the case of ethanol, the methodology adopted made it possible to identify those points. In the case of a future analysis, it will suffice to follow the designed questions (Chart 03) that will lead to the intervention points of the sugarcane ethanol system. This is so because, due to the dynamism verified in the characterization of the ethanol system, it is noticed that the system undergoes mutation phases over time. Therefore, analyzing the ethanol system requires a methodology that allows the classification of the most relevant points, depending on the moment one decides to investigate it. In other words, when analyzing the system at some future time such questions will help identify the key factors, those that influence or may influence the state of alliance or conflict in the system at the moment of analysis.

Chart 03. Guiding questions to elaborate intervention points - sugarcane ethanol system.

DIMENSION (SUBSYSTEM)	KEY FACTORS
Policy	What is the current government's influence in the sector? What are the current political and economic barriers? What national or international groups or organizations influence the sector? (Which provide money, which provide technical support, which provide data, establish standards and regulations, others). What are the existing policies related to productive activity in the economic, environmental and social spheres? What are their influences? Who are the policy actors involved in the sugarcane ethanol actor network?
Economic	How is policy influencing the industry economically? What is the degree of government intervention in the current economic system? What are the consequences of this intervention or of its absence? What is the current economic trend? How is it affecting the sugar-energy sector?
Social	What has influenced consumers' decisions in acquiring the ethanol product? What is the view of domestic and foreign consumers on the social-environmental benefits and harms of sugarcane ethanol use? What is the trend of consumer preference in the long run? Which concerns should the ethanol industry anticipate in considering possible and future changes in the behavior and, consequently, the choice of its clients-consumers? What social responsibility action has the sector taken or could take?
Technological	What are the technology trends in the industry and how do they affect or might affect organizations and consumers?
Legislation	What laws and regulations have most affected the industry currently? What are their effects on organizations and also on consumer choice?
Environmental	What are the negative environmental impacts generated by the sector? What action have the organizations taken or could take to mitigate such impact?

Source: Authors.

Thus it will be possible to identify the points of intervention of the system, that is, essential components to be considered in the discussion of ethanol sustainability.

The importance of the intervention points for the framework to select sustainability assessment models/tools is based on the fact that when choosing models or tools to discuss and assess sustainability, the most relevant factors for the sugar-alcohol sector's planning and decision making should be taken into account and thus the framework will help achieve the desired changes.

Therefore, the intervention points are the answers to the questions, which serve as a guide to reflect on what should be considered within an analyzed issue so that goals and strategies are designed and assessment models and tools are elaborated or chosen with the intention of analyzing the sustainability of projects, plans or policies.

3. GUIDING FRAMEWORK FOR A SYSTEMS SUSTAINABILITY ASSESSMENT PROCESS

The framework (Figure 04) is structured as criteria, which can be understood as parameters that clearly indicate the principles underlying them and the action to be taken to establish a choice. The main concepts of systemic holistic approach, present in the analyzed literature, were considered. The framework aims specifically to provide resources to guide the choice of models and tools that propose to assess sustainability. The criteria were organized with the goal of facilitating the sustainability assessment process from a systems viewpoint, especially regarding sugarcane ethanol production.

On the other hand, this framework can be applied to any other monoculture or theme provided the goal is to support sustainability assessment and that its system is understood, considering its complexity and dynamism through context analysis and identification of its intervention points.

Abridging the various assumptions into a systems analysis framework required integrating concepts from various disciplines due to the broad multidimensional spectrum of the issues addressed. To this end, a few implementation and integration principles were designed (Chart 04).

These establish a synthesis methodology to be used when considering variables from different disciplines and scientific areas.

4. DETAILS ON APPLYING CRITERIA

CRITERION 01

Self-explanation (see Figure 04).

Figure 04. Guiding framework for the selection of sustainability assessment models and tools.

Source: Authors.

Chart 04. Implementation and integration principles.

IMPLEMENTATION AND INTEGRATION PRINCIPLES	DESCRIPTION	SUGGESTED METHODOLOGY
Space Reference	The proposed analysis framework should refer to a previously identified geographical area or region.	Selection of a state or region integrated with influential national and international issues (carry out context analysis of the issue).
Time Reference	Complementarity/conflict among the various divergent time scales should be considered and analyzed according to the views of the various actors or dimensions.	Interview with stakeholders, actors and specialists.
Sociocultural Processes and Structures	It is important to consider society's heterogeneities from a socioeconomic and cultural viewpoint, different value systems, risk tolerance, etc., in order to design sociocultural frameworks.	Interview with stakeholders, actors and specialists.
Use of various tools	Use of information resources that facilitate and complement knowledge integration.	Investigation of relevant documents and data through different methodological procedures in order to integrate results. Use of tools that enable instructional transmission of information to all involved for their active participation.

Source: Based on Ramírez (2002), Schuschny (2009), Block et al. (1999).

CRITERION 02

In order to identify the actors involved, a mapping of the theme and policy network is recommended, as was done for the sugarcane ethanol context. The relationships of power established among the actors outline a governance structure since they form specific institutional arrangements.

The following knowledge is required to ascertain the governance level of an actors network: (i) at what levels decisions regarding the focal theme are made (local, municipal, regional, etc.); (ii) correlation between the levels and the previously identified points of concern (ecologic impacts, economic impacts etc.); (iii) to what extent formal or informal institutions restrict or increase the flexibility of the decision, since enforcement of decisions should be viewed as legitimate by users of the resource (Resilience Alliance 2007a; 2007b). When mapping an actors network and understanding their relationships of interest and conflict, and those holding formal and informal power, it is necessary to discuss and define conflict resolution mechanisms with all of them. To this end stakeholders must identify which initiatives lead to collaborative decision making, proposing such initiatives if there are none in place.

CRITERION 03

This criterion corresponds to finding the limits of the system (focal system). To this end it is based on intervention points, that is, on the main issues related to the subject.

When applying this criterion, actions identified as necessary should be carried out, such as gathering documents, interviewing people in possession of data, etc., strengthening the stage or process of understanding the system. Most importantly, the main points (system attributes) should be identified and, especially, valued by the stakeholders.

Outlining the focal system and identifying intervention points run through almost all stages of the framework process and are intrinsically related to the adaptive management criterion, since some points defined as critical and the limits of the system will possibly be modified and new ones identified due to the different views of stakeholders.

To enable the definition of a relevant time scale, the Resilience Alliance (2007a) suggests considering the natural cycle of the variables plus the planning cycle. As for spatial limitation, a systems conceptual model based on the concept of panarchy would be the most appropriate to support the task.

CRITERION 04

This criterion is best applied by using methods and procedures that stimulate discussion while capturing the views of stakeholders in the sustainability assessment process. This requires the assistance of specialists in the areas of applied humanities and social sciences to guide and analyze the procedure and, in particular, since choices are shaped by ethics, the theme to be worked on during the discussion.

As a stimulus to define the goals, the list of intervention points elaborated by the context analysis (application of criterion 03) can be used as a guideline since it includes the key issues of the focal system (social-ecological system).

By means of the application of criterion 3, stakeholders will have the possibility to broaden their understanding of the different variables and complexity of the system and thus be encouraged to outline clearer and more effective goals. For these reasons, criteria 03 and 04 are mutually subordinate.

CRITERION 05

This is a guiding criterion for all moments that require choosing an analysis procedure, whether they are models or tools that:

i) have features that facilitate their application and analysis of outcomes, such as the methodology followed, reproduction of outcomes, among others,

ii) and represent the criteria that require their application, since the framework criteria always consider the systems viewpoint of analysis.

It is suggested that the attributes indicated by Buytaert et al. (2011) (Figure 05) be checked alongside the goals (defined in the application of criterion 04) and the essential system concepts should be addressed by the chosen models and tools.

Figure 05. Essential attributes for an assessment tool.

List of attributes used to describe the characteristics of the evaluated tools.

Tool attribute	Attribute explanation
Data	
Availability	Data needed to apply the tool are readily available
Need	Balanced amount of data needed to apply the tool
Type	Preference for quantitative (metric) data input
Integration	Ability to combine descriptive and quantitative data
Correctness	Correctness of data used
Procedure	
Flexibility	Model procedure is dynamic, can easily be adapted or complemented
Coverage	Degree to which multiple sustainability issues of the four dimensions are integrated
Objectivity	Model is not susceptible to the subjectivity of the executor
Transparency	Transparency of the evaluation procedure
Validation	Ability to validate evaluation results
Time scale	Ability to process dynamic data
State-of-the-art	Degree to which the tool is operational
Results	
Univocity	Results are consistent, no contradictions in the results
Simplicity	Results are possible to understand by stakeholders, no expert knowledge required
Type	Results are preferably quantitative
Clarity	Results are compact and clear, no long lists or extensive reports
Communication	Results are represented graphically, easy to interpret
Use	
Flexibility	Ability to integrate inputs of the stakeholders
Accessibility	Possibility to interpret results without expert intervention
Application cost	Low cost to execute the evaluation task
Application field	Ability to execute evaluation tasks on different levels (micro, macro, . . .)
Time consumption	Low time demand to execute the evaluation task
Handiness	The model is easy to use
Assistance	Availability of experts to render assistance

Source: Buytaert et al. (2011).

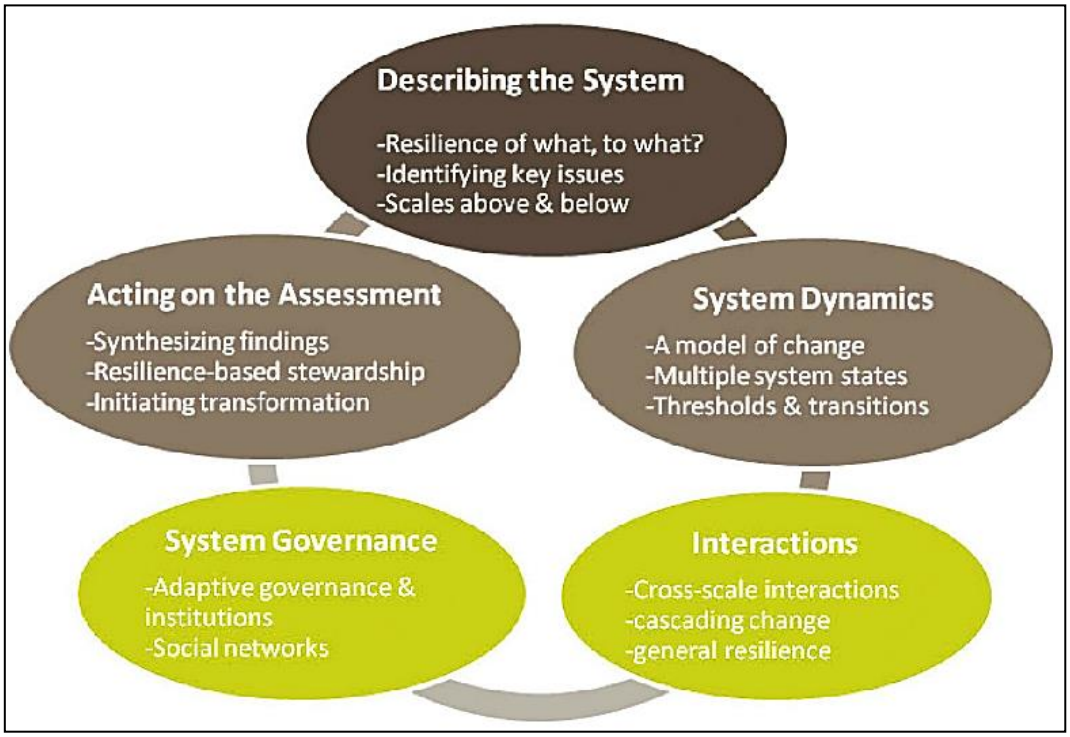
CRITERION 06

Resilience represents the system's capacity to react to changes brought about by external factors. Its relation to the thresholds concerns knowing the limitations of this system in order to devise

ways to avoid the consequences of changes or to adapt to them without impairing the functions and structures of the subsystems, the larger system and its ecosystem services.

In any case, identifying thresholds is not an easy task as they tend not to be static and can also change. Therefore it is more important to identify the factors that pressure the system than estimate the precise conditions under which a threshold breaks. Actions taken at different times may influence thresholds and transitions from one state to another. Before the transition, management interventions may avoid the breach of thresholds through mitigation. However, once a threshold has been exceeded changes in the system state may be difficult or impossible to reverse (Resilience Alliance 2007a; 2007b). One way of assessing resilience is suggested by the Resilience Alliance (2007a; 2007b), a specialist network in this field (Figure 06) that considers systems principles.

Figure 06. Conceptual model to assess the resilience of an SES.



Source: Resilience Alliance (2007a; 2007b).

According to this proposal, five stages must be followed: first, the system is described. Then, its dynamics are understood by investigating its interactions and analyzing its governance. Finally the assessment is closed, with the previous steps being resumed whenever necessary.

CRITERION 07

Trade-offs are win/lose relationships inserted in any decision process. In a sustainability-oriented decision process it is necessary to define which significant losses can cause an imbalance in the

system state and thus set limits on which losses will be acceptable or not. This form of analysis is dependent on the governance framework embedded in the decision process, since it is the actors involved and their influence and power that will guide the decision. To this end it is necessary to establish rules to agree on what will or not be accepted, setting non-negotiable limits for each dimension and considering the thresholds (criterion 06) and resilience of the subsystems and the larger system. To facilitate the process of formulating rules it is recommended to consider the results of the previously applied criteria of the analysis framework of this research. Equally important is to define potential impacts and, among them, which ones will be accepted and their justifications, and which ones should not occur for representing a significant trade-off. To this end Gibson et al. (2005) present six rules that can be used alongside those to be established by the stakeholders or to guide them. Essentially the rules are:

i) Maximum net gains: any trade-off or set of acceptable trade-offs shall lead to the progress of the whole considering sustainability principles, seek mutual, cumulative and long-term gains and favor the most positive overall result.
ii) Burden of argument on trade-off proponent: trade-off negotiations involving the acceptance of adverse effects on sustainability are undesirable until proven otherwise; the burden of proof lies with the proponent of the trade-off.
iii) Avoidance of significant adverse effects: no trade-off involving a significant adverse effect on system sustainability (for example, any effect that might compromise the integrity of a social-ecological system) can be justified unless the acceptance minimizes an even more negative and significant effect.
iv) Protection of the future: A significant adverse effect in the present cannot be displaced to the future.
v) Explicit justification: all trade-offs should be explicitly justified according to the priorities and assessment goals as well as the sustainability assessment criteria.
vi) Open Process: Proposed agreements and trade-offs must be addressed and justified through processes that involve open and effective participation of all stakeholders.

It should be noted that the last rule is the basis for the application of all others, since participation of all stakeholders is essential in the process as they have different values and views about what is or not negotiable. In addition, the expertise of a specialized team may be very useful in technical and specific decisions of the analysis.

CRITERION 08

Adaptive management deals with uncertainties and changes that may occur over time and focuses on learning from experiences throughout the process. The key issue of adaptive management is the necessary involvement of stakeholders from the planning stage to monitoring decisions taken at the outset, maintaining such involvement as a continuous and cooperative cycle of action learning (Grace and Pope 2011; Mangoyana et al. 2013).

The structural characteristics of the actors' network may influence the management of results obtained during the assessment process, either facilitating or hindering the sharing of information, access to sources and resources and opportunities for cooperation. However, there is no optimal structure (Resilience Alliance 2007a; 2007b). Therefore the governance system is essential for adaptive management.Thus, describing the network and determining the actors' impacts on the decision-making process involved in the complexity of the system are essential for a systems sustainability assessment of a sector or activity (Criterion 02).

This more detailed investigation of the network must be longitudinal, that is, performed over time in order to observe its dynamics and possible structure changes.[7]

Thus it will be possible to determine which links are "broken," which are reestablished and what are the new interrelationships arising from the insertion of new actors or the exit of some of the participants. It is important to remember that the participatory governance system, defined by the application of criterion 02 of this framework, should be preserved and adjusted when necessary.

But it is not only governance that is prone to changes, which is to a certain extent a subsystem of the larger (focal) system. The changes are related to the whole, the other dimensions, their interrelationships.

Therefore, the design of an Adaptive Management Plan is recommended, outlining the goals that have or not been reached, the measures adopted that were not adequate and the respective corrective measures, thus making it possible to decide about new priorities and learn from the process. The plan can be defined by means of examples from the literature or the use of existing software designed for this purpose.

The new knowledge generated must be integrated into the decision-making process. In presenting and discussing the results, appropriate methodologies will be necessary considering that

[7] In the context of systems, structure change relates to changing information links in a system. The content, goals, incentives, costs and feedbacks are what drive or restrain the behavior of actors, causing them to behave quite differently if they see a good reason to do so (Hjorth & Bagheri 2006).

stakeholders have different views and/or levels of technical knowledge (Cundill & Fabricius 2009). To this end, the discourse language of must be appropriate. In order to discuss the results of the analyses, the use of mixed language (semi-mathematic language alongside the use of everyday terms) is recommended, reducing ambiguities, misinterpretations and poor understanding of anyone involved. Such action should be continuous in order to monitor the dynamism of the system and thus learn from unexpected results.

CONCLUSIONS

This paper aimed to discuss the most appropriate profile for a sustainability assessment model or tool guided by systems theory, presenting in its results attributes that make it possible to reduce the limitations investigated. In the search for such attributes the main characteristics of systems theory were examined and principles of sustainability assessment were analyzed in research and assessment proposals.

Through the appraisal of systems theory and sustainability assessment principles it was concluded that a single tool, model or instrument is insufficient to provide an effective assessment process from the perspective of two theories, systems and sustainability. Therefore, the framework recommends using all resources required to perform sustainability assessment.

Regarding the results obtained, it was possible to design a criteria-based framework to support the sustainability assessment process, grounded on the demonstration of the complexity and systemism inherent in sustainability, its assessment and the sugarcane ethanol sector itself.

The analysis framework allowed the insertion of systems and sustainability principles in the assessment process of an activity, in particular mitigating the weaknesses of pragmatism, factors that limit and make it difficult to conceptualize, practice and assess sustainability, and also hinder the understanding of systems theory and thus the assessment process as a whole.

Among the difficulties encountered in conducting this research the greatest was organizing the information, data, reflections and discussions, due to the integration and overlap of subjects and results stemming from the integrated and systems analysis method used. It is understood that this proposal reached its objectives and made contributions to the subject of sustainability assessment.

Lastly, it is believed that this research made scientific and technological contributions by complementing other works aimed at discussing and assessing sustainability in the bioenergy sector, supporting the design of public policy and guiding decisions that require understanding the complexity of the sugarcane ethanol theme. According to an analysis published by the Scientific Committee on

Problems of the Environment (SCOPE) on the progress of bioenergy and sustainability research[8], it is understood that this research contributed to addressing recent and necessary issues for the development and sustainable expansion of bioenergy, such as planning, governance, impacts of bioenergy expansion, policy interconnectivity, sustainable bioenergy systems, relevance of discussion and communication among stakeholders and principles of interaction and participation.

It should also be considered that the analysis framework proposed can be understood as a conceptual model, composed of criteria that respect systems characteristics and sustainability assumptions. Therefore, it can be comprehensively applied in other cases inherent in the complex discussion of sustainability, which does not mean that the framework can be applied only to the case of ethanol. It can be applied to any other monoculture or theme provided that the goal is to support sustainability assessment and that its system is understood, considering its complexity and dynamism through context analysis and identification of the intervention points of this system.

The framework has features and requirements that characterize it as ex ante – the moment of performing a sustainability assessment to support the decision. As a normative object, the use of the framework shall enable the investigation of its weaknesses and thus help in the continuous improvement of this resource.

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[8] This is a collective effort with contributions by 137 researchers from 82 institutions in 24 countries. The volume is the result of a Rapid Assessment process, which included a meeting at UNESCO in Paris in December 2013 where 50 experts discussed transversal aspects of bioenergy sustainability (SCOPE 2015).

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Estrutura de Análise Sistêmica para Seleção de Modelos de Avaliação de Sustentabilidade: Uma Proposta para Apoiar o Caso do Etanol de Cana-de-Açúcar no Estado de São Paulo

RESUMO

No Brasil, o etanol de cana-de-açúcar tem apresentado grande destaque como biocombustível. Logo, postular a sustentabilidade para essa atividade é um desafio essencial, difícil, mas importante. Com a gama de opções de ferramentas de avaliação disponíveis, esta pesquisa focou em como essas questões complexas são consideradas no processo de seleção de modelos de avaliação, bem como como esses modelos são escolhidos e propostos. Para a busca, foi realizada uma análise contextual, identificado pontos de intervenção para o sistema de etanol de cana-de-açúcar e questões críticas envolvidas no conceito de sustentabilidade e sobre sua avaliação, e ainda, classificados os atributos por critérios sistêmicos. A pesquisa concluiu que não houve um vínculo adequado entre os modelos de análise e sua seleção, prejudicando a sustentabilidade operacional e a avaliação. Assim, o arcabouço analítico e sistêmico proposto para a seleção de modelos de avaliação de sustentabilidade, pode contribuir para o processo de tomada de decisão e para a formulação e / ou avaliação de políticas públicas voltadas para a sustentabilidade do setor.

Palavras-Chave: Avaliação de Sustentabilidade; Abordagem Sistêmica; Energia.

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