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First generation or second generation ethanol in Brazil? A comparison through economic and social environmental aspects

Etanol de primeira ou de segunda geração no Brasil? Uma comparação da ótica econômica e socioambiental

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Contents

ABSTRACT:
The main goal of this research is to compare between First Generation Ethanol (FGE) and Second Generation Ethanol (SGE) production cycles. In relation to FGE, SGE has presented environmental and social gains, as it is produced from FGE residue, employs lesser amount of natural resources and energy, as well as utilizes specialized labor alongside complex technology. However, SGE's financial costs and investments are superior to FGE's. The integrated cycle may be a solution for plants in regards to these challenges.
Key-words: Ethanol, First Generation, Second Generation, Brazil.

RESUMO:
O objetivo deste trabalho é comparar os ciclos produtivos do Etanol de 1ª Geração (E1G) e do Etanol de 2ª Geração (E2G). O E2G, em relação ao E1G, demonstrou ganhos ambientais e sociais significativos, por ser produzido a partir de resíduos, usar menor quantidade de recursos naturais e energia, bem como utilizar mão de oba qualificada numa tecnologia complexa. Contudo, os custos econômicos e os investimentos são superiores aos do E1G. O ciclo integrado constitui uma forma de superar esses desafios por parte das usinas.
Palavras-chave: Etanol, Primeira Geração, Segunda Geração, Brasil.

Introduction

Ethanol is an alternative fuel in relation to fossil fuel, therefore being considered as a renewable source of energy. It has presented a growing, competitive and low-environmental impact market. In 2007, ethanol's worldwide production was approximately 55.7 billion litters, being led by American corn ethanol and Brazilian sugarcane ethanol. However, Brazilian ethanol is more competitive, in light of its lower production cost, of US$ 0.22/liter, compared to American ethanol production cost of US$ 0.35/liter (PACHECO, 2011).

Nationally, Brazilian ethanol's production has grown overwhelmingly, starting from 22 billion liters in the 2011/2012 crops onto roughly 30 billion liters in the 2015/2016 crops. In comparison with other bioethanol production cultures, sugarcane culture indicates the best productivity levels: almost 9 thousand liters per hectare (including biomass ethanol) against 2 thousand liters per hectare from wheat culture and 4 thousand liters per hectare from corn culture.

Between the compelling factors of this sector, the environmental legislations should be worth of note, which forces the use of biofuels in basic means of transportation (in accordance to the demands of the Kyoto Protocol), the use of biofuels in current gasoline and the growing offer of bi-fuelled automobiles (PACHECO, 2011). For instance, the 13.033 Law of September, 2014, establishes that the Executive branch may increase the percentage of anhydrous ethanol that must be added to gasoline, from 25% to 27%, given technical feasibility (MILANEZ et al., 2015).

Brazilian ethanol has the advantage of an established trajectory both because of its long term production, beginning in the 1970s, and because of the National Alcohol Program (*Programa Nacional do Alcool - ProAlcool*). The technological process of ethanol production based on sugarcane must is known as First Generation Ethanol (FGE) (ABARCA, 2005).

Another source for increasing Brazilian ethanol's growth is production by other means. Ethanol's production method, alongside sugar's production method, brings forth residues in the shape of straws and bagasse, which can be reclaimed as electric energy generation and more ethanol as final product. This second method of ethanol production, which is produced from sugarcane biomass and known as Second Generation Ethanol (SGE), is in development since 2010 in Brazil, in a systematic basis, involving the Government, national and foreign private firms and research institutions. It is estimated that, in the long term, SGE production could reach 350 million liters per year and also incur in significant downfall of production cost, decreasing by an approximate cut of 60% (MILANEZ, et al., 2015; ANSANELLI, et al., 2016).

By enabling ethanol's extraction's productivity gains, measured per sugarcane ton that has been processed, at the same time as it allows better use of sugarcane treatment residues and, therefore, lower environmental impacts, SGE may be considered an environmental technological innovation (ANSANELLI, et al., 2016).

However, SGE's production method and impacts demonstrates some specificity in relation to FGE's, since it is a new process, which demands greater knowledge intensity and is accomplished through complex chemical procedures. Therefore, the goal of this research is to investigate and compare both FGE's and SGE's production-cycles through their economic, technological, social, and environmental aspects. Is their relation of substitution or complementation? In order to carry this research, the work has been divided into an introduction section and five subsequent sections. Section 1 will introduce economic opportunities for Brazilian ethanol. After the methodology, defined in section 2, the production cycles and economic, technological, social, and environmental aspects will be demonstrated on section 3 for FGE, and on section 4 for SGE. The integrated cycle will be presented in section 5. A summary of the comparison and research suggestions can be found over the conclusions of this work.

1. Ethanol's market and its improvement's opportunities for Brazil

Economic and political issues have been strengthening ethanol's market and generating opportunities for Brazil. The early 2000's saw a strong advance of world powers, especially led by the United States of America (U.S.A.), in favor of the substitution of the energy matrix basis, nowadays driven by fossil fuels, searching for alternatives focused on renewable energy. The American leadership is due to the mastery of the technology of ethanol's extraction from corn, receiving greater importance after political turmoil that involved both leader countries and Arab Middle East, more notably Iraq and Afghanistan, where conflicts between nations have led to problems in worldwide oil trade (CGEE, 2008).

In Brazil, government and private initiatives both in sugarcane and automobile sectors aimed for the creation of the flex-fuel engine, bi-fueled, implemented with success in national industry and responsible for ethanol's national market spike. Between 2003 and 2007, the national demand for hydrated ethanol increased 273.36%, growing from 3.792 thousand m³ in 2003 to 10.366 thousand m³ in 2007, demonstrating an expressive development in the sector, put together with flex-fuel engine implementation in national market, which surpassed 90% of all engines of the national low-weight automobile production in 2008 (EPE, 2008; IICA, 2008).

Despite having presented an instable performance in recent exports, decreasing 39.91% in volume and 59.72% in US currency between 2012 and 2015, national ethanol's production had significant increase of 27.17%, starting at 22.736.540 m³ on the 2011/2012 crops to 28.916.281 m³ on the 2014/2015 crops, according to Table 1. This was motivated by an external reason, which occurred in 2011, when US Congress revoked taxation over Brazilian ethanol and suspended local producers' subsidies (PETROBRAS, 2011; UDOP, 2016).

Table 1. Brazilian Ethanol's Production (in m3)

	Crop-Year				
Regions	11/12	12/13	13/14	14/15	15/16 *
North/Northwest	2.139.206	1.864.442	1.966.334	2.250.777	1.641.412
Center/South	20.597.334	21.608.912	26.045.950	26.665.504	27.346.352
Brazil	22.736.540	23.473.354	28.012.254	28.916.281	28.987.764

(*) Values updated on 01/03/2016
Source: DCAA/SPAE/MAPA

Besides U.S.A., Japan has also shown a potential market, as the country's strategies involve the addition of 10% extra volume of ethanol in the national territory gasoline's consumption. This fact, coupled with geographic conditions of Japan's archipelago, makes Japan a great candidate for Brazilian ethanol's production outlet and could increase exports of the national commodity. The European arena has also demonstrated beneficial inclination towards Brazilian ethanol, as it uses a mixture of 5.75% of ethanol in its gasoline, which should increase to 10% by 2020. Since beetroot is a product considered to be basis of the diet in many countries of the old continent, ethanol's extraction from this feedstock on a large commercial scale could represent danger for regional food supply and distribution, which is something that could strengthen the motivation for promoting Brazilian sugarcane-based ethanol's trade (ARAÚJO et al., 2013).

The energy scenario poses as another important factor. Over the year of 2007, 46.8% of Brazil's total energy consumption was provided by renewable sources, from which ethanol takes the largest amount, while the world's average was of 14% (BALANÇO ENERGÉTICO NACIONAL, 2010). Another interesting element is that Brazilian sugarcane-based ethanol's production cost is of US$ 0.22/liter, 37.14% lower than American corn-based ethanol's production cost of US$ 0.35/liter (VIEGAS, 2010). In global terms, ethanol represents over 90% of liquid biofuels' supplies currently (FAO, 2009).

A Brazilian advantage on this scenario is the long production and exposition trajectory in foreign scenery. Since the 1970's, there have been advances in the sugarcane sector, with aid from the National Alcohol Program (*ProAlcool*), resulting in the achievement of 100% of milling capacity, but also an increase in the extraction process from 93% to 97%, a general recovery rate increase of 30%, and a leap from 80% to 91% in fermentation effectiveness, regarding the 1975-1994 period. This was thanks to the implementation of incremental innovations, installation and improvement of peripheral machinery, as well as the adoption of new operational proceedings (ABARCA, 2005).

As far as the question regarding the joust between fuel and food supply, it is worth mentioning that national sugarcane production occupies a little over 2% of all agricultural lands. From 63 million hectares of all agricultural lands, 7 million are dedicated to sugarcane culture, where less than half (3.5 million) are aimed at ethanol's fuel production (SCHUTTE, 2010). Moreover, Brazilian ethanol's energy efficiency, with an energy balance of 10.2, is superior then American corn-based ethanol's, which has energy balance of 1.4. This opens the possibility for an increase in productivity without the need for land expansion, in Brazilian ethanol's case, typifying a singular advantage on worldwide sugarcane market (GOLDENBERG, 2009).

On this market, the growth of ethanol's offer, as provided by SGE, represents substantial opportunities for national sugarcane sector in a sustainable fashion. However, the SGE's production cycles, along with its economic, technological, social and environmental aspects, demonstrate discrepancies in regards to FGE.

2. Methodology

An extensive bibliographic research has been conducted focusing on recently published materials (journals in national and international research publications, reports, websites and books). Also, this paper was granted with an interview by the specialist Alexandre Figliolino, partner at MB Agro.

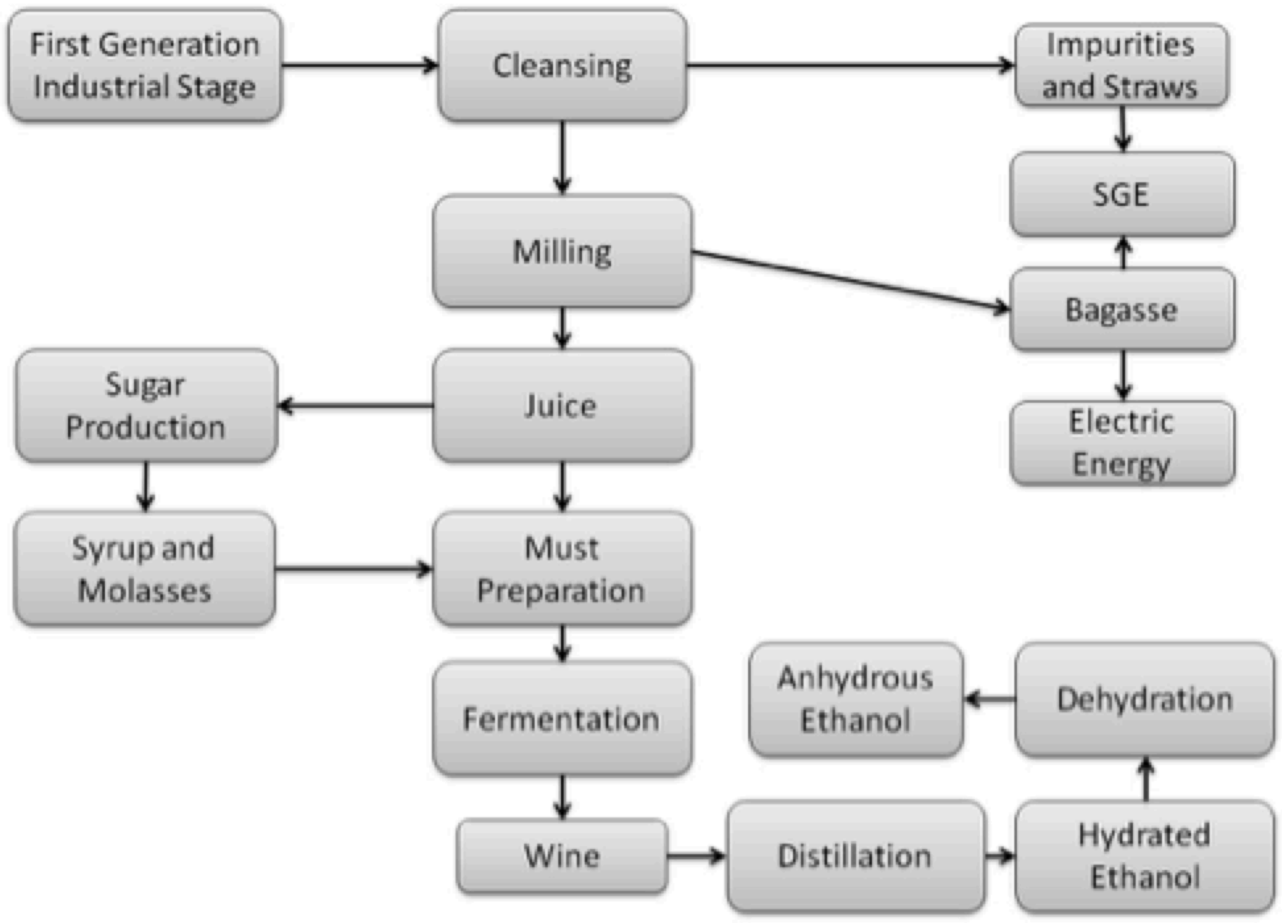
3. First Generation Ethanol's (FGE) production cycle

First generation ethanol's (FGE) production cycle begins in the Agriculture stage, which constitutes planting, cropping, farming and harvesting of sugarcane, thereafter being used as input for the next production stages. There are currently two means of harvesting sugarcane crops, mechanical or manual, and with or without the presence of field-burning practices. In this sense, sugarcane may be classified on its arrival on the sugarcane plant according to the impurity percentage presented on the material, where a "clean sugarcane" (impurity concentration < 0.6%) is considered the most adequate for ethanol production due to its low presence of impurities (ALBARELLI, 2013).

The sugarcane that was harvested during Agriculture stage can be directed towards three main sugarcane production plants: the sugar plants, autonomous alcohol distilleries with exclusive ethanol production, and integrated plants for joint production of both sugar and ethanol (ALBARELLI, 2013). For this work's objectives only those plants with ethanol production will be considered (autonomous distilleries and integrated plants) [3].

FGE's Industrial stage, illustrated by Figure 1, is composed of sugarcane cleansing, extraction, and physical treatment. Due to the kind of cropping and harvesting used in the Agriculture stage (manual or mechanical harvesting, presence of not of field-burns, climate conditions and the sugarcane's variety), sugarcane's average composition is of water (70%-76% of sugarcane mass), present solids – not counting fibers (10%-16%) – and fibers (11%-16%).

Figure 1. FGE's Industrial stage



Source: ALBARELLI (2013)

After sugarcane cleansing, which can be either dry or with water usage, it is grinded and directed for the Milling stage, where sugarcane juice is extracted and is used in sugar and ethanol production, while providing the bagasse. Sugar and ethanol production demonstrate distinctive processes for sugarcane juice's treatment. The juice, after clarification, is allocated for sugar production, becoming concentrated through steaming process, resulting in high-glucose concentration syrup. A fraction of the syrup is mixed with the clarified juice and with the molasses, which then is known as must, and which can go through the steaming concentration process, in order to achieve the desired fermentation level. The wine derived from the fermentation is then directed towards final distillation stage, where hydrated ethanol may be obtained. For the production of anhydrous ethanol, the hydrated ethanol must go through a dehydration process (HAMERSKI, 2009; USINA ESTER, 2016).

3.1 FGE's economic, technological, social and environmental aspects

In economic terms, Brazilian ethanol production has grown outstandingly, showing a boost of 35% between 2011 and 2016, due to demand (flex-fueled automobiles represent 67% of national circulation fleet), the change of percentage of anhydrous ethanol in gasoline from 25% to 27%, and the increase on gasoline's final price, caused by raise on PIS/COFINS taxes for gasoline. Nonetheless, sugarcane plants are finding themselves to be hostages of sugar prices, a direct competitor to ethanol. It is worth of note that both sugarcane productivity and quality are subject to different variables, such as: unfavorable climate events (off-season droughts) and the harmonization between mechanization process of seeding and harvesting, which require special care due to its characteristic as seasonal culture (DATAGRO, 2015; EPE, 2016; FIGLIOLINO, 2016).

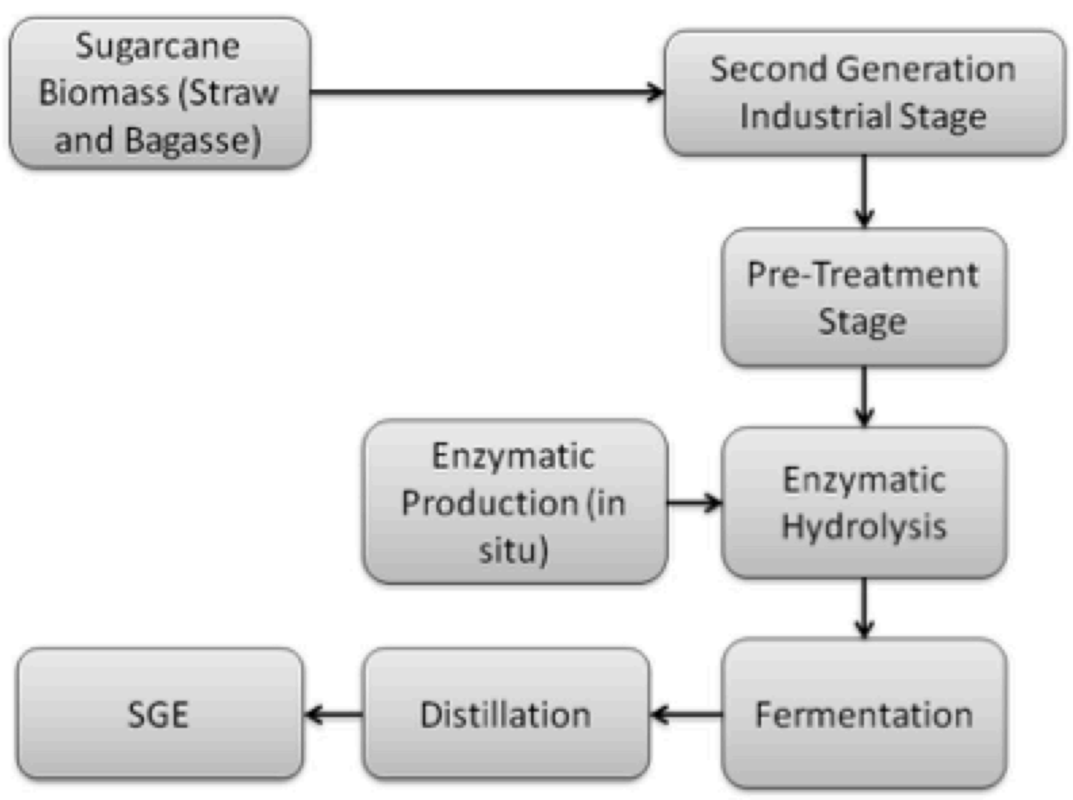
In regards to environmental characteristics, FGE has many advantages in comparison with fossil fuels and substitutes, because it presents: small planted area (less than 1% of all national agricultural lands); low land loss (62% compared to observations regarding soybean culture); downfall of water uptake by plants (from 5 m^3/sugarcane processed ton in early 1990 to 1.8 m^3/sugarcane processed ton in 2005); increase on average water reuse (from 62.7% in the 1990's to 87.8% in 2005); reduction of Greenhouse Gas Emissions (GGE) (2,7 million tons of GGEs were avoided in 2015 alone) (UNICA, 2011; LEITE, 2008; CCGE, 2008).

On the social aspects, in spite of being labor intensive especially during Agriculture stage, the sector has shown negative and positive elements. There has been an increase in formal labor on the height of harvest stage (from 1.3% of national total in 2014 to 2% in 2016), although the level of informality is still significant, representing 7% of total. Moreover, the majority of workers (57.2% from an estimated total of 385 thousand workers) are allocated on sugarcane production, against 34.2% placed on sugarcane industry and 8.6% on ethanol industry, all in 2005. A downfall on the number of workers has also occurred, owed to mechanization, albeit created tractors', mechanics', harvester drivers' and electronic technicians' job opportunities. The average worker income (head of the family) is 46% more than that of workers from other agriculture sectors, despite being lower than national average. There has also been an increase in the level of education: 5 years of education in the sector against 4 of other agriculture sectors (MTE, 2016; EPE, 2016; MORAES, 2007).

4. Second Generation Ethanol's (SGE) production cycle

Second generation ethanol (SGE) is produced from lignocellulosic material (LCM), which is a residue from first generation's production cycle. In average, each sugarcane processed ton generates 280kg of bagasse with 50% humidity, fibers being the main substratum for SGE's production. Therefore, SGE's production cycle initiates on residue stage of FGE's production cycle, as demonstrated on Figure 2. After the biomass has arrived on the plant, pre-treatment stage begins, which can be achieved either through diluted acid, steam explosion or alkaline hydrogen. The solid product of pre-treatment stage (known as pre-treatment bagasse) goes through enzymatic or acidic hydrolysis, then through fermentation and distillation, resulting in liquid ethanol (COSTA, 2014; STUCCHI, 2016).

Figure 2. SGE's Industrial stage.



Source: COSTA (2014).

4.1. SGE's economic, technological, social and environmental aspects

Sugarcane SGE presents the same characteristics as FGE in terms of final product, and enjoys, therefore, the same advantages of a rising market and demand. However, SGE's production costs are distinctive: sugarcane SGE's production cost is almost as low as FGE's production cost (R$ 0.26 per liter for SGE against FGE's R$ 0.22 per liter), but sugarcane SGE's capital cost was lower than other biomass types (US$ 100 million against more than US$ 200 million from wheat and corn residue SGE) (STUCCHI, 2016).

Over the technological side, SGE reveals to be very specific in comparison to FGE. After pre-treatment stage, there are many different technological possibilities, identified through enzymatic or acidic hydrolysis. The former represents established technology, carrying fewer financial risks, while the latter reflects more complex technology, which involves higher uncertainty for investments, despite showing significant possibility of profitability and cost reduction aspects. Therefore, there is generation and development of innovations on SGE in coevolution with potential economic gains (ALBARELLI, 2013; COSTA, 2014).

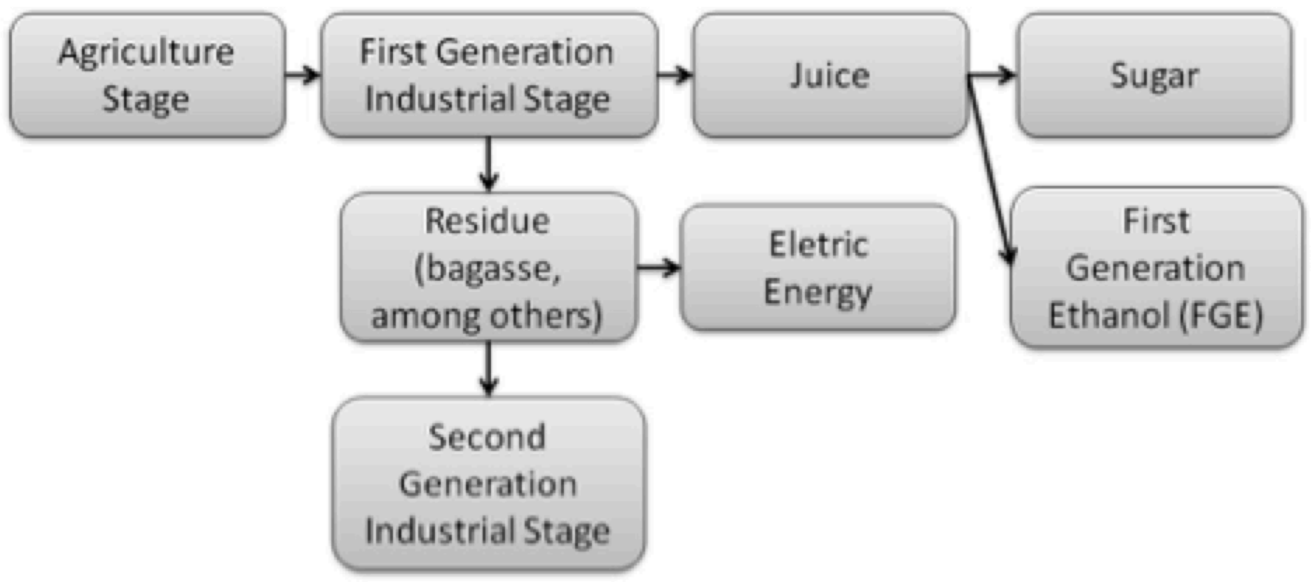
In regards to environmental aspects, SGE has demonstrated significantly lower environmental impacts than fossil fuels or other substitutes. Sugarcane's SGE can reduce environmental harm from 85% to 90% in contrast to FGE. In pre-treatment stage, the liquor may be used in biogas production, which, in association with other processes, would allow energetic recovery from 63% to 65%. In addition, bagasse can be produced for use in both ethanol production (51%) as well as energy generation (44%), in a way such as that plants may become self-sufficient, energetically speaking (MILANEZ et al, 2015; MOREIRA et al, 2014; ALBARELLI, 2013).

From the social point of view, there is a need for greater quantity of specialized labor inside SGE rather than FGE, given that new technologies are involved. The cellulosic residue conversion into ethanol, for instance, is greatly influenced by temperature, signaling the need for highly specialized labor in order to assure quality control over the duration of process steering. With regards to income, it has been observed a positive relation in the level of education, and could exhibit fluctuations of 400% between workstations (MOREIRA et al, 2014; BNDES, 2014).

5. FGE-SGE's integration

The introduction of technological paradigm for FGE and SGE, as represented in Figure 3, would bring economic, environmental and social advantages when compared to FGE's or SGE's exclusive production. Productivity could increase from 31% to 75% in relation to current level, as well as bringing down SGE's production costs by 90% of total costs. Also, costs related to transportation of lignocellulosic material could be decreased, allowing for simultaneous use of common machinery (ALBARELLI, 2013; DIAS, 2011).

Figure 3. FGE-SGE's integrated production cycle.



Source: ALBARELLI (2013).

Some projections shows financial benefits: a decrease of annualized investments costs and working capital by 10%; an increase in revenues by 41.49%, but also on economic potential, by 148.43%, and net present value (NPV), by 1402.43%.

It could be possible to have SGE's production of 350 million liters per year, in the long-term, with annual investment of approximately R$ 300 million, which would offer a possibility for production cost reduction. In this scenario, SGE could become more competitive, when integrated with FGE, before gasoline and other fossil fuels, especially in the long-term (CGEE, 2009; MILANEZ et al, 2015; ANDRADE, 2012; COSTA, 2014; ALBARELLI, 2013).

On the environmental point of view, SGE integration to FGE's current developed production process in plants has granted improvements such as a decrease in water consumption of 13.59%, a downfall of water uptake for the whole integrated cycle of 53.24%, and an increase of water reuse by 8.85%. Moreover, water usage exclusively for SGE's production process has reduced by 77.52% on integrated plants. Also, the use of bagasse as raw material for second generation process has allowed for increase in ethanol production by 19%, and in available energy in between 40% and 70% (ALBARELLI, 2013).

In regards to social aspects, SGE's integration has the potential to contribute for reduction of child labor on the crops, an increase in formalization and on education level (despite having low levels, it has presented some development) (MORAES et al, 2015).

Nonetheless, SGE still requires high levels of Research and Development (R&D) investments in order to have commercial scale feasibility, due to its incipient technology, especially concerning some pre-treatment methods.

These aspects demonstrate that SGE, when integrated to pre-existent FGE's production process, can be a feasible alternative for countries that wish to increase ethanol production without increasing farming lands, therefore being complementary to feedstock and presenting low environmental impact.

6. Comparisons and Conclusion

The main objective of this research was to compare both FGE's and SGE's production cycles, in its economic, technological, environmental and social aspects, within Brazil, by means of bibliographic review and interview with a specialist. It has been observed a growing ethanol market, both first and second generation, since the final product is the same and it does not establish a relationship of competition. As for the production process, FGE has presented a mature technology, and both economic and environmental advantages when compared with fossil fuels. On the Agriculture stage, it has been using mechanization and, despite the educational level, there is significant participation of underqualified and informal labor.

SGE still reveals higher costs then FGE, however, technological developments in mid and long terms may allow for potential revenue and productivity gains, though it would require increased levels of R&D investment. Environmental benefits, on the other hand, are far superior compared to fossil fuels and other renewable substitutes. A fact that deserves note is the higher qualification of labor education in relation to FGE's production. On the other hand, the integrated cycle could allow for overcoming the challenges of choosing between one production and another, bearing the four researched aspects in mind, which would result in better opportunities for sugar and alcohol plants. Chart 1, which follows, describes and summarizes these evidences.

Chart 1. Comparison summary between FGE's and SGE's production cycles

Aspects / Generation	**FGE (sugarcane)**	**SGE (sugarcane residue)**	**FGE-SGE integrated cycle**
Economics	In relation to gas, it presents more competitive prices Costs are focused on Agriculture Stage (70%) Anhydrous Ethanol percentage in gasoline: 25% -> 27%	Lower production costs compared to FGE Lower average minimum selling price (compared to other sources) Higher average productivity (compared to other sources)	Easy integration of production cycles Costs decrease (up to 90%) Better financial indexes (revenue increase, economic potential and

	Alterations on CIDE (tax) for gasoline Flex-fuel automobiles: majority of national fleet	Lower average capital costs(compared to other sources)	NPV) Productivity gains
Technology	Mechanized culture Low educational level of labor Presence of capital intensive technology High productivity per farmed land	High technology industry High educational level of labor Brazilian innovation (sugarcane bagasse's SGE) Differential between firms: pre-treatment stage	Improvement of assembled processes (Agriculture Stage) Higher availability for cogeneration (sugar and electric energy)
Environment	Lower land usage Lower CO2 emissions (90%) compared to gasoline	Environmental Innovation Decrease of FGE's environmental impacts	Reduction of water consumption and uptake Higher water reuse and availability of electric energy
Social	Average income and level of education higher then labor from other agriculture sectors	Improvements in labor qualification Higher income and education levels	Potential for social inclusion through labor specialization and average income level compared to labor from other agriculture sectors

Source: Own elaboration

Therefore, the main conclusion from this study shows that both cycles are complementary, and not substitutes. There are some identified gaps which could lead to future researches, such as investigating the average workstation that is created, the policies aimed towards the sector and innovative activities involved on FGE's production cycle, on SGE's production cycle, and on the integrated cycle.

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3. There are currently 372 production units registered and in activity, with integrated production of 41.453.194 m^3 of hydrated ethanol per year and 22.123.551 m^3 of anhydrous ethanol per year (EPE, 2016).

4. Conforme dados da empresa Raízen.

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