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Building the Sustainable Energy Supply Chains: A comparison of ethanol production and distribution in Brazil and USA

Abstract

This study aims to identify and assess two different energy supply chains and associate technologies in two countries, Brazil and California in USA. The first one a fossil fuel energy source, and the second one using a biomass ethanol energy source. The study provides insights for relevant actors in the society involved in managing the 'energy and global change'. Findings discussed about energy efficiency, pollution, costs, laws and regulations. In addition, this study demonstrates the importance of the government's action on energy management. With proper management it is possible to achieve energy efficiency and sustainability diminishing the pollution levels.

Keywords: Sustainable Energy Supply Chains, Sustainability, energy efficiency**,** ethanol, Brazil, USA

1. Introduction

Ethanol supply chain is the path of biomass process from the source to its use. This process requires logistics from production, pre-processing, conversion and distribution to consumption. This paper will only approach the three first steps from the supply chain.

As to any industry, ethanol supply chain has some important issues to be discussed in order to increase awareness to sustainability leading to overcoming the challenges of energy efficiency in cropping, production, feedstock and transportation; resulting in a reliable cost efficient method.

This study explores two different energy methods of ethanol production with the purpose of investigate and compare the biomass supply chain used in most ethanol plants in Brazil with the system used in most ethanol plants in California. Different issues related to the plants methods of energy management are shown so as to discuss their environmental impact and their consequences.

In addition, this study is mainly focused in the energy efficiency of the two different energy sources of the ethanol plants exploring their supply chain in order to find solutions to improve their energy system, increase their energy security, decrease their greenhouse emissions and develop the energy management efficiency sector.

The specific research questions are:

- How to achieve sustainable supply chain with biomass-to-ethanol system and a fossil fuel based energy source?
- What would be the impact and the benefits of biomass-to-ethanol sustainable supply chain?
- To what extent energy supply chains are affected by ethanol production, and efficiency?

2. Literature Review

2.1. Production

2.1.1. Brazilian production: sustainability and employees conditions contributing to changes on the old process of ethanol production

The research made on the ethanol production in Brazil points out the environmental and social challenges. Brazil is a tropical country with a considered perfect weather conditions in most of its territory favoring the sugarcane crops and has enormous natural resources available in its land. The Brazilian government realizes all the territorial advantages and it has been investing on the ethanol production market since the 70’s, as demonstrated on the graphic below:

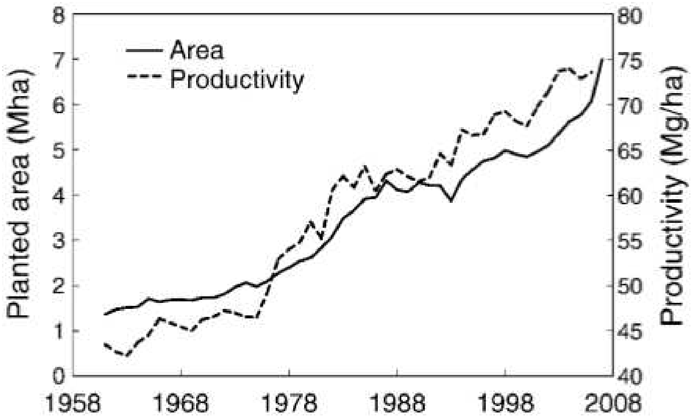

Figure 1 - Increase of sugarcane production in Brazil

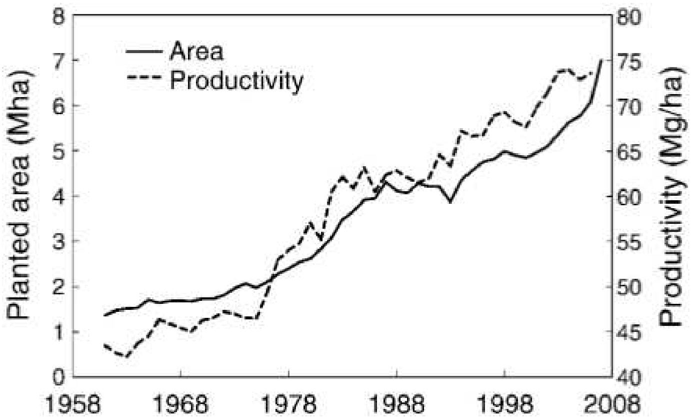

Figure 1 shows that the increase of sugarcane (source of ethanol) production is enormous going from 1.3 Mha (in 1958) to 7 Mha (in 2007/2008). However, the ethanol market expansion brings some issues related to soil degradation, deterioration, water quality, ecosystem dysfunction, and contamination from pesticides. One of the main environmental problem is the harvest burning which is a common practice in Brazil. This burning procedure facilitates the harvesting manual process by helping to separate the sugarcane from its leaves and straw. During the period of production (from April up to December), ethanol plants burn their crops during the night, increasing the pollution of the region were the ethanol plant production is based. An estimated 2.5 million hectares, or 70% of the sugarcane area, was burned in 2006 in the state of Sao Paulo (Martinelli and FIloso, 2008, p. 891). (Martinelli and FIloso, (2008) reveals that the consequences of this method are: soil damage with temperature increase, soil compact, contamination and erosion; water issues such as the decrease of water levels in rivers or lakes, water contamination; and air pollution. Biomass burning is responsible for air pollution related to aerosol particles and some ethanol plants do not respect the country's law concerning the pollution emitted. The annual average for suspended aerosol particles established by Brazilian law is 70 lg/m3, but concentrations found in the Piracicaba region were higher during the burning season 70–90 lg/m^3 (Martinelli and FIloso, 2008, p. 892). The issues demonstrated in (Martinelli and FIloso, 2008) go beyond the negative impact on the environment; it relates to how the burning affected the population health and how some ethanol plants did not improve much their working system since the 19th century. Sugarcane burning process releases to the atmosphere high concentrations of carbon monoxide (CO) and carbon dioxide (CO^2), affecting the population health and also reduces the photosynthetic activity of plants, affecting the productivity of various other crops. However, the smoke released on large amounts of gases contributes to the destruction of the ozone layer in the stratosphere. in some sugarcane fields, during the harvest, the work is still done manually, with poor working conditions and very long hours (around 12 hours/day of work). They related this action to the energy spent, if the plant would use machines instead of manual work the energy costs would be higher, however the work could be more efficient. Thus, ethanol plants in Brazil need improvement on its production practice (soil, water and pollutions matters) and proper planning on risk management for expansion.

2.1.2. Sustainable development of biomass energy methods will be possible only by taking into account safety and security of the supply and the social impacts

Another relevant research published by the electronic journal of environmental, agricultural and food chemistry named current 'trends in biofuel production and its use as an alternative energy security'. This study is done around the biofuel production and the biofuel industry and its alternative energy methods. The paper reveals the production and consumption of biofuel in different countries around the globe as this industry is growing especially in developing countries. It explains the biofuel industry on its impact, benefits and trends.

The authors explain that impacts are mostly linked to the environment such as waste and pollution, and these impacts can result on the energy market volatility. They studied certain possibilities to decrease pollution using production waste. Some of their findings are that "solid waste production is of global concern and development of its bioenergy potential can combine issues such as pollution control and bio-product development" (Okonko et al., 2009, p. 1237).

On one hand, the authors point out that biotechnology can lead to socioeconomic and sustainable development such as the creation of jobs for the population, the cut on oil imports (fuel security), international partnership and agreements, etc. Moreover considering the cost-effectiveness of the use of biomass on the biofuel production, the authors explain as a worthwhile venture, using the waste material used on the ethanol production. But on the other hand, take into consideration the trends; the biggest ones are the costs. Especially in developing countries, the costs of production and promotion of biofuels can be very high, even though many developing countries are rich in resources to make the final product and to produce the energy required such as through biomass. The authors also describe that depending on the choice of source and how it is produced; the manufacture of biofuel can increase the demand for fossil fuels. "Corn is a very energy intensive crop, which requires one unit of fossil-fuel energy to create just 0.9 to 1.3 energy units of ethanol" (Okonko et al., 2009, p. 1245).

The study explains that the production costs decreased in the USA when the government introduced the 'Energy Independence and Security Act of 2007' in order to be independent on oil. Such a distinction draws the authors attention on encouraging the ethanol producers to produce more causing a booming on the American ethanol industry and resulting on a significant agricultural resource shift away from food production to biofuels. The related stream of this research has suggested that the government did not take into account entirely at that time the pollution increase due to the energy required to produce the ethanol, which in the USA is made mostly by fossil fuels (especially natural gas). The level of legitimacy of these factors are quite important to demonstrate the role of the government on the energy management taking into account the social effects. The authors also provided the seminal definition of cost-efficiency management needs, which needs to be linked to energy effectiveness in order to be safe and secure the supply beneficiating the plant and the region where the plant is installed.

2.2.Pre-Processing – Feedstock

2.2.1. Water management an essential approach to the ethanol industry

The study on the water consumption necessary to the ethanol production from the feedstock (after pre-processing process) to the fuel processing is very fruitful when talking about water management in the ethanol process of production. On The study of Wu, Mintz and Wang on ethanol production and water consumption, the authors described how water is important in the ethanol industry. They recognize how water management is essential in the ethanol production, in the cellulosic ethanol, and in the crude oil to produce gasoline on a conventional (USA and Saudi Arabia) and nonconventional crude (oil sand such as from Canada).

The research distinguished that with the increase of the ethanol production, water management became a current subject in recent years and this is an issue that was not considered decades ago. “Corn yield has risen by over 50%, but corn acreage has remained relatively flat over the past three decades” (Wu, Mintz and Wang, 2009, p. 987). The authors explain that the water resource in an ethanol plant can come from surface water, groundwater and sometimes from municipal water supplies. They related that in the USA, water is very much used on the agricultural sector, on the crops of food and feed is consumed about 85% of the fresh water; and only 3% is designated to the thermoelectric energy generation.

The authors suggest that during the ethanol production, the water tends to be used on the irrigation of the crops and the consumption varies among different regions. However, when the ethanol plant does not produce its feedstock, the water is basically used as on the final product process for grinding, liquefaction, fermentation, separation, and drying. They highlight how water management is necessary to optimize the consumption, reduce costs and certainly, avoid pollution. According to the study, ethanol plants can optimize their water consumption avoiding water losses, which the authors argue that happens mainly throughout the evaporation from the cooling and heating processes and from leaks on the boilers (all this systems are related to energy) as well. Below is the scheme of the study definition of the water used on feedstock and ethanol production.

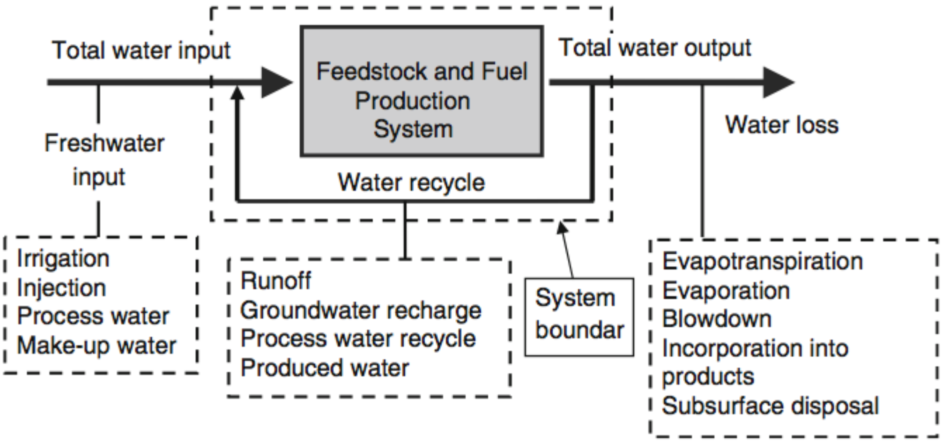

Figure 2 - System boundary, water inputs, outputs, and losses of a conceptual feedstock and fuel production szstem - source: Environmental Management Journal

Figure 2 suggests that, the total water input consist of fresh and recycled water necessary on the feedstock and ethanol production such as irrigation, injection and etc., and the water recuperated from the cooling and heating process. The total water output explained by the authors is the water consumption and the recycled water that is reused in the system during the evapotranspiration, evaporation and etc. This scheme clearly implies how water is important on the ethanol production.

The study also points out that the use of water can be minimized if the plant recycles its uses. The authors propose that the water lost from the boiler could be capture to be used on the cooler process (after the water is cool off), this may avoid the use of fresh water, especially if the plant is close by a community, as this water may be necessary to be used as vital need (for human supplies).

According to the study, the authors enlighten that with proper equipment and energy efficiency, water consumption may be diminished. "An analysis of the latest survey conducted by the RFA revealed that fresh water consumption is existing ethanol plants has decline to 3.0 L/L of ethanol produced, in a production-weighted average" (Wu, Mintz and Wang, 2009, p. 987). This result means that according to the research, with energy efficiency, the water consumption in ethanol plants could drop almost 50% of its current use probably increasing the benefits of the ethanol plant, the crop (the soil, rural areas…) and the society.

2.2.2. The optimization of waste as energy supply

The study of Demirbas et al. demonstrates how to use waste to produce energy through Waste-to-energy (WTE) technology. The paper presents solutions to the problematic of waste management and energy cost-efficiency. The authors explain how energy can be originated from waste stating that the possibilities are the waste that was "treated and pressed into solid fuel, waste that has been converted into biogas or syngas, or heat and steam from waste that has been incinerated" (Demirbas, 2011, p. 1815). The approaches used to transform the waste into energy are mostly thermal, physical and biological systems as demonstrated in Figure 3.

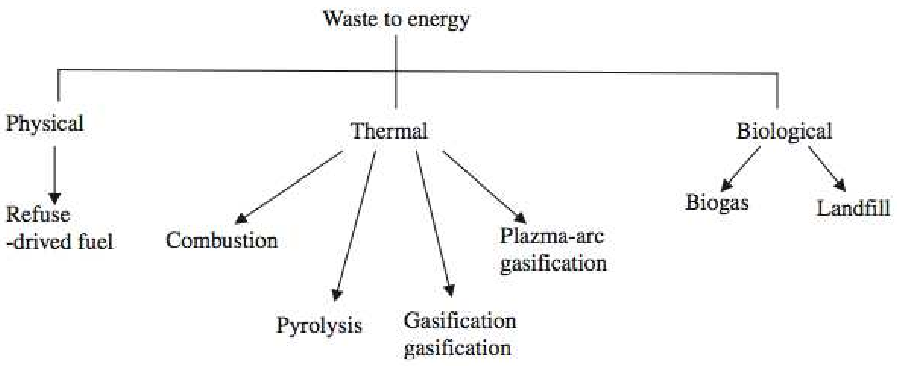

Figure 3 - Main waste to energy (WTE) technologies

The authors emphasize that this technology can be used to transform any agriculture residue into energy. They explain that these methods are mostly used due to the fact that normally the waste are solid, and solid material are not suitable nor attractive (for commercialization) as energy source. They give solutions and methods to transform the waste into a desire product in order to fit in the biomass system. The solid waste is defined as agricultural residues such as rice straws, nutshells, fruit shells, and etc., which are produced globally. The authors also refer to bio-waste, which includes wood, short-rotation herbaceous crops, animal wastes, and etc. They claim that the availability of these resources is a valuable tool when talking about biomass. They also explain that the waste-to-biomass may be very efficient and environmentally friendly. Their conclusion is that with proper energy management, companies and government should be able to take care of two problems at the same time: what to do with the waste produced, and diminish energy cost. Both actions well managed would result in sustainability, by consequence less pollution.

2.2.3. Delivery and transportation

In the paper of Bioenergy project development and Biomass supply, from the International Energy Agency (IEA) and OECD, the author talks about different types of transportation and the different steps in which the transportation is needed in biomass supply chain. He raises the issues of the transport from the crops to the plants and from the plants to consumers.

From the harvest and handling, the paper discuss about the different issues to be put into account such as access (roads), layout and different raw material used. Depending of the type of biomass (corn, sugar, wood…) different planning is required. “The collection and transport of biomass can result in increased use of vehicles, higher local air emissions from their exhausts, and greater wear and tear on the road infrastructure”. (Sims, 2007, p.33)

Sims points out the costs of transportation maintenance required for such transport. He mentions the damages caused by heavy trucks on the roads, as sometimes the crops are not closed to the plants. The paper is uncertain about who should pay for such high costs, as local authorities are not entirely responsible for ethanol plants business. The paper explain that the sugar cane energy plants (from Brazil) overcome successfully the transportation issues are the plants are build around the crops and therefore they use their trucks as main transportation form from the field to the actual plant building. According to the paper, the same logistic is not applied in other plants in other countries.

In addition, it explains that a lot need to be improved in order to reach a good planning and logistics not only in the transportation process, but also in the plant in a whole. He claims that better understanding of the technical, environmental and social issues are needed from managers, investors and developers in order to reach the purposes of a sustainable biomass supply chain. “This should help meet the industry objective to install good quality, well designed bioenergy plants in order to gain a good return on investment from meeting growing energy demands using sustainably produced biomass fuels”. (Sims, 2007, p. 60)

2.3.Conversion:

2.3.1. New technologies in the whole value chain, economical impacts and optimum production scenarios and the farming industry development

The research done by Moreira on sugarcane for energy (the recent results and progress in Brazil, published by the Energy for Sustainable Development journal, demonstrate the evolution of this biofuel that has been used in Brazil since the 70's. The research demonstrates first the country used the ethanol just as a gasoline added fuel (about 24% of ethanol was added to the gasoline in the pumps), then 100% of ethanol fuel by the end of the 90's. The paper observers that ethanol boom came on the 2000's when the technology allowed the government to demand the flex motorcars that could be fueled with gasoline or ethanol.

The research shows that the government had great interested to promote the biofuel production such as energy independency, as the nation achieve a low dependency on oil; the sustainable development of a renewable fuel, meeting the challenge of growing energy demand. Also, Moreira distinguishes the increase of jobs in the fields (rural areas) of great interest, which was a must (concern the social uncertainties), as there were a lot of unskilled and unqualified workforce labors needing jobs. Furthermore, the author has argued that by being the leader of the ethanol market internationally, Brazil today is the first country to have cars functioning on ethanol. The study also demonstrates that even though the interests on diminishing costs were very strong, the Brazilian government managed to improve the technology combining both interest: price and sustainability.

According to this article, the ethanol supply chain is on the right path, by using the sugarcane residues from the ethanol conversion, ethanol plants are not only producing their own energy through biomass-to-ethanol, but also developing the country on its energy security supply.

Within all the analysis made in this research, the author highlights an interesting one concerning energy management efficiency. The analysis demonstrates that to be more efficient an ethanol plant need to reduce the amount of steam used to produce the ethanol. "By reducing the amount of steam required in the process from 500Kg to 340kg or 280Kg per tone of sugarcane processes, additional electricity can be cogenerated at the mill" (Moreira, 2000, p. 49). Figure 4 demonstrates the author's results.

	Business as usual	First stage of economy	Second stage of economy
Steam consumption	500 kg/tC	340 kg/tC (for 50% anhydrous/ 50% hydrous facility)	280 kg/tC
Total investment (US$)	-	4.5 million	7.0 million
Amount of steam saved (kg/year)	-	115 million	158 million
Amount of steam saved per unit of additional investment (kg/US$/year)	-	25.5	22.6

Source: Leal, 1999

Figure 4 - The results of reduction in sugarcane pre-processing steam consumption

The author claims that with this method, the energy used steam consumption during sugarcane conversion would be optimized and consequently the costs of energy diminished. The energy improvement takes into account the safety and security of the energy supply.

Finally, the author concludes that the success of the ethanol production and market in Brazil is due to their sustainable method of energy. The authors recognize that this method has been helping to supply and develop the country in a whole in terms of technology and environmentally friendly solutions. Economically, as the energy industry grows, the country so far managed to reach its energy independency and on countryside creating jobs and relocating the population from the urban area to the rural area.

2.3.2. Energy efficiency may lead to greenhouse emission decrease with better allocation of resources, policies and taxation

In the study of Linares and Labanderia on energy efficiency economics and policy, the authors highlight that energy efficiency may be crucial and in need to be reached by governments and companies due to its benefits financially (by optimizing and managing the energy resources needed to produce the energy necessary) and environmentally terms (by reducing the CO2 emissions). The authors stated that energy efficiency could be reached “with the corresponding implications on resource depletion, energy security and monetary savings; and the reduction in carbon emissions (…) and in general terms, the environmental impact related to energy use” (Linares and Labanderia, 2010, p. 576). The authors explain that the energy efficiency paradox in energy consumption analyzing matters such as low prices of energy, investments costs, uncertainty and irreversibility of investments, the rebound effect and etc.

This study shows how the GHG can be diminished throughout energy efficiency and conservation (ECE), which can be achieved laying on policy and economic (with adequate investments) instruments. The authors declare that with a better allocation of resources (using the resources on a optimal way) and a good administration of the ECE policies (by the government) such as methods related to carbon taxations and the promotion of greenhouse gas emission reduction; it is possible to achieve energy efficiency saving money and ‘helping’ the environment by diminishing the GHG emissions. The study paper shows a graphic from 1990 to 2007 and the increase of the GHG emissions in the USA, demonstrated on the graphic below:

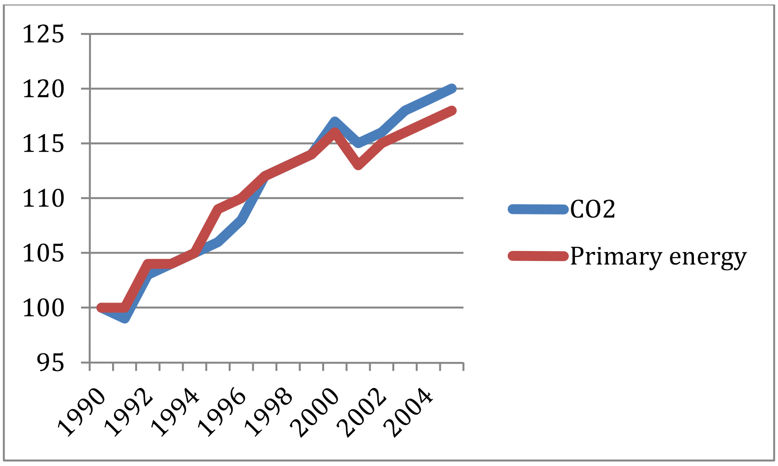

Figure 5 - Primary Energy Demand and Carbon Dioxide Emissions in the USA, 1990-2005 (Base 1990), Source: Climate Analysis Indicators (World Resources Institute, Washington, DC)

The graphic that is included here just for descriptive purposes shows that with the energy demand increase, the GHG emission also boosted drastically from 1990 to 2005. The authors describe this situation however, as one of the paradoxes highlighted in this study. They believe that there is clearly a link from the growth of energy consumption and the GHG emissions (despite the energy efficiency improvements). The other paradox is the ECE measures that unfortunately, have not been commonly applied by companies despite their apparently great benefits.

The authors stated that with the technology, it is believed that companies can make the necessary changes to be more efficiency. With a standardization of a system nations can motivate industries to optimize the energy consumption and therefore have environmental and economical benefits. Furthermore, they mention that governments have the power to impose an affected change with taxation. "When standards are absolute, i.e. when there is an obligation to save in energy consumption (usually ensured by a penalty), they are very effective in terms of energy conservation" (Linares and Labanderia, 2010, p. 584).

The technological standards mentioned on this paper, relate also to taxation (from governments to achieve the expected result on GHG emissions) and combination of policies according to the country were the energy efficiency want to be reached. Consumers are used to decisions based on the economic rationality and the government has the power to influence their decisions with taxation.

Furthermore, the authors take into account different socio-economic and environment objectives, clearly relevant to the differences of a developed and a emerging country, their necessities and their environment priorities. They conclude by saying that governments should consider environmental taxes or quotas and by consequence, the GHG emission would diminish.

2.3.3. The government's role in sustainability and innovation

Here, the author describes how the energy sustainability development can be reach with a good management strategy and that the interests and benefits of the population are seeing on the long term. To achieve energy sustainability the author proposes energy analysis methods that should be made in developed and developing countries (the paper refers to North and South countries). Also, Reddy suggests that good governance is essential for development of a sustainable supply chain. The government has a main participation in any industry, especially in energy, which is essential to any nation. The article proposes that the energy industry needs to be supported by its government and its population.

The authors of the Sao Paulo Discussion (SPD) explain why energy independency is so important. It allows people to have freedom, the country can provide for its population. "Sustainability is the key for development" (Reddy, 2003, p. 13). The SDP raise the subject that energy management is a strategy to achieve national development with social benefits and outcomes. The SDP on Self-reliant energy analysis and planning cited the example of Brazil's ethanol industry innovation (which gave to the country its fuel independency, boomed the ethanol industry internationally and brought lots of social benefits to its population). The authors of the response to the SDP argue that the Brazilian ethanol method could be followed by mostly developing country as countries with similar needs and resources can use similar strategies. In African countries for instance, they that if the resources are mobilized and the government create and motivate proper actions, countries may reach self-reliance in energy and might discontinue to be explored by industrialized countries. They also claim that not only developing countries can benefits from the Brazilian's example method, but also industrialized countries may feel inspired by the "Alcohol program" introduced in the Brazilian government during the 70's to improve the ethanol energy industry.. The SDP explained that this is possible with a better understanding and management of new technologies. And they agree that energy is a main necessity and its improvement allows a nation to develop culturally (with internationalization) and socially by creating jobs, decreasing energy costs and diminishing the pollution.

2.3.4. Innovation as the key to reach a sustainable supply chain

The study done about improving supply chain practices talks more precisely on how innovates through technology-base solutions. On the transportation subject, they mention how the demand has increased lately and how much the technology can help on finding sustainable solutions to improve productivity and efficiency. The authors claim that logistics and expertise need to walk side to side in other to reach a sustainable system. "Bringing together logistics innovation experts into a community is among the main prerequisites of building an innovation fostering environment." (Thorsten et al., 2014, p. 19)

They explain that bringing experts to identify, analyze and find solutions to relevant issues is crucial to overcome the barriers to improve a supply chain practice. The paper also mentions some issues that can be related to energy supply chain such as: costs, financial issues□deployment considerations, system governance and ownership, level of fuel emissions, □immature technology□infrastructure, □labor considerations, workforce expertise, □lack of awareness, □lack of cooperation between stakeholders, etc.

In addition, they explain that some logistics website are available to help companies to build their strategies towards a proper innovative system. Also, their approach suggests that once the barriers are identified and actions are put in place to reach positive results, the next step is to approach other subjects including managers and shareholders education, coaching, and innovation in services intermediary, monitoring and ecosystem.

The authors conclude saying that their approach is only one of many available through technology nowadays, and companies should consider overcome barriers to reach innovation and surpass competition in the market.

3. Methodology

The methodology used is a comparison study on two different ethanol plants, one in Brazil (Usina California) and one in California (Pacific ethanol).

This method is based in literature review, interviews and observation of facts. The comparisons were made with searches for evidence on causes and effects of the information obtained. With this method, the author demonstrates credibility showing the true factors of the subjects raised. With information gathered from literature review and during the interviews, the author identified the main issues related to their ethanol supply chain .

3.1.Case 1 - Pacific Ethanol

Pacific ethanol was chosen because the company is the leader on ethanol production in the western USA. “Pacific Ethanol owns a 34% interest in and operates four ethanol plants in the Western United States” (Pacific Ethanol website, 2012). The ethanol company also produces animal feed which is the final destination of the remains of the corn used to produce the ethanol.

The location was chosen because California has a nice weather for the crops and the motivation to invest on sustainability, the state requires that all electric utilities “purchase or generate from renewable resources 20% of the electricity delivered to customers by 2010. That percentage increases to 33% by 2020” (California Ethanol Power, LLC, 2011, online).

Pacific Ethanol does not produce its source material (corn). Although Pacific ethanol is considered a big company with four facilities and a capacity of 200 million gallons of ethanol per year, the Stockton facility is small with about 30 employees and it is the newest one, created in 2009. However, besides its ‘small size’ the ethanol plant produces 60 million gallons of ethanol (about 227 million of litters) per year.

3.2.Case 2 – Usina California

The second case is an ethanol plant from Brazil that uses sugarcane as raw material and the sugarcane waste (Bagasse) as its energy source. Usina California, formally called Destilaria de Álcool Califórnia Ltda. is situated in Parapuã in the State of São Paulo, Brazil. The state of Sao Paulo is the biggest producer of ethanol in Brazil and therefore the biggest generator of biomass. Operational since 1980, the ethanol plant has a lot of experience in the ethanol production industry. Usina California is considered to be a large size ethanol plant with more than 1000 employees. With a consider large experience in the field, the plant has been active since 1980 and id had its first ethanol production in 1983 when the plant used 259 thousand ton of sugarcane to produce 19.623 thousand litters of ethanol. Today with new technology, the plant produces about 192 million litters of ethanol per year.

Table 1 - Cross-comparison analysis

Cases	Pacific Ethanol	Usina California
Number of Employees	About 30	Around 1050 (among the crops staff, operation, engineers and management staff)
Production capacity of the plant	The operational capacity of 60 million gallons (about 227 million of litters) of ethanol per year	The operational capacity of 192 million litters of ethanol per year
Power consumption	It is about 4.2 MW or 4200 KW (as their energy consumption is about 3 million KWH per month)	It is about 3.2 MW or (3200 KW)
Energy source	The main energy source is the natural gas, however the company also purchases some electricity from the city	The unique energy source is the bagasse, made out of the sugarcane waste used as feedstock in the production of ethanol, they used the source to produce biomass
Energy costs	The energy cost is about 10-15% of their production cost (natural gas and electricity)	It is about 3% of the production costs
Operational schedule	The plant is operational every day of the year (365 days/year)	The plant is operational from the end of March to mid December (about 260 days/year)

Error! Reference source not found. demonstrates the different numbers very important to analyze how both ethanol plants works. These numbers provide an idea of the size and efficiency of the plants. The analysis is on the next chapter (Findings).

The comparisons were made on the following criteria:

- Energy efficiency dimension: how managers from each plant manage their energy, what are the advantages and disadvantages of each system, in order to analyze how could they improve their supply chain.
- Sustainability dimension: how the two cases deal with pollution issues, what are their concerns, and how they apply their sustainable methods to comply with regulatory aspects.

Also, the author demonstrates the link between the subjects above and the government of each country, and how the ethanol plant supply chain and the government choices can affect the population.

3.3. Validity and Reliability

The presentation of results is described as of a descriptive method. The interview data were implied according to a number of subjects that corresponded to the research questions. Unforeseen issues and concerns were raised and recurred in both interviews.

4. Findings

4.1. Case 1 – Pacific Ethanol

This plant produces ethanol to be mixed with the gasoline. “California's gasoline contains nearly 6% ethanol, amounting to about 1 billion gallons a year” (Douglass, 2008, online).

Pacific Ethanol uses natural gas as a primary source to generate energy, as most ethanol plants in the USA. “Most plants purchase an interruptible supply of natural gas as the primary fuel for heating, and substitute propane during any interruptions in the natural gas supply” (Tiffany & Eidman, 2003, p. 18). Tiffany & Eidman also explain that energy is one of the biggest primary costs related to the plants; in total it can represent up to 30% of the operating budget of ethanol plants.

The plant works on full capacity the whole year continuously 7 days a week, 24 hours a day. The energy consumed comes mainly from natural gas (about 80% of natural gas and 20% of electricity). The Stockton Pacific Ethanol plant is situated in California where normally (thanks to the government incentives), ethanol plants consume less energy than other plants in the USA, consequently consuming less natural gas. Also, Pacific Ethanol it does not dry their distillers' grain, facilitating the low pollution level. The VP explains that “in the middle west they dry those grains down to 95% dry matter and they use about (…) 1800 BTUs per gallon” (Paul Koehler, 2011, interview); and this can add up to 3200 BTUs per gallon depending on the plant. Therefore in their plant, they produce grains on a wet and dry matter (70% of wet and 30% of dry), thus consuming less energy than a plant that would dry their feedstock. It is important to highlight that the whole energy spent to produce the Ethanol does not include harvesting (as the company do not grow its source).

The equipment is bought, installed or replaced always taking into account energy efficiency and the capacity used. The VP explains that for example, “in operations in a monthly basis, we are tracking how much energy we use relative to our piers industry and try to make sure that we are efficient in that regards, we actually train our staff to do that” (Paul Koehler, 2011, interview). The VP also explains that the company takes care of the energy efficiency internally, “it is really the people who are operating the plants who can know the staff and there is a specific initiatives” (Paul Koehler, 2011, interview). He claims that in an ethanol plant there is a lot of heating up and cooling down process, so it is crucial for all the staff to know how to manage the energy necessary to keep the efficiency equalized across the plant.

Pacific ethanol says that their plants are pretty clean, saying that natural gas is relatively clean on burning. This is partially true considering that natural gas is ‘cleaner’ than coal or gasoline, but it is still a fossil fuel source, meaning that it still emits greenhouse gases into the atmosphere. Ethanol plants in California have a carbon intensity value that is different from other ethanol plants in the United States. The carbon intensity rating in the Pacific Ethanol plant in California is considered quite low compared to the plants in the middle west of the USA.

The boom of the ethanol industry in the USA had an important impact on the natural gas price. The American government had a major responsibility on the ethanol production motivating the ethanol use as a diversification on the transportation fuel in the oil crisis of 1979. “To encourage fuel ethanol production, the federal government initially provided an incentive of 54 cents per gallon of fuel ethanol used” (Wang, Wu and Huo, 2007, p.01).

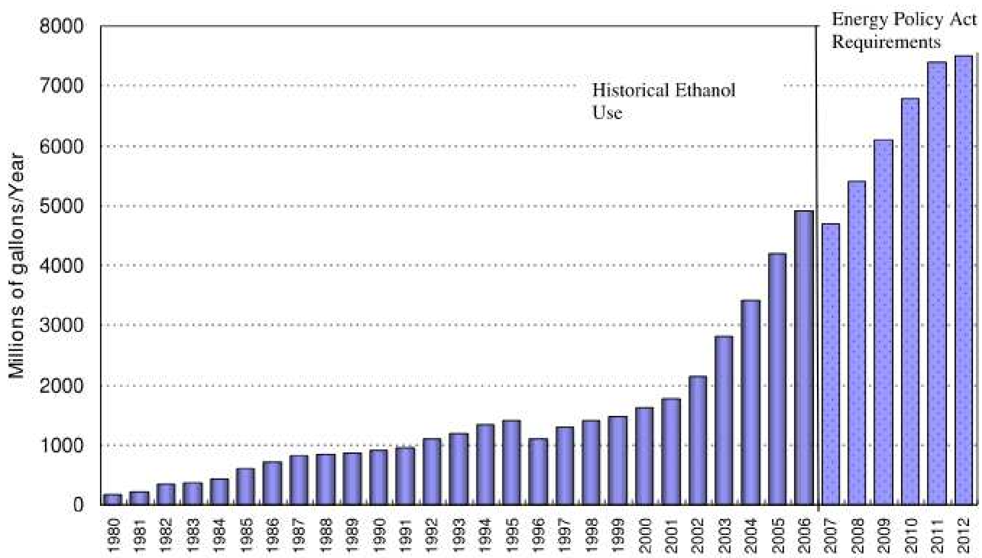

Figure 6 – Historical fuel ethanol use and the 2005 Energy Policy Act fuel ethanol use requirements (historical data are from Renewable Fuels Association (2007) and US Congress (2005))

Figure 6 shows the use of ethanol in the USA since the 80's, which it is used only to oxygenate the content requirements for reformulated gasoline. Furthermore, the state of California has 3 main federal and state laws concerning pollution: California Air Pollution Control Laws, California Air Quality Legislation and Federal Clean Air Act. Pacific Ethanol is in agreement and follows the three of them.

Pacific Ethanol has a cost-effectiveness strategy related to energy; the company does not dry its feedstock (corn). Their corn comes from the American Middle East and is transported to them 'ready to go', meaning that the corn is ready to be transformed in ethanol. With this method the ethanol plant does not have to deal with harvesting and crop schedules being functional the whole year.

4.2.Case 2 – Usina California

The Usina California produces ethanol to be used as an alternative to oil producing fuel to ethanol cars engine. The Brazilian refinery is equipped with a sustainable bioenergy (biomass) system that allows it to produce its own energy. The ethanol plant produces only the sufficient energy to maintain itself (some other plants in Brazil also produce part of the energy consumed in the city that they are based in). The ethanol plants in Brazil "are self-sufficient in energy, producing more than enough electricity to cover their own needs, the growing number of mill is generate a surplus which is sold to power companies and helps to light up newer cities towards Brazil" (Sugarcane industry association 'UNICA', 2011, video).

The energy obtained at the Usina California comes from biomass made out of the bagasse (which is the rest of the sugarcane). Biomass energy is the energy produced by vegetable sources such as renewable sources or obtained by the decomposition of waste.

The energy source of the biomass is the bagasse, which is the material remaining after the grinding of sugarcane to extract the juice, the sugar and the ethanol. The bagasse of the sugarcane is used to produce the steam in the boilers and to generate the energy necessary to keep the ethanol plant functioning. When the plant is burns the bagasse in boilers, it generates energy to supply the plants electricity and make it self-sufficient, eliminating the need to purchase electricity from utilities.

“We burn this residue in boilers and this make out plant self-sufficient in electricity, eliminating the need to buy power from the distributor” (Borba, 2011, interview).

The ethanol plant produces enough energy to produce the ethanol during the production period of the (functioning) year. They do not produce surplus energy to sell, as other ethanol plants in Brazil usually do. Ethanol plants in Brazil normally produce more energy than they need due to the availability of the source and its efficiency. They sell the surplus to the city where they are installed and make more profits out of their sales. The industrial manager explained that “it is important to understand that 1ton of sugarcane produces about 270kilos of bagasse and this bagasse for us comes for free.” (Borba, 2011, interview).

“The amount of the bagasse exceeds the amount needed to make the energy necessary to distill the ethanol. (…) at our plant the energy efficiency is about 0.14%” (Borba, 2011, interview). The industrial manager said that with the sugarcane bagasse, they have more than the necessary as energy source. The level of efficiency of burning is quite high: 3 tons of bagasse generates 1 MW.

All the employees are trained to save energy and optimize its use. The staff working on the crops cut 80% of the sugarcane, so the cane is handle more carefully, and the labor is cheaper than the machines that take care of the rest of the cane (20%). The manager claims that he cannot think on a more efficient way to produce energy than biomass-to-ethanol energy.

The Usina California uses sugarcane as their ethanol source and as their energy source (as explained above). The ethanol plant cultivates its own sugarcane crop. The total area used for cultivation of sugarcane is about 30 000ha, however, 75% are leased farms. The whole area is subject of the agricultural management of the ethanol plant. Every 5 years, 20% of the planted area is left resting on a culture of rotation, for the renewal of cane including a nursery area for new plants. This can be concluded that 24 000ha are used to meet the production of plant. This rotation method does not damage the soil. The industrial manager explains: “we produce 8.000 liter per hectare (ha), which means 192,000,000 liters per year as we have 24,000 ha for production of sugarcane” (Borba, 2011, interview). The production period of the year is from March to November, as the other months is summer in Brazil and the whether is to hot for the crops to resist.

The biomass system is in this ethanol plant almost pollution free. The actual smoke generated to turn the turbines and produce energy is CO2 free because the turbines are equipped with a layer of water on the top that capture all the smoke and its pollutions. This water is after used to irrigate the soil as adobe to the sugarcane crops. In addition, the water is reutilize in all the phases of the ethanol process. For instance, the water is never wasted. The industrial manager stated that “in the crops we promote employee awareness programs and metering water use, the staff know that the cane needs to be washed after cutting but used the sustainable way, as they make sure that the water used is kept to irrigate the crops after” (Borba, 2011, interview). Borba also said that usually, the plant does not use fresh water, as they have a system that captures the water of rain. Another important thing that can contribute to the pollution emissions is when the crop is burned to kill any type of pest and avoid the infestation of the cane, however, the industrial manager of the Usina California claimed that (normally) the plant does not use this procedure as they have scientist that continuously develop seeds resistant to pest minimizing their risk of infestation.

The other systems used by Usina California however, contributes to the air pollution, which are mainly related to transportation as they utilize diesel trucks to transport the sugarcane to the plant and then the final product (the ethanol) to the customers; and tractors used on harvesting operations.

The country does not have any law or regulation against the CO2 emission as the country has no obligation to reduce its greenhouse emissions, as the country is not imply on the Kyoto agreement or any kind of international agreement. It is also important to highlight that the majority of Brazil's emissions come from burning its forests. Nevertheless the country does incentive the production of ethanol, in 1975, the country established the program National Alcohol Program (NAP), usually known as “ProAlcool" program.

“The ProAlcool's main target was gasoline substitution by ethanol obtained from biomass, e.g. sugarcane, cassava and sorghum” (Rosillo-Calle and Cortez, 1997, p. 115). Consequently, the government had a major responsibility on the biomass development. In the mid-70s, the ethanol industry went through a major transformation changing their sugarcane focus from the food sector, to be intended for the energy sector, through the “programa Proálcool” (Alcohol program). “The Pro-alcohol included the use of ethanol to fuel cars in order to reduce country’s imported oil dependence” (Nunes Jr., n.d, p. 02). This program raised the revolution of sugarcane to produce fuel, having a positive effect on increasing the energy competitiveness of the Brazilian system as a whole. The scales of production and milling of sugarcane increased as well as gains in productivity have been successively achieved. Later, with this motivation from the Brazilian government, the country boomed its ethanol industry, with an extensive distribution network of ethanol. Moreover, they start revolutionary adapted vehicles industry, developing technologies for the use of ethanol as fuel; which today allows the country to have about 90% of their vehicles with a flex motor, being able to be fueled with gasoline or ethanol. Below there is a graphic from the Growth of ethanol production in Brazil from 1975 to 2007.

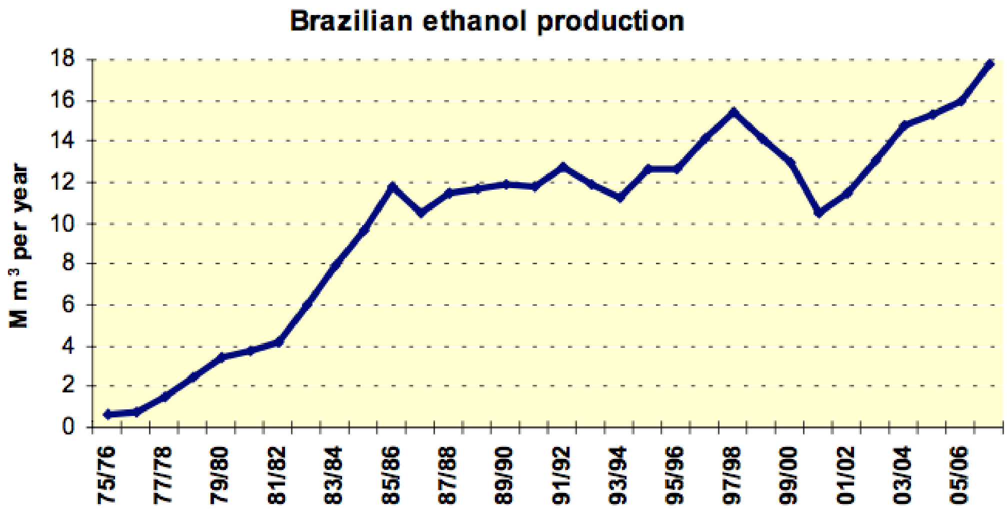

Figure 7 - Developing the ethanol Market in Brazil

Figure 7 shows the Brazilian production growing steadily after the government's incentive and motivation with the ProAlcool program.

4.3.Cross Comparison results

According to the findings on the cross-comparison table, Pacific ethanol does not need more than 30 employees to produce more ethanol than Usina California (having more than 1000 employees). Pacific ethanol consumes more energy than the Brazilian plant but besides the fact that the plant produces more as well, it is operational the whole year, different from Usina California that is open only nine months per year. Concerning the energy costs, the American plant has higher costs due to the fact that it does not produce its own energy; and the Brazilian plant has an insignificant cost because it produces its own energy through biomass using its own primary source of production waste.

4.3.1. The main advantages and disadvantages of both ethanol plants

Table 2 characterizes better their advantages and disadvantages.

Table 2 – Main advantages and disadvantages of the plant's energy method

	Main advantages	**Disadvantages**
Pacific Ethanol	Energy source	
	The energy source allows the plant to function non-stop	The energy source is a fossil fuel and emits GHG
	Energy efficiency	
	Applies energy tracking and measurement and staff trainings to assure efficiency	The method is not sustainable
	Pollution	
	Compare to other fossil fuels, the emissions are lower	Compare to biomass, the pollution level is higher
	Costs	
	The natural gas is in abundance in the country, so costs are not high	Compare to biomass, the costs are much higher
Usina California	Energy source	
	Allows the company to be sustainable and use its waste to produce energy	It is not available during the whole year, limiting the plant's functioning
	Energy efficiency	
	Very efficient - self-sufficient The plant manages its energy very well avoiding waste and promoting sustainability	There were no disadvantages found on their energy system
	Costs	
	The source has not costs besides the turbines' maintenance	On the crops, 80% of the work is done manually to diminish costs

Even though the costs are not being analyzed in study, they were shown in here just for information purposes.

The energy source is as important as the source of production in the case of ethanol. Depending on the source, plants build their strategies and base their profits along with the market prices. Among the strategies, suitable energy methods must be find to streamline the most of the plant's growth and by consequence the country's economy driven by the industry. The two studied energy sources here are represented below.

4.3.2. Natural gas versus ethanol biomass

Natural gas is the source used by the Pacific Ethanol plant. The strategy of the company is to use natural gas to maintain a relevant low cost energy source and a less pollutant source when compared with other fossil fuels such as coal. Natural gas has an important role in energy in the USA. Besides being one of the cleanest (or less pollutant) fossil fuels, it is more efficient in terms of the thermal generation. Another aspect significant for American ethanol plants, as the production process consumes a lot of energy. Is the recent discovery of abundant natural gas in the country, which allows its population to purchase a relatively 'cheap' energy source comparing to foreign sources.

The use of sugarcane bagasse burning in boilers is already a practice used by the mills in Brazil to meet the unique needs of energy, and some even have surplus available to the distributors of electricity. The Bagasse is very efficient to produce the smoke to turn the turbines due to its humidity (quite relevant for vapor production) and fibers that are composed most of cellulose. Moreover the bagasse weight is very important, as it is about 26% of the sugarcane weight making about 275Kg of bagasse for each 1ton of sugarcane. The negative aspect from an energy perspective is that the plants always produced a large volume of mulch, making it a great inconvenience as the disposal of bagasse in nature.

Normally bagasse burning in boilers does not have an optimized system of use, making it necessary to streamline the industry in which par-mills, yielding higher performance and efficiency in the process of energy production. The biomass from the ethanol came as consequence of the energy efficient applied during the Proálcool program and developed by the ethanol plants and the Brazilian government. In the state of São Paulo, the use of clean energy is quite optimize as more than 50% of the energy consumed comes from renewable sources, 38% of cane sugar. The ethanol production has allowed the state of Sao Paulo to reduce the share of oil in the energy state of 60% to 33% in the last 30 years.

The most important comparisons of the two different energy sources consist in 3 aspects:

- The pollutant side: biomass is more efficient than natural gas due to the fact that biomass does not pollute. However natural gas has demonstrated to be less pollutant than the rest of the fossil fuels.
- The economical side: biomass-to-ethanol is also more efficient as the process uses the wastage of the ethanol source, meaning that the plant does not need to purchase its energy source.
- The accessibility: natural gas is more efficient here because it always available, not the same to the bagasse (as it can not be stored for too long) and sugarcane cannot be planted the whole year. With natural gas, the plant can be functional independently of is energy source availability during the entire year.

According to the literature review, the government has a major role in the energy source and technology used in companies. The review shows that governments have the power to impose the energy sources used in their territory.

The difference between the Brazilian government and the American one is that Brazil promotes the use of biomass and ethanol, and the USA promotes the use of natural gas as the American reserves are well supplied with the source.

4.3.3. Energy efficiency

Both systems are quite efficient but on different aspects. On one hand, the biomass system has high cost-efficient results due to the source of ethanol (sugarcane) and its reutilization of its waste on the energy process of the plant. However on the other hand, sugarcane cannot be stocked and it has its crop period during the year, consequently, it cannot be functional the whole year. Quite different from the corn, which can be stocked and used during the entire year. The natural gas is quite efficient when compared to other fossil fuels such as coal because it has a higher level of performance.

Natural gas is abundant and the first energy source in the USA, reliable and it has a quite high performance compare to other fossil fuels, and it is relatively clean. However, biomass is considered to be more efficient when talking about sustainability. The biomass-to-ethanol process offers a means of connecting wastage management dealing effectively with two intangible features of an ethanol plant, such as the high cost of energy and the pollution issue.

In addition, the study of Linares and Labanderia on energy conservation and efficiency explains that efficiency is environment friendly and companies need to have a good administration of the ECE policies in order to cover their energy efficiency gaps. The result of this efficiency is the pollution decrease. This is valid for both methods (biomass and natural gas). This study explains that with energy efficiency the resources needed are cut and by consequence the pollution levels falls.

The main difference between natural gas and biomass is that biomass takes into consideration the environment very seriously.

5. Discussion

Biomass is the most efficient (comparing to natural gas) as it does not pollutes. The issues seeing along this research were the sugarcane burning (practice done by some ethanol plants in Brazil). This practice has a multiple impact on the environment such as soil, water and air and in the society (with healthy issues). According to the study of Tiffany et al., the use of biomass in ethanol plants is very successful causing the amount of GHG emission to dropped almost 50%. This can be understood as a mix of sources being used, meaning biomass and natural gas, which can be a start for a sustainable solution. Now, as this study points out, it is understood that without a good management practices, biomass can pollute as much as a fossil fuel source in the three categories: air, water and soil; making useless the use of biomass.

Nevertheless, a sustainable system (such as biomass) includes the certain management practices concerning the pollution of air, water and soil. To be efficient, the biomass system practices follow these disciplines to avoid pollution:

- Air: the system used on Usina California is a environmental friendly one as it uses layers of water on the top of their turbines to capture the heavy smoke produced during the burning process of the bagasse with the purposes to turn the turbines and produce the energy necessary to the plant's functioning. In addition the plant does not apply the burning process of the sugarcane avoiding the pollution issue.
- Water used: the consumption of fresh water for the cultivation of sugarcane is hardly used. The water is supplied mostly from the various effluents generated in the ethanol production process (treated or untreated), which are recirculating. For example, the water used on the turbines to avoid the smoke emission is again

reused to irrigate the sugarcane crops. With this kind of system, water management is use to avoid waste, optimize its sustainability and efficiency.

- Soil: The pollution of the soil is hard to be managed because the actions are not as visible as air and water. The results of soil pollution can be for instance, erosion, which is a significant issue in areas under sugarcane cultivation, particularly in tropical areas such as Brazil. The ethanol plant studied here manages the soil very carefully to protect and maintain its fertility (in some places where the sugar crops are used with a high intensity, the results are soil damage as it dries up as a result of thirsty). The plant studied here, uses the alternation strategy, meaning that they give a certain time of rest (about 5 years) where the soil does not produce.

As many studies pointed out, natural gas is considered to be the cleanest fossil fuel, but the level of pollution is still high compared to biomass. Pacific Ethanol has the government's encouragement to follow the Californian laws of pollution as the other ethanol plants do. The USA uses natural gas because of its abundances, but the earth drilling to search for the source has caused serious damage in the soil and water. It is known that the American electric generation industry is a great contributor to the country's pollution, however the government had imposed regulations and limitation on the greenhouse emissions of power plants (and ethanol plants) and this action have forced these energy generators to come up with new methods using new technology to generate power. New technologies, and the government intervention have allowed natural gas to play a progressively important role in the clean generation of the American energy system. Yet, natural gas is a big contributor to the air, water and soil, and below are the aspects of the pollution, which are different, compared to biomass.

- Air: the study points out that natural gas is still a significant air pollution source, besides its advantages compared to other fossil fuels; it releases hazardous air pollutants causing global warming pollution. The state of California does not allow companies to review their level or amount of emissions, so it is hard to tell how much does natural gas pollutes. However, in more detail, natural gas releases the greenhouse gas methane, which, to have an idea, deceives 25 times more heat than carbon dioxide.

- Water: the natural gas used by the ethanol company contributes to water pollution when extracted. The pollution often occurs by groundwater pollution due to the hydraulic fracturing which are the technologies to deep drill to look for natural gas. This process includes the injection of a ‘cocktail mix’ that includes water, salt and chemicals to open the rock formation where the fuel is extracted.

- In addition, besides the pollution there is the water management practice in the plants, “water use ranges from□1.5 to 4 gallons for each gallon of ethanol produced. The overall industry average is between 3.0 and 3.5 gallons—down from nearly 6 gallons just a few years ago” (Ethanol across America website, 2009, online).

- Soil: the findings point out that natural gas can also pollute the soil during the extraction process. The source can actually contaminate the soil by spilling the chemicals used on the extraction, which are very hazardous.

To conclude the pollution session analysis on both energy sources, environmental and source-of-supply overall features place natural gas at a disadvantage as compared to biomass even if the use of natural gas in the ethanol plant does not comply directly with the pollution of water and soil.

5.1.1. The government and its actions

The literature review demonstrates that governments have a major role when taking about CO2 emission decrease. According to the study of Linares and Labanderia, governments need to apply the strategy of taxation to achieve energy efficiency. The authors argue that they have the necessary power to impose taxes (or taxes reductions) and methods to motivate the use of 'cleaner' methods on the population. Furthermore, according to the literature review, governments tend to be more successful with their energy source supply when taking into account the social uncertainties. In the literature review chapter, is argued that the social uncertainties such as health and unemployment cannot be encompassed by a purely financial cost consideration when building the energy system strategy. Hall and al. claim that the Brazilian ethanol industry is successful due to the government's strategies mixing the energy management with technology and innovation along with social uncertainty.

The authors suggest that the energy source and the energy systems need to be complied with the appraisal of environmental and other internal social uncertainties. They stated that an energy system based on a cost-benefit approach will show results on a short term, however a energy system strategy that takes into account technology, innovation and social uncertainty is less risky and sustainable beneficiating not only the industry but also the society. The social uncertainty is an issue that when take into consideration becomes a key driver of an energy management development to improved new methods to achieve energy developments and national (and maybe global) change. The benefits of this approach are:

- Economic: besides economic growth, it would help the nation in a mix of issues such as energy security (and independency), efficiency of energy supply and distribution increase, technologies development, etc.

- Environmental: in large part this will be because of the ecological impacts of energy systems, a sustainable system will have the tendency to go against the greenhouse effect by decreasing the emissions
- Social: job creation with better working conditions and employees benefits (which would also boost the economy), a healthier environment, etc.

5.2.Managerial Implications

5.2.1. Biomass-to-ethanol

To be more efficient the biomass-to-ethanol plant needs to assure that the purposes of the method are being achieved: sustainability. The plant needs to be sustainable in all supply chain steps. The energy efficiency needs to be applied at the maximum level from the crops to the final product, and this includes:

- Water: the use needs to be optimized from the irrigation to the prevention of smoke pollution from the turbines and being relying as much as possible. Wu, Mintz and Wang explain that a sustainable ethanol plant uses the method of recycling water, which is a process known as water management, necessary to avoid waste and pollution.
- Pollution: build a system that does not pollutes and where the water prevents the dirty smoke to be release into the air. Also, stop the sugarcane burning (practice taken by many ethanol plants in Brazil to kill harms and pests and to burn the leaves). Martinelli and FIloso explain that the burning process results on serious damage to the soil, water and air.

5.2.2. Natural Gas

The way that the energy could be more efficient is if the plant uses the natural gas to cogenerate energy. This approach is possible if the plant uses the "waste" heat available in addition to the energy produced. The results would be higher energy efficiency, the reduction of the greenhouse gas emissions of about 50% as Tiffany et al. explained; and the decrease of the energy cost thanks to the Combined Heat and Power (CHP) system.

Furthermore, from a rational perspective, the use of natural gas (being the least polluting fossil fuel) together with cogeneration would contribute to a diverse and more secure resource mix. The resource mix has been proven by many researchers to be a very efficient way of producing energy. In addition, reach energy efficiency, studies have shown that innovation through technology is a valuable input. Thorsten et al. (2014, p.07) claim that by using innovation is logistics and technology a "number of barriers have been identified hindering the market uptake of innovative business models."

5.2.3. Biomass-to-ethanol supply chain

The first impact would be seen in the air quality as biomass (if well managed), does not pollute. The second would be the social uncertainties decrease. With a sustainable method the GHG emission are very low and the low-cost feedstock also is very efficient boosting the production of energy.

On the pollution aspect, as Tiffny et al. discuss, with biomass is possible to diminish the emission levels up to 79%, which is a very favorable amount. As Okonko et al. explain that biomass has a great combination to manage issue such as waste, pollution, sustainability and development. However, studies have shown that this solution to energy production is very profitable not only to the firm but also to the society as this method takes into account the social uncertainties of the country. Moreira claims that biomass-to-ethanol in Brazil is a success because the government made sure that there were some social benefits to the society such as jobs creation on rural areas, and the pollution produced was not much high. It is to understand that Brazil is the biggest leader in the field on sustainable ethanol supply chain because the government developed its energy management equipping with the largest social and sustainable energy technologies.

5.2.4. Energy supply chains affected by ethanol production and efficiency

Developing an ethanol sustainable supply chain is a challenge that managers and governments are required to accept because it questions the future energy demand and needs. Most of actual development approaches within the innovation literature focus primarily on overcoming technological and social uncertainties, and transportation issues. Many factors can influence a sustainable ethanol supply chain, but the major actor is the government. The country has the responsibility to choose and motivate the use of a certain energy source and how it is managed, it is possible to enhance energy efficiency. However, the sustainable biomass ethanol industry is an example that energy management can succeed as long as technology and innovation is taken into account from all steps of the supply chain in order to reach sustainably. Also, the management approach needs to be adapted to the social uncertainties of the country and energy management applied to achieve energy efficiency.

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