UNIVERSITÉ DE VERSAILLES SAINT-QUENTIN-EN-YVELINES

Module M2: Science & Technology – Evaluation – INDIVIDUAL ESSAY

econoving

Boubacar COLY

boubacar.coly@uvsq.fr

Alternative to fossil fuels?

Sugar-cane ethanol

EXECUTIVE SUMMARY

During these last decades, the increasing consideration of environmental and economical sustainability allowed sugar-cane biofuel to appear as one of the growing alternatives to replace petroleum based transportation fuels. While oil is being more and more scarce, more and more expensive to produce, sugar-cane exploitation is gradually rising.

In comparison with petroleum based fuel, the main factors that allowed the kick-off of sugar-cane biofuel exploitation on a global scale are the low production cost, the very low CO2 emissions and the almost endless availability of the resource as long as there are lands and sun.

However, due to the increase in food needs in the world, exploiting such resource raises some ethical and social issues that need to be taken into account. In some countries, the exploitation of this biofuel has been turned into a full development strategy; which is unfortunately reshaping their agricultural maps and altering ecosystems.

Starting from the origins and the production process here is presented a science-based analysis of the viability a sugar-cane ethanol biofuel. The main method used in this analysis is a focus on current context of sugar-cane biofuel industry adapted not only to ecologic and social challenges for the future but also to economics according to countries it is exploited in.

KEY WORDS

Sugar-cane biofuel, technology, lignocellulose, biomass, future.

Introduction

In this 21st century, it is hardly deniable that humanity's major global challenges are environmental and economic issues. Those are currently illustrated by the soaring cost of fossil fuels especially oil. This situation generated higher attention to alternative and renewable approaches such as wind, hydro, solar nuclear and the use of biomass. Focusing on sugar-cane ethanol biofuel, the problematic of our discussion can be summed up in these following questions: Is sugar-cane a viable technology for the future? In which countries? Why yes? Why not?

Referring to scientific publications, our reflexion will submit a complete analysis of sugar-cane ethanol biofuel through the following plan:

First of all, I will give a quick step back on the origins of sugar-cane biofuel technology, its process of production and its geographical context. Then I will analyze its carbon balance as well as its social impact before summarizing in a final step in a simplified SWOT diagram.

Materials and Methods

In order to fully cover the topic, the main method used here is a general comparison in references in order to submit an ecobalance analysis of sugar-cane ethanol biofuel. However, it's important to mention that some scientists cited here (especially Brazilians) are clearly supporting sugar-cane industry by having very subjective statements and positions about some aspects where there is not enough available data.

Results and discussions

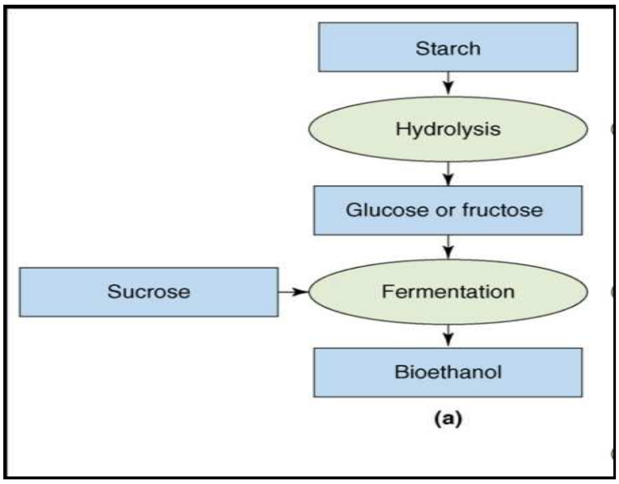
The results of this discussion will be split into: the carbon balance and net energy balance (NEB), the social impact and a comparative study. But before those steps and for a better understanding, here is a quick step back to sugar-cane ethanol origins and production processes within its geographical context. This will be summarized for a quick overview within a simplified SWOT diagram.

Origins: Native to warm temperate to tropical regions of Asia, Sugar-cane (***Saccharum officinarum***) belongs to the grass family ***Phocaea***, a seed plant family that includes maize, wheat, rice, and sorghum as well as many forage crops[1]. The main product of sugarcane is sucrose, which accumulates in the stalk. Sucrose, extracted and purified in specialized mill factories, is used as raw material in human food industries or is fermented to produce ethanol.

Production process: Like every biofuel obtained from sugar-cane or sugar beets, the Brazilian ethanol (sugar-cane) belongs to the first generation of ethanol. Its industry is very different from the U.S. ethanol (corn) industry. In Brazil, two types of ethanol are produced and sold to consumers: anhydrous and hydrous ethanol. Anhydrous ethanol, which is the standard in the U.S., contains about 0.5 percent water by volume and is blended with gasoline for fuel use. Hydrous ethanol, on the other hand, can have about 5 percent water. In the last growing season, 66 percent of the ethanol produced was hydrous ethanol and from 150kg of sugar-cane, it can be produced up to 85 Liters of ethanol[2].

Fig 1: Simplified scheme of Bioethanol production process

Source: ***Stewart, Yuan, Ahmad (2008)***



With the Lignocellulosic biomass process, plants are grown for ethanol production using the entire aboveground biomass. Lignocellulosic refers to the plant biomass that is composed of cellulose, hemicelluloses and lignin polymers[3]. Biomass can be hydrolyzed and resulting sugars can be used for ethanol production. Lignocellulosic ethanol production involves pretreatment of biomass material, hydrolysis for monosaccharide production, and fermentation to produce ethanol.

Geographical Context: For several years now Brazil has been leading worldwide sugar-cane production and exploitation (around 16% of global production i.e. 30 million metric tons and 90M ha of agricultural lands) [4]; which goes for sugar and ethanol for gasoline-ethanol. India is the second largest producer with 25 million metric tons; sugarcane is refined into sugar, primarily for consumption in tea and sweets and for the production of alcoholic beverages[5]. Today, sugar-cane is grown in over 110 countries. In 2009, an estimated 1,683 million metric tons were produced worldwide which amounts to 22.4% of the total world agricultural production by weight. About 50% of global production comes from Brazil and India[6]. Just behind the United States, Brazil is the second largest ethanol producer in the world. During the 2008-'09 sugarcane seasons, Brazil produced a total of 7.2 billion gallons (27.5 billion liters) and the trend is heavily expected to grow for the 2010-2011 official stats[7]. Since 1992, large industrial programs for production and industrialization were deployed within European and Eastern Asia countries.

However, above all the aspects analyzed in sugar-cane, there are major uncertainties regarding the Nitrogen dioxide emissions[8] during the whole process. Apart from direct greenhouse gases emissions most of Life Cycle Analysis carried out for ethanol biofuel don't include other impacts; which can heavily alter calculation basis established by the IPCC (International Program for Climate Change). There were some attempts from ADEME in 2002, Blottnitz and Curran (2006) to evaluate biodiversity alteration, acidification of the atmosphere, ozone layer destruction and aquatic pollution; but referenced methods dedicated to agricultural and environmental diagnosis are either not complete or on an experimental phase[9].

Carbon balance: The Net Energy Balance (**NEB**) is the difference between the energy output and the energy input for biomass production process. It is a very important carbon balance measurement tool as only high (NEB) results can be considered as economically and environmentally sustainable. Lignocellulosic ethanol production has a very high NEB (600 Giga Joules / ha/ year) and emits 78% less green house gases than gasoline[10]. However this is not sufficient because even the best lignocellulose ethanol is unfortunately predicted to have a positive carbon balance. That is mainly why there is a consensus between producers that a second generation of Lignocellulosic biofuel will dramatically lower the carbon balance by 2015 - 20120 but, as its production process requires more enzymes, it is expected to be more expensive. But the main issue is about the several tons of CO2 emitted by production processes in order to maximize yields per ha of land exploited:

- The use of chemical fertilizers and pesticides produces Nitrogen dioxide: a powerful green house gas that can be up to 120 years suspending in the atmosphere.
- Water pollution: To produce one liter of ethanol, 13 liters of acid liquid are required. This acid can destroy fauna and flora if rejected in the nature.
- Deforestation and monoculture: Sugar-cane is partly responsible for the deforestation of the Atlantic forest in Brazil which is now reduced up to 93% its initial surface. This has a major impact on local biodiversity.

But according to Bruckeridge and Goldman, the debate around crops expansion is useless as current alternatives are oriented to increase productivity without expanding crops areas[11].

AUTHORS	YEAR	REGION	ENERGY INPUT/OUTPUT	GH Gases reduction rate per km VS classic petrol car	ETHANOL YIELD/ha.
(Macedo and al., 2002) in (IEA, 2004)	2002	Brazil	0,12 (90%)	92%	6500 Brazil c.2002
(Oliveira and al. 2005)	2005	Brazil	0,27 (77%)		
(Pimentel and Patzek, 2007)	2007	Brazil	0,72 (37%)		
(Pimentel and Patzek, 2007)	2007	USA	0,89 (23%)		

Fig 2: SUGAR-CANE ENERGY AND CARBON BALANCE (Source: DORIN AND GITZ 2007)

Social impact:

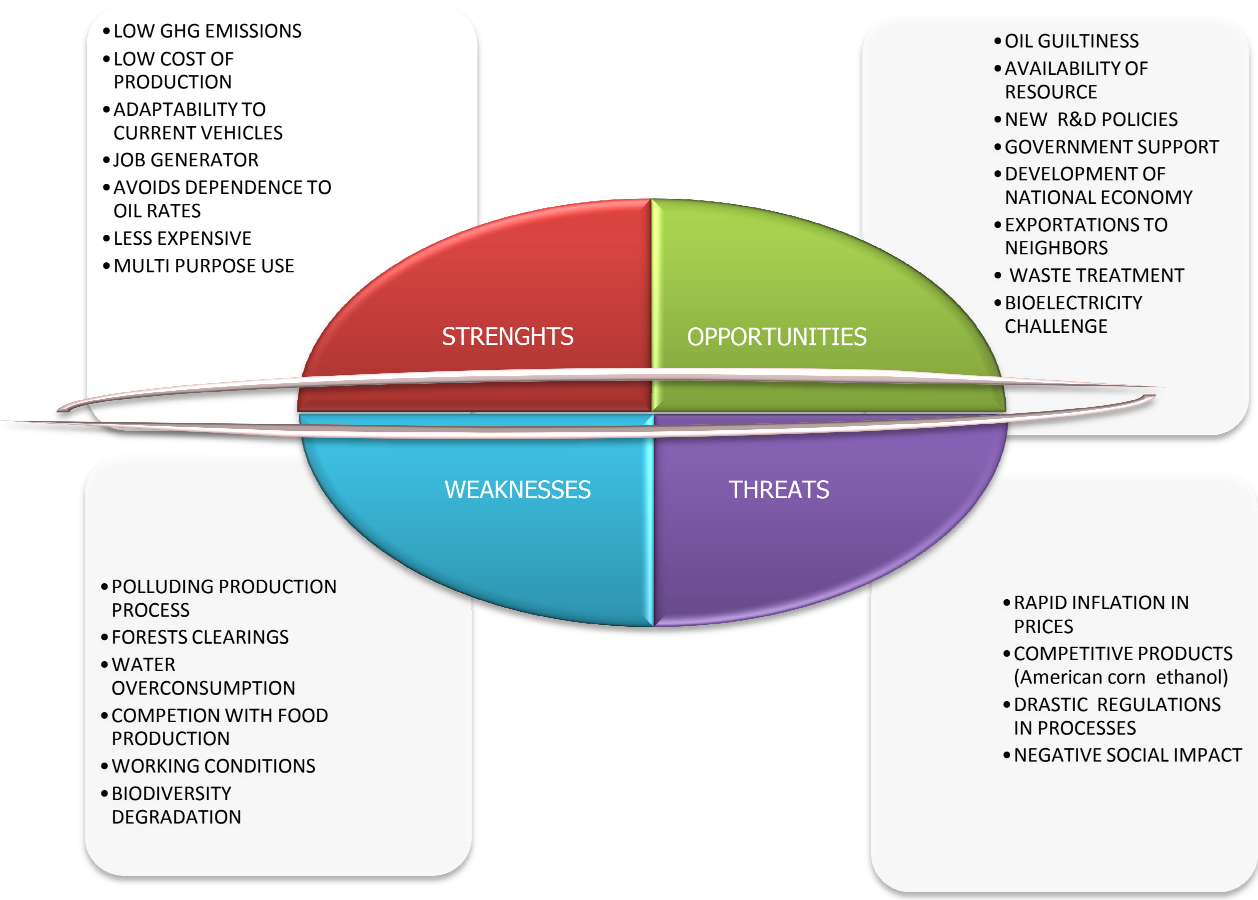
In the European Union, there are series of regulations implemented by the European Commission in order to limit any over-exploitation that might have a social impact. But the case of Brazil can be representative to the majority of other producing countries, either positive or negative; those are more visible in this area:

- Employment rate is increasing in order to fit the huge demand for refining plants and harvesters.
- But at the same time, with the mechanization of the process prevent illiterate workers from accessing more qualified jobs. (Up to 3 million jobs in Brazil only)
- There is more and more social security for workers.
- Big competition between food use and biofuel use logically generated by the increase of sugar-cane agricultural lands.

Comparative study: (The electric solution) From the initial idea of maximizing "miles per acre" from biomass and minimizing adverse impacts on climate, Elliott Campbell of the University of California and collaborators performed a life-cycle analysis of both bioelectricity and ethanol technologies, taking into account not only the energy produced by each technology, but also the energy consumed in producing the vehicles and fuels. Bioelectricity was the clear winner in the transportation-miles-per-acre comparison, regardless of whether the energy was produced from corn or from switchgrass, a cellulose-based energy crop.

For example, a small SUV powered by bioelectricity could travel nearly 22500 km on the net energy produced from an acre of switchgrass, while a comparable internal combustion vehicle could only travel about 14000 Km on the highway. (Average mileage for both city and highway driving would be 24000 Km for a bioelectric SUV and 12000 Km for an internal combustion vehicle.) The energy from an acre of switchgrass used to power an electric vehicle would prevent or offset the release of up to 10 tons of CO_2 per acre, relative to a similar-sized gasoline-powered car. Across vehicle types and different crops, this offset averages more than 100% larger for the bioelectricity than for the ethanol pathway. Bioelectricity also offers more possibilities for reducing greenhouse gas emissions through measures such as carbon capture and sequestration, which could be implemented at biomass power stations but not individual internal combustion vehicles[12]. Even if Campbell's study favors clearly bioelectricity, this encouraging step will need to be compared with other issues like water consumption, air pollution, and economic costs.

Fig 3: Simplified SWOT diagram



This diagram can be qualified as an overall summary of all the references checked for writing this document. It allows a quick and concise view of sugar-cane potentials within its competitive context.

Concluding remarks

Major scientific and economic forecastings agreed on the fact that by 2030, the world will have to face huge and rocketing needs in energy. which is been already generating an over demand for fossil energies. This scenario leads to these following main issues: rising of fossil fuels demand, increase of green house gases emissions, climate change, more and more dependence to producer countries. For emerging countries, especially in the South American area, this is a huge potential for achieving economic stability.

Within this context, global transportation sector which depends at almost 100% to fossil fuels is currently trying to find out alternatives capable of integrating economy and sustainability in the near future. Due to geographical issues European countries are mostly betting on electricity, air and compressed natural gas but less in sugar-cane ethanol. That's why it is expected to develop more in massive production areas such as Brazil and India but in a larger scale, exportations can be planned also towards emerging African countries as long as the cost is lower than oil one.

However, besides the clear economic viability, if sugar-cane biofuel industry wants to be sustainably and socially fully viable, it will need to have improvements such as: regulations for greenhouse gases footprint, establishment of referenced parameters that supply more detailed data about ozone layer impact, biodiversity alteration and aquatic pollution. But there is a key rule for every economy that seems also valid for sugar-cane ethanol: Research and Development as innovation generator is one of the most important ways to make sugar-cane biofuel fully efficient so that it can definitely play the role it deserve in this climatic challenge thanks to its low cost of production and several jobs that it creates.

Notes

1- SHARPE PETER (1998) SUGARCANE PAST AND PRESENT ILLINOIS UNIVERSITY

2 -A. da Rosa (2005) Fundamentals of Renewable Energy Processes, ELSEVIER

3- A. da Rosa (2005) Fundamentals of Renewable Energy Processes, ELSEVIER

4- *Food and Agriculture Organization of the United Nations. Retrieved 2010-06-17.*

5 -*Richard Asplund (2008) Profiting from clean energy*

6- Food and Agriculture Organization of the United Nations. Retrieved 2010-06-17.

7- Brazilian Sugarcane Industry Association (UNICA) which represents sugar, ethanol and bioelectricity producers in Brazil (2009).

8- CRUTZEN NOBEL PRIZE OF CHEMISTRY

9 - Bochu, 2002, Cunningham 2003, Doublet 2006

10 - Stewart, Yuan, Ahmad (2008)

11- Routes to cellulosic ethanol (2011)

12 - J. *E. Campbell, D. B. Lobell, and C. B. Field. Greater Transportation Energy and GHG Offsets from Bioelectricity Than Ethanol. Science, 2009*

References

1 **Daniel Ballerini** (2006) Les biocarburants: État des lieux, perspectives et enjeux du développement. *TECHNIP*

2 **Elinor L. Scott, A. Maarten J. Kootstra and Johan P.M. Sanders** (2010) Perspectives on bioenergy and biofuels. *SPRINGER SCIENCE AND BUSINESS MEDIA B.V*.

3 **Grist magazine** (2006) corporate control of the US maize ethanol market. *Special series on biofuels.*

4 **Pimentel D., Patzek TW** (2005) Ethanol Production Using Corn, Switchgrass and Wood; Biodiesel Production Using Soybean and Sunflower Natural *Rebibliographie.*

5 **FAO** (2010) Food and Agriculture Organization of the United Nations.

6 **ADEME** (2002) La filière lignocellulosique-biocombustible, *ADEME*

7 **A. da Rosa** (2005) Fundamentals of Renewable Energy Processes, *ELSEVIER*

8 **Jenkins, GH** (1966) Introduction to sugar-cane technology, *ELSEVIER publishing Co*.

9 **José Goldemberg, Suani Texeira Coelho, Patricia Guardabassi** (2007) The sustainability of ethanol production from sugar-cane *ELSEVIER*

10 **Luke Geiver and Holly Jessen** (2010) International Ethanol Report: 2010 *ETHANOL PRODUCER MAGAZINE*

11 ***Stewart, Yuan, Ahmad*** *(2008) Plants to Power: Bioenergy to fuel the future: CEL PRESS*

12 ***Pierre Audinet*** *(1998) L'ETAT ENTREPRENEUR EN INDE ET AU BRESIL: HARMATTAN COLLECTIONS*

13 **Richard W. Asplund** (2008): Profiting from clean Energy *John Wiley & Sons, Inc*.