ETHANOL: SUGAR VERSUS ETHANOL NEXUS IN PAKISTAN MARKET

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ABSTRACT

The important progress of agricultural throughput is tightly tied to the green evolution all over the world. On another side, the large need of the energetic industry on biofuels and renewable fuels has provided new paradigms for the agricultural production, once producing biofuels has to be developed accordingly to the traditional food industries with regards to eventual impacts on agricultural and social impacts. This case study describes the Pakistani Ethanol industry case. It provides a description of the Ethanol supply chain in Pakistan from sugarcane field to market. It incorporates how the Pakistani ethanol industry can play a critical role in improving the lives of rural dwellers by contributing to increased agricultural production; enhance farm output, and an increase in the income of farmers and agrarian communities. Most importantly, key environmental and socioeconomic impacts for ethanol production, including complementary energy source to the existing and ever-growing reliance on imported fossil fuels, and countless job opportunities, have been analyzed in two other countries: the US and the Brazil. It was concluded that Pakistan should invest more and introduce ethanol based fuel, as it has the potential to be a quick solution to economic, social and energy woes.

Keywords: Pakistan, Ethanol, sugarcane, ethanol, industry, Renewable, Biofuels, US, Brazil

INTRODUCTION

According to (*PSMA report*, 2020), Pakistan is the sixth greatest sugar producing country in the world. And, sugarcane molasses represent the exclusive substrate for the ethanol production, exceeding 2236 Tons in 2019-2020 year (*PSMA report*, 2020). Sugarcane molasses are a by-product of sugar processing. Nevertheless, despite the considerable potential of the sugar cane production and its positive impacts on agriculture field, the Pakistan is currently facing real problems tied to the lack of fossil fuels which present the quarter of its foreign importation. To deal with such issue, the country is encouraging researchers to strive in finding remedial solutions regarding the renewable energy and biofuel, to take the advantage of producing ethanol-based fuel from sugar cane. This case study shows how ethanol is produced from sugar cane, its energy analysis is and how to find good compromise between the use of sugar cane to serve the food industry or even to improve the energy field. The study will set a comparison the markets of sugarcane in Pakistan to other important producers such as Brazil and USA.

Before detailing the reasons for which the Ethanol production seems worthy of consideration, it is important to review the obstacles facing the Pakistani economy. As a first weakness, the foreign importation has to be reconsidered. According to (*PES*, 2020), the Pakistan is producing around 11,590,000 tons of oil per annum, whereas its consumption exceeds 19,680,000 tons per year which made it importing around 8,090,000 mt as foreign importation. In this context, it is undeniable that compensating the gap between the profitable potential of ethanol production and the weakness of the agricultural

development, the lack of the required industries for treating the raw materials, added to the lack of remedial policies of the government is a great challenge for Pakistan. Another important side, affecting the energy sector is the automobile industry which is tightly depending on the fossil fuels. This dependence has a negative impact on the environment and a huge loss of energy. In this context, according to (*Ministry of climate report*, 2012) and to (*Climate south Asia network*, 2018), the Pakistan, with a less contribution in greenhouse gas emissions, is one the most countries threatened by the global warming. From the agricultural point of view, the Pakistan has to take advantage of the abundant production of sugarcane. In fact, this production is exceeding 65 million tons during last five years, which can be considered as bulky.

According to (PSMA report, 2019), the total molasses production was 2.95 million tonnes. In (Naureen, 2013), from the sugarcane milling, 2 million tons of molasses can be produced per annum. Consequently, it is estimated that this production can yield about 457.6 million litres of ethanol, which is at the rate of about 4kg of molasses to 1 litre of ethanol. From a second point of view tied to the foreign exportation side, exporting molasses can participate actively in realizing a good economic balance to the foreign exchange. In fact, in the year 2018, about 700 million liters of undenatured ethanol added to about 0.2 million tonnes of raw molasses are exported, (Farooq, Bangviwat and Gheewala, 2020). Regarding the opportunity of producing biofuels by the sugarcane crops and compared to the other countries like the Brazil and USA, the Pakistan has to join them by reconsidering its strategy about improving its important sugarcane production to produce more and more ethanol. This latter can be blended into petrol, reduce efficiently the oil and's cost foreign import, and eventually prevent the environment from the fossil fuel danger. Henceforth, it will judicious for the Pakistan to improve its ethanol production and take its benefits on the economic and the social sides: developing rural areas and generating employment opportunities.

This paper is structured as follows: in Section II, we present the ethanol, its properties and uses. Next, we provide a life cycle assessment of sugarcane crop to detail how it is handled in Pakistan. Then, in the fourth Section, an energy analysis estimate is given to enhance the spate of interest to the energy potential of ethanol production. In the fifth Section, a comparison to the Brazilian and American models is made to discuss the eventual changes that can be handled to provide a green model with efficient potential.

What is Ethanol? How it is produced, properties and its uses?

Ethanol is called also ethyl alcohol, grain alcohol**,** or alcohol and its molecular formula is C_2H_5OH. Manufacturing ethanol consists of two possible processes the fermentation of carbohydrates process or the hydration of ethylene one. Fermentation consists in transforming carbohydrates by growing yeast cells. The main raw materials fermented to produce industrial alcohol can be sugar crops (beets and sugarcane) or even grain crops (corn). For the hydration of ethylene process, it is done by passing a mixture of ethylene and a large excess of steam at high temperature and pressure over an acidic catalyst.

Ethanol has several uses: it can be used as a solvent in the synthesis of some organic chemicals, or as a fuel automotive by adding it to gasoline to form a mixture known as a gasohol. It increases the fuel efficiency and it can be used in industries as a feedstock or also used to produce biodiesel for vehicles or to produce alcoholic beverages. The main application of ethanol in Pakistani environment is its usage in biofuels in vehicles as fuel to reduce and eventually end the import of petrol and diesel fuels and increases the use of locally produced fuel that is ethanol.

Molasses-based ethanol production model in the Pakistan

One of the most important crops in the Pakistan is the sugarcane. As shown in Figure 1, sugar cane is cultivated in a large area in the country. In fact, province distribution of sugar cane production shows a breakdown ranging from 65% of area to Punjab, to 25% to Sindh and around 10% to KPK. The sugarcane cultivation cycle can have between 2 to 5 years of growth from one plantation. Once the cycle ends, a new crop has to be cultivated for proper yield. Sugarcane cultivation has to be made preferably in autumn season.

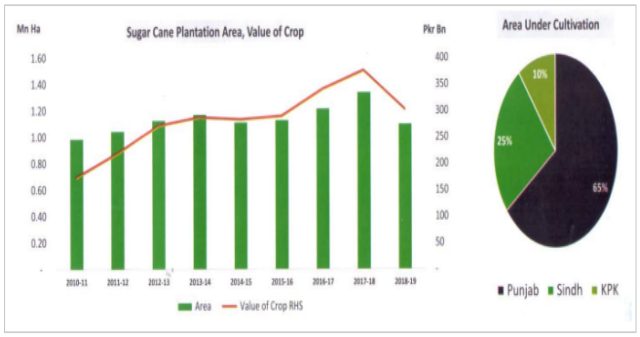


Figure-1 5% sugarcane area versus total cultivated land of Pakistan. [PSMA report, 2019]

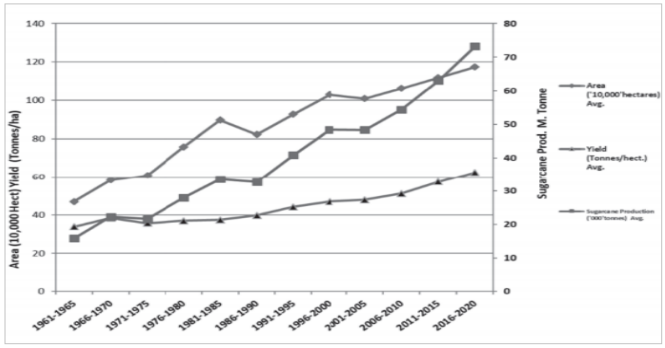


Figure-2 Evolution of sugarcane production relatively to area plantations in Pakistan (PSMA report, 2020)

Sugarcane molasses is the major source of ethanol production in Pakistan. The area and production trends of Pakistan is shown in figure 2. This processing needs the fermentation of sucrose in sugar crops that contain respectively sugarcane, sugar beet, corn, and wheat. The resulting by-product of sugar production, molasses, is used for ethanol production. Another part of Ethanol, which can be considered as a good substitute, is produced from cellulosic feed stocks like switch grasses and agricultural wastes (Farooq, Bangviwat and Gheewala, 2020). In the year 2018-19, the total molasses production in Pakistan was around 2.95 million tonnes, which means that for all the available molasses used for ethanol production, a resulting yield of about 0.74 billion liters can be obtained (as 4 kg of molasses yields about 1 liter of ethanol) (Naureen, 2013).

Sugarcane production and sugar production steps

The first step in the model is the cultivation step which consists of preparing the land, watering, maintaining the crops and managing the sugarcane crop rotation. Then, the sugar milling step is considered which consists of crushing stage, boiling, seeding and extracting sugar crystals. The resulting products of this step are respectively ne is sticky black syrup called molasses, and a straw-like residue called bagasse (Gheewala, Garivait and Nguyen, 2008). Bagasse is used to produce electricity and the molasses has the potential of producing the renewable ethanol-based fuel.

Molasses's preparation, fermentation, distillation, and ethanol production

As depicted in Figure 3, the process producing ethanol through the fermentation consists of microbial conversion using the microorganism *Saccharomyces cerevisiae*. According to (Farooq, Bangviwat and Gheewala, 2020), the obtained alcohol has a concentration of only about 5-15%, while the rest is water. Hence, the distillation step is processed to enhance the alcohol concentration of up to 95-96%. A step of dehydration is needed to obtain ~99.5% pure alcohol to be blended with gasoline as automotive fuel.

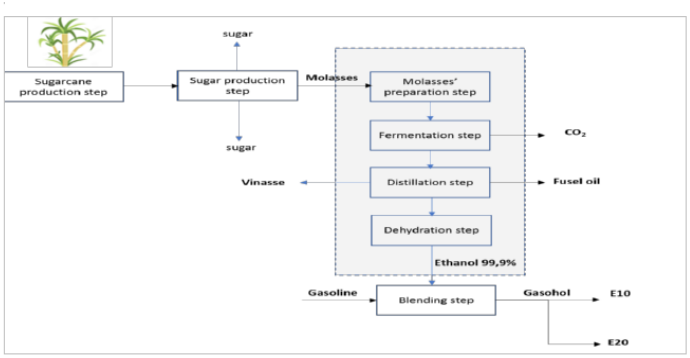


Figure-3 Molasses-based ethanol production steps

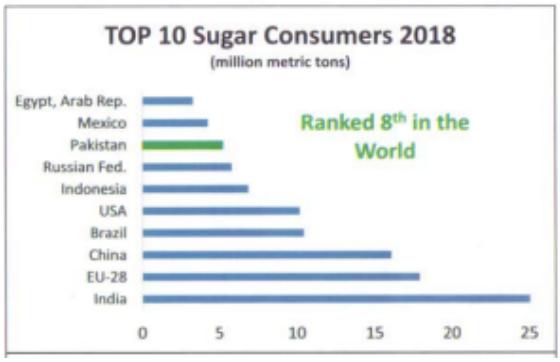


Figure-4 Pakistani sugar consumption (ISO sugar year book, 2019)

So, the main resulting byproducts during the different steps of ethanol production process are respectively carbon dioxide (CO_2) gaz in the fermentation process, Fusel and Vinasse oil in the distillation step. The resulting CO_2 has an equal amount as ethanol, while fusel oil is a kind of alcohol with more than two carbon atoms in its molecules. Vinasse, or stillage, is the wastewater left behind after ethanol extraction, has several usages: as fertilizer, animal feed, or it can be refined into biogas for energy generation.

The Ethanol is blended with gasoline to use as automotive fuel called as gasohol. Farooq, Bangviwat and Gheewala (2020) states that ethanol is used in two types of blends: E10 which is a blend of 90 % of gasoline and only 10 % of ethanol, and E20 which consists of 80 % gasoline and 20% of ethanol. Producing ethanol from molasses is the highest energy consumption step and should imperatively be optimized. The resulting stillage treatment has an important role making biofuels economical when comparing with conventional fossil fuels.

Impacts of the ethanol production process

To guarantee an efficient production of sugarcane, the Pakistan has to encourage agricultural research and to deal with key issues: the lack of water resources and fertilizers, unsuitable and poorly prepared soil, lack of handling measures for ratoon crops, and lack of advantageous measures for farmers.

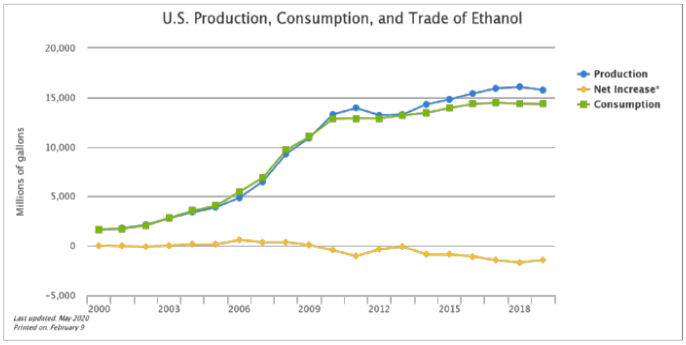
From the policy point of view, the Pakistani government is currently handling challenging directives to strengthen the sugarcane production from farmer to mill. As a first key directive, the rates for sugarcane are governed by Ministry of National Food Security and Research to be fixed, with collaboration between the mill owners and farmers. A second key directive consists in improving the agricultural research in this field by providing governmental.

A third directive made by the government is finding a good compromise between importation and exportation. Henceforth, based on the high quality of the Pakistani sugar compared to the other products, and the interesting potential of using it as fuel in more than one section in the industry, the government aims at increasing the subsidies to use the surplus of the produced sugar, to reduce efficiently the fuels' imports.

According to the statistics of the Renewable fuels Association for 2019, encouraging the production of Ethanol from crops, mainly from sugarcane should be one of the priorities of the research in Pakistan, as it is made in other countries such the USA for many reasons. A major reason is an energetic one, since the sugarcane-based ethanol production is an efficient form is the most efficient and the low-cost form of biofuel (*US department of Energy*, 2018) as it is producing around 600 gallon per acre.

A second reason is that the sugarcane-based ethanol production is not harmful for the environment as it gives 90% reduction in carbon dioxide emissions (*PSMA report*, 2019).

As shown in Figure 4. Pakistan is one the most important sugar consumer in the world. Henceforth, it will be interesting to moderate firstly this consumption, and to find a good compromise for the sugarcane exploitation between its ethanol-based production purpose and food industry one. One proposed measure was to substitute sugarcane by corn essentially in period with low available crop.



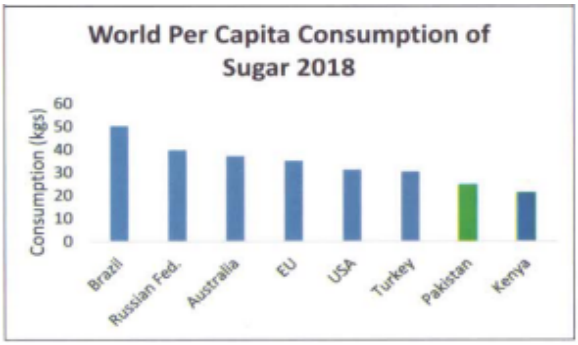


Figure-5 US market of Ethanol (US AFDC, 2019)

According to (Arshad, Abbas and Iqbal, 2019), the resulting blend E20 is a better option for gasoline substitution as compared to E10. Henceforth, the two gasohol blends have more than one economic advantage and also the ability to cut down GHG emissions and enhance opportunities for improved social welfare.

Environmental impact: Reducing the greenhouse, GHG, gas emission

It is possible to reduce efficiently the GHG generation by producing ethanol and blending it with conventional fuel. This solution has positive impact which can be noted in each step of the production process. It has more than one positive environmental impact: one tied to the transport sector, where oil consumption is minimized since it is blended to bioethanol, and consequently, the resulting air pollution is also reduced. Another impact is affecting the health side, where several diseases such as respiratory diseases, lung cancer, heart diseases are efficiently reduced (Zuberi and Baker, 2014).

Reducing the carbon dioxide, CO_2, emission
Despite the low quantity of CO emission of the ethanol compared to other fuels, the Pakistan is still suffering from high emission of CO_2 into the atmosphere. This emission is the result of the ethanol combustion during the sugarcane growth and is responsible of 66% of the whole emission into the atmosphere. Finding a balance between gases emissions should prevent this type of air pollution (Zuberi and Baker, 2014).

Social impact investing in bioethanol production should be a source of substantial employment opportunities. In fact, since the sugar industry is the biggest agro-industry in the Pakistan, it is the source of the livelihood of the majority of farmers. The ethanol industry includes also other jobs in different fields: the chemical engineering field, the biochemistry and even the microbiological one (Farooq, Bangviwat and Gheewala, 2020).

Encouraging the ethanol production should provide more job opportunities and hence finding more solutions to the employment problems in the country.

Economic impact

To improve the ethanol export, a quantity of 2.0 million tons of molasses has been converted into alcohol per year in Pakistan. The exported ethanol is oriented to the Italy and the Japan with high price in the market, ranging from US$ 800 to US$ 1000 per ton, which presents an excellent value-addition in economy (Farooq, Bangviwat and Gheewala, 2020).

Other models of ethanol producers in the world

Previously, we have presented the existing sugar-based ethanol production model in Pakistan. This section covers two other models: the US model and the Brazilian one.

As shown in Table-1, these two countries are among the world major sugarcane producing countries in the world.

Table-1 World Major sugarcane producing countries (in million Tonnes) for 5 years and their ranking (ISO sugar year book 2020)

Name	2019-20	2018-19	2017-18	2016-17	ranking
India	29.66	33.3	32	20.5	1
Brazil	29.17	29.29	31.9	38.9	2
Thailand	14,05	15.44	14.674	9.865	3
China	9.31	9.2	10.31	9.3	4
Mexico	6.18	5.92	6.007	5.975	5
Pakistan	5.3	6.25	6.615	7.074	6
Australia	4.250	4.64	4.8	5	7
USA	3.260	3.4	7.72	7.39	8
Guatemala	2.96	2.69	2.745	2.75	9

Sugarcane-based ethanol production model in the USA

In figure 5, we show that the American production of ethanol has been improved in the last decade to cover the consumption needs. In fact, American is encouraging the ethanol production which has shown that using Ethanol has affected positively more than one sector as described in the following

Ethanol production benefits as a biofuel

The Ethanol is a renewable and hence is considered as a suitable solution for transportation sector. It, as an alternative fuel, it can prevent efficiently the environment from emission. According to (US AFDC, 2019), it can be used in some low-level blends like E10 (whose composition is 10% ethanol and 90% gasoline), the E15 (which consists of 10.5% to 15% of ethanol), or also the E85 (which is flex fuel).

Its impact on the energy security

According to (US AFDC, 2019), the US is importing 3% of its petroleum, and the transportation sector presents 30% of total U.S. energy needs and consequently more than70% of American petroleum consumption. Henceforth, to decrease efficiently fuel consumption and the transportation fuel costs, it will judicious to provide advanced measures to use the ethanol as alternative fuel and consequently to enhance the national security.

Job Impacts

Ethanol production creates jobs in rural areas where employment opportunities are needed. According to the Renewable Fuels Association, ethanol production in 2019 accounted for more than 68,600 direct jobs across the country (Pocket Guide to Ethanol (2020).

Gases Emissions

As occurred with the Pakistan, based on a life cycle analysis, it was observed that GHG emissions are reduced on

average by 34% with sugarcane-based ethanol production, compared with gasoline and diesel production and use.

Sugarcane-based ethanol production model in Brazil

The Brazilian model is a benchmark for the other countries as it uses sugarcane for producing ethanol for a sustainable energy future since 1970s. It can be suited as an ideal model essentially for 3rd world countries as it does not need sophisticated technologies like imported and expensive wind or expensive solar infrastructure. Brazil's ethanol production is expected to drop 16% as sugar-based ethanol plants divert toward sugar production, according to a report from the US Department of Agriculture's (USDA) Foreign Agricultural Service (FAS) (Wang et al, 2014).

The ethanol produced from sugarcane sugar juice is referred to as first generation (1G) ethanol, and hence the Brazil has the lowest ethanol production cost worldwide compared to other sugar-derived types of ethanol (Macrelli, Mogensen and Zacchi, 2012). Currently, with the improvement of the capacity of the 1st G ethanol industry and the adding of the 2nd G of ethanol (which produced from lignocellulosic biomass like wood, straw and sugarcane bagasse), the Brazilian biofuel industry is expected to enlarge to meet the increasing domestic market needs (*MAPA*, 2012).

As depicted in Figure 6, the total ethanol production was estimated at 37.38 billion liters in 2019. According to the he global sugar market, the Brazil is the second-largest producer of ethanol, after the USA, with an output of 35 billion liters in 2019. Whereas the American ethanol market is based on corn production, the Brazilian one is relied on sugarcane production.

In figure 7, it is clear that ethanol plays a key role in the Brazilian market and participates for almost 50% of fuel demand.

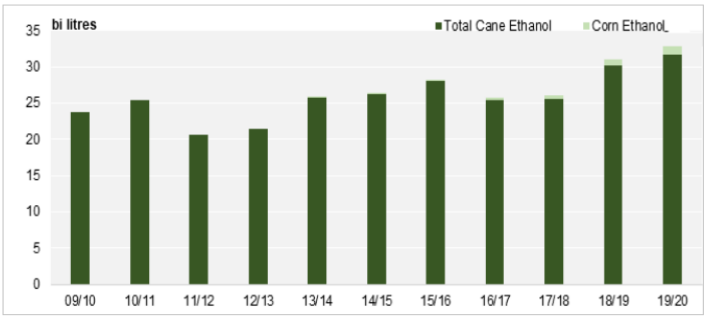


Figure-6 Sugarcane versus cane-based ethanol production in Brazil

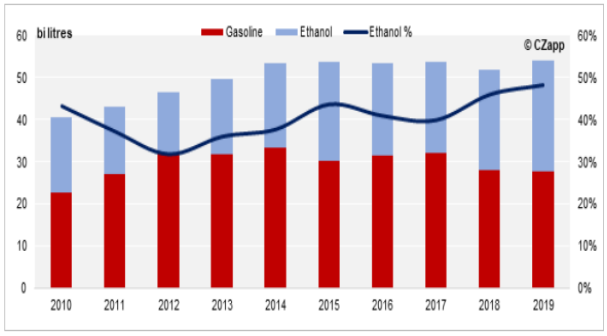


Figure-7 Brazilian Fuel Demand

Ethanol production benefits to replace gasoline

Replacing fossil fuel by producing ethanol in several sectors was the key decision considered in the history of Brazil since 1920, a measure that pushes Brazil in the first rank in the world to be the best example in replacing fossil fuels. In the last decade, producing ethanol becomes the most dominant product in in the Brazilian market. In fact, other measures were adapted respectively in 1975 and 1979 to face fossil fuel crises; these measures were based on blending ethanol to gasoline, or using entirely ethanol in cars to efficiently reduce the oil import cost. Many other government policies were proposed as financial policies to promote the total change towards ethanol production such as: loans with low interest or opportunities for state-owned companies. This governmen-tal interest can be shown in Figure 7, where the curve presenting the Brazilian ethanol demand is increasing in the last decade compared to Gasoline.

Gases emissions

The change to ethanol and ethanol blend has decreased emissions of harmful gases through the atmosphere and helped Brazil to reduce harmful impact of such gases on the environment especially for transport emissions. Since produced sugarcane-based ethanol helps to reduce GHG emissions by between 40-62 % compared to other fuels like gasoline, São Paulo has authorized a first fleet for ethanol-powered buses (Wang et al, 2014).

Ethanol role in foreign export

According to Figure 8, thanks to its foreign export strategy, the Brazil has been ranked as the world's ethanol largest exporter for many years, but since 2014, it lost its rank to the US.

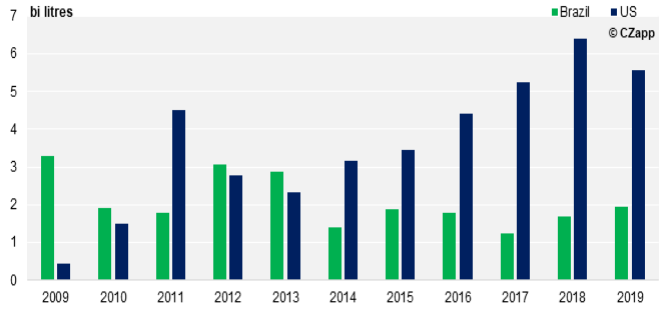


Figure-8 Brazil versus US Ethanol exports , (The Energy Series: The Brazilian Ethanol Market, 2020)

Adopted policies to improve Brazilian Ethanol industry

Many policies were adopted to promote ethanol-based fuels in Brazil. One key purpose was tied to the automobile industry, where it was required to redesign cars and engines to be suitable to such biofuel. Consequently, 80% of Brazilian cars in Brazil are flex fuel-based engines, with blends including alcohol and gas.

DISCUSSION

In Pakistan, to realize a good compromise between food security and a sustainable advancement in energy sector, it is required to opt for the molasses-based ethanol production. In this context, this solution can be suitable for many targets: promoting bioethanol technology to take socioeconomic advantages and reduce pollution atmosphere. Due to lack of proper research, industry has also not been initiated in Pakistan yet. There is a long way to go. Therefore, the government has to step up for a sustainable solution to our energy crises. It is really hard to import from abroad, as US and European countries are also facing their own crisis on energy. Therefore, Pakistan should invest and introduce ethanol based fuel, as it has the potential to be a quick solution to our energy woes. With regards to the Brazilian ethanol production model, the possibility of ethanol fermentation directly from sugarcane is worthing a spate of interest and suitable governmental policies should be eventually made. As far as the environmental benefits are considered, using biofuels overshoots conventional fossil fuels with a total respect to the energy sustainability. Besides, the gases' emissions can be efficiently reduced if biofuels and even their blends are used. Another key advantage consists in producing energy from bagasse and stillage; it will be innovative for the industry to be equipped with novel units for wastage processing in order to have energy efficient coproducts. A third requirement is tied to finding good compromise for food market, especially for sugar one by realizing a balance between sugar-based Pakistani foods needs and foreign export. Finally, according to (Tariq et al. 2014), Pakistan will have a potential of 563 million liters of ethanol production per year, which indicates an important decrease in the use of fossil fuels. Henceforth, when considering biofuel-based transport, it is necessary to provide an infrastructure for flex fuel

engines. Finally, the export of molasses and alcohol must be stopped by the Government to ensure the availability of molasses for local ethanol production.

CONCLUSION

In the light of this study, sugarcane-based ethanol production presents a great potential for the Pakistan. The lack of governmental policies and suitable infrastructure bars the sector from flourishing. Financial encouragement incentives and research is required to improve the sugar agriculture and encourage farmers. Following the US model and particularly the Brazilian one, such policies should make ethanol as a successful fuel substitute. In this context, the Pakistani government has also to provide subsidies to some industries using biofuels and flex engines, and to control the bad impacts on environment by boosting the biofuel use.

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