A REVIEW OF ENERGY ANALYSIS OF ETHANOL FUEL IN PAKISTAN

Ali Hussnain Khan Khichi
Demontfort University Leicester, UK
Emial: dr.alikhichi@gmail.com

ABSTRACT

Pakistan is the 5th largest producer of sugar cane in the world and ranks 8th in the consumption of sugar. Corn also forms an important cereal crop of the county. Despite of the enormous potential of sugar cane and corn growth, the country suffers from energy and economic crises owing around 25% of its foreign imports to fossil fuels. With the country's focus shifting towards renewable energy and biofuels, production of ethanol-based fuel from surplus sugar cane is an emerging area of research. Pakistan has around 90 operational sugar mills, but the production of sugarcane has fallen from 7200 tons in 2018 to 5500 tons in 2019 mainly due to farmer's discontent regarding the pricing and the delayed start of crushing season. This research will review techniques of producing ethanol from corn and sugar cane, its energy analysis and striking a possible balance between the use of sugar cane for servicing the food industry and the energy sector simultaneously. The research will also consider the markets of sugarcane and corn in the country.

Keywords: Ethanol, Gasohol, Renewable Fuels, Biofuels

INTRODUCTION

As Pakistan gears up for its aspirations to explore renewable energy potential of the country amid serious energy and economic crises, biofuels form an important factor in the equation of sustainability. The country drives its economic strength from agriculture, which is the foremost industry of the country. Pakistan has four seasons and ideal soil conditions for the growth of various type of crops.

However orthodox techniques of agricultural development and poor infrastructure along with weak policies of the government have reduced the productivity of the sector as compared to its net potential. Lack of industries for processing raw materials is also an area of concern as it forces the country to export raw material instead of finished goods and thus the profitability decreases.

Another avenue that needs attention in the country are the increasing imports which cause a considerable amount of foreign exchange to flow out. Pakistan total consumption of oil product was about 19,680,000 tons per year from which 11,590,000 tons per annum was produced from the local refineries and rest 8,090,000 mt was imported (Ministry of finance, 2020). It makes the 41.105 of the total need of Pakistan. Similarly, the energy sector is also heavily depended on these fuels as hydal and renewable generation infrastructure is minimal.

Similarly, another sector of the industry that depletes most of the fossil fuels is the automobile industry. Non efficient fuels and engines cause loss of energy and cause a lot of environmental hazards. According to ministry of climate (2012) Pakistan forms a part of the most vulnerable countries to global warming. Although Pakistan contribute very less to greenhouse gas emissions, but according to Climate south Asia network (2018) Pakistan is one of the countries which is hit hard by the global warming. The sector also lacks innovation and technological development.

In view of the above considerations, Pakistan has a huge potential of producing biofuels from its key crops of sugarcane and corn. Many countries including Thailand, Malaysia, India, and Brazil have made unprecedented success in using sugarcane to produce ethanol which is further mixed with gasoline to make blends. Pakistan is the 5th largest producer of sugar cane in the world with around 90 sugar mills processing the crop (Iso Sugar, 2020). Therefore when Pakistan is among the top 10 producer of sugar cane and also sugar, it has the ability to produce more ethanol, which can be blended into petrol to bring down the cost of foreign import of oil and save the environment.

Life cycle assessment of the aforementioned crops need to consider understanding how they are handled, and a primary energy analysis estimate is given to understand the energy potential of ethanol from these crops. The methods of evaluation of these parameters have also been discussed in this paper.

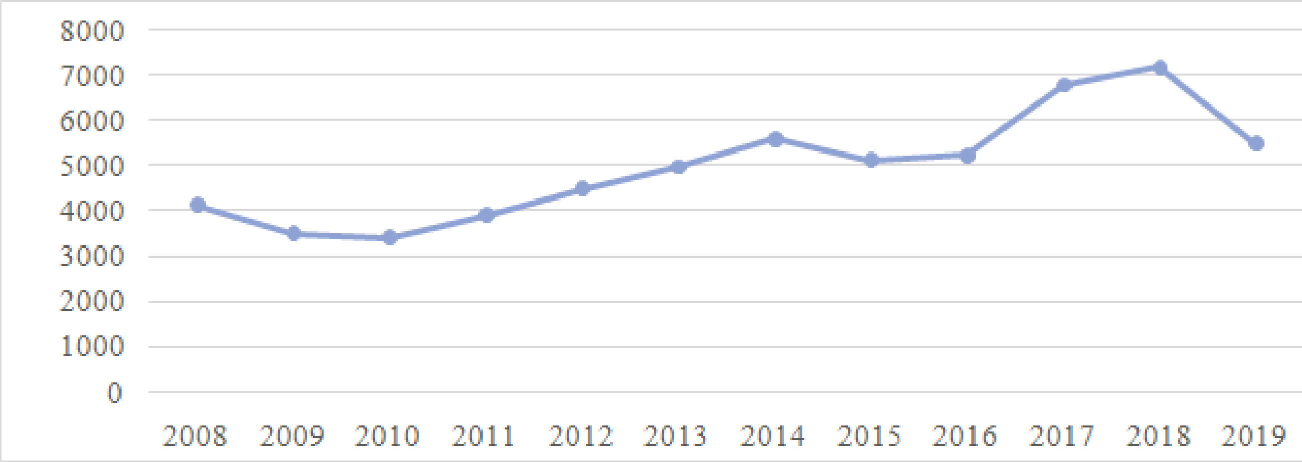
I. Corn and sugarcane production in Pakistan

Pakistan being an agricultural country has favorable conditions for the cultivation of corn and sugarcane. Starting from corn, it is one of the most important cereals produced by the country after rice and wheat. Its production per annum is approximately 7.2 million MT and it grows on approximately 1.4 million hectares (Ministry of Finance, 2020). The production is increasing due to increase in area, better seeds quality for yield and favorable returns. This crop is only grown in KPK province and Punjab province. It is cultivated twice a year in Punjab and once a year in KPK. The yield of KPK is higher than Punjab corn (USDA Foreign Agriculture Services ,2019). It gives a great opportunity to have a first distillery based on corn and to have a value-added product such as DDGS which is a high fiber feed.

Sugar cane is one of the key crops of Pakistan. Sugar cane is grown on high delta areas in the country. Its cultivation has a particular cycle which ranges between 2 to 5 years of growth from one plantation. After the cycle ends, new crop has to be cultivated for proper yield. Province wise breakdown of sugar cane production indicates a distribution of 66.8% of sugarcane area to Punjab, 24.8% to Sindh and around 8.2% to KPK (PSMA, 2020). Sugarcane is planted in either spring or autumn. However, the preferred season for the activity is autumn. Having an enormous potential in the subject plantation, Pakistan lags behind due to some pressing issues that are yet to be answered. Some of the key issues with respect to the cultivation and growth of sugarcane are shortage of water resources, improper land and its preparation, poor handling of ratoon crop, uneven use of fertilizers, lack of incentives for farmers, soil infertility and lack of agricultural research and education.

On the policy level, the government is taking initiatives to strengthen the sugarcane industry. The rates for sugarcane are determined in consultation with the mill owner and farmer representatives and governed by Ministry of National Food Security and Research. The tariff for 40kg sugar ranges between 180 PKR to 182 PKR (PSMA, 2020). Agricultural research institutes are being set up and funded by the government for effective research in the subject area. The sugar produced in Pakistan is of higher rate as compared to the international market due to which subsidies are given to export the surplus sugar (PSMA, 2020). however, the government in order to discourage imports, also offers certain subsidies to the sector. Apart from the potential of sugarcane to be effectively used as a fuel it is directly or indirectly used in many industries including paper, chip board, chemicals, plastics, synthetics, and detergents etc. The growth trends of sugarcane with respect of time have been given in figure 01.

Fig. 1. Sugarcane Production in Pakistan Source: Author data taken from Psma annual report 2019



II. CORN AND SUGAR CANE BASED ETHANOL PRODUCTION

The two main methods of producing ethanol are from corn and molasses (sugar cane). A lot of research has been done in an attempt to compare the effectiveness of corn-based ethanol against molasses-based ethanol. One of the primary examples is USA where most of the ethanol is produced from corn and its successfully running and they are working on E15 and E85 (Renewable fuels association, 2019). A challenge is to integrate the existing sugarcane and corn production with sub systems than can produce ethanol. Another challenge is to strike a balance between using corn and sugarcane for food industry and the energy sector simultaneously. But this problem can be tackled as corn is not the major food crop in Pakistan but mostly used by the feed industry. A good thing about corn-based ethanol is that it produces very high protein DDGS feed as by product. Sugarcane based ethanol is the most efficient form of biofuel with respect to corn and cellulose (US department of Energy, 2018). It is also the cheapest method of achieving the fuel. Rapeseed produces around 100 gallon of biofuel per acre, Corn produces around 400 gallon per acre and sugarcane produces 600 gallon per acre. It is also environment friendly as it gives 90% reduction in carbon dioxide emissions (Hira, 2011). A bottleneck in the production of ethanol from sugarcane is that the sugarcane crop is not available around the year. To solve this issue, corn feedstock methods may be employed in period in which sugarcane is not available. The Brazilian model is a benchmark for the world with respect to using sugar cane-based ethanol for a sustainable energy future which was set up in 1970s. It is an ideal model for 3rd world countries as it does not require specialized technologies such as imported and expensive wind and solar infrastructure. It is also pertinent to note that all research indicates that initially the cost of this ethanol-based fuel is more than conventional fuels. However, it is important to work towards the optimization of renewable fuels as it is inevitable for a sustainable growth, keeping in view the depleting fossil fuel resources. On a policy level, subsidies will be required to promote ethanol-based fuels. Over a period of time, as technology evolves, optimization in the cost of production of renewable fuels will be achieved. The automobile industry would have to redesign their engines so that they comply with ethanol-based fuels. Such steps were taken by the Brazilian government to promote ethanol-based fuels by motivating the automobile industry. 80% of the cars in Brazil today are flex fuel-based vehicles with alcohol and gas blends.

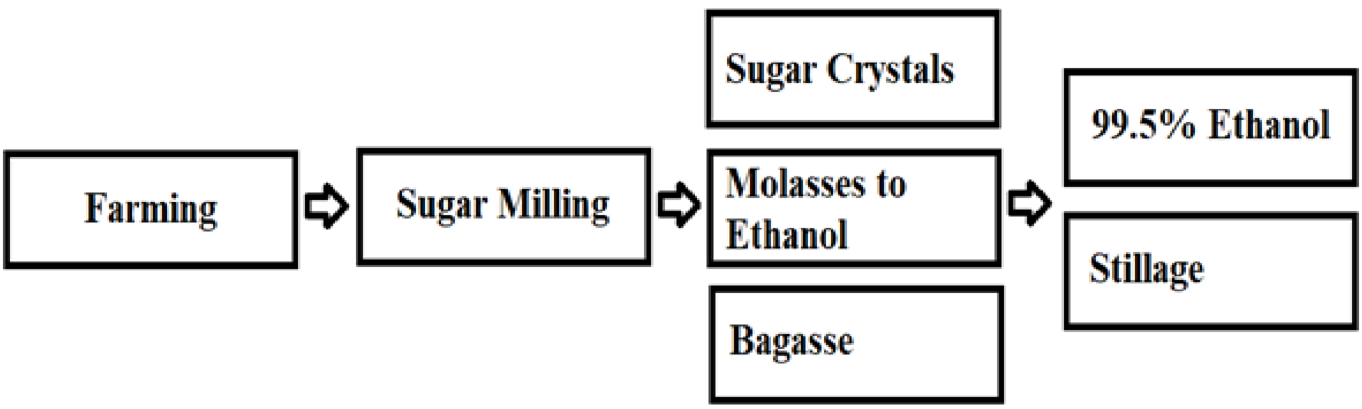
III. LCA and energy analysis for sugar cane based ethanol

The Life cycle assessment of the ethanol production from sugarcane begins with defining the system boundaries. A very similar and simple model is considered as given in (Gheewala et al., 2008). The first step in the cycle is "farming & cultivation" which includes the preparation of land, watering, maintenance of crops and managing the sugar cane crop rotation. The next step is sugar milling which includes the important crushing stage, boiling, seeding and extraction of sugar crystals. The outcome of this produces two sub products, molasses, and bagasse. Bagasse is already being used to produce electricity and the molasses has the potential of producing the renewable ethanol-based fuel. The next step is producing ethanol from molasses which is the highest energy consumption process and has room for optimization. According to an estimate, the ethanol conversion takes up to 68.6% of total energy (Gheewala et al., 2008). Molasses is converted into dilute alcohol using the fermentation process. The resultant material is distilled and dehydrated to achieve remainder of this process is termed as stillage and can be used for electricity generation. Stillage treatment has an important role making biofuels economical as compared to conventional fossil fuels. Rice husk and wood waste can also be used for this purpose. Generally, coal is used as driving fuel to convert molasses to ethanol. The last important component in this LCA is the transportation involved on different levels from cultivation to flex fuel transportation. It is pertinent to note that almost all the sugar mills in Pakistan have co-generation plants for using bagasse for electricity generation, however inefficiency prevails. This development is a recent phenomenon after incentives were given to the sugar mill owners to finance these plants. The engineering processes in this regard will become more efficient over time. The energy analysis on a Life cycle assessment accounts for the energy cost for all processes. There are three important parameters to be considered while accounting for the total energy analysis, the formulas for which are given below:

$$EnergyRatio(ER)=\frac{Renewab}{FossilF}$$

$$NetEnergyValue(NEV)=EnergyContent$$

Keeping in view the above key parameters research per (Gheewala et al. 2008) suggests that Energy Ratio of ethanol-based fuel to fossil fuels is 0.72 MJ which shows the inefficiency of the process. However, if we calculate energy value with respect to gas and diesel respectively, the values come out to be 1.24 and 1.19 MJ respectively which is an encouraging result. Similarly, the Net Energy Value of this process is also low and comes out to be around -5.67 MJ per liter mainly due to low ethanol conversion rate and recovery from stillage. Similarly, the process has a total energy input of around 706.2 MJ out of which 39.9% is contribution from fossil fuel and 29.6% is petrol input. However, the net renewable energy values for ethanol are good and come out be around 5.95 MJ per liter and its ER is 1.39. In conclusion, the production of molasses depends on the sugarcane industry. Ethanol can also be produced from sugar juice, but it will bring down the production of sugar. According to (Tariq et al. 2014), Pakistan has a potential of producing 274 million liters from 24.5-million-ton excess sugarcane.



IV. LCA and energy analysis of corn based ethanol

The Life Cycle of corn is similar to that of sugar cane. The processes involved in extracting ethanol from corn broadly starts from corn production which includes seeding, irrigation, and fertilization. Then transportation of corn is carried out to the plants where ethanol is produced. The various steps involved in the production of ethanol from corn include the conversion of starch to glucose, fermentation, distillation, filtration, and dehydration. The byproduct of this process are dried distillers' grains which are used as a livestock feed. Stillage is also achieved which may be used to produce energy. The positive estimate of Energy ratio including the co products comes out be around 1.08 and the lower estimate is around 0.8. Now if ethanol-based fuel may be used in the process instead of fossil fuel in a suitable ratio, better values of ER may be achieved. The carbon emissions are substantially reduced as a consequence of using corn-based ethanol fuel. It can be understood by the following chemical reactions.

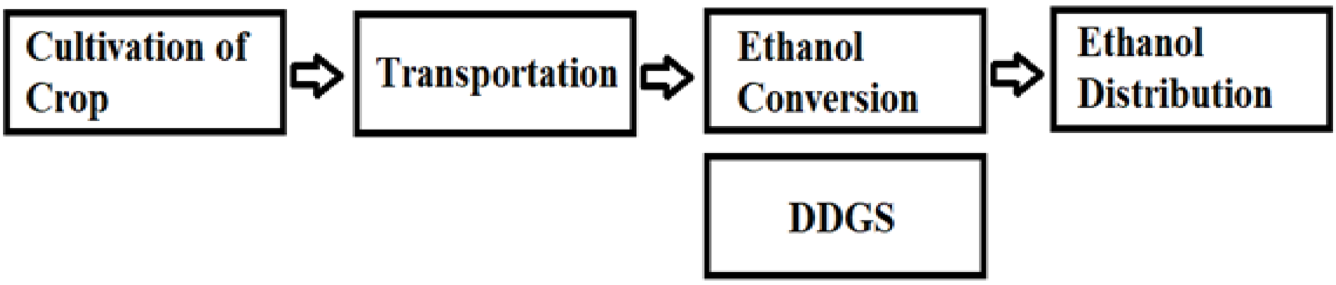
$$2C_2H_5OH + 2CO_2$$

The combustion of gasoline is given as

$$16CO_2 + 18H_2O$$

Fig. 3. Treatment of Corn is Pakistan

It is evident that acarbob emiisions are reduced by a factor of 14 when ethanol based biofuels are employed. The life cycle of corn based ethanol is given in Figure 03.



DISCUSSION AND RESULTS

Analyzing the life cycle and energy analysis trends for ethanol production from corn and sugarcane, interesting results can be inferred. As far as the environmental advantages are concerned, biofuels surpass conventional fossil fuels with respect to the sustainability of energy resources. The carbon emissions are substantially reduced if biofuels or their blends are used. Similarly, production of energy from conventional wastage such as bagasse and stillage is also an important advantage. It presents an innovative way forwards where the existing industries may be equipped with additional units to process wastages to produce energy efficient co products. It also presents a way forward to use the wastage from other industries such as rick husk etc. as a source of energy. There are also certain global obstacles to biofuels starting from ties with food commodity markets. Lack of commodity exchange-based trade, Protectionism in sugar markets, strong groupings of sugar mill owners, lack of infrastructure and the need of flex fuel vehicles. Some recommendations for the optimization of the process are also discussed further. Production of ammonia should be done by nitrogen fixation instead of steam reforming. Engine efficiencies of the agricultural machines must be increased to save fuel. Less energy intensive crops such as sugarcane should be preferred over corn. Non thermal methods of pretreatment of crop must be used. The boiler efficiencies for the distillation process must also be increased. Anaerobic fermentation should also be given preference where applicable. Another important avenue for the use of biofuels are flex fuel vehicles. It is important to note that if ethanol is mixed with conventional fuels in ratios of less than 20% no change in the engine design is necessary. According to an estimate, Pakistan will have a potential of 563 million liters of ethanol production annually (Tariq et al. 2014). This also indicates a consequent decrease in the use of gasoline and conventional fossil fuels.

CONCLUSION

In the light of the above discussion it is concluded that Pakistan has an enormous potential of producing Ethanol from Sugar cane and corn but due to the lack of infrastructure, lack of political ownership and bad policies, the sector has not flourished.
The processes employed in the life cycles are not optimized and fairly orthodox which result in energy wastages and lower values of energy ratios and net energy values. Resources and further research is required to improve the areas as identified in this paper starting from the nitrogen used in the fertilizers to the treatment of stillage.
Sugar mill owners must be empowered with effective policy making to take ownership of this venture and work towards making ethanol a successful fuel substitute, following the Brazilian model which has been extremely successful. Along with that the government also needs to provide subsidies to the industries working in the field of biofuels and flex vehicles.
Lastly, the environmental deterioration must be controlled, preserving the depleting natural resources and the use of biofuels is an important step in this regard.

REFERENCES

Gheewala, S, Garivait, S, Nguyen, T 2008, “Full chain energy analysis of fuel ethanol from cane molasses in Thailand”, *Applied Energy,* vol no. 85, pp. 722-734.
Hira, A 2011, “Sugar rush: Prospects for a global ethanol market”, *Energy Policy,* vol no. 39, pp. 6925-6935.
Tariq, A, Zuberi, J, Baker, D 2014, “Ethanol Production and Fuel Substitution in Pakistan promoting sustainable transportation and mitigating climate change”.
Ministry of Finance (2020) *Agriculture,* [online] Available at: *http://www.finance.gov.pk/survey/chapter_20/14_Energy.pdf* Accessed: 1st Sep 2020)
MINISTRY OF CLIMATE CHANGE (2012) NATIONAL CLIMATE CHANGE POLICY, [online] Available at: http://www.mocc.gov.pk/gop/index.php?q=aHR0cDovLzE5Mi4xNjguNzAuMTM2L21vY2xjL3VzZXJmaWxlczEvZmlsZS9Nb2NsYy9Qb2xpY3kvTmF0aW9uYWwlMjBDbGltYXRlJTIwQ2hhbmdlJTIwUG9saWN5JTIwb2YlMjBQYWtpc3RhbiUyMCgyKS5wZGY%3D Accessed: 1st September 2020
Climate South Asia network (2018) *Global Warming and Its Impacts In Pakistan,* [online] Available at: *http://climatesouthasia.org/global-warming-impacts-pakistan/* Accessed: 1st September 2020
ISO. (2020). About Sugar | International Sugar Organization. [online] Available at: https://www.isosugar.org/sugarsector/sugar.(Accessed: 1st September 2020)
Ministry of Finance (2020) *Agriculture,* [online] Available at: *http://www.finance.gov.pk/survey/chapter_20/02_Agriculture.pdf* Accessed: 1 September 2020
USDA Foreign Agriculture Services (2019) *Pakistan Grain and Feed Annual,* [online] Available at:*https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Grain%20and%20Feed%20Annual_Islamabad_Pakistan_3-28-2019.pdf* Accessed: 1 September 2020
Pakistan Sugar Mills Association (2020) *Annual report 2019,* [online] *Available* at: *https://www.psmacentre.com/documents/PSMAAnnualReportColorcopy2019.pdf* Accessed: 1st Sept. 2020
US department of Energy (2018) *Ethanol Production and Distribution,* [online] Available at: *https://afdc.energy.gov/fuels/ethanol_production.html* Accessed: 1 September 2020.
Renewable fuels association (2019) *Focusing Beyond E10,* [online] Available at: *https://ethanolrfa.org/wp-content/uploads/2020/02/RFA_beyondE10.pdf* Accessed: 1 Sept. 2020.