Environmental Research Journal
MEDWELL PUBLICATIONS SINCE 2000

Techno Economic Analysis of Bio-Ethanol Production as Bio-Fuel in Karnataka State

M.R. Srinivas and A.C. Lokesh
Faculty of Management and Commerce, Ramaiah University of Applied Sciences, 560 054 Bangalore, India

Key words: Bio-ethanol, ligno-cellulosic ethanol, techno-economic analysis, energy, growth

Corresponding Author:
M.R. Srinivas
Faculty of Management and Commerce, Ramaiah University of Applied Sciences, 560 054 Bangalore, India

Page No.: 83-87
Volume: 13, Issue 3, 2019
ISSN: 1994-5396
Environmental Research Journal

Abstract: India is the second largest commercial energy consumer in Non-OECD East Asia, comprising 19% of the region's total primary energy consumption. Economic growth in India has largely been associated with increased energy consumption. While 60% of total energy needs in India are met by commercial energy sources, remaining 40% are comprised of non-conventional fuels. To increase the percentage of non-conventional fuel the government of India has planned to blend 10% of ethanol to the gasoline which requires 2660 mL of ethanol but currently, we have only 1340 mL of ethanol production capacity from sugarcane industries from all over India with a blend rate of 5%. As per the bio-fuel policies of India, the feed stocks used for producing bio-fuel must come from non-edible source only. Ethanol produced as of now in India is through molasses which is a by-product of sugar industry. This ethanol has a well-established market in liquor, pharmaceutical and in other industries. Hence, other sources of ethanol production feed stock as per Indian policies is from cellulose. In view of this rational, this study was carried out to analyse cellulosic ethanol production from five feed stocks (i.e., straw, bagasse, eucalyptus, poplar and switch grass). This techno-economic analysis of cellulosic ethanol production of the five feedstock revealed that poplar based ethanol production was economically (Rs.49/L) and environmentally (carbon foot print: 10.6 kg/mega joule) feasible.

INTRODUCTION

World energy resources: World energy resources are the estimated maximum capacity for energy production given all available resources on Earth. They can be divided by type into fossil fuel, nuclear fuel and renewable resources.

Fossil fuel: Estimating the remaining fossil fuels on the planet depends on a detailed understanding of the Earth's crust. While modern drilling technology makes it possible to drill wells in up to 3 km of water to verify the exact composition of the geology, one half of the ocean is deeper than 3 km, leaving about a third of the planet beyond the reach of detailed analysis.

Coal: Coal is the most abundant and burned fossil fuel. This was the fuel that launched the industrial revolution and has continued to grow in use; China which already has many of the world's most polluted cities (the middle landfill) was in 2007 building about two coal-fired power plants every week. Coal is the fastest growing fossil fuel and its large reserves would make it a popular candidate to meet the energy demand of the global community, short of global warming concerns and other pollutants.

Natural gas: Natural gas is a widely available fossil fuel with estimated 850 000 km³ in recoverable reserves and at least that much more using enhanced methods to release shale gas. Improvements in technology and wide exploration led to a major increase in recoverable natural gas reserves as shale fracking methods were developed. At present usage rates, natural gas could supply most of the world's energy needs for between 100 and 250 years, depending on increase in consumption over time.

Oil: It is estimated that there may be 57 ZJ of oil reserves on Earth (although, estimates vary from a low of 8 ZJ (statistical report oif world energy, 2009), consisting of currently proven and recoverable reserves, to a maximum of 110 ZJ consisting of available but not necessarily recoverable reserves and including optimistic estimates for unconventional sources such as tar sands and oil shale. Current consensus among the 18 recognized estimates of supply profiles is that the peak of extraction will occur in 2020 at the rate of 93-million barrels per day (mbd). Current oil consumption is at the rate of 0.18 ZJ per year (31.1 billion barrels) or 85-mbd.

Indian Ethanol production: India is the largest producer of sugar in the world. In terms of sugarcane production, India and Brazil are almost equally placed. In Brazil, out of the total cane available for crushing, 45% goes for sugar production and 55% for the production of ethanol directly from sugarcane juice. This gives the sugar industry in Brazil an additional flexibility to adjust its sugar production keeping in view the sugar price in the international market as nearly 40% of the sugar output is exported. The annual projected growth rate in the area under sugarcane at 1.5% per annum has doubled during the last 5 years. This is because it is considered to be an assured cash crop with good returns to the farmers vis-a-vis other competing crops. India is currently passing through a glut situation with closing stocks at the end of the year of over 100 lakh tons, since, 1999-2000. Correspondingly, molasses production has also increased.

Review of literature: The technical analysis of bio-ethanol production from lingo-cellulosic residues like empty fruit brunches, rice husks and sugar cane baggase (Aden, 2008). The ethanol production was figured utilizing aspen plus. The composition of the three feed-stocks, i.e., empty fruit brunches, rice husks and sugarcane baggase were required for simulation which was collected from the literature study and web. This process of producing bio-ethanol from lingo-cellulosic residues is more economical than producing bio-ethanol from maize or sugar cane. Among the three lingo-cellulosic residues considered Rice husk and Empty fruit brunches are cheaper compared to sugarcane baggase and have high yield value of ethanol, i.e, 0.52 and 0.38, respectively. However, the sugarcane baggase are comparatively costlier and have low yield value of ethanol. Due to their abundant availability and cheaper purchase price the lingo-cellulosic residues are more economical when compared to the conventional way of producing ethanol.

This techno-economic study compares several process technologies for the production of ethanol from lingo-cellulosic material, based on a 5-8 year time frame for implementation (Aden and Foust, 2009). While several previous techno-economic studies have focused on future technology benchmarks, this study examines the short term commercial viability of biochemical ethanol production. With that goal, yields (where possible) were based on publicly available experimental data rather than projected data. Four pretreatment technologies (dilute-acid, 2-stage dilute-acid, hot water and Ammonia Fiber Explosion or AFEX) and three downstream process variations (per-vaporation, separate 5-carbon and 6-carbon sugars fermentation and on-site enzyme production) were included in the analysis. Each of these scenarios was modeled and economic analysis was performed for an ''nth plant" (a plant with the same technologies that have been employed in previous commercial plants) to estimate the Total Capital Investment (TCI) and Product Value (PV). PV is the ethanol production cost including a 10% return on investment. Sensitivity analysis has been performed to assess the impact of process variations and economic parameters on the PV. The dilute-acid pretreatment process has the lowest PV among all process scenarios which is estimated to be $1.36/L of Gasoline Equivalent (LGE) ($5.13/gal of Gasoline Equivalent (GGE)). Sensitivity analysis shows that the PV is most sensitive to feedstock cost, enzyme cost and installed equipment costs. A significant fraction of capital costs is related to producing heat and power from lignin in the biomass (Aden *et al*., 2002). Cellulosic ethanol production has yet to be commercialized. Hence, a pioneer plant is expected to be more costly to build and operate than an nth plant. To assess the impact of technological maturity on pioneer plant cost, a cost growth analysis was performed. The estimated value of PV for the pioneer plant is substantially larger than for the nth plant. The PV for the pioneer plant model with dilute-acid pretreatment is $2.30/LGE ($8.72/GGE) for the most probable scenario, and the estimated TCI was more than double the nth plant cost (Aden and Foust, 2009).

Aim: To carry out a techno-economic analysis of Bio-ethanol production as bio-fuel In Karnataka state.

Objectives of the study:

- To study the status of bio-fuel requirements in Karnataka
- To study and analyze the value chain of bio-ethanol production process from various feedstock's
- To study the economics of bio-ethanol as bio-fuel in Karnataka
- To suggest feasible Bio-ethanol production based on Techno-economic analysis of various feedstock's

MATERIALS AND METHODS

So, now the total project investment for various feed stocks is represented: From Table 1 the feed stock poplar has a low project investment, the reason for the low cost investment is because in the hydrolysis process cellulose and hemicelluloses will get separate easily within the available biomass treatment capacity but whereas for other feed stocks biomass treatment capacity must be increased by 1 or 2 as per the requirement (Badger Engineers, Inc., 1987; Anonymous, 1987).

Now, we shall see what would be the total cost to produce an ethanol through various feed stocks: From the graph (Fig. 1), we can make out the fluctuation of total cost from Rs30.75-Rs50/L of feed stocks bagasse and switch grass, respectively, this variation occurs due to fluctuation in raw material cost which includes transportation of feed stocks to plant and unloading those.

Now, we shall consider the Ethanol yield for various feed stocks: From the above graph (Fig. 2) it clearly shows the range from 200-349 L ton^{-1} of feed stocks bagasse and poplar respectively, the reason behind the rate of fluctuation is because of moister content in the feed stock. If there is less moist it gives more yields likewise if it contains more moister then it ends up with less yield (Table 3).

Now let us concentrate on the carbon foot print of different feed stocks ethanol: From the above graph (Fig. 3) it can be found the different rate of carbon content in the final product value (Ethanol), the high carbon content can be observed in molasses, i.e., 15.1/mega joule and low carbon content is eucalyptus, i.e., 9.7/mega joule from Table 4.

Now, we shall see the calorific value for various Ethanols: From the above graph (Fig. 4), the information regarding how much energy that can be obtained by using various feed stocks when it is burnt that 6 can be obtained through calorific vaue. The Ethanol from bagasse feed stock will release more energy, i.e., 29700 kilojoules/kilogram and where as Ethanol from eucalyptus feed stock will release less energy, i.e., 26578 kilojoules/kilogram from Table 5.

Table 1: The total project investment for various feed stocks

Feed stock	Total project investment in Rupee
Molasses	100000
Bagasse	125000
Straw	99500
Eucalyptus	93000
Poplar	90500
Switch grass	95400

Table 2: The total cost to produce an Ethanol through various feed stocks

Feed stocks	Total cost to produce an Ethanol in rupee (L)
Molasses	Rs. 39
Bagasse	Rs. 30.75
Straw	Rs. 47
Eucalyptus	Rs. 36.10
Poplar	Rs. 49
Switch grass	Rs. 50

Table 3: The Ethanol yield for various feed stocks

Feed stocks	Ethanol yield (L ton^{-1})
Molasses	238
Bagasse	200
Straw	291.3
Eucalyptus	339.9
Poplar	349
Switch grass	314.1

Table 4: The Carbon foot print of different feed stocks Ethanol

Feed stocks	Carbon foot print (mega joule)
Molasses	15.1
Straw	12.5
Bagasse	10.2
Eucalyptus	9.7
Poplar	10.6
Switch grass	11.4

Table 5: The calorific value for various Ethanols

Feed stocks	Calorific value (kilojoules kg^{-1})
Molasses	28500
Straw	27190
Bagasse	29700
Eucalyptus	26578
Poplar	28908
Switch grass	27650

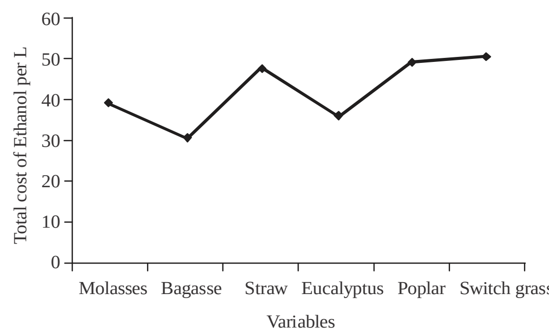

Fig. 1: The total cost of Ethanol per L

Till now it is been discussed with various graphs with respect to total project investment, total cost of ethanol, ethanol yield rate from various feed stocks, carbon foot prints of various feed stocks and calorific value of various

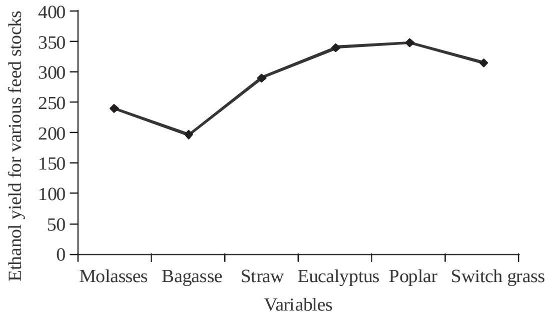

Fig. 2: Ethanol yield for various feed stocks

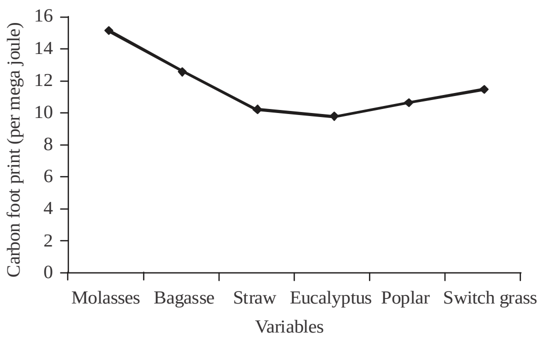

Fig. 3: Carbon foot print for various feed stocks

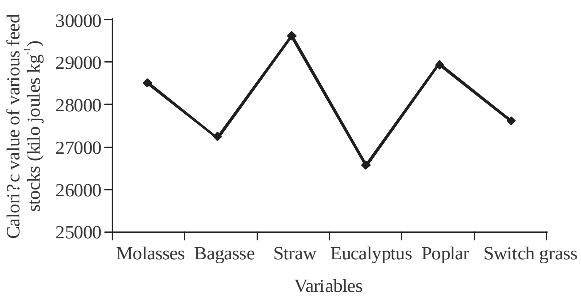

Fig. 4: Calorific value of various feed stocks

feed stocks. So, all these were carried out to suggest best feed stock from which the Ethanol plant can be installed in Karnataka. Before carrying out this study our key focus was towards to increase the supply rate of ethanol (so that, we may increase the blend rate from E5 to E10) and also stop the toxic gases emitted from automobiles (like carbon monoxide, hydrocarbons, sulphuric dioxide and nitrogen oxides) by keeping this two factors the study was titled by "Techno Economic Analysis of bio-ethanol production as bio-fuel in Karnataka state". So, now we shall see which feed stock will be feasible as per the study carried out:

- Poplar will be the feasible total project investment among various feed stocks that is Rs. 90500
- Bagasse will be the feasible total cost of Ethanol among various feed stocks that is Rs. 30.75/L
- Poplar will be the feasible Ethanol yield among various feed stocks that is 349 L ton^{-1}
- Eucalyptus will be the feasible or best Ethanol that can be used with respect to carbon foot print that is 9.7 kg of carbon will be emitted per mega joule
- Bagasse will librates more energy when it is been burnt and its calorific value will be 29700 kilo joules kg^{-1}

RESULTS AND DISCUSSION

Key findings of the study: Poplar feed stock will give a best feasible cost for total project investment. Though Bagasse feed stock's total cost is lesser than other feed stock, as we know the total cost of all feed stocks are majorly affected by the cost of raw material of feed stocks with respect to transporting (loading and unloading). So, if we make sure that the feed stock is available next to Ethanol plant then obviously the cost of feed stock will come down and hence, better to go with poplar feed stock.

Poplar feed stock will yield best Ethanol that is 349 L ton^{-1} as per this study among other feed stocks considered. Though eucalyptus and Bagasse emits 9.7 and 10.2 kg of carbon per mega joule, respectively, it doesn't make lot of difference when we consider Poplar feed stock that is 10.6 kg per mega joule.

Coming on to energy produced, bagasse will stand first that is 29700 kilo joules/kg. Poplar feed stock will stand in second place where it librates 28908 kilo joules/kg of Energy.

CONCLUSION

As per this study poplar can be considered to be the feasible feed stock among other feed stocks because as Poplar feed stock will contributes more towards feasibility. Here, five feed stocks are been considered and according to that poplar feed stock will contribute more towards profit and yield. As discussed in future direction third generation feed stocks are at growth stage and if it is been considered then there may be more yield and profit gained per litre of ethanol with good purity but only we can take into consideration of that after it is been implemented in pilot plant till then it would be better to consider the second generation (lingo-cellulosic) feed stock for the purpose of ethanol extraction.

REFERENCES

Aden, A. and T. Foust, 2009. Technoeconomic analysis of the dilute sulfuric acid and enzymatic hydrolysis process for the conversion of corn stover to ethanol. Cellulose, 16: 535-545.

Aden, A., 2008. Biochemical production of ethanol from corn Stover: 2007 state of technology model. NREL Report TP-510-43205, National Renewable Energy Laboratory, Golden, Colorado.

Aden, A., M. Ruth, K. Ibsen, J. Jechura and K. Neeves *et al*., 2002. Lignocellulosic biomass to ethanol process design and economics utilizing co-current dilute acid prehydrolysis and enzymatic hydrolysis for corn stover. NREL Report TP-510-32438, National Renewable Energy Laboratory, Golden, Colorado.

Anonymous, 1987. Economic feasibility study of an enzymatic hydrolysisbased ethanol plant with prehydrolysis pretreatment. Subcontract Report SERISTR-231-3135, Badger Engineers, Inc., Cambridge, MA. Chem Systems, Inc., Tarrytown, New York.

Badger Engineers, Inc., 1987. Economic feasibility of an acid-hydrolysis-based ethanol plant. Subcontract Report SERI-STR-231-3142, Prepared under Subcontract ZX-3-03096-2, Badger Engineers, Inc., California, USA.