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TECHNO-ECONOMIC AND ENVIRONMENTAL STUDY FOR BAGASSE DRIVEN ETHANOL - A CASE STUDY

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Abstract- Nowadays, the use of ethanol as automotive fuel has been given much attention by the developing countries, such as Iran. The emergence of air pollution of mega cities in the country has forced to replacing fossil fuel by ethanol. Therefore, in this research ethanol production from bagasse is studied from techno-economic and environmental point of views. Among of different technologies for ethanol production, concentrated acid method has been chosen, because it is more applicable than others. Moreover, in this research economic parameters such as breakeven point, net present value (*NPV*), internal rate of return (*IRR*) and payback period (*PBP*) are determined and discussed. The result of this study shows ethanol production from bagasse is feasible economically.

Keywords: Automotive Fuel, Bagasse, Economic, Environmental, Ethanol, Gasoline, Technical.

I. INTRODUCTION

Air pollution has been changed into one of the difficulties of the modern societies. Tehran and other mega cities are not an exception. The main reason for air pollution in these cities is related to the traffic of various types of cars. In order to find a solution to this problem, it is necessary to offer clean fuel for them. One of the secure ways to achieve this goal is to use bio-ethanol, which could be as an additive or substitute for gasoline without negative effects on environment [1-5]. Currently, principal raw materials for production of ethanol are agricultural crops such as sugarcane juice (sucrose) and corn (starch). However, there is a strong challenge that expansion of ethanol production requires alternative sources, such as agricultural wastes, which has affluence state, low price and diversity of application. Among these resources, the fiber waste of sugarcane industry, which is called bagasse, has attracted the views [2-4]. Most of the time, the first application which is considered for bagasse, is to burn them in the boilers at combined heat and power plants (CHP). Nevertheless, bagasse is a proper feedstock for biochemical processes to produce ethanol; because of the high rate of carbohydrate, the relatively low rate of lignin, and accessibility [5-7].

Most of the developing countries including Iran are still using the oxygenate additives such as lead and MTBE in the gasoline. However, the impacts of ethanol application as an additive in gasoline are significantly less than those associated with continued use of MTBE and lead. Therefore, the time has come to replace these materials with ethanol to reduce their side effects on human and environment.

Using ethanol as vehicle fuel, alone or combined with other fuels has attracted much attention in recent years. The reason is the long-term environmental and economic benefits as compared with fossil fuels and the results of many researches confirm this issue. In 2002, a comparison was made between producing ethanol from bagasse and burning it in the farm. The result of this study showed that the production of ethanol from bagasse is preferable environmentally [1]. In other study in 2006, a comparison was carried out for comparing the production of ethanol from bagasse, and burning it to produce energy in the CHP plants in India. The study proved, by the near future, application of bagasse in CHP will be preferable environmentally, as compared with the production of ethanol in enzyme hydrolyze form. However, when the enzyme technology finds necessary development, it will have superiority in the application of energy production [5].

In 2005, in Brazil, the application of ethanol 99.6 gl in the state of adding to gasoline in sizes of (20-26%) (anhydrous ethanol) and ethanol in the form of net fuel 95.5 gl (hydrated ethanol) were compared from the viewpoint of the rate of CO_2 gas emission. The rate of reduction of CO_2 gas emission for the two states of consumed ethanol, is 5.4 MtC, in which the share of anhydrous ethanol is 53 percent, whereas in the case of hydrated ethanol, it was 47% [8]. In 2011, a research was made on one unit of producing sugar from sugarcane to study the application of bagasse in producing ethanol and energy production with the help of prevailing systems from technical, economic and environmental standpoints. The results of this research showed, at present method of energy production is economic but in not very far future, production of ethanol in enzyme form, which has a higher output, will be more economic [9].

The production and application of bio-ethanol from biomass resources, with regard to the unique features of this compound as a vehicle fuel, can play an undeniable role in connection with the sustainable development of Iran in the economic, environmental and social pivots. The establishment of production units near production place has many economic advantages. Out of lignocelluloses resources in Iran, sugarcane bagasse is noticeable for planning either qualitatively (combination of lignocelluloses parts) and quantitatively (the considerable rate of annual production) and either from the viewpoint of concentration of production centers (part of Khuzestan province).

This paper intends to do a feasibility study for a typical unit of bio-ethanol production from bagasse in moderate size with an applicable method in Iran.

II. APPLICATION OF ETHANOL AS AN AUTOMOTIVE FUEL

The application of ethanol as a secure, clear and economical fuel has received much attention in recent decades. The two main pivots of paying attention to ethanol fuel automobiles are the improvement of the fuel combustion, and noticeable reduction of the environmental pollutants. Gasoline is a mixture of hundreds of hydrocarbon which has usually 7 to 12 carbons. The oxygenated gasoline is resulted by adding ethers or oxygenated alcohols. Ethanol and MTBE are at present the famous combinations of oxygenated additives, which are consumed in the world.

The application of ethanol in the automobile fuel is performed in two ways. The first state is the application of pure ethanol, which will require many changes in the engine of automobiles. This will make it get less attention. The other state is to add ethanol to gasoline in fewer quantities such as 5 and 10 percent for which there will be no need to any change in automobile engines. The characteristics of different combinational percentage of gasoline and ethanol are presented in the Table 1.

Table 1. Features of different mixtures of ethanol and gasoline [1]

Features	Gasoline/Ethanol				
	100/0	90/10	80/20	70/30	0/100
Thermal value (kJ/kg)	42680	41050	39430	37850	26800
Density (kg/lit)	0.7336	0.7375	0.7448	0.759	0.7439
Octane number	95	96.7	98.3	100	106
Fuel consumption (lit/100km)	9	8.9	9.2	10.3	12.3

III. SITUATION OF GASOLINE PRODUCTION AND CONSUMPTION IN IRAN

The main oil products, which are produced at present in 9 refineries, in the country, include gasoline, liquefied petroleum gas (LPG), kerosene, gasoil, fuel oil and air fuels. In 2010, their total production amounted to the level of 82.7 billion liters (226.5 million liters per day). This quantity has had 4.4 percent reduction in comparison with the year 2009, which has been due to reduction in gasoline consumption. From the total consumption of energetic oil products, gasoil with the share of 42 percent (34.7 billion liters), gasoline with the share of 27.1 percent (22.4 billion liters) and fuel oil with the share of 17.8 percent (14.7 billion liters) allocate the first to the third rank to themselves [10].

Since Iranian crude oil is recently heavy oil, and on the other side, the local demand is mainly for light and distilled productions, so the existing refining capacities in the country cannot respond the increasing daily demand for some of these products such as gasoline and gasoil. In recent years, for the supply of gasoline and gasoil, the country has become dependent on imports of these products and this has been associated with a high cost. Iran is the fourth large producer of oil in the world but the shortage of refining capacity and high local demand for oil products, have converted Iran into an importer of gasoline. Therefore, considerable financial damages have been imposed [12]. Figure 1 shows the rate of gasoline import during 1982-2010. According to the Figure 1, the gasoline imports in 2010 amounted to 10.34 million liters per day, which has had a 5.1 percent reduction in comparison with the previous year (21 million liters per day). In this year, more than 3.8 billion liters gasoline for 2.2 billion dollars was imported into the country. Thus, about 16.9 percent of gasoline needed by the country has been supplied through imports [10].

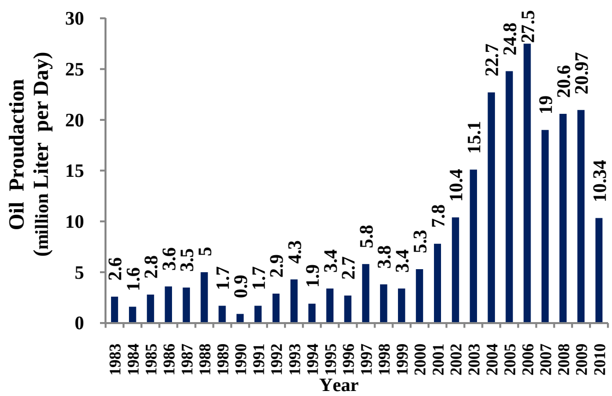

Figure 1. Gasoline imports in 1982-2010 (million liters per day) [10]

According to the studies, it has been shown that the increase of octane number by adding the suitable additive material, such as ethanol has a direct effect on the rate of gasoline production in refineries, in the country. This causes the reduction of the import of this product. Regarding to the Table 1, by adding 10 percent ethanol to gasoline, the octane number will move up, and the rate of fuel consumption will decrease.

The gasoline consumption in 2010 amounted to 61.3 million liters (58.6 million liters of gasoline and 2.7 million liters of super gasoline) per day which has had a 5.4 percent reduction as compared with the previous year. Figure 2 shows the comparison of production and consumption of gasoline during 1989-2010. The reduction of gasoline quota and replacement of CNG instead of gasoline at the rate of 15.2 million cubic meters was the main reason for the reduction of gasoline consumption in 2010. The average daily consumption of each automobile with the calculation of consumption of each 3.5 motorcycle equal to one automobile was 4.5 liters in 2010. Also in this year, the average per capita of gasoline consumption in lieu of per person is 313 liters.

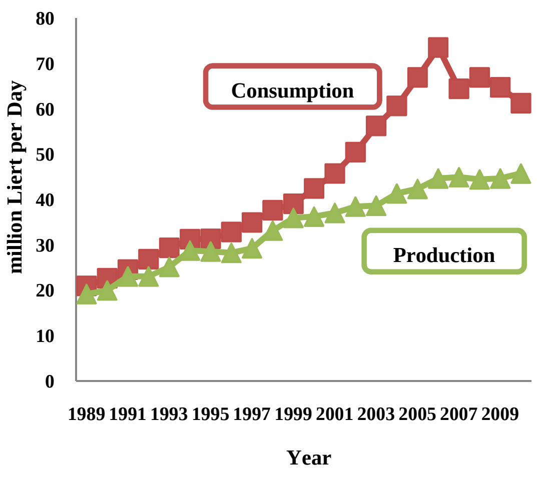

Figure 2. A comparison between production and consumption of gasoline during 1989-2010 (million liters per day) [10]

Table 2. The comparison emission of pollutants and greenhouse gases in the energy consumption sectors in Iran (Ton) [12]

Sector/Gas (Ton)	NO_x	SO_2	CO	SPM	CO_2	CH_4
Energy end use Residential, commercial and public	122915	108508	55047	11491	138430655	4045
Industry	166167	343374	33740	18278	84862090	2137
Transportation	910778	543911	8382221	307270	133940429	39640
Agriculture	72365	73758	28545	31487	13662214	827
Energy sector consumption	-	-	-	-	17247491	356
Refineries Power plants	564040	608527	151517	24873	150385016	3345
Total	1836265	1678078	8651070	393399	538527894	50314

IV. GASOLINE PRICE IN IRAN

The rate of gasoline subsidies in 2009 amounted to 8.1 billion dollars (9300 Rials equal to 1 USD in 2009), which has had 82.2 percent reduction in comparison to the previous year. The average gasoline per capita subsidies in lieu of per person amounted to 113.7 US$ in this year [11]. According to the information obtained from National Company for Oil Products Distribution in Iran, the cost price for the production of per liter regular gasoline was 0.76 US$ in 2009. At the same time, the regular gasoline was sold per liter for 0.43 US$. In 2012, the subsidies of gasoline is decreased more, and one liter of gasoline price changed to 0.65US$ (12260 Rials equal to 1 USD in 2012).

V. THE ENVIRONMENTAL IMPACTS RESULTING FROM GASOLINE CONSUMPTION IN IRAN

Air pollution as one of the dimensions of environmental pollution, have negative effects on human and natural societies in local, regional or global scale. Therefore, developed countries by making investment in the section of renewable energies, improvement of energy and new technologies have taken significant steps in controlling the environmental pollutions of energy section. Although, developing countries such as Iran still are facing serious challenges. According to the views of experts of environment, Iran ranks sixth to eight from the viewpoint of total production of greenhouses in the world. Of course, with the increasing trend of automobile production in the country and avoiding production and consumption of biofuels instead of gasoline and gas oil, it is likely that the rank to go up [13].

Table 2 shows the rate of emission of polluting and greenhouses gases in the transportation sector as compared with other energy consuming sectors in 2009 [12]. The transportation sector has the highest share in the emission of various types of gases (except CO_2, and SO_2) among energy consuming sectors in the country. Moreover, the total amount of emission pollutants for transportation is more than 144 million tons which is ranked in the second after power plants sector.

VI. PRODUCTION AND CONSUMPTION OF MTBE IN IRAN

At present, MTBE is the main materials being added to gasoline as oxygenate material. It is such that the application of this material in the country in 2004 was about 900 thousand tons and all of these quantities have been imported from abroad into the country. The total value of MTBE imports into the country in this year was about 250 million dollars. However, by launching the first phase of the MTBE production line in Imam Khomeini Petrochemical Complex, it was reduced about 300 thousand tons from the volume of the annual import of this material.

The MTBE production line of Petrochemical Complex of Imam Port was launched with an investment cost of 214 million dollars. Its nominal capacity was 500 thousand tons per year.

The percentage of MTBE added to gasoline in the country is varying and has been announced by Fuel Efficiency Consumption Organization in the range of 3-15 percent. The price of imported MTBE is 0.84 US$/liter (according to Singapore price).

VII. PRODUCTION AND CONSUMPTION OF ETHANOL IN IRAN

More than four decades pass from the beginning of the industrial production of ethanol in Iran. Ethanol in Iran is produced mainly with the purpose of medical and hygienic applications and in two general forms of industrial alcohol (ethanol with purity degree of mainly 70 and 90 percent along with other additives to prevent the illegal application) and white alcohol (ethanol with the purification of 70, 90, 96 and recently about 100 percent without additives). In 2010, totally 40 registered production units inside the country has been working on producing ethanol in the country.

The process is being used in all mentioned production units is the fermentation of simple sugar materials (monosaccharide) by using the microbial ordinary fermentation. The primary material in this processes are molasses of sugar beet, date and sugarcane molasses.

The nominal capacity of ethanol production in the country is 273 million liters but due to lack of proper market; most of the alcohol factories operate below their nominal capacity. The medical and hygienic consumption in Iran are about 60 million liters per year, which are supplied in form of 60, 120 and 600 milliliter bottles [14].

VIII. BAGASSE THE UNIQUE BIOMASS RESOURCE FOR PRODUCING ETHANOL

Bagasse is one of the by-products of the sugar industry, which is obtained after sugar extraction. Each ton of sugarcane produces 250-300 kilogram of bagasse [15, 16]. Its chemical combination is cellulose fibers, water and some solvable solid materials. The bagasse fiber, due to the high rate of carbohydrate can be considered as the proper primary materials in biological procedures to produce ethanol [17]. Bagasse in average includes 3 percent Sucrose, 38 percent cellulose, 27 percent hemicelluloses, 20 percent Lignin and 12 percent of other materials.

Only 70 percent of produced ethanol at the global level is produced through chemical methods. The rest of necessary ethanol is supplied through fermentation of agricultural crops (first generation bioethanol). 60 percent of agricultural crops are sugarcane, and sugar beet and the rest are starchy materials, which produce ethanol through fermentation methods. Since these materials are in the food cycle, so that they are expensive. The cost of starchy materials for the present production of bioethanol is estimated to be 40-70 percent of production cost [18, 19]. Using agricultural products such as sugarcane and beet demands a high amount of cultivable lands and proper water supply. This case, i.e. producing from the agricultural products can hardly be a proper way to produce ethanol to supply alcohol fuel in the country. Using lignocelluloses materials such as bagasse (second generation bioethanol) as the cheaper primary material makes bioethanol more competitive compare with fossil fuels [20, 21, 22].

IX. THE CURRENT STATUES OF SUGARCANE AND BAGASSE PRODUCTION IN IRAN

At present, the main sugar cane plantation and industry complexes in Iran are Haft Tapeh, Karun, and Sugar Cane & Side-industries Development. The overall area under sugar cane is 114,000 hectares, and there is a capacity to increase this in the future. The annual production of sugar cane in recent years is about 10,000,000 tones, and bagasse production is about 3,000,000 tones. Although, one third of the bagasse (about 1,000,000 tones) is already being used in various ways, some is used inefficiently, and about 2,000,000 tones remains unused and is destroyed annually.

X. THE ENVIRONMENTAL ADVANTAGES OF THE APPLICATION OF BIOETHANOL FROM BAGASSE AS AN AUTOMOTIVE FUEL

The environmental effects resulting from the replacement of gasoline with bioethanol from bagasse in automobiles have many advantages, which are presented as below precisely:

- Accumulating and applying additional bagasse in plantation and industry of sugarcane companies and converting them into ethanol will prevent from burning a noticeable rate of bagasse in the nature. Moreover, it reduces air pollution resulting from different pollutants, such as CO_2 and CH_4.
- Protecting water and soil resources due to reduction of air pollution resulting from consumption of fossil fuels.
- The transportation sector is responsible for one third of CO_2 emission to biosphere and consequently the replacement of fossil fuels with clean fuels with a natural base, such as ethanol, will play a considerable role in reducing greenhouse gases and consequently the greenhouse effect. If pure ethanol to be used instead of gasoline for car fuel, up to 90% reduction in the rate of emitted CO_2 from car exhaust will be obtained. Also, if 10% of ethanol to be mixed with gasoline, there will be about 20-30% reduction of CO_2 [23].
- By adding 10 percent of ethanol to gasoline, due to the increase of oxygen of fuel, and consequently better efficiency of combustion, the rate of emitting CO from exhaust will be reduced by about 25 to 30 percent [23].
- The mixture of ethanol and gasoline for 20 percent ethanol and 80 percent gasoline shows that CO and HC have decreased in them noticeably [1]. The studies, which have been done by Ford Company in Brazil, show that the emission of harmful materials in the cars which use the mixture of gasoline and alcohol reduces CO by 43%, CH by 24%, and NO_x by 21% in comparison with the gasoline fuelled cares [20].
- A considerable reduction in other emitted environmental pollutants from automobiles exhausts:

- PM10 (suspending particles less than 10 micron): They can enter the lower lung and are extremely poisonous.
- SO_x: As ethanol does not have sulfur, the rate of emission of SO_x from ethanol fuel is zero.
- The aromatic compounds: Opposite to gasoline of which 45% are aromatic compounds such as poisonous gases of benzene and toluene, the ethanol does not have these materials.

- Another crucial issue is the lack of lead in exhausted gases, which are added to enhance the number of octane to gasoline.
- The content of oxygen in ethanol is higher than MTBE (two times of MTBE), so the efficiency of ethanol in the equal volumes is two times of MTBE. By replacing MTBE by ethanol, the environmental harms resulting from it, which includes following materials, are omitted.

- In studies which have been performed on animals, it has been proved that they are potentially cancer producing and dangerous.
- The high emission and durability of this material (half life to two weeks) creates an intensive pollution in surface and subterranean waters.
- During production, transfer, distribution and application, they are evaporated. They enter blood circulation through inhalation and may create symptoms such as headache, vomiting, nose or mouth irritation, coughing, giddiness and imbalance.

XI. APPROPRIATE TECHNOLOGY FOR ETHANOL PRODUCTION FROM BAGASSE IN IRAN

Different processes have been introduced to convert different cellulosic feed stocks into ethanol by hydrolysis [24, 25]. In light of the importance given to the commercial of a process, it was necessary to review the existing processes to ascertain their performance in terms of adoption status and economics, especially for a case study in Iran. The main factors for choosing process are complexity technology, equipment, and highly qualified personnel. These complexities sharply limit the applicability of hydrolysis in developing countries, such as Iran.

There are many methods to produce bioethanol of which the most prevailing one are the application of acid for hydrolyze cellulose and hemi-cellulose which following that, the action of fermentation on sugar and production of ethanol is performed [24]. Other method, which has been noticed by many researchers, due to its higher potential, is the method in which hydrolyze is done by Enzyme. This method demands further work due to the complexity of technology and higher costs [5]. However, it is forecasted that it will be developed and become more economic in the near future [24, 26]. The factors, which are influential in reducing the costs of ethanol production through this method, include: reduction of enzyme price, progress of the stages of process.

The process of producing ethanol is performed in four stages of pretreatment, hydrolyze, fermentation and purification. The main challenge in the conversion of biomass into ethanol is the pretreatment step. The pretreatment is required for its degradation, due to the structure of the lignocellulosic complex. It is necessary to remove lignin, hydrolyze the hemicelluloses, and to decrease crystalline cellulose fractionally. The hydrolyze stage is performed by concentrated sulfuric acid and then acid recycles. Also, the fermentation stage is done by microorganisms' activities on the simple sugars, which lead to ethanol production. The purification of ethanol includes two stages of fractional distillation and molecular screening which leads to the production of ethanol with purity of 95% and 99.5%. Basically, acid hydrolysis is a process in which the cellulosic fraction of a waste is suspended in an acidified aqueous medium that is maintained under pressure at an elevated temperature. Cost of acid, percentage of acid recovery, and rate of acceleration of corrosion establish the maximum permissible acid concentration. For sulphuric acid, the concentration would be about 0.5% in most situations. Yield of sugar is highest at the higher temperature levels and acid concentrations. In Figure 3, the diagram of the production of ethanol from bagasse in the method of concentrated acid application is presented.

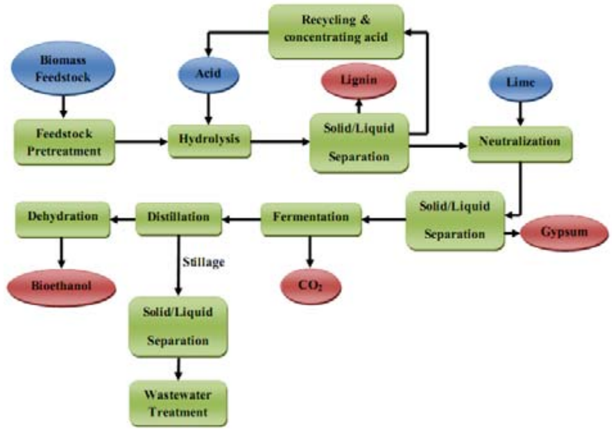

Figure 3. Flow diagram of concentrated acid process for ethanol production

XII. ECONOMIC ANALYSIS OF PRODUCING ETHANOL FROM BAGASSE

The purpose of this research has been the production of ethanol from sugarcane bagasse with a purity degree of 99.5% with the application ability in automobile fuel.

The forecasted nominal capacity in the research is 100 tons of dried bagasse, which leads to production of about 22400 liter per day bioethanol with 99.5% percent of purity. This process could be the type of closed loop. It means that all energy needs of the process are producible from its sideline products, but this issue has not been considered in this research. The design has been made only based on ethanol production. It is evident that if the process to be applied in the condition of closed loop, it will have a noticeable effect on the profitability rate of the project [24, 27, 28]. The quantities of raw materials and consuming energy and the products resulting from the processes in this capacity are presented in Tables 3 and 4. It is worth mentioning that the source of biomass as the primary materials can include all lignocellulosic materials such as paper garbage.

Ethanol production costs on a per liter basis depend on largely by feedstock and investment costs. If only non-feedstock costs are taken into account, investment costs represent an average of 75%. Second generation bioethanol is indeed heavier on investment than first generation production pathways. Economic analysis of this case study has been done according to Iran conditions. Furthermore, four important parameters (breakeven point, internal rate of return, net present value, and payback period) were calculated and analyzed, for making decision of implementing project [26, 29, 30].

Table 3. The inputs of the process of production of ethanol from bagasse in forecasted capacity

Inputs	Quantities
Materials	
Bagasse (ton/day)	100
Sulfuric acid 98% (ton/day)	5
Lime (ton/day)	11
Energy	
Electricity (KWh/day)	7200
Natural gas (m^3/day)	1000

Table 4. Outputs of the process of producing ethanol from bagasse in forecasted capacity

Outputs	Quantities
Main Product	
Ethanol 99.5% (liter /day)	22400
Secondary products	
Lignin (ton/day)(air dry)	30
Gypsum (ton/day)(air dry)	20
Carbon dioxide (ton/day)	17
Single cell protein (SCP)(ton/day)	1.2

These parameters are illustrated in details for better analyzing as follow:

A. Breakeven Point

Regarding to Equation (1) breakeven point is calculated with operating costs and total sale (*P*). The operating costs are included fixed costs (*F*) and variable costs (*V*). The fixed costs do not change with changing of production rate, including insurance, salary of fixed staffs and labors and depreciation. Moreover, variable costs are the costs that change with increasing or decreasing of production rate, including raw materials costs, energy and installations consumptions, salary of production labor, etc. If the breakeven point of the projects is much lower, it is better for the project. However, suitable and logical number for the project based on investment amount, raw materials costs, and production capacity is 30-50% [29].

$$Breakeven\ Point = \frac{F}{P - V} \quad (1)$$

B. Internal Rate of Return (*IRR*)

It is determined based on Equation (2). In this relation *R*, *C*, *r*, *I*, and *t* are income, costs, *IRR*, *FCI*, time in year until *n* (life time of the project). *IRR* is the rate that with this rate net present value (*NPV*) is equalized zero. IRR shows actual benefit rate of investment. This rate is one of the main and important economic index for making decision about implementing project. The suitable *IRR* is defined regarding account discount rating for long-term loan of banking (12-15%) in industrial projects.

$$I = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+r)^t} \quad (2)$$

C. Net Present Value (*NPV*)

The *NPV* is calculated by algebra summation of all of the inputs and outputs of cash flows or net cash flow from start of investment until the end of useful life time of the project, with defined account discount rate in a specific time that is present time (Equation (3)). Usually, useful lifetime of the projects is between 10-15 years that it is 15 years in this case study. If *NPV* has a positive value, therefore the project has acceptable economic efficiency and if not (negative value), the project is unacceptable.

$$NPV = \sum_{t=1}^{n} \frac{R_t - C_t}{(1+i)^t} \quad (3)$$

D. Payback Period (*PBP*)

Payback period is the number of years that total fixed capital investment (*FCI*) return through annual income (*AI* = net profit + depreciation + interest) of the project according (Equation (4)). The acceptable time for this period in medium scale of Industrial project is 5-7 years.

$$PBP = \frac{FCI}{AI} \quad (4)$$

Regarding to the calculations in this case study, and Tables 5 and 6; breakeven point of the project, internal rate of return, *NPV*, and payback period has been obtained 48.27% (between 30-50%), 17.3% (higher than 12-15%), positive value, and 5.72 years (between 5-7), respectively. These results prove the project is feasible as economic point of view. Moreover, the annual profit of project in comparison with fixed capital investment (*FCI*) and the costs is acceptable and economic. It is clear that implementing these projects with higher capacities of production for Iran will be more economical.

Table 5. Important values for economic analysis

Parameters	Values (US$)
Fixed Capital investment (*FCI*)	12787313
Working Capital	463210
Operating Cost (Fix and Variable Cost)	5362204
Gross Added Value	5340000
Net Added Value	6585148
Total Sale	7614580
Annual Profit	2252376

Table 6. Calculated parameters for economic analysis

Parameters	Values
Annual Production (Liter)	7392000
Product Cost (US$/Liter)	0.725
Product Sale Price (US$/Liter)	1.03
Breakeven Point (%)	48.27%
Internal rate of return (%)	17.3%
Net Present Value (*NPV*)@12% (US$)	+2533314
Net Present Value (*NPV*)@15% (US$)	+383163
Pay Back Period (Year)	5.72

XIII. DISCUSSIONS AND CONCLUSIONS

Increasing concerns about air pollution in the mega cities, in the country have motivated the search for alternative forms of automotive fuel, or additive for fuel. Since transportation sector is responsible for one third of CO_2 emission to biosphere, substitution of fossil fuels by biofuels, like ethanol, could significantly decrease environmental impacts. Ethanol and MTBE are both added as additives to gasoline for better fuel burning in the car engine. Both of these materials are added to gasoline as oxygenate materials. However, the content of oxygen in ethanol is higher than MTBE (two times of MTBE), so the efficiency of ethanol in the equal volumes is two times of MTBE. Ethanol is a fully healthy and secure material, whose combustion will lead to the production of insignificance rate of water vapor and carbon dioxide. It has a greater effect, in comparison with MTBE in connection with the reduction of poisonous emissions, greenhouse gases and formation of photochemical smog.

The design of cost-effective processes for fuel ethanol production implies the selection of the most appropriate feedstocks, and the selection and definition of a suitable process making possible the conversion of raw materials into the ethanol. Result of comparison of different technologies for ethanol production showed that the most applicable ones is concentrated acid. Therefore, a typical size of this technology was designed and studied economically. The costs of feedstocks are reduced, when the lignocellulosic materials are used as feedstocks. Bagasse is one of the main lignocellulosic materials which are found in vast quantities. In Iran, about 2000000 tones of bagasse are destroyed annually; and it is necessary to determine the efficient application for extra bagasse.

Economic analysis in this study was carried out in a typical unit of ethanol production with 100 tons/day bagasse, which leads to production of about 22400 liter per day bioethanol with 99.5% percent of purity. The results showed the breakeven point, *NPV*, internal rate of return (*IRR*), and payback period of this project are in acceptable values; therefore, this project with this capacity or higher is feasible for implementation.

NOMENCLATURES

IRR: Internal rate of return (%)
MTBE: Methyl tert-butyl ether
NPV: Net present value (US$)
PBP: Payback period (Year)

REFERENCES

[1] K.L. Kadam, "Environmental Benefits on a Life Cycle Basis of Using Bagasse-Derived Ethanol as a Gasoline Oxygenate in India", Energy Policy, Vol. 30, pp. 371-384, 2002.
[2] R.P. Beeharry, "Extended Sugarcane Biomass Utilization for Exportable Electricity Production in Mauritius", Biomass and Bioenergy, Vol. 11, Issue 6, pp. 441-449, 1996.
[3] M.S. Bhatt, N. Rajkumar, "Mapping of Combined Heat and Power Systems in Cane Sugar Industry", Applied Thermal Engineering, Vol. 21, pp. 1707-1719, 2001.
[4] R. Mohee, R.P. Beeharry, "Life Cycle Analysis of Compost Incorporated Sugarcane Bioenergy Systems in Mauritius", Biomass and Bioenergy, Vol. 17, pp. 73-83, 1999.
[5] T. Botha, H.V. Blottnitz, "A Comparison of the Environmental Benefits of Bagasse-Derived Electricity and Fuel Ethanol on a Life Cycle Basis", Energy Policy, Vol. 34, pp. 2654-2661, 2006.
[6] C. Martin, M. Galbe, C.F. Wahlbom, B. Hahn-Hagerdal, L.J. Jonsson, "Ethanol Production from Enzymatic Hydrolysates of Sugarcane Bagasse Using Recombinant Xylose-Utilising Sccharomyces Cerevisiae", Enzyme and Microbial Technology, Vol. 31, pp. 274-282, 2002.
[7] L. Luo, E. Van der Voet, G. Huppes, "Life Cycle Assessment and Life Cycle Costing of Bioethanol from Sugarcane in Brazil", Renewable and Sustainable Energy Reviews, Vol. 13, pp. 1613-1619, 2009.
[8] A.S. Szklo, R. Schaeffer, M.E. Schuller, W. Chandler, "Brazilian Energy Policies Side Effects on CO_2 Emissions Reduction", Energy Policy, Vol. 33, pp. 340-364, 2005.
[9] E.A. Seabra, I.C. Macedo, "Comparative Analysis for Power Generation and Ethanol Production from Sugar cane Residual Biomass in Brazil", Energy Policy, Vol. 32, pp. 421-423, 2011.
[10] "Statistic Letter, Consumption of Iranian Oil Products", National Iranian Oil Products Distribution Company (NIORDC), August 10, 2012, www.niordc.ir .
[11] H. Aghayan, "Statistic Letter, Consumption of Iranian Oil Products", National Iranian Oil Products Distribution Company, Iran, 2009.
[12] Ministry of Energy, "Energy Balance Sheet", Global Changes of Energy Sector, Office of Deputy for Electricity and Energy Affairs, Office of Macro Planning for Electricity and Energy, Tehran, Iran, 2009.
[13] Guilds of Iranian Ethanol Producers, "Second Rank in the World for Iran", News-Professional Journal, No. 29, August-September 2011.
[14] Guilds of Iranian Ethanol Producers, "Approved Price for Ethanol Sale", News-Professional Journal, No. 25, April-May 2010.
[15] WADE (World Alliance for Decentralized Energy) "WADE Report on Global Bagasse Cogeneration: High Efficiency Bagasse Cogeneration Can Meet", 2004.
[16] D.A. Cerqueira, G. Rodrigues, C.D. Meireles, "Optimization of Sugarcane Bagasse Cellulose Acetylation", Carbohydr. Polym., Vol. 69, pp. 579-582, 2007.
[17] C.A. Cardona, J.A. Quintero, I.C. Paz, "Production of Bioethanol from Sugarcane Bagasse: Status and Perspectives", Bioresource Technology, Vol. 101, pp. 4754-4766, 2010.
[18] J.A. Quntero, M.J. Montoya, U.J. Sanchez, U. Garaido, C.A. Gardona, "Fuel Ethanol Production from Sugarcane and Corn: Comparative Analysis for a Colombian Case", Energy, Vol. 33, pp. 385-399, 2008.
[19] J. Sendelius, "Steam Pretreatment Optimization for sugarcane Bagasse in Bioethanol productions", Master of Science thesis, Lund University, Sweden, 2005.
[20] S.S. Madaeni, "Feasibility Study of Using Sugarcane for the Production of Energy and Basic Materials in Comparison with Oil", Faculty of Engineering, Razi University of Kermanshah, Shekarshekan Monthly Review, No. 34, pp. 24-28, 1999.
[21] P. Alvira, E. Tomas-Pejo, M. Bllesteros, M.J. Negro "Pretreatment Technologies for an Efficient Bioethanol Production Process based on Enzymatic Hydrolysis: a Review", Bioresource Technology, Vol. 101, pp. 4851-4861, 2010.
[22] L. Cucek, M. Martin, I.E. Grossmann, Z. Kravanja, "Energy, Water and Process Technologies Integration for the Simultaneous Production of Ethanol and Food from the Entire Corn Plant", Compu. Eng., Vol. 35, pp. 1547-1557, 2011.
[23] K.L. Kadam, "Environmental Benefits on a Life Cycle Basis of Using Bagasse-Derived Ethanol as a Gasoline Oxygenate in India", Proc. S. Afr. Sug. Technol. Ass., Vol. 75, pp. 358-362, 2001.
[24] C. N. Hamlinck, G.V. Hooijdonk, A. Faaij, "Ethanol from Lignocelluloses Biomass: Thechno-Economic Performance in Short, Middle, and Long Term", Biomass and Bioenergy, Vol. 28, pp. 384-410, 2005.
[25] P. Dwivedi, J.R.R. Alavalapati, L. Pankaj, "Cellulosic Ethanol Production in the United States: Conversion Technologies, Current Production Status, Economics, and Emerging Developments", Energy for Sustainable Development, Vol. 13, pp. 174-182, 2009.
[26] M.O.S. Dias, T.L. Junqueira, O. Cavalett, M.P. Cunha, C.D.F. Jesus, C.E.V. Rossell, R.M. Filho, A. Bonomi, "Integrated Versus Stand-alone Second Generation Ethanol Production from Sugarcane Bagasse

and Trush", Bioresource Technology, Vol. 103, pp. 152-161, 2012.
[27] L. Tao, A. Aden, R.T. Elander, V.M. Pallapolu, Y.Y. Lee, R. Garlock, "Process and Technoeconomic Analysis of Leading Pretreatment Technologies for Lignocellulosic Ethanol Production Using Switchgrass", Resources Technology, Vol. 102, pp. 11105-11114, 2011.
[28] H.A. Shayanfar, G. Derakhshan, A. Ameli, "Optimal Operational of Micro Grids Using Renewable Energy Resources", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 10, Vol. 4, No. 1, pp. 97-102, March 2012.
[29] S.M. Seyedhossini, M. Amoozegar, "Engineering Economic and Decision Analysis", Iran University of Science and Technology, Tehran, Iran, 2009.
[30] G.Sh. Mammadov, U.F. Samadova, F.F. Mammadov, "Economical Estimation of Solar and Wind Energies Application as Alternative of Fire Wood", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 3, Vol. 2, No. 2, pp. 8-12, June 2010.

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