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Research Article

Bioethanol and Biodiesel from Second Generation Feedstocks: A Promising Solution to Energy Shortages in Pakistan

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Abstract: Pakistan is facing acute shortage of energy which, in turn, is adversely affecting its economic growth besides discomfort to its vast population. Concurrently, the country is faced with gigantic challenges of rapid increase in population, increased number of motor vehicles on the roads, and urbanization; these adverse developments are leading to ever increasing demand for energy. Having inadequate indigenous energy resources, Pakistan relies heavily on expensive oil imports in the face of foreign exchange scarcity. Thus, the import bill for oil is a big drain on its financial resources. Therefore, alternate sources of energy are need of the hour. Biofuels offer a number of benefits: environmental, economic and geo-political benefits. This article reports an in-depth secondary research with the objective of addressing energy shortages by utilizing an alternate means. The issues related to use of ethanol and biodiesel are energy sources are discussed; and it appears that use of biofuels in Pakistan can help in reducing energy shortage to some extent.

Keywords: Biofuels, first-generation biofuels, second-generation biofuels, ethanol, biodiesel

1. INTRODUCTION

Energy is an essential requirement for day to day activities of life; one cannot think of living without this utility in modern age. Electricity is the most common form of energy used by the mankind. It is needed for cooling, heating, producing food items, running industrial units, transportation of goods, travelling from one place to another, running hospitals, offices, malls, universities and colleges. Other forms of energy like coal, lignite, oil and gas are also extensively used in industrial sector, transportation and power generation. Many countries are faced with the problem of energy shortage. The problem is more severe in developing countries. According to a MIT News (of September 13, 2013) [1], nearly 1.3 billion people live without electricity in the developing countries. The shortage of electricity contributes many vital social challenges, such as lack of food and water and inadequate healthcare. It is reported that three-quarters of the world's population still uses just 10 percent of global energy. Shortage of energy in the developing world is a symptom of much larger problem related to economic growth. Pakistan is also struggling to meet its energy requirements.

Various strategies have been adopted by many countries to deal with the energy requirement in industry as well as in daily life. These strategies include the followings:

- Energy efficient systems design;
- Use of energy efficient equipment;
- Use of alternative fuels;
- Use of waste materials as energy sources;
- Process optimization for improving energy use; and
- Reducing energy waste.

The strategies to address energy crisis can be short term, medium term and long term. In order

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to address the grave challenge of energy shortage, all the approaches may be followed. Out of a wide range of options for reducing energy shortage in the country, exploitation of renewable energy (like energy from sun, wind, water and biomass) are among the attractive options. This paper is based on secondary research and focuses on shortage of energy in Pakistan for developing a strategy to address the problem. The paper examines issues regarding use of biofuels for mitigating energy shortage in the country. The advantages offered by biofuels and disadvantages in their use are discussed. Use of ethanol or biodiesel in the prevalent economic situation of the country appears to be a viable option.

2. BIOFUELS

Unlike fossil fuels such as coal and petroleum, which are produced from prehistoric biological matters by geological processes, biofuels are produced from biological processes in agriculture. Biofuels can be obtained directly from plants or indirectly from the wastes from agriculture, industry, and other processes.

2.1 Production of Biofuels – The Global Scenario

The review report 'Biofuel Market, 2014' suggests the use of liquid biofuels since 1900 due to concerns related to greenhouse gas emissions from fossil fuels. Sugar and cereal crops such as maize, sugar cane, sugar beet, cassava, wheat and sorghum are important feedstocks for ethanol production while oilseed crops such as rapeseed (canola), soy, palm oil and jatropha are important for biodiesel (SSI Review, 2014) [2].

Production of biofuel increased globally over the years. According to REN2 [3], the global production of biofuel was only 23 billion liters per year in 2002 which reached to a level of over 110 billion liters per year in 2012. When the production of the biofuel gradually increased during this period, the market of the biofuel decreased during 2011-2012. The annual production of biofuels in 2015 was approximately of the same level as that of the year 2010. The production of ethanol increased to a level of 85.6 billion liters in 2010, which was more than twice the level of production in 2005 and further increased to 94 billion liters in 2014 [3]. Production of biodiesel increased from 3.9 billion liters in 2005 to 18.1 billion liters in 2010 and 30 billion liters in 2014 (Table 1) [3].

Table 1. Global production of ethanol and biodiesel from 2005 to 2014.

	Production (Billion liters per year)		
Biofuel	2005	2010	2014
Ethanol	< half of 85.6	85.6	94
Biodiesel	3.9	18.1	30

Source: Renewables 2016 Global Status Report (2014)

Some key statistics about top producers, top consumers, global production and expected growth of biofuels till the year 2022 are presented in Table 2 (SSI Review, 2014) [2].

Table 2. Key statistics about biofuel in global scenario.

Factor	Status
Top 5 producers of ethanol and biodiesel (87% of the total) (2010-2012)	United State (42%), Brazil (23%), European Union (14%), China (7%), India (2%)
Top 5 consumers (88% of the global) (2010-2012)	a. United States (40%), Brazil (21%), European Union (18%), China (7%), India (2%). b. United States, the European Union and Brazil consume about three fourth of the world's biodiesel and bioethanol. c. In the European Union, biodiesel accounts for approximately 70% of all renewable energy used for transportation.
Global production of ethanol and biodiesel (2010-2012)	124,141 million liters
Expected future growth	Biodiesel and bioethanol production and consumption are expected to grow about 60-70% by 2022.

Source: OECD & FAO

2.2 First Generation Biofuels

According to UNCTAD [4], the first-generation biofuels are defined based on the source of fuel from which the biofuel is derived rather than the physical nature of the biofuel itself. The Starch, sugar and oil-based food crops, as well as animal fats are main feedstock sources to first-generation biofuels. Biodiesel (mainly produced from canola, soybean and barley) and bioethanol (mainly produced from corn, wheat and sugarcane), followed by other types of vegetable oil and biogas from crop residues, are the most popular first-generation biofuels. The characteristics of these biofuels are presented in Table 3.

Table 3. Characteristics of conventional biofuels.

Biofuel Type	Feedstocks	Feedstocks Characteristics
Biodiesel	Soybean, rapeseed, mustard seed, palm, jatropha, waste vegetable oils and animal fats.	Range of feedstocks with different crop yields per hectare Production cost varies widely among countries Co-products include high-protein meal.
Ethanol	Switch grass, miscanthus, sugar cane, sugar beets, corn, cassava, sorghum and wheat	Range of feedstocks with wide yield and cost variations Co-products include animal feed, heat and power from bagasse residues Advanced biofuels are starting to become fully commercial and still have higher production costs

2.3 Second-generation Biofuels

According to the International Energy Agency (IEA) [5], second-generation biofuels are produced from lignocellulose based (composed of cellulose, hemicellulose and lignin) biomass residues. These biofuels can be used by blending them with petroleum-based fuels designated as E-10, E-20, etc. depending upon the composition of fossil fuel to bio-ethanol ratio in a blend. IEA [5] explains that second generation fuel can be used in adapted vehicles also. Some of the examples of the second generation fuels are Cellulosic ethanol and Fischer-Tropsch fuels. According to Curriquiry et al. [6], second-generation biofuels produce greater energy output than the fossil fuels. Such biofuels include a wider range of feedstock options minimizing competition on land and have much less environmental impacts. Allied Market Research [7] forecasts an attractive growth of 50 per cent market of the second-generation biofuels during 2014-2020. It is expected that the market value of second generation biofuels will be US$ 23.9 billion by the year 2020. According to Navigant Research [8], the global biofuel consumption in the road transportation sector is likely to increase from more than 122.6 billion liters per year in 2013 to more than 193.41 billion liters per year in 2022. This will boost the demand for advanced fuels by about 58%.

3. ENERGY SCENARIO IN PAKISTAN

Pakistan like many other developing countries faces considerable constraints in economic growth due to shortage of energy as well as high cost of energy. Ahmad et al. [9] state that electricity generation in Pakistan consumed 15 million tons of oil in 2008 equaling to 28% of petro-fuels consumed by the country. Pakistan imported 71% of its oil requirements in 2008 (HDIP, Pakistan Energy Yearbook [10]. At the end of the year 2005, electricity was in surplus of 1230MW but by the end of the financial year 2010 there was a shortage of 5885MW (NEPRA, State of Industry Report [11]. The average annual rise of electricity need from 2005–2010 was 8%, and is predicted to continue till 2035. It is estimated that at this rate of growth in demand, the electricity demand by the year 2050 will be 474 GW. According to Pakistan Economic Survey [12], the average electricity supply will be growing at an average annual growth rate of 11% till 2030.

Ali et al. [13] reported an increase of 63% in consumption of petroleum from 10.98 million tons in 1991-92 to 17.91 million tons in 2008-09. The import of the oil increased during this period by more than 100% (GOP, 2010a) [14]. The number of vehicles in Pakistan has increased due to increasing population and industrialization. According to NBP [15], the energy demand in Pakistan is increasing due to industrialization, growth in agriculture and service sectors, electrification of rural areas, development of new cities and increasing per capita income. According to GOP [16], the number of motor vehicles has greatly increased from 4.3 million in 1998 to 6.56 million in 2010, which accounted for an increase of 52.4%. The pollution on the roads of the urban cities in Pakistan has greatly increased over the years and is about seven times higher than the minimum standards laid down by the World Health Organization. ADB [17] argues that higher volume of greenhouse gases, sulfur oxides and particulates are the biggest contributors to pollution in Pakistan. One of the main reasons of energy crisis in Pakistan is due to lack of its own energy resources to meet the increasing demand of energy. Pakistan meets its energy requirements through import of crude oil and other petroleum products. According to GOP [14] the import by Pakistan during the period 1991-92 to 2008-09 increased by more than 100%. The rising costs of the petroleum products in the international market and increasing demand for energy has added pressure on the Pakistan's economic condition.

4. BIOFUELS: AN OPTION FOR REDUCING ENERGY CRISIS IN PAKISTAN

Asad and Khalid [18] discuss the recent tendency to reduce the petrol consumption by most of the countries in view of the increasing shortage of energy, which is due to industrialization, changing life style, urbanization and economic growth of the countries. Everyone concerned with the energy production and energy consumption is looking for alternate sources of energy. Bekiaris [19] finds biofuels as an alternative to the fossil fuels to meet the increasing demand and rising cost of energy. He cites three areas for the current interest in biofuels in Pakistan, which include environmental factors, economic factors and geopolitical factors.

- **Environmental Factors**
  - Harmful emissions of gases in industrial operations, road transport and other activities require measures to reduce the impact of the rising pollution.
  - Global warming is a serious concern and a reason for diversifying sources of energy.
- **Economic Factors**
  - High crude oil prices
  - Increasing cost of fuels due to higher cost and increasing consumption puts pressure on the economic condition and growth of the country**.**
- **Geopolitical Factors**
  - Growing dependency on foreign oil supplies provide incentives to pursue alternative fuels sources, for example use of ethanol and biodiesel [20].
  - Considering agriculture as a way to diversify energy sources of the country for a more secure and renewable energy future.
  - Effective utilization of farm based energy by producing liquid fuels derived from crops and agricultural wastes, or biofuels.

Mushrush et al. [21] suggest use of recycled soybean-derived biofuels or diesel fuel for ground transportation vehicles. Msangi et al. [22] highlight the factors that drive the demand for biofuels as rising fuel prices, growing energy demand, awareness of renewable energy resources and possibilities to expand the crop market internationally beside the long-term and important issue of global warming.

4.1 Advantages of Biofuels in Pakistan

Asad and Khalid [18] discuss the various advantages of use of biofuel in Pakistan based on the analogy from the lessons learnt from other developing countries. The advantages of use of biofuels can be classified under three major categories: Environmental factors, Economical factors and Geo-political factors (Fig. 1).

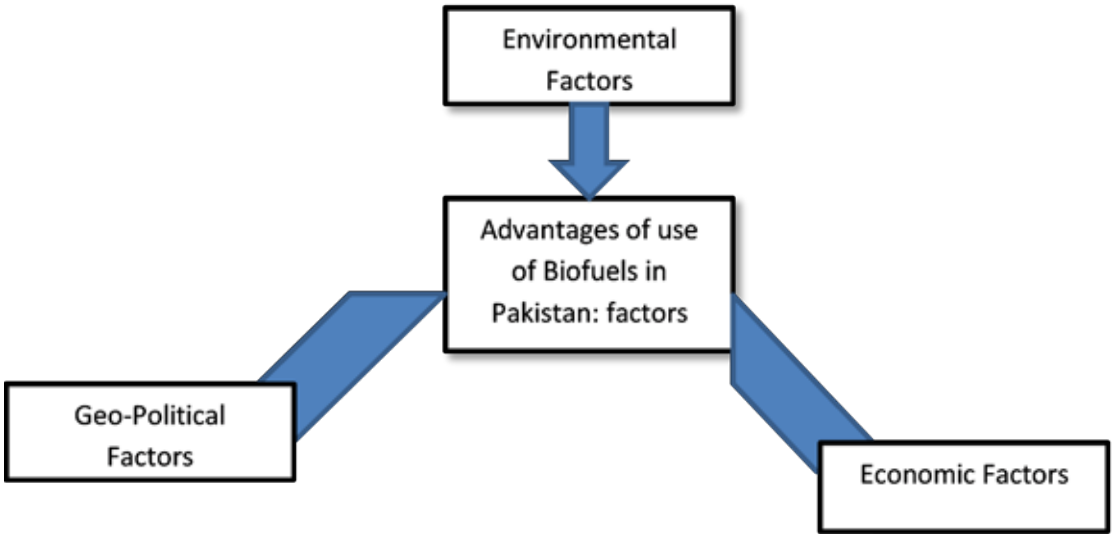

Fig.1 : Classifications of factors for advatages of using bio-fuel in Pakistan.

4.1.1 Advantages of Use of Biofuels-related to Environmental Factors

Use of bio-fuels will have number of advatages in improving the environment in Pakistan. Some of these advantages are listed below:

- Lower greenhouse gas emissions.
- Controls soil erosion [23].
- Environmental improvement by cultivation of barren land, protecting watersheds and creation of new habitats [24].
- Environmental improvement by effective utilization of agricultural waste and manure.
- Improved sustainability of environment

4.1.2 Geo-political Advantages of Using Biofuels

Use of bio-fuels will have number of advatages in improving the environment in Pakistan. Some of these advantages are listed below:

- Cheap and secure energy supply from renewable biofuels.
- Increase in rural jobs.
- Effective utilization of agricultural waste and manure by conversion into biofuels.
- Saving of human resources in collecting firewood.
- Saving money spent on import of costly fosile fuels.
- Utilization of production surpluses into biofuels reduces their dumping.
- Improved economically sustainable agriculture and prices.
- Enabling farmers to diversify their production by cash crops and use of non-food crops for biofuels

4.2 Consequences using Biofuels in Pakistan

Although use of biofuels in Pakistan offers number of advantages, there are number of areas of concern in view of economic and political situation in Pakistan. Asad and Khalid [18] discussed some of these concerns which are narrated in brief here.

4.2.1 Shortage of Food Products in Pakistan

Selection of crops or use of lands for biofuels production will have adverse effect on the food supplies. Farmers are able to get better prices from the sale of bio-fuels in comparison to food products. The choice for better returns from the crops is likely to create shortage of food commodities. Increasing the use of biofuels on a large scale in Pakistan is likely to create shortage of food products.

4.2.2 Higher Prices of Food Commodities

Asad and Khalid [18] assert that Pakistan is a free economy in which demand and supply in the

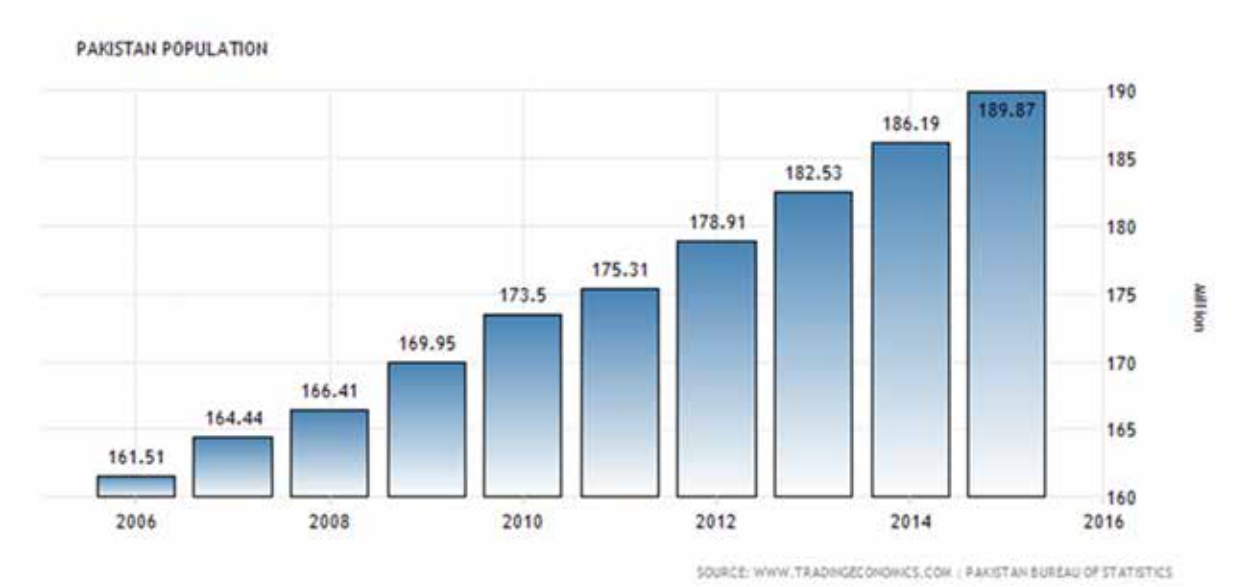

Fig. 2. Population growth in Pakistan during the period 2006 – 2016.

39.45 million and increased to 172.80 million in 2008, an increase of more than four times from independence. The increasing population of Pakistan may not be able to bear this.

Reviewing the problems of Pakistan, a populous food producing nation, Akbar [26] argued that the agriculture sector in Pakistan has been suffering from the decline for thepast three decades due to low productivity, low yields per unit area and critical investments in developing new plant varieties, farming technology and lack of water infrastructure. The shortage of food products and higher prices of food items will put pressure on the government of Pakistan. Akbar [26] further argued that food price inflation in Pakistan has averaged 18% for the last four years while the purchasing power of the poor people has deteriorated significantly.

4.2.4 Problem of Deforestation and High level of funds required for Biofuel Production

Bekiaris et al. [18] highlight the need for huge investment in producing and use of the biofuels.Growth of bio-fuel crops will require land which will be created by cutting of forests. This reduction in forests would result in serious impact on the greenhouse gas and biodiversity. It will also lead to land erosion including reduced availability of wood for housing and other local needs. Sungi

4.2.6 Depletion of Water Resources

Many bio-fuel crops require large quantity of water for their cultivation. The increased requirement for the water will have serious effects in areas of water shortage and would add to excessive load on water resources.

4.2.7 *Possibility of Greater Poverty*

Expansion of biofuels may need increasing concentration of the land for sugarcane leading to concentration of land in the hands of few larger farmers. Small farmers may lose their land. The transfer of land from small farmers to larger farmers can result in socio-economic problem in the region. The large size operations in agriculture would seek for mechanization of operations in place of manual labor. Poor people in the region may be out of job and may be driven to poverty.

4.2.8 Land Degradation

Recent trend towards use of second generation bio-fuels has its own impact on certain issues. Second generation fuels are produced from feedstocks such as switch grass, miscanthus, jatropha and crop residues after harvesting. Removal of these agricultural wastes from the land can adversely affect the productive capacity of the land.

5. USE OF ETHANOL IN PAKISTAN

Arshad [29] argues for suitability of use of ethanol in place of fossil fuel, especially as a transport fuel. He reports that about 27% of primary energy worldwide is used for transportation [30]. It is added that more than 80% of the energy consumed by the transport sector in the EU25 countries is used in road transport itself [31]. Transport sector in EU25 countries takes away a major share of 28% out of the total energy consumed in these countries. Qin, et al. [32] suggested 12 million tons per day requirement of oil, which is likely to go to a level of 16 million tons per day by 2030. Share of global oil consumption in transport is about 30%. The demand for oil is expected to increase by 60% by the year 2030.

Arshad [28] further argues that petroleum products have a major share of 40% in the energy mix in Pakistan. Gasoline and fuel oil are the main source of energy. Both public and private sector consume gasoline for transportation [33]. A strong case is made for the use bioethanol along with the oil fuel in Pakistan. Arshad [28] high lights the following points in favor of the use of ethanol blended with fuel oil:

a. Ethanol has the lowest CO_2emission among the major transport fuels.
b. Ethanol has high fuel characteristics such as high heat of vaporization, high octane number of 120 as compared to 108.6 of petrol, and low flame temperature. Thus blending of ethanol with fuel oil improves the octane number of the blended fuel without the addition of any other material.
c. Lower energy content of 26.9 MJ/kg as compared to 44.0 MJ/kg for petrol.
d. For a 10% ethanol blend the fuel economy advantage of a petrol engine would be only 3%.
e. Higher flammability limit of 19 per cent in air in comparison to 7.6 per cent of petrol.
f. Higher auto-ignition temperature of 363 degree than the 280 degree of petrol.
g. Ethanol is safer than the petrol due to its lower characteristics of catching fire.
h. Blending of ethanol requires no change in existing engines (E-10);
i. Engine performance improves.
j. Ethanol burns clean and more efficiently;
k. Ethanol is more biodegradable.
l. The cost of ethanol produced directly from sugarcane molasses is Rs.45/liter ($0.53/liter), which is lower than the current world price of petrol.

Surplus Ethanol

Khan and Dessouky [34] report a high production of ethanol (300,000 tons of cane per day) in Pakistan at present with 76 sugar mills operating in the country. In addition, 21 distilleries are operating with processing capacity of 2 million tons of molasses, a byproduct of sugar cane. 21 distilleries in Pakistan have a production capacity of 400,000 tons ethanol, which is in excess than the need for ethanol (Ministry of Industry, GOP). The present need of ethanol and the export of ethanol to other countries amount to 80,200 tons resulting in a surplus of about 318,000 tons of ethanol. The surplus ethanol can be converted into biodiesel

6. USE OF BIODIESEL IN PAKISTAN

Ahmad et al. [9] state that vegetable oil is treated with either methanol or ethanol to synthesize biodiesel. The preferred choice world over is to use methanol being cheaper. The main source of methanol is coal. Pakistan has large reserves of 180 billion tons of coal and is the 5th largest reserve in the world. Pakistan is an agricultural country with 70% of its population working in farms. The stock of bioethanol in Pakistan is large and is in surplus than the requirement. The surplus quantity of ethanol can be converted into biodiesel. It is reported that biodiesel can be made by combining alcohol (usually methanol) with animal fat, vegetable oil, or recycled cooking grease. In view of these factors the Economic Coordination Committee (ECC) of the National Cabinet in its conference held on 14th February, 2008 approved the strategy for gradual introduction of biodiesel fuel blends with petroleum diesel as an alternate energy source so as to achieve a minimum share of 5% by volume of the total diesel consumption in the country by

the year 2015 and 10% by 2025.Ahmad et al. [9] conclude that Pakistan can meet variety of its energy requirements such as producing electricity, providing energy for kitchen in the homes, fueling vehicles and supplying energy to industries by effective usage of biodiesel for producing energy.

6.1 Present Policy on the Use of Biodiesel in Pakistan

Siddiqui [35] highlight the policy direction enunciated by AEDB in 2008 for biodiesel which include the followings:

a. Introduction of 5% biodiesel blended fuel by 2015 and 10% by 2025 in Pakistan.
b. Oil marketing companies were to buy B (100) biodiesel from biodiesel fabrications and market the biodiesel blended fuel (B-5) at their points of sale.
c. Oil gas regulatory authority was to regulate the pricing mechanism of various blends of biodiesel.
d. All imported plants machinery, equipment, and specific items used in the production of biodiesel were to be exempted from customs duty, income tax, and sales tax.

7. FUTURE OF USE OF BIOFUELS IN PAKISTAN

Pakistan has been a late starter in introducing the use of ethanol in transport vehicles in comparison to other countries (Table 4). Its initial efforts in a pilot study conducted in 2006 in three cities of Karachi, Lahore and Islamabad in the use of 10% ethanol blended with motor gasoline failed due to poor coordination among the participating organizations and gaps at the planning and implementation stages [28].Government of Pakistan (GOP) took initiative to impose a 15% duty on export of molasses to encourage the use of molasses for ethanol production. It is estimated that if all the molasses is converted into ethanol it can reduce the gasoline consumption in Pakistan by 5-7%. In view of abundant availability of ethanol in the country, the surplus quantity of ethanol is going to be converted into biodiesel. Biofuels in the form of ethanol as well as biodiesel promises great benefits to mitigate the energy shortage in Pakistan

Table 4. Biofuel program implemented by some countries in the world gasoline.

Name of the country	Blending	Since
Brazil	E 24-26	1970
USA	E-10	2004
China	E-10	2004
Australia	E-02	2002
Japan	E-03	2007
India	E-05	2003
	E-10	2008
Pakistan	E-10	2006
European Union	E-02	2003
	E-10	2008
Taiwan	E-03	2007
Columbia	E-05	2003
	E-10	2008

8. CONCLUSIONS

Pakistan, like many other developing countries, is facing acute shortage of energy and imports oil from other countries spending huge amount of money to meet its increasing energy demand. Use of biofuels (ethanol and biodiesel) offers great potential in replacing the need for import of the oil in the country. Research shows that there is surplus quantity of ethanol in Pakistan after meeting all the requirements, which can easily be converted into biodiesel. Biodiesel is a much cheaper biofuel and has already been tried in many other counties successfully. Although Government of Pakistan (GOP) has already taken initiative in the use of ethanol and biodiesel, the need is to implement the program expeditiously to gain the advantage and alleviate the energy shortage in the country. Increasing the use of biofuels in Pakistan is a solution to the problem of shortage of energy in the country and will go a long way.

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