A CRITICAL REVIEW OF BIOFUELS AS AN ALTERNATIVE FUEL TO DIESEL IN GULF REGIONAL CORPORATION (GCC) REGION: CURRENT MARKET TRENDS AND FUTURE OPPORTUNITIE

Faisal O. Mahroogi[1], Sunny Narayan[2,*], Muhammad Usman Kaisan[3], Abdulkabir Aliyu[4], Ibrahim Yahuza[5], Ivan Grujić[6], Nadica Stojanović[6]

[1]Mechanical Engineering Department, Islamic University of Madinah, Saudi Arabia
[2]Mechanical Engineering Department, Qassim University, Burydah, Saudi Arabia
[3]Mechanical Engineering Department, Ahmadu Bello University, Zaria, Nigeria
[4]School of Water Energy and Environment, Cranfield University, Bedford Shire, United Kingdom
[5]Department of Automotive Engineering, Airforce Institute of Technology, Kaduna, Nigeria
[6]Department of Motor Vehicles and Motors, University of Kragujevac, Kragujevac, Serbia

*E-mail of corresponding author: rarekv@gmail.com

Resume
Bio Fuels are considered as good alternatives for conventional fossil fuels. By the year 2020, in the GCC region these fuels are able to meet around 0.5 - 1% of total transportation fuel demand. This industry grew at rate of 3.4% over the period of 2015-2020 with a strong projected growth in the Kingdom of Saudi Arabia (KSA). Bio fuels are used to operate automotive for mining and construction industries. Critical barriers in foreign investments pose a major challenge for growth of this sector in the GCC region.
The presented work discusses situation and growth predictions of Bio-Fuel industry in the GCC region. It also discusses about current growth, trends, opportunities and challenges being faced by major companies operating in the GCC region.

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1 Introduction

Use of biofuels has played a vital role in transformation of global economy towards sustainable and renewable resources [1-23]. Along with electric vehicles, these fuels can help to move away from using traditional oil resources [23-35]. Liquid biofuels provide bright future scope for the road, shipping and aviation-based industries. These fuels face challenges on fields of technological innovations, supply chain, market and policy making. The costs of production for biofuels have been estimated to about USD 0.60-1.10 per litre by the year 2045. However, various innovations may reduce this by up to a third over coming period. These fuels have a potential to reduce greenhouse gas (GHG) emissions by 60 - 95% [36]. Figure 1 shows economic comparisons of biofuels with fossil fuels over the period of 2015-2045. Diesel and gasoline substitute fuels have highest costs.

2 Background

The most well-known first-generation biofuel additive is ethanol, that is produced from fermentation of sugar extracted from starch. Global production of bio-ethanol in the year 2006 was about 51 billion litres [37]. China and India contributed about 11% to it. Various raw materials for ethanol, include feedstock like cane, corn, starch and other sugars. Table 1 compares various merits and demerits of first-generation biofuels.

The second-generation biofuels are produced from lignocellulosic biomass, enabling the use of lower-cost, non-edible feedstocks. These biofuels can be further classified as: biochemical or thermochemical. Ethanol or butanol-based fuels are made via biochemical processing, while all the other are made by thermochemical processing. The second-generation includes methanol, Fischer-Tropsch liquids (FTL), dimethyl ether (DME), green diesel and pyrolysis oils. Table 2 presents a summary of the secondary biofuels, their applications and properties.

Ethanol based biofuels have a higher latent heat of evaporation and thus a poorer cold start ability in winter [38]. Damage and driveability issues occur for vehicles operating on ethanol blends. Use of biodiesel needs much lesser engine modifications as compared to use of bio gasoline blends [38]. For some vehicles, rubber seals in the fuel lines may require replacement with

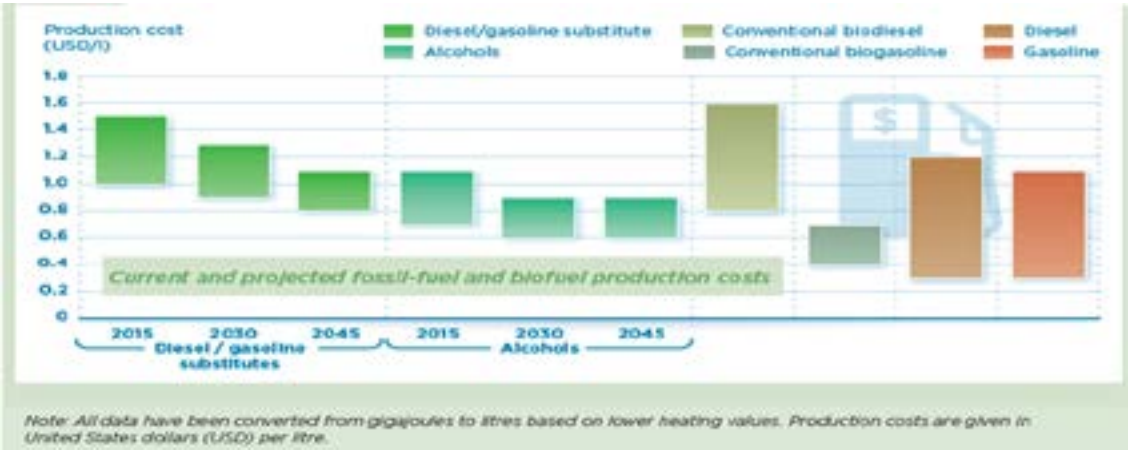

Figure 1 *Current and projected production charges of fossil fuel and biofuels [36]*

Table 1 *Summary of comparisons of primary biofuels [37]*

Merits	Disadvantages
Easily available feed stocks.	Feed stocks compete with food stocks.
Simpler production methods.	Higher costs of feedstock.
Variable production capacities.	Modest reductions in greenhouse emissions.

Table 2 *Summary of applications of secondary biofuels products*

Product	Description	Application and product replacement	Blending limits
Methanol	Single carbon atom alcohol with energy density 50 % lower as compared to gasoline	May be used with gasoline as methyl tert-butyl ether as a Transportation fuel	May be converted to dimethyl ether (DME) as replacement.
Fischer-Tropsch fuels	Paraffinic hydrocarbons similar to diesel.	May be mixed with gasoline, diesel or jet fuels	Fischer-Tropsch kerosene is mixed for maximum ratio of 50 % with jet fuel.
FAME biodiesel	Fatty acid methyl ester (FAME)	May be mixed with diesel for use in transportation.	Up to 7 % FAME mixed with diesel as per euro EN 590.
Butanol	Four carbon alcohol having density similar to gasoline.	May be mixed with gasoline or diesel as transportation.	Up to 16 % butanol mixed with gasoline as per US standard -ASDMD 4814.
Synthetic aromatic fuel	Hydrocarbon fuel containing aromatic compounds.	Mixed with jet fuel for aviation use.	ASTM certification needed

non-rubber products. Biodiesel becomes thick during the cold weather. It may cause issues during starting. Fuel heating system or using biodegradable additives may be a good alternative. The use of multiple injections with an increased pressure reduces the NOx emissions [38-39].

The heating of biodiesel decreases viscosity making them suitable for diesel engines [39-41]. There is a decrease in unburned hydrocarbon, carbon monoxide and BSFC and an increase in thermal efficiency.

Engine wear by using the biodiesel has been found to be lesser than that of the petroleum diesel. Deposits and clogging are due to oxidization of low-quality biofuels.

Pollution in engine exhaust is much lesser due to its higher oxygen content.

Depending on the type of engine, the components of engine coming in contact with biodiesel can be made from compatible materials. Oil leakage to crankcase has an impact on engine durability and longevity. Impacts on injectors, filters and other system components can deteriorate engine performance. Emission after treatment systems, like catalysts and particulate filters, can be affected by biodiesel fuels.

3 Biofuels as an alternative for GCC region [42]

Results from the biomass resource and bioenergy potential modelling for each GCC country are presented in Table 3 [42].

Table 3 *Biomass potential in GCC region*

	Biomass resource potential (Mtpa)				Bioenergy potential (PJ ^{elec})[a]	Proportion of overall electricity consumption (%)[b]
	Animal wastes	Crop Residue	Sewage	MSW		
Bahrain	0.27	0.01	0.02	0.68	6.59	6.3
Kuwait	1.71	0.64	0.06	1.17	23.10	10.1
Oman	3.57	0.07	0.07	0.85	27.59	22.5
Qatar	1.39	0.47	0.04	0.68	16.40	9.9
Saudi Arabia	14.35	0.20	0.51	12.50	179.45	14.4
UAE	4.24	0.30	0.15	3.46	50.71	11.0
Total	25.52	1.68	0.87	19.35	303.84	13.0

[a]based on assumption of thermal conversion efficiency of 36% used by IEA bioenergy

[b]based on national electricity consumption levels for2019

Saudi Arabia had the largest overall potential, followed by UAE and Oman. For each region the dominant categories of biomass potentially available for bioenergy are waste resources generated by animals and organic MSW materials. Agricultural residue and sewage wastes have lesser opportunities.

According to the International Energy Agency (IEA), the share of biofuels in the Middle East reached 5% by 2020 [42]. With more and more biofuel companies coming into the picture in the Middle East, there is an acute increase in the market share of biofuels.

The demand for fossil fuels is ever increasing against a tight economic environment. Consumption of oil and gas in Saudi Arabia has shown a rise of 5.9% over the past five years. The demand for electricity has seen an annual growth rate of 8%. Although the GCC countries are the world's leading producers of energy, many clean technology projects have been launched recently indicating the region's need to exploiting renewable sources of energy. Found in the Middle Eastern arid region, algae are available significantly. It can withstand hot temperatures, as well as grow in higher salinity ranges making the prospects of algae-based biofuels production for the Middle East region as appealing. The region is suitable for the mass production of algae due to following factors:

- Presence of non-arable lands and extensive coastal area.
- Presence of oil refineries and power plants to capture CO_2.
- Highest annual solar radiations.
- Presence of a number of sewage and wastewater treatment plants.

Algae Research Laboratory at Abu Dhabi and Microbial Environmental Chemical Engineering Laboratory (MECEL) of the Masdar Institute of Science and Technology, are currently taking up projects to analyze the algae-based fuel production for use as aviation and jet fuel. Lootah Biofuels based in Dubai has made an agreement to develop raw materials for production of algae oil. Photo bioreactors (PBR) and solar-powered, open pond constructions for algae production are becoming an attractive choice for producing algae in the Middle East region.

The King Abdul Aziz City for Science and Technology (KACST) is working on a project to screen lipid hyper-producer algae species in Saudi Arabian coastal waters for biofuel production. The aim of this project is to increase research in algae-based biofuel production for use in bio refinery within the next ten years.

With Etihad Airways commercial flight operation powered by fuel produced from plant matter, the UAE has demonstrated importance of biofuel development [13]. To help in further development, the Sustainable Bioenergy Research Consortium (SBRC) located is working to implement Bio jet Abu Dhabi, a project being that brings together various sectors of fuel development, energy, aviation, refining, environmentalists as well as financial/investors and legal fraternity.

Investing in the UAE's sector could also provide an annual revenue of US$7.6 billion by the year 2023, with $69 billion being invested in new production capacity worldwide over the next 10 years.

4 Economic scenario

This section deals with study of economic potential of biofuels, that also needs analysis of production and refining methods. The costs of production of biofuels depends on available feedstock, conversion process and production scale. Among all the parameters, the costs of raw feedstock play a major role in overall costs. One of the factors that have limited use of biofuels is perception of higher costs. However, this is just a myth as the biodiesel provided by Lootah Biofuels in UAE is cheaper than the conventional diesel.

Amongst all the fuels Ethanol has the lowest costs, higher octane fuel additive available to gasoline operated systems. During year of 2011, The National Renewable Energy Laboratory (NREL) projected a minimum support value of 0.57 US$/L. Some of the major contributors to production cost of ethanol includes

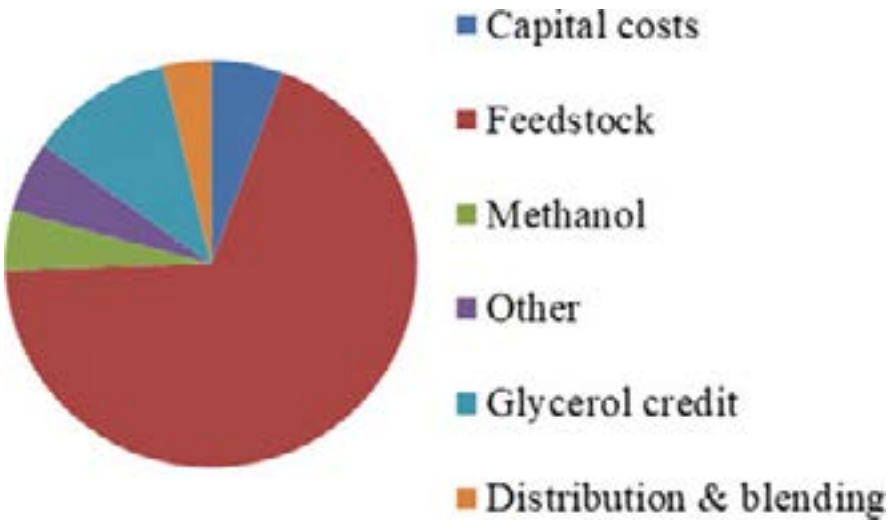

Figure 2 *Production costs of the palm oil based biodiesel*

Factors	Conventional Velicles	Electric Velicles	Methanol velicles
Resources			
Energy Density			
Emissions			
Fueling Infrastructure			
Price			
Status	Excellent	Good	Poor

Figure 3 *Comparison of vehicles operated on various fuels*

feedstock costs (23 - 28 %), costs of capital (40 - 49 %), yield and enzymes costs [15].

Zhang et al. [39], Marchetti et al. [40] and Apostolakou et al. [41] have done analysis of economic requirement for production of biodiesel fuels. The production costs of biodiesel were higher as compared to diesel. Graboski and McCormick studied benefits of using glycerol in order to reduce the production costs in KSA [42]. An approximate distribution of production costs of palm oil based biodiesel is shown in Figure 2. Explicitly, the feedstock costs are predominant and with an economic return on glycerol, the choice of larger plant has lowered the price.

Figure 3 presents a rough comparisons of automotive vehicles operated on conventional fuel, electric and methanol based biofuels.

Methanol based biofuel vehicles performed best in terms of emissions, fuel infrastructure, price and resources.

Microalgae is a good choice for the sustainable production of biofuels. Algae produce lipids that have the potential for aviation fuel and cultivation of microalgae could mitigate carbon dioxide and other greenhouse gases Oman has a good potential to cultivate algae being richer in water resources as compared to rest of region. The government is looking for ways to use biofuels for transportation and power generation. Qatar is also investing in algae biofuels industry. In 2019, Total company and Qatar University initiated two projects to investigate microalgae. In 2018, the country had a biomass installed capacity of 38 Megawatt.

The GCC algae biofuel prospects market is consolidated. Some of the key players in this market include Total SA, Royal Dutch Shell PLC, Chevron Corporation, Exxon Mobil Corporation, Qeshm Microalgae Biorefinery Co.

5 Future trends

The global biofuels market alone was projected to grow to $139 billion by 2021. Commercial use of various biofuel is still in the phase of being implemented in the GCC region. In the Middle East region growing market demand provides an opportunity in transportation fuels and petrochemical derivatives. Algae producers have established pilot and demonstration scale projects that are able to produce fuels from microalgae, cyanobacteria and other microbes. These factors make it imperative on GCC nations to develop a robust research, development and market deployment plan for a comprehensive approach for bio product synthesis.

6 Conclusions

This paper presents a comprehensive review of production and adoption of biodiesel as an alternative source of fuel for the GCC region. Based on the findings, as well as data gathered from available literatures on this subject, the following conclusions can be made:

1. The high demand for various fossil fuels has increased the need to explore alternative resources of renewables like biodiesel that are derived from cheap sources giving rise to improvements in exhaust emissions and engine performances.
2. An increasing trend has been seen in the use of biodiesel from production rates and usage as various new jobs are created to meet up with labour requirements for expansion of industry.
3. Reduction in greenhouse gas emissions can be achieved through increase in production of biodiesel.

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