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A review on the prospects of sustainable biodiesel production: A global scenario with an emphasis on waste-oil biodiesel utilization

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ABSTRACT

Due to the large amount of diesel fuel demands worldwide and the negative environmental and health impacts of its direct combustion, biodiesel production and consumption have been globally increasing as the best short-term substitute for mineral diesel. However, using edible and non-edible oil feedstocks for biodiesel production has led to several controversial issues including feedstock availability and cost, greenhouse gas (GHG) emission, land use changes (LUC), and fuel vs. food/feed competition. Fortunately, these problems can be effectively overcome using non-crop feedstocks. In this context, waste-oriented oils/fats have been proposed as the excellent options to produce biodiesel by overlooking the trivial collection/recycling costs. In this review article, a comprehensive collection plan followed by an elaborated integrated utilization strategy called "waste oil biodiesel utilization scenario" (WO-BUS) is proposed for Iran in order to achieve cost-effective and eco-friendly production/consumption of biodiesel. WO-BUS is adoptable by the countries with similar situations and infrastructures.

1. Introduction

The world's total primary energy consumption (TPEC) is increasing day-by-day because of increasing population and modernization. In the year 2015, the world's TPEC stood over 150,000,000 GW h and it has been envisaged to rise by 57% by the year 2050 [1] (Fig. 1). This dramatic growth of energy consumption will eventually result in more GHG emissions and more environmental problems [2]. Today, over 80% of the total energy used in the world is provided by fossil fuels, leading to their severe contribution to environmental and health concerns [3,4].

Due to the above-mentioned concerns, tremendous efforts have been made to find the best alternative fuels for overcoming the economic and environmental impacts of fossil fuels consumption around the world [5–10]. In case of Iran, this issue becomes more serious because of the extreme dependency of the country's manufacturing and transportation sectors on low-price energy resources, making its economy very vulnerable to any changes in policies such as the fossil fuels subsidies removal state program implemented in 2010. Therefore, it is vital to scrutinize the country's current and future situations and potentials in order to find practical ways to manage its national energy scenarios more efficiently and in a less risky manner. According to Zarifi et al. [11], Iran's transportation sector is the second largest energy consumer of the country. Thus, replacement of a portion of national gasoline and diesel demands, which are the major transportation energy careers in Iran, with renewable and carbon-neutral fuels like bioethanol and biodiesel can effectively mitigate the high vulnerability of this sector in terms of fossil-derived fuels dependency.

Abbreviations: B2, 2% biodiesel/98% petro-diesel blend; B5, 5% biodiesel/95% petro-diesel blend; B20, 20% biodiesel/80% petro-diesel blend; B100, Neat biodiesel; BRTeam, Biofuel research team; BTE, Brake thermal efficiency; CNG, Compact natural gas; DI, Direct injection; FAME, Fatty acid methyl esters; FFA, Free fatty acid; GDP, Gross domestic product; GHG, Greenhouse gas; IBS, Iranian biofuel society; IKCO, Iran Khodro company; LDC, Least developed countries; LUC, Land use changes; ML, Million liters; NDP, National development plan; NER, Net energy-balance ratio; NIORDC, National Iranian oil refining and distribution company;; NRDDI, National renewable diesel demonstration initiative; PAHs, Polycyclic aromatic hydrocarbons; RIPI, Research Institute of Petroleum Industry; ROI, Return on investment; RTFO, Renewable transport fuel obligation; TPEC, Total primary energy consumption; UNDP, United nation development program; WCO, Waste cooking oil; WO-BUS, Waste oil biodiesel utilization scenario; WOF, Waste oil/fats

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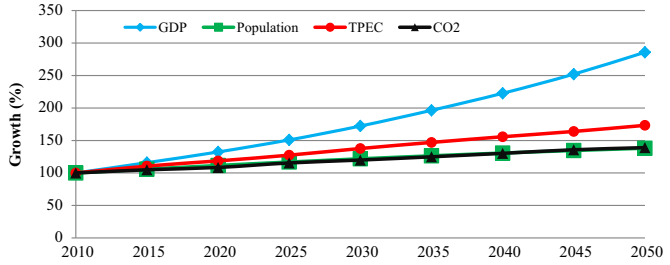

Fig. 1. Trends in global gross domestic product (GDP), population, TPEC, and Carbon Dioxide (CO_2) emissions vs. time [1].

Such a sustainable strategy not only can boost energy efficiency but also can balance economic and social development through environment protection.

The present manuscript was aimed at comprehensively discussing various aspects of energy resources and demands in Iran, particularly diesel fuel, with a focus on biodiesel production and consumption as a suitable and sustainable diesel alternative. In this regard, a detailed survey was conducted to achieve the most compatible feedstocks with Iran's current situation, needs, and transportation fleet. Based on the thorough investigation carried out herein, WCO was found to be an economically-viable feedstock in Iran for biodiesel production. Accordingly, biodiesel production from the WCO was thoroughly discussed in a separate category because of its different GHG footprint and LUC compared with the other biodiesel feedstocks. After presenting a financial feasibility analysis, a comprehensive collection plan followed by an elaborated integrated utilization strategy called "WOBUS" was finally proposed for Iran's situation in order to attain sustainable production and consumption of biodiesel.

2. Overview of energy resources and consumption

Iran is a developing country with a total population of over 80 million [12]. The country is ranked as the world's 9th energy producing country [13] possessing the second and fourth largest proven natural gas and petroleum reserves in the world, respectively [14] (Figs. 2 and 3). Hence, the majority of energy demands in Iran is fulfilled by its own conventional energy resources. For instance, natural gas and oil products contribute to nearly 98% of the country's total energy consumption, while coal, hydropower, nuclear, and non-hydro renewable energies have a marginal share on Iran's energy market [14]. Fallaciously, it may be imagined that Iran, having such a huge reserve of fossil fuels, does not need to plan for any other alternative fuels. In contrast, the country is obligated to diminish the present over-dependence on fossil fuels and more importantly the associated environmental impacts. Moreover, Iran is always at high risk of losing its market since the country economy depends to a significant extent on oil export revenues (a political economy). For instance, Iran experienced a shocking decline of about 40% in the petroleum products export revenues in the year 2013 compared with the year 2011 because of the U.S. and EU sanctions [14]. On the other hand, the global fossil oil reserves are anticipated to be depleted within the next 45 years [15].

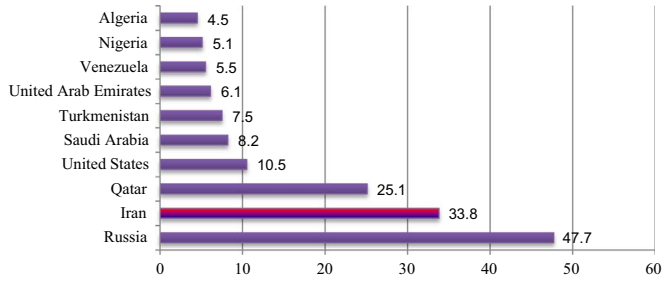

Fig. 2. Largest proven reserve holders of natural gas (billion m^3), January 2014 [14].

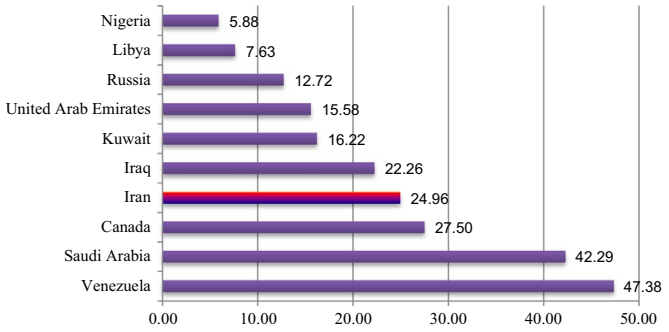

Fig. 3. Largest proven reserve holders of crude oil (billion m^3), January 2014 [14].

These are why the renewable energy production will turn to be one of the most important economic growth criteria of the countries in the near future.

It is worth quoting that as a developing country, Iran is also suffering from tremendous increases in the rate of energy demand and consumption. According to a report published by British Petroleum (BP), Iran's TPEC stood at 3107536 GW h in the year 2015 i.e. 2% of the world's TPEC [16] (Fig. 4). The country experienced a dramatic increase in the energy consumption by more than 50% since 2005 ranking it as the 1st and 10th energy-intensive country in the Middle East and the world, respectively [16]. Iran's TPEC is expected to further grow given the current state policies being implemented in order to boost the population (Fig. 5). It is worth noting that even though the population growth rate of Iran was only 1.27% in the year 2015, its TPEC growth rate was 2.5%. This manifests that the energy consumption pattern in Iran depends on various factors in addition to the population growth rate such as economic growth, uncontrolled urbanization [17], luxury consumption behavior among the Iranian consumers, generous subsidy programs, and weak resource management. These in turns have led to rapidly-growing energy consumption and high-energy intensity levels over the past decades [18].

Based on the statistics released by Iran Energy Efficiency Organization (IEEO), the country's energy consumption per capita in agriculture, housing, transportation and industry sectors were 3.1, 1.8, 1.5, and 1.4 times higher than those of the global averages in the year 2015, respectively [20], drastically complicating its energy management scenarios. As a result, although Iran has a unique status in the global energy supply, this country was one of the biggest petroleum products importers. In the year 2014, the country imported almost 9.7 million liter per day of petroleum derivatives, out of which 94% was gasoline to meet the high demands of the transportation sector [14]. In addition, Iran not only consumes almost all of its exploited natural gas, but also imports a portion of its natural gas demands for household application in cold seasons [14]. Such continuing trend of rising energy consumption will bring about new challenges for Iran by shrinking oil export revenues and subsequently restraining economic activities.

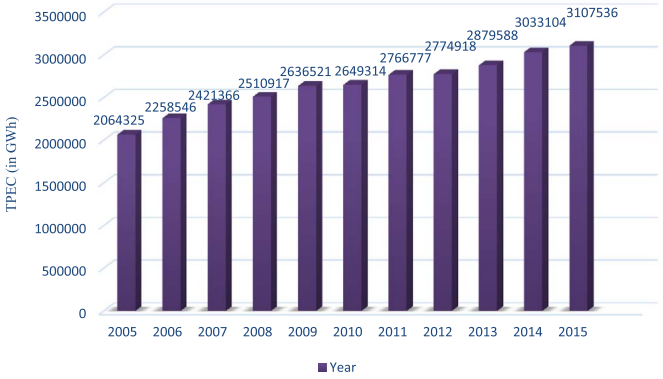

Fig. 4. Trends in TPEC in Iran 2005–2015 [16].