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Sustainable alternative fuels in aviation

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ABSTRACT

In recent years, renewable energy resources have become more important due to the limited number of regions for production of petroleum-based fuels, which are continuously depleting. The aviation sector in terms of commercial and cargo transportation has an increasing need for conventional, as well as, alternative fuels. Derivatives of petroleum fuels used in aviation have negative impacts on air quality. Factors causing greenhouse gas emissions (GHG) in the aviation sector must be reduced. However, such fuels used in the aviation sector are not sustainable. Biofuels which have the potential to replace petroleum fuels and help with emissions are heavily investigated in developed countries for independency, creating a better environment and sustainability. Biofuels which are already used for ground vehicles could also be implemented in the aviation sector to reduce fuel cost and emissions. Overall, aviation fuels made of sustainable resources would also support social and economic development. Numerous industrial initiatives have emerged to find alternative ways to attain bio-aviation fuels. Therefore, there is an increasing level of research with regards to alternative aviation fuels made of biomass in recent years. It is important to obtain basic feedstocks and to develop biofuel production processes in a cost-effective way. This study examines the necessity and the types of biofuels in the aviation sector. By designing unique fuel systems for air vehicles, it is possible to formulate biofuels which can be used for both air and ground vehicle applications. This type of consensus would help with sustainability and a better environment.

1. Introduction

As technological developments are happening at a fast pace, energy is playing a more important role in the daily lives of all people and social-economical development of every country [1,2]. Industrialization, an increasing world population, globalization, more urban developments and other factors are the main reasons for demand on more natural resources and energy. Cost-effective, secure and clean energy has become one of the most important challenges nowadays and developing countries are in need of more energy due to their social-economic growth [2–4].

In 2014 and 2015, global energy consumption increased about by 1.0%, much below its 10-year average of 1.9%. Fossil fuels are the primary sources of the energy to date. 544.284 GJ energy consumed in 2015 consisted of 32.94% petroleum, 29.2% coal, 23.85% natural gas, 4.44% nuclear energy and 9.57% other renewable energy resources (hydro, solar, wind and e.g.) [5–7].

Petroleum based liquid fuels are used in the transportation sector. In 2011, the world's petroleum resources were consumed by air, ground, sea and railroad transportations (54%), industry (18%), commercial and agriculture (11%), petro chemistry (10%) and electric production (7%) [5,8–10]. It is projected that 74% of petroleum based energy will be consumed in the transportation sector by 2020. In addition, the need for oil in the transportation sector is growing rapidly and expected to increase by 1.3% per year until 2030. Based on the current statistics, 1.2 billion motor vehicles are used world-wide and this number is anticipated to reach to 2 billion until 2035 [6,11]. Thus, it is important to monitor and know the number of vehicles per person by the oil producers. As of 2009, the statistics shows that 70% of 870 million cars in the world belonged to The Organization for Economic Co-operation and Development (OECD) countries [11–13].

Pollutants are released to the atmosphere due to production and consumption of energy worldwide. Most of these pollutants occur because of fossil fuels [11]. With the increasing number of motor vehicles in the developing countries, it is necessary to take preventive measures to reduce exhaust emissions [14]. As the number

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of motor vehicles increases, the amount of pollutants from those vehicles increases with a higher percentage of contribution. Even a small change in atmospheric gas balance could lead to climate change. Carbon dioxide (CO_2) has a great impact on climate change and global warming based on the Kyoto protocol [11,12]. CO_2 emissions increased 4.6% in 2010 as compared to 2009. In 2010, 36% of total CO_2 emissions was petroleum based and 22% of that was due to the transportation sector [13]. By 2030, it is expected to have 80% increase in carbon emissions from the transportation sector as well as the energy requirement [13]. The aviation section is an important part of the transportation sector. Developed and developing countries have made the most investment on the aviation sector. Like automobiles, aircrafts depend on fuels derived from fossil fuels and thus, the aviation sector needs environmental and economic regulations. With the increasing standards of the modern world, the aviation sector has to take an important role to protect the environment [14–16]. Thus, air and ground vehicles need to be supported by sustainable energy resources. The most important resource for sustainable energy that will meet the need for liquid fuels for these sectors should be domestic and easily producible sources [17–19].

Biomass has been effectively used over the years for the production of alternative fuels for ground transportation [1,3,17,20]. Similarly, biomass will be the best potential for use in the aviation sector which is one of most the common forms of transportation. Any agriculture and animal feed based biological materials with carbohydrate are considered biomass energy resources. And, fuels made of biomass are called biofuels [18–21]. Biomass, which are sustainable energy resources, reduce greenhouse effects, improve air quality, reduce oil dependency and produce new job opportunities [20]. Countries with biomass potential usually have large resources of vegetable oils, inedible materials and bioalcohols. There are two ways to use biomass: 1) direct combustion of biomass for electric or heat generation 2) conversion to biochemicals and thermochemical process such as biodiesel or other fuels [22]. Fig. 1 shows biomass feedstock and consumption [23,24].

Petroleum fuels have limited reserves in the world. Sudden jump of oil prices, limited resources, greenhouse effects, environmental issues and other important aspects, force the use of renewable energy resources [25]. With that, biomass is an important source to produce biofuels which are advantages as compared to petroleum based fuels and can be used for air and ground vehicles [26].

The aviation sector which is primarily used for commercial transportation do contribute to atmospheric pollution. Air vehicles produced 2% of CO_2 emissions in 2012 worldwide with a projected amount of 3% by 2050 [27]. There are numerous measures which have been taken to reduce CO_2 emissions [28]. Better engines and fuel technologies are contributing factors to reduce emissions and use fuels more efficiently in the aviation sector as compared to forty years ago. Jet fuels constitute a large sector for the consumption of fossil fuels. World jet fuel demand is expected to increase by about 38% until 2015 [29]. Commercial airliners are facing aviation fuel cost as a major expenditure out of their total operational cost. However, more aerodynamic and lighter aircrafts, more efficient turbine engines and major improvements in the efficiency of the air traffic control system are some of the reasons for 70% more fuel efficient airline industry as compared to 40 years ago [30,31]. Fuel consumption per 100 km/traveler used to be 3.5 L which was reduced to 3 L in recent years.

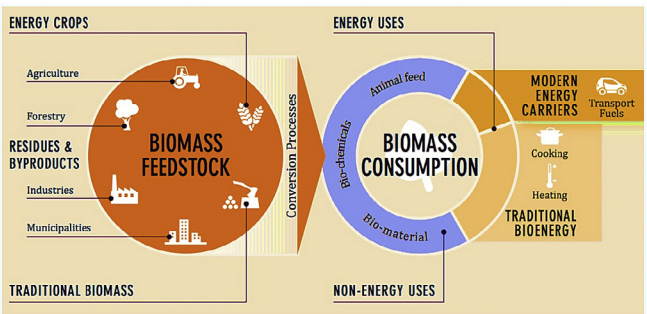

Fig. 1. Biomass feedstock and consumption [23].

The fuels used in the aviation sector need to have high energy content, good flow characteristics and thermal stability [32]. Energy resources which meet these requirements should not challenge the food production and ecosystem while not harming the environment nor causing deforestation. It is the expectation of companies that aviations fuels are economical as well [33,34]. Besides lower fuel consumption, it is also important to release neutral-carbon emission. In addition, alternative aviation fuels must offer low carbon emission over their lifecycles. In a limited number of studies, non-edible oil crops such as camelina, jatropha, algae, halophytes, municipal and sewage wastes, forest residues etc were used aviation fuel production process [35–37]. Biofuel production uses thermo chemical and biochemical techniques. After 2008, numerous test flights were performed with biofuels and ASTM standards were achieved in 2011 in order to allow aircraft and engine manufacturers to use biofuels in air vehicles [34]. It is anticipated that consumption of second generation biofuels will be 6% in the aviation sector, which is supported by Boeing [38,39]. It is emphasized that aviation biofuel production will show progress with respect to the developed standards by national and international organizations. International Air Transport Association (IATA) predicts 30% biofuel in jet fuel by 2030 [39,40]. If this goal is achieved, biofuel use will result in a great deal of positive impact on economy and environment in developing countries. Biofuels, produced from various raw materials that are easy and widely available, improve the fuel properties. This will increase the variety of alternative fuels to be used throughout the world. Thus, biofuels which can be maintained economically, ecologically and socially have the potential to spread [41].

In coming years, alternative fuels used in both air and ground transportation will support the energy policy of countries [42]. Due to economical and environmental disadvantages of fossil fuels, alternative energy resources have also been investigated to reduce dependency on petroleum based fuels and protect environment. Overall, manufacturers of air and ground vehicles focus on design of engines and vehicles compatible with alternative fuels [43–45]. More research is needed for the compatibility of alternative fuels in ground vehicles which use mostly liquid fuels. In this regard, it is also important to note that internal combustion engines and gas turbines could potentially use fuels of similar properties with new fuel injection technologies and designs.

Gasoline engines use alcohol based alternatives fuels in ground transportation. Diesel engines, which are used more widely than gasoline engines for transportation, use alcohols, biodiesel and synthetic fuels, which have been compared over the years against one another in terms of energy value and engine characteristics. With respect to the economic development of countries, air transportation and aviation has become an important transportation part of the system. This sector needs a special fuel whose characteristics are placed in between those of gasoline and diesel fuels. Thus, the need for alternative fuels in the aviation sector has led to economical developments but also new resources for raw fuels. Like in the transportation sector, fuels used in the aviation sectors must be tested over the years and reliable fuels in terms of environmental and performance impacts. As a result, bio-aviation

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