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In pursuit of Sustainable Development Goal (SDG) number 7: Will biofuels be reliable?

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ABSTRACT

Driven by the desire to mitigate climate change and reduce overdependence on fossil fuels, biofuels have been actively pursued in recent years because they are believed to be inherently environmentally friendly. In the past few years, however, critics have objected to the basis for which it should be adopted due to potential negative trade-offs. Sustainable Development Goals (SDG) number seven seeks to substantially increase contribution of renewable energy to global energy supply, as well as double the rate of improvement in efficiency of energy. Biofuels are likely to play a key role in the pursuit of these goals being one of the most advanced alternative energy sources. This review assesses the potential of biofuels to contribute to the set SDGs by presenting an appraisal of their development over the years. It sheds light on some main arguments surrounding biofuels from the perspective of proponents and critics alike. Even though biofuels have a great potential in aiding climate change mitigation, its large scale adoption is regarded as problematic in its current state. This is because of its potential negative trade-offs in terms of land use change and emissions, especially for first and second generation biofuels. However, a combination of plant biology, carbon capture techniques and novel bioconversion processes provided by third and fourth generation biofuel technologies have set open an era of fuels that will be abundant, energy efficient and clean to support the seventh SDG.

1. Introduction

1.1. The Issue of Biofuel- Its rise, necessity and prospects for the future

The world population is continuously growing since the last 50 years, resulting in a large increase in primary energy consumption. In 2010, world primary energy consumption grew by 5.6%, which is the largest percentage growth in almost 40 years [1]. Hence, the world is currently facing two major challenges, which are energy crisis and environmental pollution [2]. With a growing recognition of this dual challenge, the world has formally enshrined the pursuit of renewable energy targets in the Sustainable Development Goals (SDGs) to meet the growing demand for energy and curb pollution [18].

Global energy crisis in the past decades has been attributed to the substantial decrease in fossil fuel deposits and volatility in world prices. Extensive use of fossil fuel for power generation and transportation fuel has caused high carbon dioxide (CO_2) emissions into the atmosphere and there is an urgent need to reduce its emission to avoid harmful impacts of global warming. In its starkest report yet, the fifth assessment report (AR5) of the United Nations' Intergovernmental Panel on Climate Change published in 2014 suggested that fossil fuels must completely be phased out by 2100 [3]. Currently, the report indicates that renewable energy makes up about 30% of global energy supply and should increase to at least 80% by 2050 if the 2100 target is to be reached. Previous studies conducted by Shell International Petroleum Company indicated that biofuel will be a major supplier of energy after 2020. Furthermore, detailed analyses have suggested that it will contribute to future energy production more than all other renewable energy sources combined [4–7].

Historically, biomass has always been a very important source of energy for households, especially in developing countries. In recent years, however, its use has steadily increased in developed countries such as Sweden, Austria, Denmark, USA, Finland, and UK among others [5,7–9]. Havlík, Schneider [10] have stated that the interest in developing biofuel first arose in after the oil crisis in the 1970's and now, the declining cost of production due to subsidies provided by national governments, and the continued swelling up of oil prices are contributing to its competitiveness.

Currently, renewable energy is said to be more subsidized than

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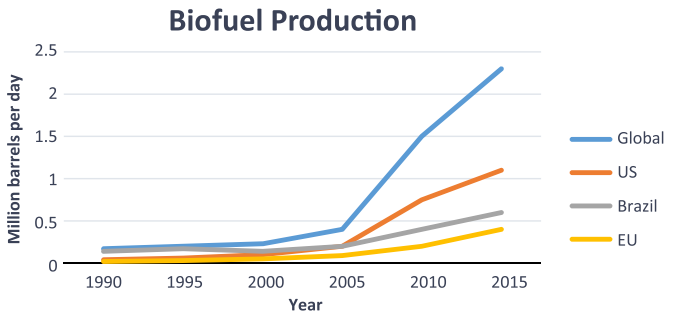

Fig. 1. Biofuel Production of the world from 1990–2015 as adapted from Rapier [16] and IEA [17].

fossil fuels globally, with the exception of China. In Europe and Australia, the biofuel industry is said to enjoy substantial excise tax rebates and exemptions [106,107,109,110]. As a matter of fact, in Australia, the biofuel industry had an effective rate of assistance (ERA) of 100% or more by 2006; far greater than agriculture and manufacturing which averaged around 5% in 2006/2007 [106]. In Canada, subsidies on a litre of ethanol from corn to substitute an equivalent litre of fossil energy is also said to be enough to purchase a litre of the displaced fuel [108].

Several advanced countries continue to set very ambitious targets for themselves as far as biofuel development is concerned. In the United States (US), it is mandated by the Energy Independence and Security Act in 2007 to produce over 36 billion gallons of biofuel by 2022 [11–13]. In the European Union (EU), to achieve a target of reducing GHG emissions by 20% in 2020 compared to 1990 levels, it is a goal to increase the share of renewables in the EU's final energy consumption to 20% with a 10% share of biofuels expected in member states [11,13]. Between 2000 and 2007, biofuel production more than tripled around the globe from a little below five billion gallons to about 16 billion gallons, primarily from food crops [14,15]. As illustrated in Fig. 1, the biofuel production in the world has been rising steadily with the major contributors being US and Brazil [56].

Advocacy for renewable energy has always been deeply rooted in the fact that they are 'green' and therefore may serve as a low-carbon source for future energy needs. The qualities biofuels share with fossil fuels have, however, through studies been shown not to be limited to that stated above but also a tendency for air emissions especially at its conversion state. There have been several debates with proponents and critics on two ends of the spectrum about the grounds on which biofuel is to be adopted. This debate is likely to intensify as the world has formally transitioned from the era of Millennium Development Goals (MDGs) to the Sustainable Development Goals (SDGs) era with specific targets for renewable energy development.

Including renewable energy targets in the SDGs is especially critical because while the MDGs acknowledged the need for reliable energy supply to meet global goals, it did not emphasize specific targets of renewable energy in the global energy mix. In the SDGs, however, the need to employ sustainable and renewable energy sources to achieve global goals has been illuminated in goal number seven. Some specific targets within SDG number seven are as follows: to substantially increase the share of renewable energy to global energy mix by 2030; to double the rate of improvement of energy efficiency around the globe; and to increase supply of modern and sustainable energy services for all in developing countries through infrastructure expansion and technology upgrade [18]. Biofuels, being the most advanced alternate source of energy, will be expected to play a key role in the pursuit of these goals. However, if biofuels are expected to be pivotal in the pursuit of SDG renewable energy targets in phasing out fossil fuels mainly on the grounds of its environmental friendliness, then it is only prudent to assess how it fully merits its consideration.

This paper aims to present a critical appraisal of biofuels, assessing arguments from the perspectives of both proponents and critics, on two sides of the spectrum. That is how large scale adoption of biofuels may affect environmental quality and land use changes, and how advanced biofuel technology will affect the concepts and prospects of future energy production. The review also proffers recommendations towards achieving the set SDG targets. The paper is structured as follows; after this introductory section is a brief description of the various types of biofuels. The third section considers arguments for and against the large scale and long term adoption of first and second generation biofuels as primary global fuel. General overview of third generation biofuels is also presented, with focus on how progress of microalgae-based biofuels is impacting the dynamics of biofuel debate. An overview of progress with fourth generation biofuels ends the third section. The fourth section is a brief summary of issues in the preceding sections. Finally, the paper ends with recommendations for policy and priority research areas necessary for achieving the set SDGs.

2. Types of biofuels

Biofuels can be produced via various renewable feedstocks such as edible oil (e.g. palm oil), non-edible oil (e.g. jatropha) and lignocellulosic biomass (e.g. wood). Biofuels are currently driven by biological material from plants, microorganisms, animals and wastes. Different feedstocks are utilized by different countries and regions for the production of biofuels (Fig. 2).

Biofuels depend on the photosynthetic conversion of solar energy to chemical energy. In fact, the line between renewable biofuels and non-renewable fossil fuels is sometimes unclear as the source of biofuel feedstock can have a significant impact on the debate surrounding biofuels. Therefore, only complete life-cycle analyses can reveal which feedstock is more sustainable and environmentally friendly for biofuel production [19]. Based on the source and production technology, biofuels are classified into the first, second, third [20] and the fourth generation biofuels (Fig. 3). Brief descriptions of the four categories of biofuels are presented below.

2.1. First generation biofuels

Biofuels obtained from technologies that make use of the conversion of feedstock such as sugar and starch portions of sugarcane, cassava and sugar beet cereals into ethanol are classified under first generation biofuels. Belonging to this category are also biofuels obtained from technologies that utilize oil-seed crops such as rapeseed, sunflower, soybean and palm oil [30]. These forms of biofuels have reached the most advanced forms in biofuel production and are commercially available. As a matter of fact, oil palm and sugarcane is said to account for more than 90% of total biofuel feedstock investments in tropical countries since the year 2000 [46].

2.2. Second generation biofuels

Second generation biofeuel technologies utilize more flexible and energy-efficient lignocellulosic feedstock such as biomass from agricultural and forest residues as well as feedstock such as trees, jatropha, straw, bagasse, and purpose energy crops grown on marginal lands [12,15,18,30]. These feedstocks are converted into ethanol and methanol [12]. Unlike the first generation biofuels, this type of biofuels do not only utilize the grains, sugars or fats but the entire plant which means energy yields per hectare of land can be much higher [15].

2.3. Third generation biofuels

The third generation biofuels are based on improvements in biomass production as the algae and other feedstock primarily utilized as its energy source are specially engineered through advanced biotechnology [11,15,21–23]. According to Chisti [21], the algae are