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An assessment on the sustainability of lignocellulosic biomass for biorefining

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ABSTRACT

Biofuels are promoted in a wide-scale as a means of achieving energy security and reducing greenhouse gas emissions. Biofuels derived from lignocellulosic biomass, particularly from agricultural crops are being massively supported worldwide for meeting multiple strategy objectives such as climate change mitigation, energy security and development of the rural economy. Recently, the negative implications of using food crops for fuel have been realized to possess a significant threat towards global food security and competition for arable land. In contrast, lignocellulosic biomass in the form of waste residues from agriculture, forestry and energy crop systems are geographically abundant worldwide and have the potential to support the sustainable production of liquid transportation fuels. This paper encompasses the improvement in biofuels sector in relation to revitalizing and restraining the rural economies across the globe along with the global statistics for lignocellulosic biomass availability. In addition, the socio-environmental impacts of energy and greenhouse gas emissions from biomass conversion technologies have been addressed through highlights on life-cycle assessment of several biomasses.

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1. Introduction

Bioenergy has drawn considerable interest as a sustainable energy source to replace the exhausting fossil fuels and help in dealing with the rising fuel prices. The world population is estimated to increases from the current 7.2 billion to 8 billion by 2030 [1]. With a human birth in every eight seconds, the energy consumption per capita tends to upsurge. In addition to the basic needs of survival, i.e. food, water and oxygen, human life needs supplementary energy sources (e.g., electricity) for sustenance. Fossil fuels as crude oil, gasoline, coal and natural gas dominate the global energy market worth about $1.5 trillion [2]. From

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various econometric models developed by Shafiee and Topal [2] the estimated timescales for depletion of oil, coal and gas are around 35, 107 and 37 years, respectively.

With the rise in world population and economic growth, the energy consumption is projected to increase by 1.1% per annum, i.e. from 5.3×10^{20} J in 2006 to 7.4×10^{20} J in 2030 [3]. The world energy consumption in 2008 being 533 EJ is estimated for increase to 653 EJ by 2020 and 812 EJ by 2030 [4]. It is foreseeable that about 84% of this energy supply will be from fossil fuels, 6% from nuclear sources and 8% from renewable resources [2,5]. The consumption of fossil fuels has intensified dramatically in the last three decades (Fig. 1). Unlike most nations that illustrate recent reductions in fossil fuels' consumption, countries such as China, India, Thailand and UAE show a positive trend. In emerging countries such as India and China, the demand for fossil fuels is increasing at the rate of 3.9% and 3.5% per year, respectively [7]. The worldwide use of petroleum and other liquid fuels being 85.7 million barrels per day in 2008 could escalate to 97.6 million barrels per day in 2020 and 112.2 million barrels per day in 2035 [4].

Although fossil fuels have accelerated the global industrialization over the years, yet their experiential adverse effects cannot be repudiated. The direct effects from fossil fuel uses include but are not restricted to increase in greenhouse gases (especially CO_2), air pollution, smog in urban areas and water pollution by oil spills. The indirect effects include acid rain, global warming, climate change and other extreme weather conditions. Recently, with an increase in the frequency of earthquakes, it is believed that hydraulic fracking applied for the extraction of natural gas and oil could be a factor of consideration for these natural disasters. Hydraulic fracturing deals with the injection of fluid under high pressure to create tensile fractures for increased permeability of rock or shale formations in order to stimulate the flow of natural gas [8]. Ellsworth [9] reported that fracking for fossil fuel extraction intentionally induces micro-earthquakes with magnitudes less than one in most cases.

Despite their rising prices, the demand for fossil fuels is increasing every day. Fig. 2 highlights a few countries and their gasoline prices as in the current year. It could be seen from this figure that majority of European countries (e.g., Norway, Netherlands, Italy, Greece, Germany, UK, France, Switzerland, Spain, etc.) have the highest gasoline prices per gallon, i.e. between U.S. $7.43 and $9.79 [10]. However, Venezuela, Saudi Arabia and Iran are the countries with the lowest gasoline prices per gallon (U.S. $0.04–1.52).

The emission of greenhouse gases (GHG), particularly CO_2 is directly proportional to the consumption of fossil fuels. The trend for the emission of CO_2 since the last five decades has been shown in Fig. 3. It is distinguishable to notice that Qatar and UAE are the top two CO_2 emitters in the world today having surplus fossil-oil reserves. With 55.4 t of CO_2 emission per person, Qatar has the highest footprint globally, which is about ten times the global average [11]. A huge fraction of this CO_2 emission is attributed to burning fossil fuels to generate electricity and power vehicles. The key factors such as: (1) increasing energy demand, (2) exhausting fossil fuel resources, (3) rising fuel prices, (4) domestic energy security, (5) increasing GHG emissions, and (6) global warming have propagated the attention towards renewable sources of energy [12]. Although most of the alternative energy resources such as wind, solar, geothermal and nuclear are capable of generating heat and power, they cannot produce gaseous or liquid transportation fuels. In contrast, waste plant biomasses are rich in organic carbon that could be potentially transformed to hydrocarbon fuels.

Bioenergy is comprehended as a promising resource as its environmental and economic advantages are becoming more perceptible due to improvements in technology. National and international bodies concerned with promoting agricultural and environmental sustainability through the reduction in GHG emissions have been expanding their interest in biofuels. Furthermore, the policy makers are investing their efforts in diversifying bioenergy as a possible significant contributor towards the socio-economic development of rural communities and a means to reduce poverty by generating local employment and income [13]. Due to this augmented awareness in bioenergy sector, it is now considered as one of the sustainable development agendas for the achievement of 2015 Millennium Development Goals, especially in alleviating global hunger and poverty, adopted by the United Nations General Assembly in 2000 [14].

For a long-term economic sustainability of energy, transportation and industrial sectors, adoption of a wide-range of renewable

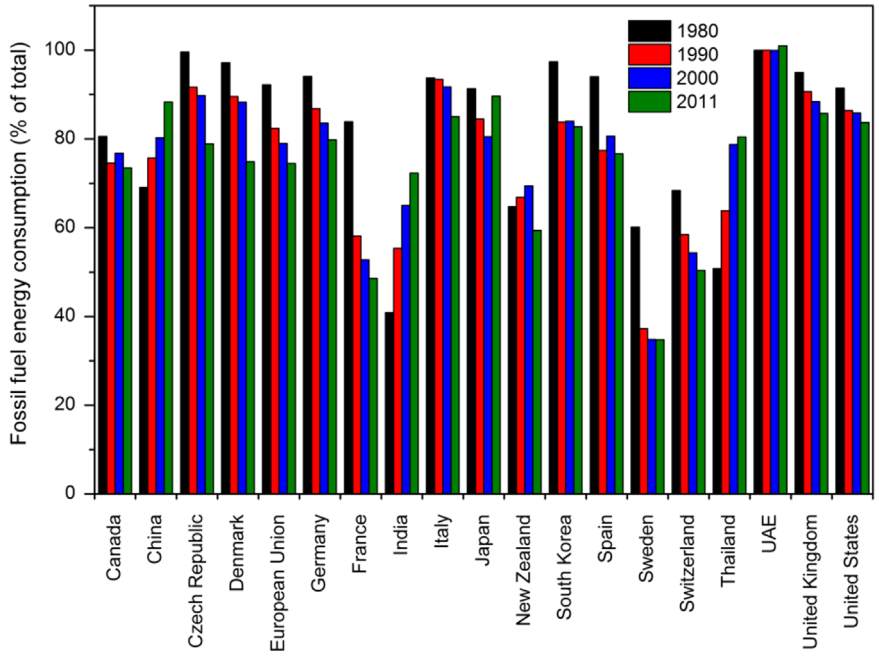

Fig. 1. Consumption of fossil fuel energy over the years, 1980–2011 (Data source: [6]).