The Efficacy of Biofuel Production as a Means of Increasing The Energy Base in Nigeria

Famurewa, J. A. V.

ABSTRACT

This study critically reviews the efficacy of biofuel production as a means of increasing the energy base in Nigeria. It aims at assessing among others, the progress made so far in this direction. Biofuels are renewable liquid fuels coming from biological raw materials which are good substitutes for both fossil fuel and energy. It has the exciting potential for mitigating the grave threats of global warming, reducing the world's dependence on imported oil from insecure sources and reducing the skyrocketing costs of oil that are threatening to undermine the world's economies and are devastating the people in non-oil producing developing countries. This study unveils the fact that Biofuels were once our primary source of fuel and as old as civilization itself in the solid form like wood, dung and charcoal ever since man discovered fire. Liquid biofuel such as olive oil and whale oil have also been in used at least since early antiquity. Rising taxes on ethanol, combined with a decreasing price of petroleum and an aggressive campaign run by large oil producers kept ethanol out of the mainstream. As a result of the several fossil fuel crises since 1970s, biofuel came back to fashion. Therefore, in the quest for a more sustainable feedstock with the potential in solving the challenges in converting cellulosic materials, and produce the quantities of fuel needed at affordable prices today, scientists are converting the lipids and hydrocarbons produced by algae into a variety of fuels and these algae-based biofuels are being touted by some as a path to a sustainable energy supply.

Keywords: *Biofuels, renewable liquid fuels, biological raw material, fossil fuel and energy*

INTRODUCTION

The environment is facing a reduction of global fossil fuels resources, like petroleum, natural gas, or charcoal, while energy requirements are progressively growing up. In fact, the search for sustainable alternatives to produce fuel and chemicals from non-fossil feedstocks has attracted considerable interest around the world, to face the needs of energy supply and to respond to climate change issues. Alternative resources of energy are being explored in order to reduce oil dependence and increase energy production by exploring solar, wind, hydraulic and other natural phenomena. Besides these sources of energy, also biomass possesses a potential target for fuel and power production as well as for chemicals or materials feedstocks. Thus biomass can efficiently replace petroleum-based fuels for a long term. (Sanchez and Cardona, 2008; Brehmer, Boom and Sanders, 2009; Gonzalez-

Famurewa, J. A. V. *(Ph.D) is a Senior Lecturer in the Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria. E-mail: jav_murewa@gmail.com*

ISSN: 2141-2731

Garcia *et al*., 2009; Alvarado-Morales Terra, Gernaey, Woodley and Gani, 2010; Mussatto *et al*., 2010). Biofuel is the term given to any type of fuel derived from biomass, it refers to any organic matter of recent origin that has been derived from animals and plants as a result of photosynthetic conversion process. The biomass energy are derived from plant and animal materials such as wood from forests, residues from agricultural and forestry processes, industrial waste from humans or animals (Balat, 2006). Biofuels may be solid, liquid or gaseous and include all kinds of biomass and derived products used for energetic purposes like cooking, electricity and transport. This "bioenergy" is one of the so-called renewable energies. Biomass are converted to convenient energy containing substances in three different ways: thermal, chemical and biochemical conversions.Biofuels are renewable liquid fuels coming from biological raw materials which are good substitutes for both fossil fuel and energy. It has the exciting potential for mitigating the grave threats of global warming, reducing the world's dependence on imported oil from insecure sources and reducing the skyrocketing costs of oil that are threatening to undermine the world's economies and are devastating the people in non-oil producing developing countries.

It is the worldwide acceptance solution to energy security, rural employment and improving agricultural economy. Ethanol has its production origin similar to the process used in preparing beverages like whisky or vodka using variety of sugar and starch-rich crops, while biodiesel were sourced from plant and seed oil used directly in running diesel engines. The ever increasing demand of biofuel coupled with the competition between biofuel feed stocks of crops and land used for food production which have serious adverse effects on food supplies has led to the use of non-food crops called cellulose material for production. In the quest for a more sustainable feedstock with the potential in solving the challenges in converting cellulosic materials, and produce the quantities of fuel needed at affordable prices today, scientists are converting the lipids and hydrocarbons produced by algae into a variety of fuels and these algae-based biofuels are being touted by some as a path to a sustainable energy supply. The main producing countries for transport biofuels are the U.S., Brazil and the EU. Brazil and the U.S. produced 55 and 35 per cent, respectively, of the world's ethanol production in 2009, while EU produced 60 per cent of the total biodiesel output (Josling, Blandford and Earley, 2010).

U.S. production consists mostly of ethanol from corn; in Brazil the main product is ethanol from sugar cane; and in the EU most of the biofuel is biodiesel from rapeseed (Alonso, Stepa nova, Leisse and Kim, , 2003). U.S. and Brazil are the main ethanol producers while the EU is the largest biodiesel producer. High production cost limits the economic viability of biofuels with the exception of ethanol production in Brazil (U.S. EPA, 2003); thus, rendering the biofuel industry very dependent on public support. The European Union (EU), as well as many other countries, has introduced several policies to promote the production and use of biofuels. The new Renewable Energy Directive (RED) establishes a common framework for the promotion of energy from renewable sources (BRDB, 2008). The RED sets a mandatory target of 20% for the overall share of energy from renewable sources in gross final consumption of energy by 2020 (BRDB, 2008a). As regards the transport sector, each Member State has to achieve a 10% share of energy from renewable sources (including biofuels) in total fuel consumption in transport in 2020 (BRDB, 2008b). The benefits of biofuels over traditional fuels include greater energy security, reduced environmental impact, foreign exchange savings, and socio-economic issues related to the rural sector. Furthermore, biofuel technology is relevant to both developing and industrialized countries. For these reasons, the share of biofuels in the automotive fuel market is expected to grow rapidly over the next decade. Biofuels could be peaceful energy carriers for all countries. They are renewable and available throughout the world. Policy-makers will need to pay more attention to the implications for the transition to biofuel economy. The concepts of sustainable development have the potential to promote rural development, embodies the idea of the inter-linkage and the balance between economic, social and environmental concerns. The increase in the demand of biofuel has led to the change in the trend of production from the use of staple food crops which hinders food security to lignocellulose biomass and gradually to the use of micro alga because of the difficult steps involved in the conversion of the Lignin into glucose. Biofuels for transport are commonly addressed according to their current or future availability as first, second and third generation biofuels (OECD/IEA, 2008). Second and third generation biofuels are also called "advanced" biofuel.

Biofuels were once our primary fuel. It is as old as civilization itself in the solid form like wood, dung and charcoal ever since man discovered fire. Liquid biofuel such as olive oil and whale oil have also been in use at least since early antiquity. Rising taxes on ethanol, combined with a decreasing price of petroleum and an aggressive campaign run by large oil producers kept ethanol out of the mainstream. Biofuel came back to fashion because of the several fossil fuel crises since 1970s, others are: 1973 oil crisis caused by the Organization of Arab Petroleum Exporting Countries (OAPEC) oil export embargo; 1979 oil crisis caused by the Iranian Revolution and 1990 oil price shock caused by the Gulf War (US EPA, 1998). This led many countries, such as the US and Brazil to begin modern large-scale production of biofuels. In the last 10 years, biofuels have been embraced as a way to help resolve some of the world's greatest challenges: declining fossil fuel supplies, high oil prices and climate change (Webb and Coates, 2012).

Biomass Feedstock

A feedstock is a material used as the basis for manufacture of another product. Biomass feedstocks are sources of organic matter that are used as key inputs in production processes to create bioenergy. Both agricultural/energy crops and waste/opportunity fuels can be used as biomass feedstock.

Traditional Crops

Several traditional crops that are grown for food and other uses can also be used to produce bioenergy, primarily as biofuels. Crops currently used as biomass feed stocks include: corn, sorghum, soybeans (BRDI, 2008), rapeseed and sugarcane (OEERE, 2008). Corn is the primary biomass feedstock currently used in the United States to produce ethanol (BRDI, 2008). Rapeseed is the primary feedstock used in Europe to produce biodiesel (OEERE, 2008). Sorghum is used in the United States as an alternative to corn for ethanol production. As of 2008, 15 percent of U.S. grain sorghum is being used for ethanol production at eight plants (BRDI, 2008). Soybeans are the primary biomass feedstock currently used in the United States to produce biodiesel from soybean oil (BRDI, 2008). Brazil uses sugarcane to produce ethanol and uses the sugarcane residue for process heat (OEERE, 2008).

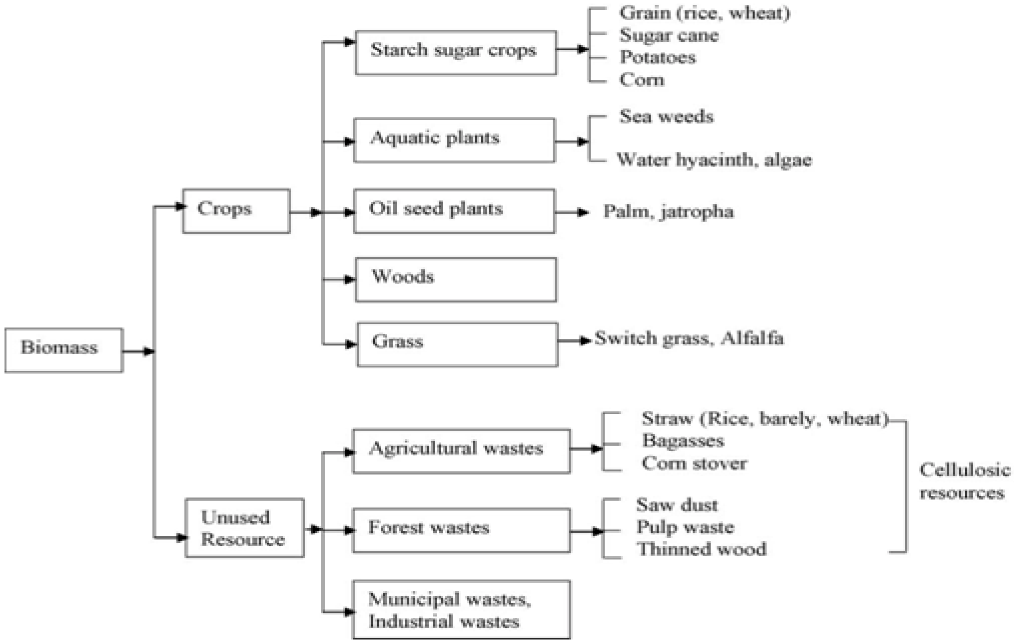

Figure 1: Biomass renewable feed stock for biorefineries.
Source: Naik, Goud, Rout and Dalai, 2010).

Energy Crops

Other crops that are planted and harvested specifically for use as biomass feedstocks in the production of bioenergy are referred to as “energy crops.” Energy crops are fast-growing and grown for the specific purpose of producing energy (electricity or liquid fuels) from all or part of the resulting plant. The advantages of using crops specifically grown for energy production include consistency in moisture content, heat content and processing characteristics, which makes them more cost-effective to process efficiently (US EPA, 2007a). Emerging energy crops include: (i) Switch grass, poplar and willow trees. These energy crops are not yet being grown commercially in the United States for bioenergy, but may have the greatest potential for dedicated bioenergy use over a wide geographic range. The U.S. Department of Energy (U.S. DOE) estimates that about 190 million acres of land in the United States could be used to produce energy crops such as switch grass and poplar and willow trees (U.S. EPA, 2007a; Antares, 2003). Several States in the Midwest and South could produce significant biopower using switch grass, which is currently grown on some Conservation Reserve Program acres and on hay acres as a forage crop (U.S. EPA, 2007a; Ugarte *et al.*, 2006).

Waste/Opportunity Fuels

Biomass feedstocks from waste materials are often referred to as "opportunity" fuels because they would otherwise go unused or be disposed of; bioenergy production is an opportunity to use these materials productively. Common opportunity fuels include biogas Biogas, consisting primarily of methane, is released during anaerobic decomposition of organic matter. Facilities that deal with large quantities of organic waste can employ anaerobic digesters and/or gas collection systems to capture biogas, which can be used as a source of on-site bioheat and/or biopower. Major sources of biogas include: waste water treatment plants (WWTPs), landfills, sewage sludge from wastewater treatment plants, crop residues; food processing wastes, forest residues, municipal solid wastes and wood wastes. Anaerobic digesters can be used during treatment of wastewater to break down effluent and release biogas, which can then be collected for subsequent use as a source of bioenergy. According to an analysis by the U.S. EPA Combined Heat and Power Partnership, as of 2004, 544 municipal WWTPs in the United States use anaerobic digesters. Only 106 of these facilities utilize the biogas produced by their anaerobic digesters to generate electricity and/or thermal energy.

As of April 2009, 125 operators in the United States collect and use their biogas. In 113 of these systems, the captured biogas is used to generate electrical power, with many of the farms recovering waste heat from electricity-generating equipment for on-farm use. These systems generate about 244,000 MWh of electricity per year. The remaining 12 systems use the gas in boilers, upgrade the gas for injection into the natural gas pipeline, or simply flare the captured gas for odor control (US EPA, 2009b). As the organic waste buried in landfills decomposes, a gas mixture of carbon dioxide (CO_2) and methane (CH_4) is produced. Gas recovery systems can be used to collect landfill emissions, providing usable biogas for electricity generation, CHP, direct use to offset fossil fuels, upgrade to pipeline quality gas, or use in the production of liquid fuels. As of December 2008, EPA's Landfill Methane Outreach Program estimated that, in addition to the approximately 445 landfills already collecting LFG to produce energy, 535 landfills are good candidates for landfill gas-to-energy projects (U.S. EPA, 2008a).

Biosolids can be dried, burned, and used in existing boilers as fuel in place of coal or cofired with coal to generate steam and power. Bio-solids can also be converted into biogas for bioenergy. The high water content of most bio-solids can present challenges for combustion. As a result, bio-solids must generally go through a drying process prior to being used for energy production. More than 300 million acres are used for agricultural production in the United States. As of 2004, the most frequently planted crops (in terms of average total acres planted) were corn, wheat, soybeans, hay, cotton, sorghum, barley, oats, and rice (Famurewa and Babatola, 2011). The harvest of many traditional agricultural crops, residues such as crop stalks, leaves, cobs, and straw are left in the field. Some of these residues could be collected and used as bioenergy feedstocks (U.S. EPA, 2007a; USDA, 2009). Food processing wastes include nut shells, rice hulls, fruit peels, cotton gin trash, meat processing residues, and cheese whey, among others. Because these residues can be difficult to use as a fuel source due to the varying characteristics of different waste streams, the latter two of these food processing wastes are often disposed of as industrial wastewater. Many anaerobic digester operators are currently adding agricultural and food wastes to their digesters to provide enhanced waste management and increased biogas generation (US EPA, 2007a). Residues from silvi-culture (wood harvesting) include logging residues such as limbs and tops, excess small pole trees, and dead or dying trees. After trees have been harvested from a forest for timber, forest residues are typically either left in the forest or disposed of via open burning through forest management programs because only timber of a certain quality can be used in lumber mills and other processing facilities. An advantage of using forest residues from silvi-culture for bioenergy production is that a collection infrastructure is already in place to harvest the wood. Approximately 2.3 tons of forest residues are available for every 1,000 cubic feet of harvested timber (although this number can vary widely); these residues are available primarily in the West (US EPA, 2007a). Municipal Solid Waste (MSW) - trash or garbage - can be collected at landfills, dried, and burned in high-temperature boilers to generate steam and electricity.

Mass burn incineration is the typical method used to recover energy from Municipal Solid Waste, which is introduced "as is" into the combustion chamber; pollution controls are used to limit emissions into the air. Some waste-to-energy facilities have been in operation in the United States for more than 20 years (US EPA, 2008a). More than one-fifth of incinerators use Refuse-Derived Fuel (RDF), which is Municipal Solid Waste that has been thoroughly sorted so that only energy-producing components remain (US EPA, 2009a) RDF can be burned in boilers or gasified (US DOE, 2004). The waste-to-energy industry currently generates 17 billion kilowatt-hours (kWh) of electricity per year. However, based on the total amount of MSW disposed of in the United States annually (250 to 350 million tons), Municipal Solid Waste could be used as fuel to generate as much as 70 to 130 billion kWh per year (US EPA, 2008a). Wood waste includes mill residues from primary timber processing at sawmills, paper manufacturing and secondary wood products industries such as furniture makers. It also includes construction wood waste, yard waste, urban tree residue, and discarded consumer wood products that would otherwise be sent to landfills (US EPA, 2007a). Wood wastes such as woodchips, shavings, and sawdust can be compressed into pellets, which offer a more compact and uniform source of energy (BERC, 2007).

TYPES OF BIOFUEL

Biofuels are all types of solid, gaseous and liquid fuels that can be derived from biomass. Solid biofuels include the traditionally originated one like wood, charcoal and bagasse, sawdust, grass trimmings, domestic refuse, agricultural waste, to the modern use of nonfood energy crops, and dried manure. This biofuel can be divided into two groups namely: (i) those that can be burned directly in their raw state, for example, fire wood. (ii) the raw biomass in an inconvenient form that requires further processing before use. The process is aimed at densifyinf the biomass which involves grinding to an appropriate particulate size known as hogfuel, depending on the densification type, can be from 1 to 3cm (0 to 1 in), which is then concentrated into a fuel product (USDA, 2008; Josling, Blandford and Earley, 2010). Solid biomass densification processes produce wood pellets, cubes, the other types of densification are larger in size compared to a pellet, and are compatible with a broad range of input feedstocks. The resulting densified fuel is easier to transport and feed into thermal generation systems, such as boilers. The advantage of solid biofuel is that it does not compete with food for resources because it is a by-product, a residue or waste-product of other processes (Carp, 1996; Yano, Blandford and Surry, 2010). The combustion of raw biomass emits considerable amounts of pollutants, such as particulates and polycyclic aromatic hydrocarbons have become the common disadvantage of solid biofuel. Even modern pellet boilers generate much more pollutants than oil or natural gas boilers. Pellets made from agricultural residues are usually worse than wood pellets, producing much larger emissions of dioxins and chlorophenols (Demirbas, 2006).

The major gaseous fuels are Biogas and Syngas. Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes (Echols, 2009). It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. Biogas can be recovered from mechanical biological treatment waste processing systems and naturally occurring anaerobic digestion. Syngas also called producer gas is a mixture of carbon monoxide, hydrogen and other hydrocarbons which is produced by partial combustion of biomass, that is, combustion with an amount of oxygen that is not sufficient to convert the biomass completely to carbon dioxide and water (Fraley *et al.*, 1983). Before partial combustion, the biomass is dried, and sometimes pyrolysed. The resulting gas mixture, syngas, is more efficient than direct combustion of the original biofuel; more of the energy contained in the fuel is extracted.

Syngas can be used to produce methanol, Dimethyl ether as well known as methoxymethane (DME) and hydrogen, or converted via the Fischer-Tropsch process to produce a diesel substitute, or a mixture of alcohols that can be blended into gasoline. Liquid Biofuels are classified into (i) Bioethanol and (ii) Biodiesel. Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum. The ethanol production methods used are enzyme digestion (to release sugars from stored starches), by mixing sugar, water and yeast bacteria, which are then allowed to ferment in warm environment. The fermentation process is a series of chemical reactions wherein simple sugars are converted into ethanol and release of carbon dioxide. There is a simple formula that represents the process of simplified fermentation reaction, which is as follows:

$C_6H_{12}O_6$ (glucose) -> 2 CH_3CH_2OH (ethanol) + 2 CO_2 (carbon dioxide)

Ethanol can also be derived with advanced technology from cellulosic biomass, such as trees and grasses and more recently from the algae. A unique use of ethanol in the world is called Flex Flue (Thompson, Seth and Pat, 2009). Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing car petrol engines can run on blends of E85 is an alternative fuel that contains up to 85% ethanol. It is used mainly in the Midwest and South Vehicles that use E85 are specially named as Flexible Fuel Vehicles (FFV) up to 15% bioethanol with petroleum/gasoline (Hertel, Tyner and Birur, 2010). The advantage of Bioethanol, according to Balat M., Balat H. and Oz (2008); Mussatto, *et al*. (2010) is that it has a higher octane number, broader flammability limits, higher flame speeds, heat of vaporization and compression ratio and a shorter burn time. The use of bioethanol can also contribute to the reduction of carbondioxide (CO_2) build. This is achieved because in the growing phase of the source crop, CO_2 is absorbed by the plant and oxygen is released in the same volume that CO_2 is produced in the combustion of the fuel (Sanchez and Cardona, 2008; Gonzalez-Garcia *et al*., 2009; Chen, and Qiu, 2010a; Balat, 2011). Moreover, combustion of ethanol results also in lower NO_x emissions, being free of sulphur. However, as disadvantage of bioethanol, ethanol has an energy density lower than gasoline, it is fully miscible in water and its lower vapour pressure makes motor cold start more difficult (Balat M., Balat H. and Oz, 2008; Gonzalez-Garcia, *et al*., 2009; Chen and Qiu, 2010a; Mussatto *et al*., 2010; Balat, 2011). Biodiesel is a liquid similar in composition to fossil/mineral diesel produced from oils or fats using transesterification process. Chemically, it consists mostly of Fatty Acid Methyl (or ethyl) Esters (FAMEs). The feedstocks for biodiesel include animal fats, vegetable oils, soy, rape seed, jatropha, mahua, mustard, flax, sunflower, palm oil, hemp, field pennycress, Pongamiapinnata and algae. Pure biodiesel (B100) is the lowest-emission diesel that can be used directly but requires certain engine modifications to avoid maintenance and performance problems or may be blended with petroleum diesel at any concentration in most injection pump diesel engines. The blends system is known as the "B" factor to state the amount of biodiesel in any fuel mix including the following: 20% biodiesel, 80% petrodiesel is labeled B20, 5% biodiesel, 95% petrodiesel is labeled B5, 2% biodiesel, 98% petrodiesel is labeled B2 (Taheripour, Hertel, Tyner, Beckman and Birur, 2010). According to Hiei, Ohta, Komar and Kumashiro (1994), biodiesel is gaining recognition in the United States as a renewable fuel due to increasing environmental concern which may be used as an alternative to diesel fuel without any modification to the engine.

Properties of biodiesel

1. Biodiesel has better lubricating properties and much higher cetane ratings than today's low sulfur diesel fuels.
2. Biodiesel addition reduces fuel system wear.
3. The calorific value of biodiesel is about 37.27 MJ/kg. This is 9% lower than regular Number 2 petrodiesel (Gressel, 2008).
4. Biodiesel gives better lubricity and more complete combustion thus increasing the engine energy output and partially compensating for the higher energy density of petrodiesel.
5. Biodiesel is a liquid which varies in color - between golden and dark brown - depending on the production feedstock.
6. It is slightly miscible with water, has a high boiling point and low vapour pressure.
7. The flash point of biodiesel (>130°C, >266°F) is significantly higher than that of petroleum diesel (64°C, 147°F) or gasoline ("45°C, -52°F).
8. Biodiesel has a density of ~ 0.88 g/cm³, higher than petrodiesel (~ 0.85g/cm³).
9. Biodiesel has virtually no sulfur content, and it is often used as an additive to Ultra-Low Sulfur Diesel (ULSD) fuel to aid lubrication, as the sulfur compounds in petrodiesel provide much of the lubric.

The advantages of Biodiesel are enormous; among them are: the use of biodiesel in conventional diesel engines substantially reduces emissions of unburned hydrocarbons (HC), carbon monoxide (CO), sulfates, polycyclic aromatic HCs, nitrated polycyclic aromatic HCs and particulate matter (PM). Biodiesel use also reduces greenhouse gas emissions because the carbon dioxide released in biodiesel combustion is offset by the carbon dioxide sequestered while growing the feedstock (Klein, Weissinger, Tomes, Schaa, Sletten and Sanford, 1988). Biodiesel has a few drawbacks. One of such problems is the increase in NO_x in biodiesel emissions. Often, in diesel fuel manufacturing, when you decrease the amount of particulate matter in the emissions there is a corresponding increase in nitrogen oxides, which contribute to smog formation. Currently, there are technologies being researched to reduce this problem. Some older diesel vehicles may experience clogging with higher concentrations of biodiesel. Since biodiesel has the ability to loosen deposits built up in the engine, it is a good idea to replace the fuel pump and also the fuel lines when using biodiesel for the first time. Most biodiesels are manufactured at B5 and B20, which are low concentrations of biofuel to diesel (Gressel, 2008). Most automobile manufacturers guarantee this mixture will work with no modification to the engine whatsoever (Knothe, 2010).

DEVELOPMENT IN BIOFUEL PRODUCTION

Biofuels for transport are commonly addressed according to their current or future availability as first, second or third generation biofuels (OECD/IEA, 2008). The Third Generation is also called "advanced biofuels".

First Generation Biofuels: The Biofuel in this category depend solely on edible food crops for its production. The United States produces its ethanol from corn, Brazil ethanol is from sugar cane, and in the European Union is mostly biodiesel from rapeseed (UNEP, 2009). However, on many levels (environmental, societal), the fact that food resources could be used to produce biofuels shows several limits, as this would create land pollution, a lack of agricultural land (world hunger) and deforestation (NRC, 2007; Ishida, Ohta, Hiei, Komar and Kumashiro, 1996). For example, in some European countries such as France, the arable lands available for cultivation of oleaginous plants used for 1st generation biofuels production will not be able to support the biofuels demand by 2015, except by saturating the lands in fallow, which would create soil impoverishment problems (Boudet, Kajita, Grima-pettenati and Goffner, 2003).

Second Generation Biofuels: Second generation biofuels are the cellulosic-based biofuels obtained from non-food crops materials (wood, leaves, straw, etc.). These biofuels include bioalcohols, bio-oil, 2.5-dimethylfuran (BioDMF), biohydrogen, Fischer-Tropsch diesel, wood diesel (Román-Leshkov, Barrett, Liu and Dumesic, 2007; FatihDemirbas, 2009). They can be broadly grouped into those produced either biochemically or thermo-chemically, using lignocellulosic feed stocks sourced from crop, forest or wood process residues, or purpose-grown perennial grasses or trees. Such crops are likely to be more productive than most used in first generation in terms of the energy content of biofuel produced annually per hectare (GJ/ha/yr).

Advantage of Second over First generation biofuels: The great advantage for the choice of Lignocellulosic Biomass (LCB) as feedstock is the non-interference with food chain, which allows the production of bioethanol without using arable lands (Zhang, 2008; Sanchez and Cardona, 2008). LCB is a complex raw material which can be processed in different ways to obtain other value-added compounds contributing to the possibility of establishing a biorefinery. Different value-added products such as lactic acid, acetic acid, furfural, methanol, hydrogen and many other products can be obtained from its sugars. Lignin, the non-carbohydrate component, can be used for the production of advanced materials, polymers and aromatic aldehydes (Zhang, 2008; Sanchez and Cardona, 2008). In this way, LCB can be used as substrate for the production of second generation biofuels, contributing to the diversification of energy supply and gas mitigation, offering less competition for the food and feed industry (Lee, Speight and Loyalka, 2007). The use of these raw materials to produce fuel, power and value-added chemicals, fits well into the biorefinery concept invoked to decrease the dependence from fossil resources and to improve the economic sustainability (Alvarado-Morales, Terra, Gernaey, Woodley and Gani, 2009). The use of LCB as feedstock for bioethanol production results in significant reduction of gas emissions (Sanchez and Cardona, 2008; Brehmer, Boom and Sanders, 2009) and in economic profits increase due to low-cost raw-materials (Balat M., Balat H. and Oz, 2008).

Second generation biofuels limitation: The composition of LCB depends on the plant species and consists primarily of cellulose, hemicelluloses and lignin, which are the integral part of cell wall in plant tissues (Spolaore, Joannis-Cassan, Duran and Isambert, 2006). Lignin is an amorphous aromatic biopolymer composed of phenyl propane structural units linked by either and/or carbon-carbon bonds, supplying tissues stiffness, antiseptic, and hydrophobic properties amongst others Lignin contributes to 15-30% of plant biomass and is the principal non-hydrolysable residue of LCB (Suter, 2008). Cellulose and hemicelluloses are hydrolysable structural polymers of cell wall and the main sources of fermentable sugars (Lawford *et al*., 1993; Sanchez and Cardona, 2008). Hemicelluloses contribute to 10-40% of plant material and are essentially heteropolysaccharides constituted (Tyner, Taheripour and Baldos, 2009). Lignocellulose ethanol production, because of its recalcitrance, is still under development (Akin, 2007; Himmel, *et al*., 2007). In fact, a great effort has been made to increase the lignocellulose conversion rate, but the difficulty remains with two crucial factors: biomass pretreatment and enzymatic degradation. It is determined by cellulose crystallinity and lignin linking-styles of the plant cell walls (Singhania, Sukumaran, Pillai, Szakacs and Pandey, 2006; Singhania, Parameswaran and Pandey, 2009). In spite of extreme pretreatment conditions that can be a solution, such as strong acid/base, or extreme temperature/pressure, it leads to a negative economic profit of biofuel production together with a secondary environmental pollution (Boudet, Kajita, Grima-pettenati and Goffner, 2003).

Third Generation Biofuels: Third generation biofuels are microorganisms (yeast, fungi) biofuels and algae-based fuels like vegetable oils, bio-oil, jet-fuels, biohydrogen, biodiesel, renewable diesel and many others (FatihDemirbas, 2009; Stevens and Verhe, 2004).

Algae fuel, also called oilgae, is a biofuel from algae and addressed as a third-generation biofuel (OECD/IEA, 2008). Algae are feedstocks from aquatic cultivation for production of triglycerides (from algal oil) to produce biodiesel. The processing technology is basically the same as for biodiesel from second-generation feedstocks. Other third -generation biofuels include alcohols like bio-propanol or bio-butanol, which due to lack of production experience are usually not considered to be relevant as fuels on the market before 2050 (OECD/IEA, 2008), though increased investment could accelerate their development trend. Microalgae can provide several different types of renewable biofuels. Figure 2 is a schematic overview of microalgal chemical intermediates and the fuels that can be produced from these important components. The three major macromolecular components that can be extracted from microalgal biomass are lipids, carbohydrates, and proteins. These chemical components can be converted into a variety of fuel options such as alcohols, diesel, methane, and hydrogen.

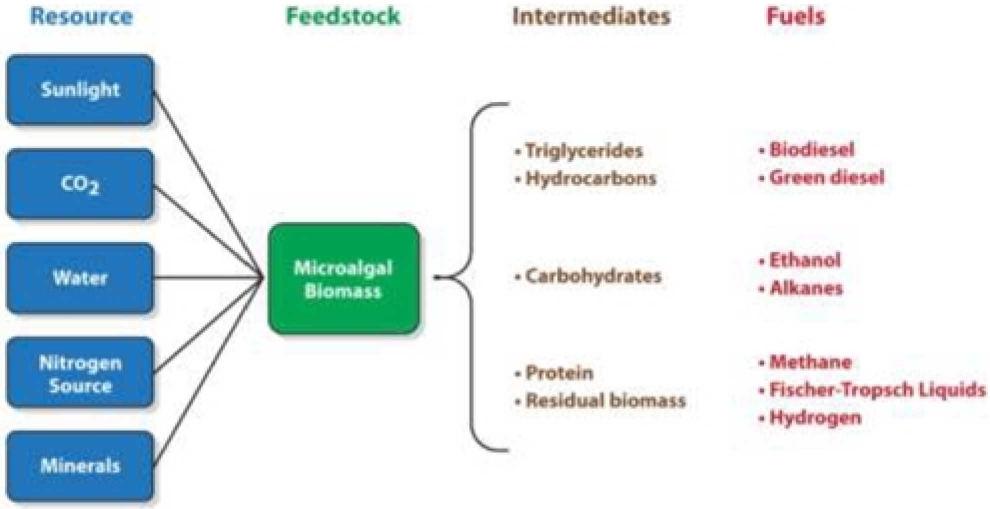

Figure 2: Fuel Production Options from Microalgal Cell Components.
Source: Mohan, Pitman and Steele (2006).

Comparison of Third Generation with Second and First Generation

Microalgae were among the first life forms on earth (Sjostrom, 1993). They are capable of fixing large amounts of carbon dioxide (CO_2) while contributing to approximately 40 per cent to 50 per cent of the oxygen in the atmosphere thereby helping to support the majority of life on our planet. Microalgae are highly productive on a global scale, with cell doublings of 1-4 per day (Fargione, Hill, Tilman, Polasky and Hawthorne, 2008). While microalgae make up only 0.2 per cent of global biomass generated through photosynthesis, they account for approximately 50 percent of the total global fixed organic carbon (Swinbank, 2009a). Microalgae, like terrestrial plants, grow and multiply through photosynthesis, a process whereby light energy is converted into chemical energy by-fixing atmospheric CO_2 by the following reaction:

$6CO_2 + 6H_2O$ + light energy '! $C_6H_{12}O_6$ (sugars) + $6O_2$

The sugars formed by photosynthesis are converted to all the other cellular components (lipids, carbohydrates, and proteins) that make up the biomass. The photosynthetic process in microalgae is similar to that found in terrestrial plants. However, microalgae, due to their simple structure, are particularly efficient converters of solar energy. Because microalgae do not need to generate elaborate support and reproductive structures, they can devote more of their energy into trapping and converting light energy and CO_2 into biomass. Microalgae can convert roughly 6 per cent of the total incident radiation, into new biomass (Shafizadeh, 1982). By comparison, terrestrial crops have generally lower photosynthetic conversion efficiencies. Sugar cane, one of the most productive of all terrestrial crops, for example has a photosynthetic efficiency of 3.5 to 4 per cent (Thompson, Seth and Pat, 2009). Based upon this distinguishing feature, microalgae have become a target for scientific studies on biomass energy production, biofuels production, as well as the potential utilization of CO_2 currently being released into the atmosphere through the use of fossil fuels.

Advantages of Micro algae Biofuel

Algae belong to a large group of simple photosynthetic organisms. Microalgae, are small free-living microorganisms that can be found in a variety of aquatic habitats. They are able to thrive in freshwater, brackish, marine and hypersaline aquatic environments (McNeeley, 2007) and have been reported in desert crust communities thereby being able to endure temperature extremes and low water availability. Microalgae have been reported to a mass more than 70% lipid on a dry weight basis (NREL, 2007). However, the production cost of microalgae as a biofuel feedstock was higher compared to the final yield of the product. Despite this issue, microalgae remains imperative as a future energy feedstock, as it requires less land compared to other commercial crops such as palm oil or jatropha (NREL, 2008; RFA, 2008). The upstream impacts of microalgal cultivation such as the demand for carbon dioxide (CO_2) can be reduced by using flue gas (RFA, 2009), which in turn favours the reduction of environmental issues such as global warming.

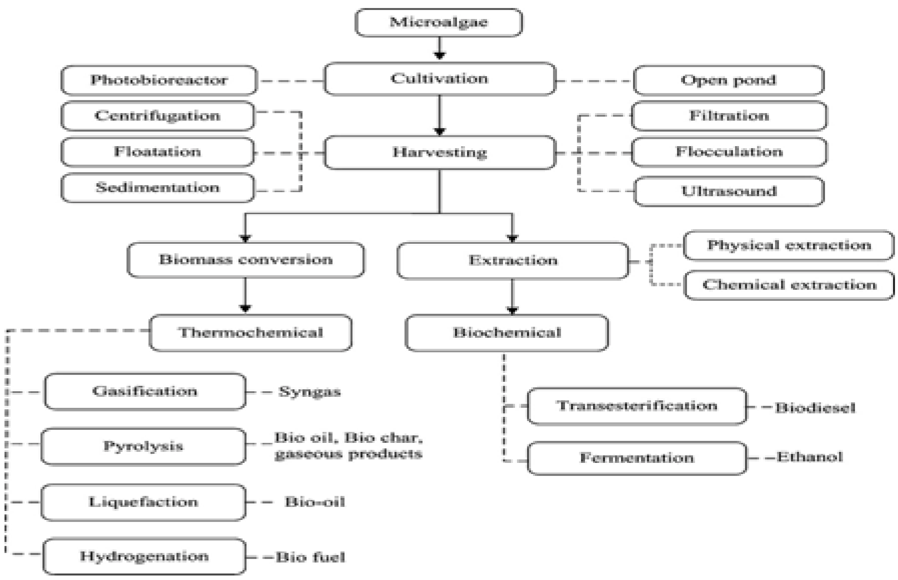

Figure 3: A summary of microalgal transformations into biofuel.
Source: Sanchez and Cardona (2008)

CONCLUSION

The production of first generation biofuel mainly from traditional food crops has increased rapidly over the past few years in response to concerns about energy supply security, rising oil prices and climate change. The result of the Life cycle Analysis shows that sugarcane ethanol has Green House Gas (GHG) emission avoidance potential and sustainability and tagged "good " while other traditional food crops are "less good" because of low GHG emission avoidance, unsustainable production relation to deforestation, water use and competition for food crops feed stocks pushing up the food commodity prices hence the need for non-food energy crops grown specifically for feedstock known as Lignocellulose Biomass. The recalcitrance nature of Lignocellulose makes it still under development. In fact, a great effort has been made to increase the lignocellulose conversion rate, but the difficulty remains with two crucial factors: biomass pretreatment and enzymatic degradation which is based on cellulose crystallinity and lignin linking-styles of the plant cell walls. In spite of extreme pretreatment conditions that can be a solution, such as strong acid/base, or extreme temperature/pressure, it leads to a negative economic profit of biofuel production together with a secondary environmental pollution. Algae fuel, also called oilgae, is a biofuel from algae and addressed as a third-generation biofuel. Algae are feedstocks from aquatic cultivation for production of triglycerides (from algal oil) to produce biodiesel. Microalgae have current applications in the production of human nutritional supplements and specialty animal feeds. Microalgae are currently cultivated as a source of highly valuable molecules such as Polyunsaturated Fatty Acids (PUFAs) and pigments such as *â*-carotene and astaxanthin. They also play an important role in the aquaculture business and in waste water treatment facilities.

REFERENCES

Akin, D E (2007). Grass lignocellulose: Strategies to overcome recalcitrence. *Applied Biochemistry. Biotechnology,* 15(3),137–140

Alonso, J. M., Stepa nova, A. N., Leisse, T. J. and **Kim, C. J.** (2003). Genome-Wide Insertional Mutagenesis of Arabidopsis thaliana. *Science,* 301(5633), 653-657.

Alvarado-Morales, M., J. Terra, K. V. Gernaey, J. M. Woodley and **R. Gani** (2009). Biorefining: Computer aided tools for sustainable design and analysis of bioethanol production. *Chemical Engineering Research and Design,* 87(9), 1171-1183.

Antares Group, Inc. (2003). Assessment of Power Production at Rural Utilities Using Forest Thinnings and Commercially Available Biomass Power Technologies. Prepared for the U.S. Department of Agriculture, U.S. DOE, and NREL.

Balat, M. (2006). Sustainable transportation fuels from biomass materials. *Energy Education Science Technology,* 17, 83–103

Balat, M. (2011). Production of bioethanol from lignocellulosic materials via the biochemical pathway: A review. *Energy Conversion and Management,* 52(2), 858-875.

Balat, M., H. Balat and **C. Oz** (2008). Progress in bioethanol processing. *Progress in Energy and Combustion Science,* 34 (5), 551-573

Biomass Energy Resource Center (BERC) (2007). Wood Pellet Heating: A Reference on Wood Pellet Fuels & Technology for Small Commercial & Institutional Systems. Montpelier, VT. *www.biomasscenter.org/pdfs/DOER_Pellet_Guidebook.pdf.* Accessed on 15th October, 2014.

Biomass Research and Development Board (BRDB) (2008a). National Biofuels Action Plan. Washington, DC, October 2008. *www1.eere.energy.gov/biomass/pdfs/nbap.pdf.* Accessed on 10th August, 2014.

Biomass Research and Development Initiative (BRDI) (2008b). Increasing Feedstock Production for Biofuels: Economic Drivers, Environmental Implications, and the Role of Research. Washington, DC, 2008. *www1.eere.energy.gov/biomass/pdfs/brdi_feedstock_wg2008.pdf* Accessed on 10th August, 2014.

Boudet A M, Kajita S, Grima-pettenati J. and **Goffner D.** (2003). Lignins and lignocellulosics: A better control of synthesis for new and improved uses. *Trends Plant Science,* 8, 576–581

B**rehmer B., R. M. Boom** and **J. Sanders** (2009). Maximum fossil fuel feedstock replacement potential of petrochemicals via biorefineries. *Chemical Engineering Research & Design,* 87(9), 1103-1119.

Carp, N. (1996). Structure and biogenesis of the cell walls of grasses. *Annual Review of Plant Physiology and Plant Molecular Biolology,* 47, 445-476

Chen, H. Z. and **Qiu, W. H.** (2010a). Key technologies for bioethanol production from lignocellulose. *Biotechnology Advances,* 28(5), 556-562.

Demirbas M F. (2006) Current technologies for biomass conversion into chemicals and fuels. *Energy Sources,* 28, 1181–1188

Echols, M. (2009). Certification of Biofuels. ICTSD Issue Paper No. 19.

Famurewa J.A.V and **Babatola J. O.** (2011): Biogas Generation from Three Animal Composite Wastes at Mesophillic Temperature. *Journal of Sustainable Technology,* 2 (1), 50 – 54

FatihDemirbas, M. (2009). Biorefineries for biofuel upgrading: A critical review. *Applied Energy,* 86 (SUPPL 1), 151-S161

Fargione, J., J. Hill, D. Tilman, S. Polasky and **P. Hawthorne** (2008). Land Clearing and the Biofuel Carbon Debt. *Science,* 319,1235–1238

Fraley R R. S., Horsch R., Sanders P., Flick J., Adam S. S., Bittner M., Brand L., Fink C., Fry J., Gallupp I. G., Goldberg S., Hoffmann N. and **Woo S.** (1983). Expression of bacterial genes in plant cells. Proceedings of the National Academy of Sciences, 80, 4803-4807.

Gonzalez-Garcia, S., C. M. Gasol, X. Gabarrell, J. Rieradevall, M. T. Moreira and **G. Feijoo** (2009). Environmental aspects of ethanol-based fuels from Brassica carinata: A case study of second generation ethanol. *Renewable & Sustainable Energy Reviews,* 13(9):2613-2620.

Gressel, J. (2008) Transgenics are imperative for biofuel crops. *Plant Science* 174: 246-263.

Hertel T., Tyner W. and **Birur D.** (2010).. The Global Impacts of Biofuels Mandates. *The Energy Journal* 31(1), 75-100.

Hiei Y., Ohta S., Komar i T. and **Kumashiro T.** (1994) Efficient transformation of rice (Oryza sativa L.) mediated by Agrobacterium and sequence analysis of the boundaries of the T-DNA. *Plant Journal* 6(2), 271-282.

Himmel M. E., Ding S. Y., Johnson D. K., Adney W. S., Nimlos M. R., Brady J. W., and **Foust T. D.** (2007). Biomass recalcitrance: Engineering plants and enzymes for biofuels production. *Science* 315, 804–807.

Ishida , Y. S., H, Ohta , S., Hiei, Y., Komar i, T. and **Kumashiro, T.** (1996) High efficiency transformation of maize (Zea mays L.) mediated by Agrobacterium tumefaciens. *Natural Biotechnology,* 14: 745-750.

Josling T., Blandford D. and **Earley J.** (2010). IPC Position Paper September 2010 Biofuel and Biomass Subsidies in the U.S., EU and Brazil: Towards a Transparent System of Notification. Food and Agricultural Trade IPC position Paper, September 2010.

Klein T. F. M., Weissinger A., Tomes D., Schaa F. S., Slett en M. and **Sanford J.** (1988) Transfer of foreign genes into intact maize cells with high-velocity microprojectiles. Proceedings of the National Academy of Sciences 85: 4305-4309.

Knothe, G. (2010). Biodiesel and renewable diesel: A comparison. Progress in Energy and Combustion. *Science,* 36(3): 364-373

Lawford, H. G. and **J. D. Rousseau** (1993). Production of ethanol from pulp-mill hardwood and softwood spent sulfite liquors by genetically-engineered Escherichia-coli. *Applied Biochemistry and Biotechnology,* 39:667-685

Lee S., Speight J. G. and **Loyalka S. K.** (2007). Hand book of alternative fuel technologies. USA: CRC Taylor and Francis Group

McNeeley, J. (2007): Governing the risks and opportunities of Bioenergy Risks and opportunities of significantly increasing the production of biomass energy, International Risk Governing Council (Concept Note) pp. 6.

Mohan D., Pitman C. U. and **Steele P. H.** (2006). Pyrolysis of wood/biomass for bio-oil: a critical review. *Energy Fuel,* 20:848–89.

Munns W. R Jr, Helm, R. C. and **Adams, W. J.** (2009). Translating ecological risk to ecosystem service loss. *Integr Environ Assess Manag* 5(4), 500-514.

Mussatto S. I., Dragone G. , Guimaraes P. M. R. , Silva J. P. A. , Carneiro L. M. , Roberto I. C., Vicente A. , Domingues L. and **Teixeira J. A.** (2010). Technological trends, global market, and challenges of bio-ethanol production. *Biotechnology Advances*, 28(6):1873-1899.

Naik, S. N ; Goud, V V; Rout, P. K. and **Dalai, A K.** (2010). Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews*. 14:578-597**.**

National Research Council (NRC) (2007). Water Implications of Biofuels Production, In: National Research Council, 01.07.2010, Available from http://nationalacademies.org/wstb Accessed on 15th October, 2014.

NREL (2007). Research Advances—Cellulosic Ethanol: NREL Leads the Way. NREL/BR-51040742. NREL, Golden, CO. www.nrel.gov/biomass/pdfs/40742.pdf. Accessed on 15th October, 2014.

NREL (2008). Research Review. NREL/MP-840-42386. NREL, Golden, CO. www.nrel.gov/research_review/pdfs/2007/42386.pdf. Accessed on 8th September, 2014.

OECD/IEA (2008). Energy technology Perspectives Scenarios and Strategies to 2050. Paris.

Office of Energy Efficiency and Renewable Energy (OEERE) (2008). Biofuels. U.S. DOE, Washington, DC. www1.eere.energy.gov/biomass/. Accessed on 10th October, 2014.

Ravindranath N. H., Manuvie R., Fargione J., Canadell J. G., Berndes G., Woods J., Watson H. and **Sathaye J.** (2009) Greenhouse gas implications of land use and land conversion to biofuel crops. Pages 111-125 In R.W. Howarth and S.Bringezu (eds) *Biofuels: Environmental Consequences and Interactions with Changing Land Use.* Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach Germany. Cornell University, Ithaca NY, USA. (http://cip.cornell.edu/biofuels/).

Renewable Fuels Association (RFA) (2008). Ethanol Biorefinery Locations.Renewable Fuels Association, Washington, DC. www.ethanolrfa.org/industry/locations. Accessed on 18th October, 2014.

Renewable Fuels Association (RFA) (2009). Historic U.S. Fuel Ethanol Production.Renewable Fuels Association, Washington, DC. www.ethanolrfa.org/industry/statistics/#A. Accessed on 11th September, 2014.

Román-Leshkov, Y.; Barrett, C. J.; Liu, Z. Y. and **Dumesic, J. A.** (2007). Production of dimethylfuran for liquid fuels from biomass-derived carbohydrates. *Nature,* 447: 982-985

Sanchez, O. J. and **Cardona, C. A.** (2008). Trends in biotechnological production of fuel ethanol from different feedstocks. *Bioresource Technology*, 99(13): 5270-5295.

Shafizadeh F. (1982). Introduction to pyrolysis of biomass. *Journal Analalytical and Applied Pyrolysis* 3:283–305.

Singhania R. R., Sukumaran R. K. Pillai A. Szakacs G. and **Pandey A.** (2006). Solid-state fermentation of lignocellulosic substrates for cellulase production by Trichoderma reesei NRRL 11460. *Indian. Journal of Biotechnology,* 5, 332-336.

Singhania R. R., Parameswaran B. and **Pandey A.** (2009). Handbook of Plant-Based Biofuels,CRC Press, ISBN 978-1-56022-175-3, Boca Raton, United States of America.

Sjostrom, E. (1993). Wood Chemistry. Fundamentals and Applications, Academic Press, ISBN 0126474818, New York, USA

Spolaore P., Joannis-Cassan C., Duran E. and **Isambert A.** (2006).Commercial applications of microalgae. *Journal of Bioscience and Bioengineering*, 101(2), 87-96

Stevens C. V. and **Verhe R.** (2004). *Renewable bioresources scope and modification for nonfood application.* England: John Wiley and Sons Ltd.

Suter, G. W. (2008) Ecological risk assessment in the USEPA: a historical overview. *Integrated Environmental Assessment Management* 4(3):285"289.

Swinbank, A. (2009a). EU Support for Biofuels and Bioenergy. 'Environmental Sustainability' Criteria, and Trade Policy, Geneva: International Centre for Trade and Sustainable Development. Issue Paper no. 17.38 Josling, Blandford and Earley

Taheripour, F., T.W. Hertel, W.E. Tyner, J.F. Beckman, and **D. K. Birur** (2010). Biofuels and their By-Products: Global Economic and Environmental Implications. *Biomass and Bioenergy,* 34, 278-89.

Thompson W., Seth M. and **Pat W.** (2009). Renewable Identification Numbers are the Tracking Instrument and Bellwether of US Biofuel Mandates. *Euro Choices*, 8 (3): 43-49.

Tyner, W. E., F. Taheripour and **U. Baldos** (2009). Land Use Change Carbon Emissions due to U.S. Ethanol Production, Draft Report to Argonne National Lab, January 2009. *http://www.agecon.purdue.edu/papers/biofuels/Argonne-GTAP_Revision%204a.pdf* Accessed on 12th October, 2014.

UNEP (2009). Assessing Biofuels: Towards Sustainable Production and Use of Resources," UN Environment Program, Paris and Geneva

US Department of Agriculture (USDA) (2008). Brazil – Biofuels Annual Global Agriculture Information Net-work report BR8013 United States Department of Agriculture. Washington, DC. USA.

US Department of Agriculture (2009). USDA Agricultural Projections to 2017. Long-term Projections Report OCE-2008-1. Washington, D.C.: Office of the Chief Economist, World Agricultural Outlook Board

U.S. DOE (Department of Energy) (2003). Industrial Bioproducts: Today and Tomorrow, Washington, DC.

U.S. DOE (2004). Combined Heat and Power Market Potential for Opportunity Fuels. Resource Dynamics Corporation, Washington, DC.

U.S. DOE (2005). Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. U.S. DOE, Washington, DC. DOE/DO-102995-2135. feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf. Accessed on 10th October, 2014.

US EPA (Environmental Protection Agency) (1998) Guidelines for ecological risk assessment. Risk Assessment Forum, Washington DC; EPA/630/R-95/002F. Available online at http://www.epa.gov/raf/publications/pdfs/ECOTXTBX.PDF Accessed on 12th October, 2014.

U.S.EPA (Environmental Protection Agency) (2003) Generic ecological assessment endpoints (GEAE) for ecological risk assessment. Risk Assessment Forum, Washington, DC; EPA/630/P-02/004F. Available online at http://www.epa.gov/raf/publications/pdfs/GENERIC_ENDPOINTS_2004.PDF. Accessed on 12th October, 2014.

U.S. EPA (2007a). Biomass Combined Heat and Power Catalog of Technologies. U.S. EPA, Washington, DC, 2007. www.epa.gov/chp/documents/biomass_chp_catalog.pdf Accessed on 12th October, 2014.

U.S. EPA (2008a). Landfill Methane Outreach Program (LMOP). U.S. EPA, Washington, DC, www.epa.gov/lmop/overview.htm Accessed on 12th October, 2014.

U. S. EPA (Environmental Protection Agency) (2008b). Integrated science assessment (ISA) for oxides of nitrogen and sulfur-ecological criteria. Office of Research and Development, Research Triangle Park, NC; EPA/600/R-08/082F. Available online at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=201485. Accessed on 12th October, 2014.

U. S. EPA (Environmental Protection Agency) (2009a) Summary report: risk assessment forum technical workshop on population-level ecological risk assessment. Risk Assessment Forum, Washington, DC, EPA/100/R-09/006. Available online at http://www.epa.gov/raf/files/population_level_era_report_supp_materials.pdf.

U. S. EPA (2009b). Guide to Anaerobic Digesters. U.S. EPA, Washington, DC, 2009. www.epa.gov/agstar/operational.html Accessed on 12th October, 2014.

Ugarte D., English B. , Jensen K., Hellwinckel C., Menard J. and **Wilson B.** (2006). Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion. University of Tennessee, Knoxville, TN, 2006. *beag.ag.utk.edu/pp/Ethanolagimpacts.pdf.* Accessed on 18th August, 2014.

Webb, A. and **Coates, D.** (2012). Biofuels and Biodiversity Secretariat of the Convention on Biological Diversity. Montreal, Technical Series No. 65

Yano, Y., Blandford D. and **Surry Y.** (2010). The Impact of Feedstock Supply and Petroleum Price Variability on Domestic Biofuel and Feedstock Markets – the Case of the United States. Working Paper 2010:3, Department of Economics, Swedish University of Agricultural Sciences (SLU), Uppsala.

Zhang, Y. H. P. (2008). Reviving the carbohydrate economy via multi-product lignocellulose biorefineries. *Journal of Industrial Microbiology & Biotechnology*, 35(5):367-375