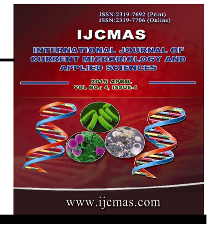

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Review Article

Production Technologies, Economic Performance and Future Development Policies of Alternative Fuels: An Environmental Approach

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A B S T R A C T

Keywords

Biofuels, Environment, Energy, Fossil Fuels, Sustainable, Renewable.

Fossil fuels are declining in order to maintain the current energy demand in near future.Biofuel is an important renewable energy sources derived from harvesting biomass such as trees crops or agricultural waste and using it to generate heat, electricity or transport fuels. There are also environmental concerns about the effects of using fossil fuels such as pollution and climate change. Therefore is a need to find alternatives of non renewable energy sources. Biofuels may be part of the solution to these problems which ensure adequate fuel supplies at a time when yields from fossil oil fields are declining and new fields are not yet up and running. Biofuels are still anticipated to provide an estimated 80% reduction in overall CO_2 lifecycle emissions compared to fossil fuels. Biofuels promotes better social impact particularly in rural countries by improving economic, health and nutrition security, and job opportunities. The potential for production of more advanced biofuels technology is essential need for future energy demand. 21st Century is looking for a shift to alternate fuels and green processes to produce fuels from renewable biomass resources. This review focuses on sustainable cost effective ecofriendly, biofuels energy and the processes to convert biomass into biofuels.

Introduction

Biofuels are drawing increasing attention worldwide as substitutes for petroleum-derived transportation fuels to help address energy cost, energy security and global warming concerns associated with liquid fossil fuels. The term biofuel is used here to mean any liquid fuel made from plant material that can be used as a substitute for petroleum-derived fuel [NYK, Geneva, 2008]. Biofuels may also be derived from forestry, agricultural or fishery products or municipal wastes, as well as from agro-industry, food industry and food service by-products and wastes [FAO, 2008]**.** Emerging- and developing countries produce roughly 40% of the total global supply of biofuels [IEA, 2010]. Overall, bioenergy covers approximately 10% of the total world energy demand. Traditional unprocessed biomass such as fuel wood, charcoal and animal dung accounts for most of this and represents the main source of energy for a large number of people in developing countries who use it mainly for cooking and heating [IEA, 2010]. A first-generation fuel is generally one made from sugars, grains, or seeds, i.e. one that uses only a specific (often edible) portion of the above-ground biomass produced by a plant, and relatively simple processing is required to produce a finished fuel. Second-generation fuels are generally those made from non-edible lignocellulose biomass, either non-edible residues of food crop production (e.g. corn stalks or rice husks) or non-edible whole plant biomass [NYK Geneva, 2008]. Biofuels may be of special interest in many developing countries for several reasons. Climates in many of the countries are well suited to growing biomass. The potential for producing rural income by production of high-value products (such as liquid fuels) is attractive. The potential for export of fuels to industrialized-country markets also may be appealing. Expansion of biofuels production and use also raises some concerns, the most important among which may be diversion of land away from use for food, fiber, preservation of biodiversity or other important purposes. [NYK Geneva, 2008]. Under the force of society demands and voluntary initiatives such as Responsible Care, chemical industries are urged to consider environmental, health and (E H S) aspects when developing a new process [Hook, 1996]. The available analysis on safety and health in biofuel production is scarce despite its great importance to human [Jeerawongsuntorn et al, 2011]. The matrix is simple and suitable for the R&D stage as detailed information on the process is not required. For health analysis, the available studies focused only on the health impacts upon biofuel consumption, Life Cycle Assessment (LCA) is commonly used to evaluate impacts of life cycle and production chain under the environmental framework. Most of the LCA studies emphasis on the comparison of primary energy and greenhouse effect of biofuels against its fossil-equivalent fuels, e.g. biodiesel vs. diesel. Majority of the studies revealed biofuels as a more environmentally friendlier option in comparison to fossil fuel [Kim and Dale, 2008] but the calculated indicator values vary from one study to another.Even with the discrepancy among the indicator values, the GHG saving appears to be positive value for all the first generation biofuels [Havlík et al, 2011].

Types of biofuels on the basis of feedstocks

A relatively recently popularized classification for liquid biofuels includes "first-generation" and "second-generation" fuels **(Table 1.Biofuel classification)**

First Generation Biofuels

First generation biofuels have been considered for a long time as prominent alternatives to conventional fossil fuels which have the potential to provide energy security, carbon savings, reduced reliance on crude oil imports and rural development opportunities [IEA, 2010]. To date, the cost of biodiesel production remains fairly high, but it can be reduced by developing more advanced innovative technologies, using co-solvents to facilitate the processing of the reaction and increasing feedstock yields [Demirbas, A. 2008]. The market for biodiesel can create numerous socioeconomic benefits associated with income in the local and regional economy, increased employment, rural growth and poverty reduction. Given that biodiesel is produced from common biomass material, many developing countries [NurmukhanbetovaG, et.al.2012].Another problem is associated with the release of nitrous oxide (NOx) upon combustion of the biofuels (Table 2: Pros and cons of first generation biofuels) made from the crops fed with nitrogen-based fertilizers [IPCC, 2007]. Main environmental benefits of using bioethanol are associated with its ready availability, renewability and biodegradability [Demirbas, A. 2006]. Bioethanol has also high evaporation heat, octane number and flammability, so when it is added to unleaded gasoline it improves engine performance, increases combustibility and reduces exhaust emissions [Najafi, et al 2009]. Although, ethanol is much cleaner than biodiesel, compared to conventional energy sources, it saves only 50–60% of carbon emissions and cannot be regarded as carbon-neutral [Bothast, R. J. 2005]. Overall, biofuel projections in the developing world are uncertain due to small production rates in recent years and high processing cost. Therefore, the controversy surrounding biofuels has attracted attention to advanced second and third generation biofuels which can be produced in a more sustainable fashion with a zero or even negative net CO_2 impact [Nurmukhanbetova G. et.al.2012].

Second-Generation Biofuels

Second-generation biofuels produced from lignocellulosic biomass, enabling the use of lower-cost, non-edible feedstocks, thereby limiting direct food vs. fuel competition. Second-generation biofuels can be further classified in terms of the process used to convert the biomass to fuel: biochemical or thermochemical. Second-generation ethanol or butanol would be made via biochemical processing, while all other second-generation fuels discussed here would be made via thermochemical processing. Second-generation thermochemical biofuels may be less familiar to most readers than second-generation ethanol, because there are no first-generation analogs. The other thermochemical biofuel is green diesel, for which there is no obvious fossil fuel analog. Unrefined fuels, such as pyrolysis oils, are also produced thermo chemically, but these require considerable refining before they can be used in engines [NYK Geneva, 2008].

Technologies of Biofuel Production

The conventional production technology for the first generation biodiesel is called transesterification process. In the process, triglycerides react chemically with alcohols to form esters of fatty acids as product biodiesel and glycerol as by-products. There are four basic methods of transesterification, namely base-catalysed, acid-catalysed, enzymatic and supercritical (using methanol or methanol/co-solvent) transesterification. Base-catalysed and enzymatic trans esterification are mainly used on oil reactant with free fatty acids (FFA) less than 0.5 wt.% whereas acid-catalysed process can be used on the oil reactant with FFA higher than 10 wt.% such as waste cooking oil. [Liew W. H. et al 2013]. For second generation biofuel, the lignocellulose feedstock is normally processedin bio-refinery. The biomass conversion technologies can be widely divided into three categories, namely physical conversion, thermo-chemical conversion and bio-chemical conversion (Table 3: Biofuel technology matrix). Physical conversion normally acts as pre-treatment process which prepares the raw biomass into more process-able forms by chopping, grinding and drying prior to the downstream processes. Thermo-chemical process employs heat to transform the complex molecule (biomass) into small molecules and energy. The examples of thermo-chemical processes are liquefaction, pyrolysis, gasification and direct combustion. After the biomass is converted to intermediates (e.g. syngas, bio oil, etc.) via thermo-chemical processes, the intermediates are then further converted to wide range of synthetic biofuels (e.g. dimethyl ether, methanol, ethanol, etc.). Meanwhile, biochemical conversion uses living organisms to convert biomass into fermented sugar, ethanol and biofuels. At present, the energy balance of algae processing route is relatively poorer than other type of biofuels. Therefore, more studies and developments are highly in need for making biofuel production from algae an economically viable technology [LiewW. H. et al 2013].

Economic Performance of Biofuel Production

The actual economic growth of biofuel production lies on the overall economic performance of the plant. The economic performance can be evaluated through techno-economic analysis, which combines the economic analysis with the technological assessment.For the first generation biofuel, the main economic barrier is the cost of feedstock due to the usage of expensive vegetable oil. Even with the credit in GHG emission reduction, the cost of biodiesel production accounts to at least 1.5 times higher than petroleum fuel [Zhang et al 2003]. The technologies for the production of second generation biofuels are yet to be considered as mature technologies and its techno-economic performances are under active studies. It is noted that the most influential factors causing high production cost for the second generation biofuels are the total capital investment, followed by feedstock cost, assumed contingency and plant availability [Fornell et al 2012]. For the third generation, study shows that biofuel production from algae with open pond cultivation and on-site harvesting and extraction is less economically competitive than the petroleum-based transportation fuel [Sun et al 2011].

Policy for Biofuel Development

Agriculture both supplies and uses energy, so agriculture and energy markets are closely linked. The rapidly increasing demand for liquid biofuels is connecting agriculture and energy more closely than ever, both through market forces and government policies encouraging biofuel use. Liquid biofuels such as bioethanol and biodiesel which are derived from agricultural crops compete with fossil fuels on energy markets Agricultural crops grown for energy production also compete with food crops for resources.When the value of biofuel feedstocks is high, prices for other agricultural crops tend to rise. For this reason, producing second generation biofuels from non-food crops, such as wood or grasses, will not necessarily eliminate the competition between food and fuel biofuels have not generally been competitive with fossil fuels without active government support to promote their development and subsidies their use, even at high crude oil prices [FAO2008].

The Drivers of Biofuel Policies

Energy Security secure access to energy is a longstanding concern in many countries. The recent increases in oil and other energy prices have increased the incentive to promote alternative sources of energy.Strong demand from rapidly developing countries, especially China and India, is adding to concerns over future energy prices and supplies. The transport sector depends mainly on oil. Liquid biofuels represent the main alternative source that can supply fuels suitable for use in current vehicles, without radical changes to transport technologies.

Table.1 Biofuel Classification

S.No.	**First- generation Biofuels** (from seeds, grains or sugars)	**Second- generation Biofuels** (from lignocellulosic biomass, such as crop residues, woody crops or energy grasses)
1.	Petroleum- gasoline substitutes • Ethanol or butanol by fermentation of starches (sugar beets , sugar cane)	Biochemically produced petroleum-gasoline substitutes • Ethanol or butanol by enzymatic hydrolysis
2.	Petroleum diesel substitutes • Biodiesel by transesterification of plant oils, also called fatty acid methyl ester (FAME) and fatty acid ethyl ester (FAEE)	Thermo chemically produced petroleum-gasoline substitutes • Methanol • Fischer- tropsch gasoline • Mixed alcohols
3.	From rapeseed (RME), soybeans (SME) sunflowers, coconut, palm, jatropha, recycled cooking oil and animal fats pure plant oils (straight vegetable oil)	Thermo chemically produced petroleum-diesel substitutes • Fischer –tropsch diesel • Dimethyl ether (also a propane substitute) • Green diesel

Source: New York and Geneva, 2008,Biofuel production technologies: status, prospects and implications for trade and development.

Table.2 First- generation biofuels

S.No.	Pros	Cons
1	Simple and well- known production methods	Feedstocks compete directly with crops grown for food
2	Familiar feedstocks	Production by- products need markets
3	Scalable to smaller production capacities	High cost feedstocks lead to high–cost production (except Brazilian sugar cane ethanol)
4	Fungibility with existing petroleum-derived fuels	Low land –use efficiency
5	Experience with commercial production and use in several countries	Modest net reductions in fossil fuel use and greenhouse gas emissions with current processing methods (except Brazilian sugar cane ethanol)

Source: New York and Geneva, 2008, Biofuel production technologies: status, prospects and implications for trade and development.

Table.3 Biofuel Technology Matrix

S.No	Feedstock type	Type of biofuel	Majored –use	Crops in temperate climes	Crops in tropical climes	Conversion technology	Technology maturity	Commercial maturity
1	Sugar and starch	Ethanol	transportation	Corn, sugar beet, wheat,	Sugarcane, sorghum, cassava	Biochemical conversion (Fermentation)	High	High
2	Oil seeds	Biodiesel	Transportation	Soy, Rapeseed	Palm, jatropha* castor	Transesterification	High	High
3	Wood**	Fuelwood syn-gas	Cooking, heating, electricity	Willow, poplar	Eucalyptusacacis, prosopis	Direct combustion, thermochemical conversion	High	High
4	Municipal and agricultural waste**	Syn-gas or biogas	Heating, electricity	Na***	Na	Direct combustion, thermochemical, anaerobic digestion	High	High
5	Perennial grasses (cellulose)	Ethanol	Transportation	Switch grass, miscanthus	-	Biochemical (enzymatic) chemical (acid hydrolysis) conversion	Low	Nil

* Crop names in italics refer to those which are not commercial yet
** Wood, municipal wastes and agricultural residues can also be converted to ethanol like perennial grasses using techologies
*** na not applicable

Source: Deepak Rajagopal and David Zilberman, 2007, Review of Environmental, Economic and Policy Aspects of Biofuels.

Climate change there is increasing concern about human-induced climate change, and the effects of greenhouse gas emissions on rising global temperatures. Bioenergy is often seen as a way to reduce greenhouse gas emissions [FAO.2008].

Biofuel Production Expected to Evolve in The Future

In the long term, the International Energy Agency (IEA) foresees a significant expansion of the role of liquid biofuels for transport. From 19 million tonnes oil equivalent (Mtoe) in 2005, biofuel production could increase to 102 Mtoe or even 164 Mtoe in 2030 if all measures and policies currently under discussion are implemented. Nevertheless, even these large increases represent only a very small portion of the total transportation energy needs in 2030. In contrast, current and projected production levels of crops to make biofuels are substantial compared to total agricultural production. Increased biofuel production could come from using more cropland for biofuel production and from improved yields.IEA projects an increase in the share of worldwide cropland devoted to biofuels from 1% in 2004 to 2.5% in 2030 with current policies and measures. [FAO. 2008].For the medium term, various projections have been made in the OECD-FAO Agricultural Outlook 2008-2017 for future supply, demand, trade and prices for ethanol and biodiesel.Significant growth is also projected for biodiesel from soya in Brazil and from palm oil in Indonesia and Malaysia. In Africa and India there has been some investment in biodiesel production from jatropha. Impact of removing trade-distorting biofuel policies for ethanol Impact of removing trade-distorting biofuel policies for biodiesel [FAO. 2008].

The term biofuel is used here to mean any liquid fuel made from plant material that can be used as a substitute for petroleum-derived fuel. Biofuels currently provide approximately 1.5% of global transport fuel, as a result of rapidly increasing production over the last decade. Emerging- and developing countries produce roughly 40% of the total global supply of biofuels**.** Biomass production is inherently rural and labor-intensive, and thus may offer the prospects for new employment in regions where the majority of populations typically reside. The available analysis on safety and health in biofuel production is scarce despite its great importance to human. In the long term, the International Energy Agency (IEA) foresees a significant expansion of the role of liquid biofuels for transport. From 19 million tonns oil equivalent (Mtoe) in 2005, biofuel production could increase to 102 Mtoe or even 164 Mtoe in 2030 if all measures and policies currently under discussion are implemented.

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