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Liquid biofuels and sustainability

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ABSTRACT

Liquid biofuels can provide a much needed substitute for fossil fuels used in the transport sector. They can contribute to climate and other environmental goals, energy security and economic development. In this paper,we first give the definition of sustainable development,then economic and environmental sustainability of biofuel are discussed. Finally, the social dimensions of biofuel sustainability are prospected.

KEYWORDS

Biofuel;
Sustainability;
Economic;
Environmental;
Social.

INTRODUCTION

The world currently faces a systematic energy and environmental problem of increased CO_2 emissions,decreased soil-carbon content,and global-climate change. To solve the massive global energy and environmental sustainability problem,it likely requires a comprehensive portfolio of R&D efforts with multiple energy technologies.

Biomass can be used to provide energy in many forms including electricity, heat, solid, gaseous, and liquid fuels. These bioenergy options have been actively pursued in both the developed and developing world. Different people are pushing development of biofuels for different reasons. Some see biofuels as a substitute for high priced petroleum, either to ease the burden on consumers, to diversify the sources of energy supplies, or to reduce escalating trade deficits. Some have focused on biofuels as a way to extend available energy in the context of increasing world demand for transportation fuels. Others target biofuels as a substitute for more carbon intensive energy. Still others see biofuels as an economic opportunity.

Today, plant-based fuels like ethanol and biodiesel seem to be emerging as a serious alternative fuel ahead of technologies like fuel cell vehicles, electric/hybrid vehicles, and natural gas vehicles. There are several reasons for the excitement surrounding biofuels[1-5].

• Biofuels are replenishable

Biofuels are an inexhaustible resource since the stock can be replenished through agriculture.

• Biofuels can reduce carbon emissions

Biofuels are sometimes considered as a solution to climate change. It is true that direct carbon emissions from combustion of biofuels are insignificant compared to fossil fuels.

• Biofuels can increase farm income

Today decline in farm income is a problem the world over. With biofuels, most countries will be able to grow one or more types of crops in which they possess a comparative advantage and use them to meet either domestic or foreign demand or both.

• Biofuels can improve energy security

The above fact also means that countries can produce their own fuel, and reduce their dependence on foreign sources for energy.

• Biofuels can create new jobs

Biofuels are more labor intensive than other energy technologies on per unit of energy delivered basis. The production of the feedstock and the conversion require greater quantities of labor compared to that required for extraction and processing of fossil fuels or other industrially based technologies like hydrogen and electric vehicles.

DEFINITION OF SUSTAINABLE DEVELOPMENT

The simplest definition of sustainable development was given by the World Commission on Environment and Development[6]:"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."In the bioenergy sector, sustainability is *a sine qua non* for long-term viability for the following reasons[5,7]:

- biofuels are promoted as part of renewable energy precisely to put human society on a sustainable path with respect to energy use as opposed to the continuous dependence on finite and exhaustible fossil energy;
- biofuels are aimed at lowering greenhouse gas(GHG)emissions, rendering climate change conditions more hospitable to human life in the long run;
- the potentially large share of land, labour and resources required for biomass production may overwhelm what is currently used for food and feed production, and hence jeopardize the long-term capacity to meet food and energy needs, even as biofuels could satisfy only 5% to 10% of total or global energy demand.

Tackling bioenergy sustainability requires dealing simultaneously with its many dimensions – economic, environmental and social. The latter dimension encompasses such considerations as social and gender equity, participation and equal rights[8].

ECONOMIC SUSTAINABILITY OF BIOMASS-BIOFUELS

Three of the most important criteria for economic sustainability are *profitability*(the price of the biofuel exceeds the production costs), *efficiency*(the maximum amount of yield is obtained with a given quantity of resources)and *equity*(distribution of benefits or value added among actors along a biomass-biofuel value chain or across generations)[4-5].

• Profitability and efficiency

The first criterion for long-term viability of a production system utilizing resources to produce a marketable output is that it shows economic profitability:producers will only be willing to pursue biofuel production if it is economically profitable. Key factors that can affect profitability include alternative competitive uses of the feedstocks and energy prices. Alternative uses of the feedstock play an important role in the decision making process of producers. If prices for biofuels fall below the prices of other possible end-products(food, feed, timber, etc.)it would be more profitable to cultivate these products than to derive fuel out of the feedstock.

The economic profitability of biofuels has been invariably attributed to government subsidies or mandates, the only exception being Brazil's sugar cane ethanol. Some argue that biofuels, by pushing prices up through increased demand, could lower the very need for farm subsidies. The problem thus far is that most biofuel programmes in advanced economies are themselves maintained largely through government subsidies and demand-generating mandates.

In general, feedstock costs account for the main part of the production costs, while by-products can increase the economic viability of biofuel production. Two exceptions to this general pattern are ethanol derived from sugar cane in Brazil and from sugar beet in the EU.

• Economic Equity

The concept of intra-generational equity, referring to fairness in allocation of resources between simultaneous competing interests, has received relatively less attention than inter- generational equity(between present and future generations). It implies social and economic justice, quality of life, democracy, public participation and empowerment; the incidence and magnitude of unsustainable practices originate from power inequality. It is in this context that the environmental limits of supporting ecosystems are defined[8].

The growing global demand for liquid biofuels and the attendant environmental and socio-economic transformations might have different impacts on men and women in the same household, as regards their access to and control of land and other productive assets, their level of participation in decision-making, and their food security. Both the nature and the magnitude of these impacts will depend on the specific technology and on the socio-economic and policy context.

The potential high land-use requirement for biofuels might put pressure on the so-called "marginal" lands(perceived as less critical for food production), prompting their conversion to biofuels production.

• Competition with food

One of the key drivers determining longterm economic viability of biofuels is competition with food. This is because biofuel production(through the use of biomass)may compete with food for the same resources, notably land, labour and water. Food security is a key developmental goal and the potential conflict with energy security can play out at many levels including national and even regional. Which takes priority and to what extent food security could impede large-scale biofuel development depend on the overall balance between size of population, projected growth, availability of land(or its scarcity) as well as its suitability for food crops versus energy crops only. Other contributing factors include prospects for increased productivity and the implications for land availability to meet multiple demands, as well as the relative profitability of feedstock for biofuels versus alternative uses of land, water and labour – for food, feed or other industrial uses. In the end, incentives for feedstocks for bioenergy versus food or other crop uses will boil down to which end-product offers greater value added and raises the incomes of farmers, who can then afford greater access to food and nutrition[9-11].

• Trade competition

Along with economic sustainability, equity of trade refers to the possibilities open to different countries for entering the international bioenergy market. Given the size of the energy market, future energy demand, the distribution of land resources and the environmental priorities, industrialized countries are expected to remain major consumers of biofuels while many developing countries have the potential to become main producers and exporters. But biofuel trade has been restricted in recent years by industrial countries through a combination of subsidies and tariffs to ensure that the support is directed towards domestic producers only. Still, trade is expected to play a significant role in the global development of biofuels[5].

ENVIRONMENTAL SUSTAINABILITY OF BIOMASS-BIOFUELS

In this section,we will discuss this issue in the following five aspects [5,12]:

• Energy balance

One important motivation for bioenergy policies is to increase energy security. Fossil fuels are finite and prices are expected to rise substantially in the future. Renewable bioenergy is seen as a way to diversify the energy sources.

The contribution of any biofuel to energy supply depends both on the energy content of the biofuel and on the fossil energy going into its production. Fossil energy balance, defined as the ratio between renewable energy output of the resultant biofuel and fossil energy input needed in its production, is a crucial factor in judging the desirability of biomass-derived biofuel: this concept measures to what extent biomass is qualified to replace fossil fuels. An energy balance of 1.0 indicates that the energy requirement for the bioenergy production is equal to the energy it contains. In other words, the biofuel provides no net energy gain or loss. A fossil fuel energy balance of 2.0 means that a litre of biofuel contains twice the amount of energy as was required for its production.

Conventional petrol and diesel usually have an energy balance ranging between 0.8-0.9 because some energy is consumed in refining crude oil into usable fuel and transporting it to markets. If a biofuel has a fossil energy balance exceeding these numbers, it contributes to reducing dependence on fossil fuels. For crop-based ethanol, the estimated balances range from 1.34 for maize to around 2–8 for sugar cane.

• Greenhouse gas and other air pollutants

Tackling global warming and the possibility of reducing GHG emissions is the second main driver for biofuel development. Given that fossil fuels used in transport and heating and cooling systems are the largest contributors to global warming(about 75 percent of total CO_2 emissions), one of the most important targets will be to cut emissions in this area. GHG emission assessments typically include those of CO_2, methane(CH_4), nitrous oxide (N_2O)and halocarbons. The gases are released during the whole-product lifecycle of the biofuel depending on the agricultural practices(including fertilizer use, pesticides, harvesting, etc.), the conversion and distribution process, and the final consumption and use of by-products.

Concerns about climate change and the need to reduce GHG emissions have become increasingly important in continuing policy support for biofuels. The biofuel industry is therefore increasingly required to demonstrate that the net effect is lower GHGs when taken across the whole lifecycle, from crops to cars. While plants absorb CO_2 from the atmosphere when they are growing, which can offset the CO_2 produced when fuel is burned, CO_2 is also emitted at other points in the process of producing biofuels.

• Life cycle assessments

In order to determine whether a biomass biofuel system results in a net reduction in GHG emissions or an improved energy balance(input-output energy ratio), a Life-Cycle Assessment(LCA)is commonly used. According to ISO 14040, an LCA is a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle." In an LCA, all input and output data in all phases of the product's life cycle including biomass production, feedstock storage, feedstock transportation, biofuel production, biofuel transportation and final use are required. Also, all outputs are accounted for including gases(leaked or captured) and by-products.

LCAs of the environmental impacts of biofuel production and consumption have shown a wide disparity in results, from net reduction in GHG emissions to a net increase, as well as risks of unintended negative environmental impacts, depending on the kind of feedstock used and how it is produced and processed. LCA analyses are challenging not only because they require large amounts of information, but also because they attempt to combine disparate quantities in ways that require considerable explanation and interpretation.

• Land use change (LUC)

The next key challenge facing LCAs is how to factor in land-use changes. A common method to estimate land-use change is to use remote-sensing images, especially for monitoring deforestation. On the basis of spatial patterns, different techniques are then used to identify the agents involved in the land-use change. Further, the use of primary and secondary data on areas planted and harvested in the past can help predict future land-use patterns – even at the local level, if such data readings can be matched with other crops[13].

There is a distinction between direct and indirect land-use change. When newly demanded products – such as biofuel feedstocks – are grown on converted land, this is described as direct land-use change (DLUC) and is typically included in the carbon accounting procedure in most life cycle analyses. Indirect land-use change refers to second, third and higher degrees of land substitutions. This is harder to measure and remains unresolved. There is currently a debate about measurement of GHG emissions resulting from indirect landuse change that may occur when increased demand for biofuel crops displaces other crops to new areas.

The indirect land-use change impact(ILUCs)of biofuels describe the unintended consequences of releasing more carbon emissions because of land-use changes induced by the expansion of croplands for ethanol or biodiesel production in response to the increased global demand for biofuels. As farmers worldwide respond to higher crop prices in order to maintain the balance between global food supply and demand, pristine lands are cleared and converted to new cropland to replace the crops for feed and food that were diverted elsewhere to biofuels production[14].

• Biodiversity

Biomass production for bioenergy can have both positive and negative impacts on biodiversity. When degraded land is used, the diversity of species might be enhanced. The reduction in global biodiversity has emerged as one of the greatest environmental threats of the 21st century. Urban and agricultural development have traditionally been the primary drivers of encroachment on important, biodiversity sustaining ecosystems.

Water contamination with fertilizers and pesticides could also be a threat for biodiversity. Leakage of phosphorus and nitrogen into surrounding water can lead to a decrease in the variety of plants and animals, as well as an increase in unwanted algae. This is known as hypoxia, which means low oxygen, and is primarily a problem for estuaries and coastal waters. Hypoxic waters contain dissolved oxygen concentrations of less than 2-3 ppm. Hypoxia can be caused by a variety of factors, including excess nutrients, primarily nitrogen and phosphorus, and waterbody stratification due to saline or temperature gradients. These excess nutrients – eutrophication – promote algal growth. As dead algae decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water. Thus high-input managed biomass crops may bring negative impacts on biodiversity. Conversely, native and perennial crops that do not involve much input are likely to be less damaging, especially when crop-rotation is considered[15].

In agriculture, crops that require less irrigation, fertilizer and pesticides, and that provide better year-round erosion protection will likely produce fewer negative water impacts. Crops can be either rain-fed or irrigated. Irrigation water can come from groundwater or surface water. Some of the applied water is incorporated into the crop, but most of it leaves the fields as evaporation from the soil and transpiration from plants(evapotranspiration), runoff to rivers and streams, and infiltration to the surficial aquifer[16].

SOCIAL FACTORS IN BIOFUEL SUSTAINABI;ITY

In this section, we focus on three aspects of social sustainability[17-18]: land ownership rights, local stewardship of Common Property Resources and labour rights.

• Land ownership rights

Climate change and expanding biofuel production are likely to lead to greater competition for access to land. This increased competition poses a threat to the livelihoods of the millions of farmers, pastoralists, fisherfolk and forest dwellers living in areas with no formal land tenure rights. Sound land tenure policies and planning will be crucial.

Given that land is a limited resource, the appropriate use of land depends on the value it can provide to those who hold rights over it. The value can be measured in many ways – e.g. wealth generation, conservation and ecosystem servicing. Biofuels are believed to offer commercial opportunities to enhance the contribution of land to individuals, groups and governments. Access to land(usage or ownership)depends on the decisions of those who hold rights over the land.

• Local stewardship of common property resources

For many developed countries, the goal of sustainable rural development implies preservation of local productive capacity and natural resources. Mechanization, while generating higher returns on land and labour, has lowered agricultural prices. As a result, government subsidies have been established to prop up farm incomes, and, in the process, have became a constant feature of agriculture in rich countries. In developing countries, safeguarding local productive capacity and natural resources implies local stewardship of Common Property Resources(CPRs). CPRs occupy an important place in the economy of the landless and land-poor.

• Labour effects

For many developing countries, the chance to spur rural employment by producing biofuels has acted as a major driver. Biofuels can spur rural development and stimulate local employment by attracting capital to the agricultural sector and a flow of new technologies including better access to fertilizers, infrastructure and highyielding varieties. Biofuels production could also increase access to energy services with positive effects on welfare.

Overall, the social dimension of sustainable biofuel production, trade and use requires adhering to a number safeguards, such as ensuring human rights to local communities when investments in land and potential relocation and compensation are required; integrating small-scale farmers and the local population, including women, in the biofuel supply chain throughout-growers schemes; ensuring that new biofuel developments bring maximum employment opportunities for local populations; and ensuring that international standards for workers' rights, including those enshrined in the concept of "decent work", are fully respected and maintained. These prerequisites improve the chances of social acceptance and hence place the local communities on a path towards social sustainability.

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