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Environmental aspects of new generation fuels through energy balance, biodiversity and agriculture

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A B S T R A C T

The current energy supplies in the development of world are unsustainable from economic and environmental aspects as they are limited and nonrenewable. Environmental pollution is increasing due to industrialization and economic growth by the consumption of different types of fossil fuels. Therefore is a need to find alternatives of non renewable energy sources. Biofuels may be a 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. The policies used by Governments to promote and support biofuel development include: biofuel supply chain at different stages, agricultural policies, blending mandates, subsidies and support tariffs or import barriers, tax incentive and research & development. This paper focuses on how the biofuels can be used as a source of energy to substitute fossil fuels oil shortages and green house effects and play a key role in sustainable development.

Introduction

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). The impacts of biofuels on the environment are extensive which include greenhouse gases (GHG) emissions, land use and carbon stock change, fertilizerL efficiency, co-product and residues utilization, impact on water resources and biodiversity (Liew *et al.*, 2013). 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 (FAO, 2008). 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. Biofuels have only started to be seen as a serious alternative to oil worldwide over the last five years or so. Their reduced carbon emissions compared to conventional fuels and their positive impacts on rural development, together with the current high oil prices, are key elements behind their market development. An increase in trade in biofuels would imply crop expansion in several countries. This would have implications for sustainable development that would need to be investigated. On the one hand, biofuels could lead to greater economic gains, rural development and reduced GHG emissions compared to oil fuels (Dufey, 2006).

Energy balance through biofuel production

Estimating the net impacts of biofuels' energy balance is a very complex issue. Energy balances need to consider the entire fuel cycle, from feedstock production to final consumption – the so-called 'well-to-wheels' approach. Assessments should also include energy paybacks associated with the co-products - the so-called 'co-products credits (IEA, 2004). Energy balances vary depending on the type of feedstock used and methods of cultivation as well as the conversion technology. There are also differences depending on the methodology used to calculate the energy balance (e.g. assumptions regarding co-products energy balances). In addition, nearly all conversion plants' processing energy is provided by 'bagasse' (the remains of the crushed cane after the sugar has been extracted) which means energy needs from fossil fuel is zero (IEA, 2004).

Greenhouse Gas (GHG) emissions through biofuel production

One of the greatest advantages associated with biofuels and one of the main driving forces behind worldwide biofuel uptake are their alleged reduced GHG emissions, and hence their potential to help minimize climate change. The basic argument is that because growing feedstocks absorb CO_2, the release of CO_2 emitted during biofuel combustion does not contribute to new carbon emissions since the emissions are already part of the fixed carbon cycle. However, there is considerable variation in GHG savings ranging from negative to more than 100%. Estimates vary according to the type of feedstock, cultivation methods, conversion technologies, energy efficiency assumptions and disparities regarding reductions associated with co-products (Koonin, 2006).

Air quality improvement by biofuels

In addition to reduced GHG emissions, biofuels also have the potential to reduce emissions of key toxic substances usually associated with standard fuels. It suggests that engines running on these types of biofuels or on a blend of standard fuels and biofuels tend to have lower particulate and CO emissions and lower sulphate emissions. While bioethanol also shows reductions in ozone forming volatile organic compounds, it has higher ethanol and acetaldehyde emissions. Biodiesel shows higher emissions of nitrogen oxide, though the differences are not substantial. There are also reductions in household air pollution when crop-based biofuels substitute other traditional forms of fuels usually used in the poorest countries, such as charcoal, fuelwood and paraffin. These forms of fuel have been identified as major killers of women and children in developing countries (Woods and Read, 2005).

Impact on soil, water and biodiversity

Feedstock plantations for second-generation biofuels are usually perennial tree or grass species. Therefore, the plantations provide year-round soil cover and require less soil preparations than annual crops. The permanent cover can considerably reduce the impact of erosion through wind and water and increases the water-retention capacity. Energy crop plantations could contribute to reduce advancing degradation with both environmental and social benefits. Since crop breeding takes decades, constraints exist to prevent potentially invasive crop species from being introduced to these regions when biomass demand for second generation biofuel production increases. There are also negative aspects related to the use of pesticides and fertiliser. Though these inputs are expected to be lower than for conventional biofuel feedstocks (*e.g.* maize, canola), they can cause negative impact on freshwater reserves and potential acidification of soils (IEA, 2010). Using secondary residues as feedstock is expected to have only little negative impact on the environment, since these residues are usually disposed at the processing site and not returned to the field. Primary residues on the other hand, are often left on the field where they act as fertiliser. Their removal could thus lead to nutrient extraction that has to be balanced with synthetic fertilisers to avoid decreasing productivity. Since access to freshwater is a growing concern in many countries, in particular India, China and South Africa, feedstock sources that do not require irrigation like agricultural and forestry residues, should be given priority in these countries (IEA, 2010).

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 (Table 1: Characteristics of traditional and modern biofuels). 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).

Environmental impacts associated with crop production

There are several additional environmental impacts associated with intensive feedstock cultivation. Among the most important are monocropping and biodiversity loss, usually associated with large scale cultivation water consumption and reduced water flows, especially for irrigated crops water quality and effluent run-off problems (whether the crop is irrigated orrain-fed) from agrochemicals and sediment in some cases these impacts can extend to downstream ecosystems land degradation, also associated with monoculture and the use of agrochemicals.

Table.1 Comparison of characteristics of traditional and modern biofuels

Characteristics of Technology	Traditional	Modern
Fuel	Mostly gathered or collected and in some cases purchased	Commercially procured
Labor	High labor intensity at household level in collection of fuel	Low labor intensity at household level but overall high labor intensity compared to other energy sources
Conversion process	Low efficiency and poor utilization of biomass	Higher efficiency and higher utilization of biomass
Energy uses	Energy for cooking and heating in poor households in developing countries	Commercial heating electricity and transportation
Emission controls	Poor emission controls	Controlled emissions
Co-product	No co-products	Commercially useful co-products

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

Conclusions

Environmental pollution is increasing due to industrialization and economic growth by the consumption of different types of fossil fuels. The impacts of biofuels on the environment are extensive which include greenhouse gases (GHG) emissions, land use and carbon stock change. Biofuels have only started to be seen as a serious alternative to oil worldwide over the past few years. An increase in trade of biofuels would imply crop expansion in several countries. This would have implications for sustainable development that would need to be investigated. On the other hand, biofuels could lead to greater economic gains and rural development.

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