Sustainable Biofuel Production: Opportunities for Rural Development

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Abstract

Exploring energy options from renewable sources is a top priority in most countries owing to increasing energy demands coupled with future shortages in the supply of current energy sources and its associated uncertainties, and, climate change concerns. As a promising alternative, modern biofuels - derived primarily from renewable biomass - are being increasingly recognized as holding a potential for offering a sustainable energy future, which at the same time, could have the potential for creating opportunities for achieving environmental and socio-economic goals in the sustainable development paradigm. In many nations, rural development is one of the primary objectives behind promoting biofuel projects. This paper reviews biofuel development, through exploring the rural development implications of sustainable bioenergy / biofuel production. It is argued in this review that the bioenergy / biofuel projects that are implemented in an environmentally and socially acceptable manner have a better fit with the development of rural areas, particularly in developing countries. This potential is attributed to its capacity to enable energy services to the rural community, improve jobs and livelihood options, and create a local healthy environment. Therefore, if biofuel projects are developed in a manner conducive to sustainable development, they will more likely make a meaningful strategy for socio-economic growth. However, at the same time, it is realized that such projects are not the only vehicle to address energy and development problems for rural areas, and therefore, assessment of all options should be made before making such decisions.

Keywords

Bioenergy; Biofuels; Rural Development; Sustainability; Socio-economic Aspects

Introduction

Energy is vital for social and economic development. As the energy demand increases worldwide, governments are beginning to explore renewable energy options. Along with this, the increased global concern on climate change threat is setting a further impetus for employing energy from sustainable sources which are both renewable and environment friendly. Fossil fuels – which largely supported the development of global economies for nearly half century -- are proving to be environmentally costly (i.e. they release Greenhouse Gases) and are limited in their future supply (Goldemberg 2007). As a promising alternative, biofuels are gaining attention as being an important source of renewable energy source for competing with the fossil fuels and to address energy needs of the world (Kartha and Larson 2000; CARC 2003). It is increasingly acknowledged that the biofuels hold the potential to offer a sustainable energy future which would create opportunities for achieving environmental and socio-economic goals of the sustainable development (US Department of Energy 1998; Kartha and Larson 2000, Hardy 2002].

Biofuels are derived primarily from biomass, but also, to a lesser extent, from biodegradable portion of industrial and municipal waste. These biofuels can be utilized for various purposes including heating, cooking, transportation, electricity generation etc. (Dufey 2007). However, in many instances, biomass is also used for cooking and heating by direct combustion (e.g. wood, crop residues). Thus all fuels can be broadly divided into *modern* and *traditional* biofuels (Rajagopal and Zilberman 2007; Goldemberg and Coelho 2005). This review focuses on the modern biofuels[1] which typically include liquid fuels (ethanol and biodiesel) and biogas. Ethanol and biodiesel are the two most common forms of biofuels that are widely used in the energy sector.

It is argued that the global biofuel sector is driven by a diverse mix of policies (Rajagopal and Zilberman 2007;

[1] We adopt the definition of modern biofuels as provided in Goldemberg and Coelho 2005. Modern biofuels refer to fuels produced in a sustainable way for electricity generation, heat production and transportation, from agricultural and forest residues and solid waste. Alternatively traditional biofuels are produced in an unsustainable way and are used as a non-commercial source—usually with very low efficiencies for cooking in many countries (Goldemberg and Coelho 2005)

Sorda et al 2010). However, in general, there are four motives or policy goals that are considered to influence biofuel development projects in both developing and industrialized countries. They are: energy security; rural development; trade development, and mitigation of adverse impacts of climate change (Dufey et al 2007). Having cited these primary objectives, it is likely that the countries have different priorities to these policy goals when considering development of a biofuels project (Rajagopal and Zilberman 2007; Dufey et al 2007).

Although the policy goals may vary among countries, socioeconomic benefits of biofuel industry, particularly rural development and employment generation, are being the significant driving forces in increasing the share of bioenergy (Rosillo-Calle 2000; Domac et al 2005; Domac et al 2005; Faaij and Domac 2006). This perhaps is the case in developing as well as developed nations (Demirbas 2007). Globally, biofuel industry has created nearly 1.5 million direct jobs in 2009 through global biofuel production of over 93 billion litres, which displaced the equivalent of an estimated 68 billion litres of gasoline (REN21 2010). Additionally, biofuels could prove promising for communities (both rural and urban), particularly in those countries that have a limited access to modern form of energy, by providing clean, accessible energy that is vital for rural development and poverty alleviation (WWI 2006). Currently about 1.5 billion people worldwide still lack access to electricity, and approximately 2.6 billion are reliant on wood, straw, charcoal, or dung for cooking their daily meals (UNDP and WHO 2009). Therefore, biofuels could be a major influence in rural transition from traditional to modern clean forms of energy in many countries.

While the socio-economic and rural development aspects are being the primary drivers of implementing biofuel projects (Dufey et al 2007; Domac et al 2005; Demirbas 2007), very less attention has been given towards examining the potential of biofuel industry that triggers rural economic development (Remedio and Domac 2003; Leistritz and Hodur 2008). Much of the main stream literature considers mostly the potential environment implications of bioenergy projects. In this article we, therefore, discuss how bioenergy[2] / biofuel projects that are implemented in an environmentally and socially acceptable manner (i.e. sustainable) influence development of rural areas, especially in developing countries.

The specific objectives of this review are: i) to provide an overview of rural development aspects of modern biofuels which are key drivers propelling many governments to undertake bioenergy projects across the world. ii) to discuss possible pathways through which biofuels production could lead to rural development and iii) to identify key measures to increase the rural development benefits of biofuels. This review is a product of critical evaluation of several scholarly literatures (i.e. articles from refereed journals, policy briefs and reports from sources like World Bank, United Nations Development Program, International Energy Agency etc.). We hope that the content of this article help facilitate further discussions on rural development aspects of biofuels production.

The article is organized in five sections including introduction. Section two provides an overview of biofuels explaining their types, production processes, global production trends and sustainability aspects. Section three explores the rural development implications of sustainable biofuels production. This is followed by a discussion on policy approaches to maximize rural development benefits of biofuels. Conclusions and future actions are highlighted in the final section.

Biofuels and Sustainable Development

Energy from Biofuels

In general, three types of biofuels are produced: namely ethanol, biodiesel and biogas. Agricultural residues and feedstocks, forest wastes and other plant biomass are generally used in the production of these biofuels. A brief discussion of the processes adopted to produce biofuels using agriculture feedstock is provided in Table 1.

Global Biofuels Production

The production and use of biofuels are increasingly gaining attention in many countries to address various energy needs. Ethanol and biodiesel are the two dominant biofuels, which are extensively used in the transportation sector. Currently, ethanol and

[2] A *bioenergy project* is defined as a particular application of bioenergy in a specific locality (ESMAP 2005). Bioenergy (or biomass energy) refers to the energy produced from the biomass to provide different energy services such as heat, electricity etc. (ESMAP 2005). Biomass is any organic material, of plant and animal origin, derived from agricultural and forestry production (e.g. sugar crops, cereal grains) and resulting by-products (e.g. manure) and industrial and urban wastes, used as feedstocks for bioenergy (OECD 2004).

biodiesels are blended with gasoline and petroleum-based diesel, respectively and, used in conventional diesel-fueled vehicles (WWI 2006). By the end of 2009, global biofuel production has increased by 178% of the level in 2004 (see Table 2). Between end of 2004 and end of 2009, worldwide biofuels production increased from 33.2 to 92.6 billion liters (REN21 2010; REN 21 2005). This translates into an increase of 558 million litres of biofuel per year.

Trends in global biodiesel production have been dramatic where the production increased from just 2.2 million liters in the end of 2004 to 16.6 million liters by the end of 2009 – almost an eight-fold increase. The production of ethanol also has increased in these five years and currently, it accounts for about 82 percent of total biofuel production. The total ethanol production rose from 31 million liters in the end of 2004 to 76 million liters by the end of 2009 – an increase of 132%. The United States, Brazil, France, Germany and China are the top five biofuel producing countries in the world (see Table 3) (REN21 2010). These countries together accounted for nearly 87% of global total biofuels production in 2010.

Concept of Sustainable Development

United Nations World Commission on Environment and Development defined sustainable development as a "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*." (Brundtland 1987). In this context, Pretty and Hine (2000) emphasize that any system (e.g. community, biofuels industry, economy etc.) that is sustainable should have the ability to accumulate or increase the contributions of all forms of resources overtime (e.g. *Natural* – soil, water, air; *Economic* -- savings, infrastructure, equipment, technology, and *Human resources* – knowledge, skills, health), and on the other hand, unsustainable systems deplete by spending resources and leaving less for present as well as for future generations (Pretty and Hine 2001).

The three pillars of sustainability -- environment, economic and social components, are interlinked and hence, changes or activities of one component are, to a larger extent, dependent on the other. For example, meeting essential needs of people, such as food, clothing, shelter, jobs etc, clearly requires economic growth (Brundtland 1987). Further, this economic growth is dependent on the natural resource base (provided by environmental resources) both renewable (e.g. forests) and exhaustible (e.g. minerals)

TABLE 1 DETAILS ON BIOFUELS PRODUCTION BY TYPE OF BIOFUELS

Biofuel	Feedstock	Processes
Ethanol	Agricultural crops containing starch; sugar; lignocellulosic biomass	Fermentation: sugars are converted into ethanol using micro-organisms under anaerobic conditions Hydrolysis: the long chains of polymers of starch molecules are first broken down to simple molecules of glucose and then glucose is fermented to produce ethanol. Pretreatment and acid hydrolysis: cellulose and hemicellulose in the lignocellulosic biomass are broken down to simple individual sugars and sugars are fermented to produce ethanol
Biodiesel	Oilseed crops such as soybean, canola, sunflower, palm oil	Transesterification: fat or oil is mixed with an alcohol to form methyl esters known as biodiesel and glycerol
Biogas	Biomass, cow dung, animal carcasses, etc	Hydrolysis: insoluble organic materials (e.g. lipids, proteins, fats etc.) are transformed to soluble organic materials Fermentation: where soluble organic materials are fermented to acetic acid. These are converted into a mixture of methane called biogas and carbon dioxide

Source: (Abdeshahian et al 2010; Yadvika et al 2004; Yuan et al 2008; Ma and Hannah 1999; Wyman 1994)

TABLE 2 GLOBAL BIOFUEL PRODUCTION

Biofuel type	End of 2004 (million liters)	End of 2009 (million liters)	% increase in five years
Biodiesel	2.2	16.6	654
Ethanol	31	76	132
Total	33.2	92.6	178

Source: (REN21 2010; REN 21 2005)

(Goodland 1995). Therefore, the sustainable development that entails progressive transformation

of an economy or a society requires regenerative environmental resource base.

The other dimension of sustainability involves equity issues, where resources are meant to be shared between generations (i.e. inter-generation) and within a generation (i.e. intra-generation).

TABLE 3 TOP FIVE BIOFUEL PRODUCERS IN THE WORLD

Country	Ethanol (million liters)	Biodiesel (million liters)	Total
United States	41.0	2.1	43.1
Brazil	26.0	1.6	27.6
France	0.9	2.6	3.5
Germany	0.8	2.6	3.2
China	2.1	0.4	2.5
Subtotal	70.8	9.3	80.1
Rest of the World	5.2	7.3	12.5
Total	76.0	16.6	92.6

Source: (REN21 2010)

Attributes of a Sustainable Bioenergy/Biofuel System

Applying the above concept of sustainability to biofuel /bioenergy suggests that activities associated with their production should help prevent environmental degradation and socio-economic disruption (WWF 2006) and also assist in providing equal energy services to all groups of the society. Several ways through which biofuel production contribute to sustainability are briefly discussed below.

Production of bioenergy/biofuel feedstocks could be achieved through utilizing barren land, reclaiming waterlogged and saline soils, protecting watersheds and using water conservation measures including harvesting rainwater. These practices, on the one hand, help restore the environmental resources and, on the other hand, do not jeopardize basic necessities such as food, fodder, fuel wood, construction materials, other agricultural crops, etc. (Kartha and Larson 2000). A review of 15 international small-scale biofuels projects showed that they successfully contributed to natural resource efficiency by using marginal and non-forested lands and intercropping with other food crops to avoid conflict with existing natural capital or food production and reusing organic fertilizers which are the by-products of oilseed pressing to increase soil fertility and to reduce polluting run-off into rivers from inorganic fertilizers (Practical Action Consulting 2009).

Agricultural or forestry residues and municipal solid wastes are important sources for the production of biofuels. In this way, biofuel production utilizes unwanted solid wastes and residues, avoiding the pests and pollution (including greenhouse gas emissions) problems of residue disposal. In addition, the raw material for biofuel production (e.g. ethanol) could be obtained from dedicated crops (e.g. switchgrass). This helps absorb the carbon dioxide from the atmosphere, resulting in a process of bioenergy / biofuel production that reduces carbon by increased photosynthesis (Petrou and Pappis 2009). Furthermore, bioenergy projects can contribute to fulfilling social needs by creating livelihoods opportunities resulting from improved productivity, by offering better energy services, especially in rural areas where access to clean energy provides new services, infrastructure and establishes entrepreneurial opportunities (Kartha and Larson 2000; Dufey 2007; Dufey et al 2007; Domac et al 2005). On the whole, if appropriately implemented, the biofuels industry could prove sustainable by contributing to the environmental and socio-economic goals.

In spite of having the potential of accomplishing many of sustainability objectives (i.e. income generation, restoration of degraded land, creation of complementary land use options), biofuel industry may not have received equal political and public attention due to concerns over environmental and food security issues such as loss of ecosystem habitat and biodiversity, deforestation, depletion of soil nutrients and water sources, acquisition of traditional land and competition with food crops etc. (these negative impacts and measures to overcome are discussed in detail in Kulshreshtha et al. 2011). Nevertheless, decision makers in most countries are positive that these issues could be addressed if above mentioned sustainability safeguards are adopted (Kartha and Larson 2000; Dufey et al 2007; Hahn-Hägerdal et al 2006; Dufey 2006). As a result of obligations to achieve various sustainability objectives, both developing and industrialized countries have a diverse mix of policy agendas driving their bioenergy projects (Rajagopal and Zilberman 2007). Since energy is largely responsible for country's economic growth, enhancing energy security is generally a priority of any nation in developing a biofuel production

program. Given uncertainties in the future fossil fuels supply, increased oil prices propel governments to seek for such options. Furthermore, as price of fossil based energy increased, biomass based energy becomes more competitive.

In terms of rural development, biofuels development creates demand for agricultural products and improves agricultural diversification, livelihoods and employment. Further, biofuels can be a way to develop an export market for agricultural produce and increase export revenues of many countries. Finally, biofuels may provide an opportunity for nations to help address the climate change threat. (Rajagopal and Zilberman 2007; Dufey et al 2007). An overview of social aspects of biofuels and implications of sustainable biofuel production on the rural development are described in the following section.

Implications of Modern Biofuels for Rural Development

Socio-economic aspects of bioenergy broadly include the issues of people and institutions that interact and interplay within the bioenergy/biofuel sector (Remedio and Domac 2003). In general, implications of biofuels on rural areas are the alterations or changes to the normal way of living of rural people caused directly or indirectly by its development. List of major changes generated by biofuel production that are linked to rural development are shown in Table 4. These rural development outcomes are achieved more successfully if such developments are implemented in an environmentally and socially acceptable manner, particularly in developing countries. In contrast, if biofuel projects are implemented without applying sufficient sustainability safeguards, there could be some costs faced by rural people along with some benefits. In this section we first identify and discuss direct, indirect and cascading positive implications that sustainable biofuel production on rural development and then offer discussions on key measures that help enhance the conditions to facilitate development of rural areas through biofuel project.

Linking Pathways of Sustainable Biofuel Production and Rural Development

Different types of direct and indirect rural development implications of biofuel production can be identified in development of a bioenergy/biofuel sector.

The immediate direct effect of such a development is seen in terms of local job creation; improved energy services and local health improvement. These direct implications, in combination with other implications, could positively impact several aspects of rural development, such as improved rural infrastructure; knowledge and skills; rural productivity and quality of life. All these changes may ultimately result in more stable rural communities. Influences of sustainable biofuel production on rural development are presented in Figure 1.

TABLE 4 VARIOUS RURAL DEVELOPMENT ASPECTS ASSOCIATED WITH BIOFUEL PRODUCTION

Aspects to rural development	Direct Relationship	Indirect Relationship
Local job creation Higher level income	X	
Better energy services	X	
Improved local health	X	
Good infrastructure facilities		X
Improved knowledge and skills		X
High productivity Quality of life		X
Stabilized local economy	X	

1) Employment and Better Livelihood Options

Employment and other income generation during construction, operation and regular maintenance of the biofuel plant are of great importance as an output of a biofuel project in the local community. Direct employment includes the creation of job opportunities from increased biofuel feedstocks production, transportation and construction and operation, and maintenance of conversion processing plants. In addition, indirect employment is also created through the supporting industries, such as those in marketing and distribution of end products generated by biofuel industry (Domac et al 2005). This implies that the additional generated indirect jobs are substantially greater than the people employed directly at the plant (Thornley et al 2008). The United States and Brazil, the top two biofuels producers, are successful in creating jobs in their biofuel industry where about 400,000 and 900,000 jobs, respectively, have been created (Urbanchuk 2010; De Almeida et al 2007).

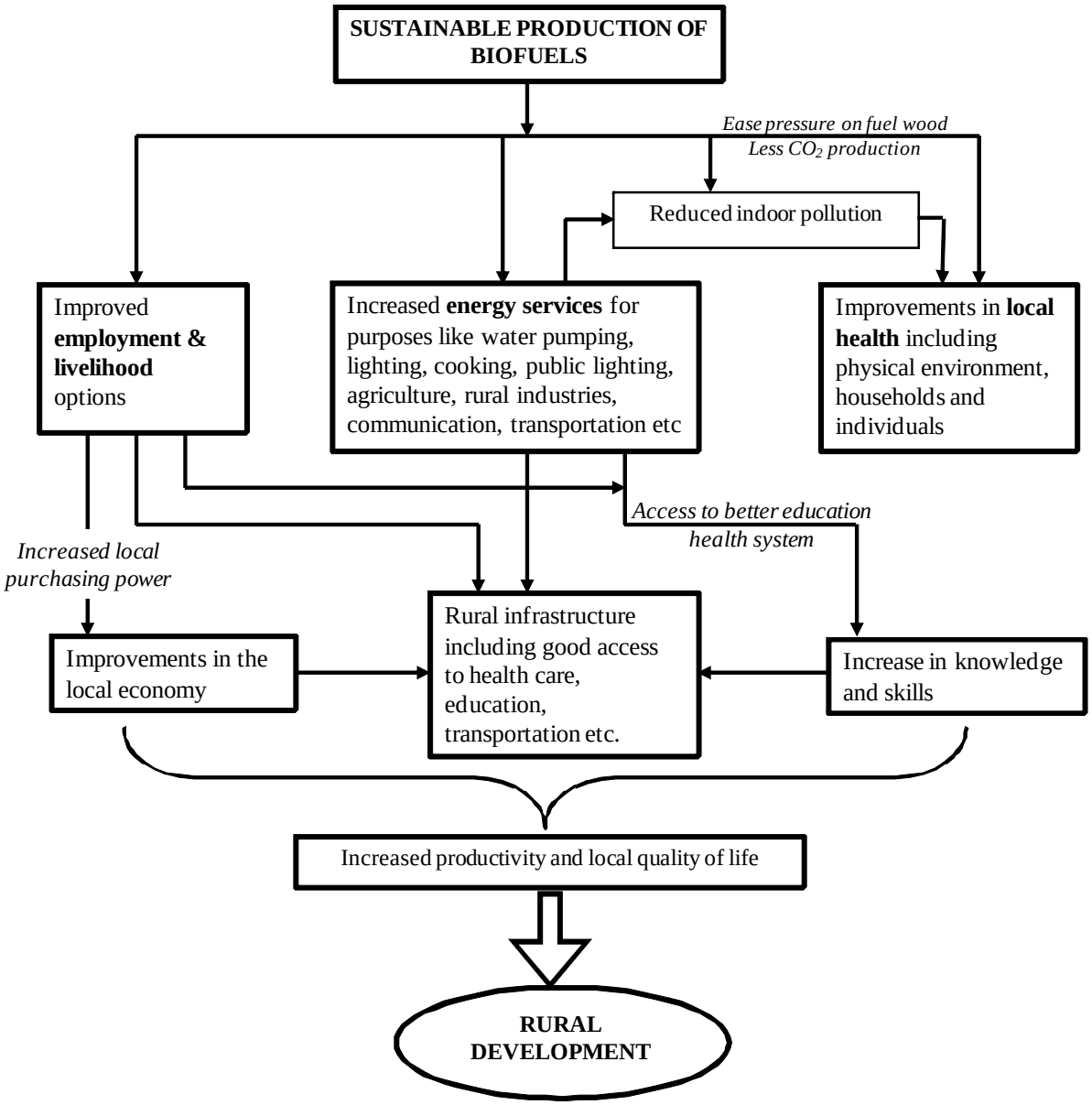

FIG 1. INFLUENCES OF SUSTAINABLE BIOFUEL PRODUCTION THAT CONTRIBUTES TO RURAL DEVELOPMENT (INTERACTIONS OF THESE ASPECTS ARE EXPLAINED IN THE TEXT)

The improved employment opportunities created either by direct employment in the biofuel processing units or through indirect employment in supporting industries prevent landless, unskilled, illiterate poor from migrating to other regions (particularly urban areas). Establishment of biofuel plants can also bring significant development and boost to the local economy as people buy their basic necessitates including food, cloths, tools etc near where they live and they pay tax revenues, which in turn further accelerates the process of community development (Urbanchuk 2010; WWI 2007). Rural communities benefit by this increased spending for local purchases of goods and services, resulting in further downstream effects on the communities. All these changes, in turn, create more employment and revenue that is circulated and retained through the local economy (Urbanchuk 2010).

The expansion of biofuel industry increases the ability of farmers to produce diverse agricultural products such as oilseeds, grains of different quality etc., and this heterogeneity of commodities contributes to the increased profits for the producers (Timilsina 2010). Some of these products may also be destined for export market, which, in some cases, may indirectly influence level of exports of agriculture commodities (Timilsina 2010).

An increase in feedstock production for bioeneregy /biofuel industry also results in an increased production of co-products and residues that are in turn utilized as raw materials for several other sectors. For example, the cosmetics and pharmaceutical industries could benefit from the availability of glycerin, a by-product of biodiesel production (IEA 2009). Additionally, agricultural equipment manufacturing units and fertilizer industries will need to produce higher quantity of their output to support the increased biomass production activity (Han et al 2011). If biofuels are produced using fermentation process, by-products such as dry distilled grain supplement can be instrumental in enhancing livestock production in the region. Such production processes, being very labor intensive, may further enhance job opportunities for the local workers.

The increased household income in the community would further help increase a community's or individual's accessibility to good education, health care, resources (e.g. water, land), food products and employment opportunities etc. Biofuel industry, being located in rural areas, may provide many of these benefits by establishing livelihood opportunities for the local people. The increased income may help strengthen the cohesion or stability of a community through reduced migration and better quality of life. This may also increase their adaptive capacity to exogenous changes**.**

Further, development of biofuel industry can create demand for agricultural lands and could conceivably fuel into rising food prices. This eventuality would happen if more agricultural lands are redirected into biofuel feedstock production. Although higher food prices represent higher income for local farmers, and helps maintain rural development and food security, this is at the cost of consumers.

2) Energy Services to the Local Community

One of the direct benefits that biofuel projects can provide to rural communities, especially in the developing countries, is the availability of fuel itself, which can generate different energy services (WWI 2007). The amount and quality of available energy greatly affect the living conditions in rural areas, which is currently a major limitation in many developing countries (Rosillo-Calle 2000). To that end, two important problems have been identified in the energy sector of developing countries namely: i) the extensive use of traditional forms of energy sources (e.g. fuelwood and agricultural residues), which has a very low combustion efficiency and thus posing environmental, and health threats, among others; and ii) the highly uneven distribution and use of modern energy sources (e.g. electricity, petroleum products etc.) in rural areas, which poses important issues of economics, equity, and quality of life (Barnes and Floor 1996). Almost half the global population (45 percent) still relies on solid fuels for household use, resulting in dramatic impacts on health, especially for children and women (UNDP and WHO 2009). Worldwide, almost 2 million deaths occur annually from pneumonia, chronic lung disease, and lung cancer, which are associated with exposure to indoor air pollution resulting from cooking with biomass and coal. It is estimated that 99 percent of them occur in developing countries (UNDP and WHO 2009). Since traditional bioenergy sources are unable to provide clean, cheap and efficient energy (such as electricity and ethanol fuel), and given their potential to pose serious environment and health effects, it is important to address the above energy related problems from environmental, energy sustainability and economic perspectives (Rosillo-Calle 2000).

Access to energy services is closely linked to a range of social and economic development and human welfare (Goldemberg and Johansson 2004; WEHAB, 2002). Energy services can greatly reduce the amount of time and effort that rural women and children spend on collecting fuelwood and performing household activities. This extra time can be used on more productive as well as social activities, including educational and income-generating activities. People cannot perform efficiently or produce goods if much of their time is being spent searching for fuels or if much of their income is utilized to pay for inefficient power (Barnes and Floor 1996).

It has been argued that access to higher quality energy sources can assist improvement in a variety of human development activities, such as education, health, poverty alleviation and creating good local environment (Kanagawa and Nakata 2008; Cabraal et al 2005). Energy services in transportation enable children to achieve higher education; electricity that provides lighting for

rural homes increases the number of hours children study; and energy services can make available communication and information tools, such as internet, radio, broadcast, distant education learning etc. Similarly, in the health sector, access to energy services enables clinics to have lights, water pumps, medical refrigeration to store drugs and vaccines, medical instruments, fans and sterilizers, and allows increased tests and treatments -- all of these are key to help reduce child and maternal mortality and to combat diseases (WEHAB, 2002; Ezzati et al 2004). Provision of energy can also increase income generation through small-scale activities including grain and saw milling; fruit, meat and vegetable processing, tobacco and coffee curing, textile dyeing and weaving; and production of handicrafts. Some of the large-scale rural industrial activities that benefit from energy access include production of sugar and silk; brick manufacturing units; carpentry; wielding units, among others (Ezzati et al 2004; Kaygusuz 2011).

3) Improvements in Local Health

In addition to above advantages of energy enabled health care system, sustainable biofuel production creates good health environments for local population in several ways. Firstly, diversified bioenergy feedstock production significantly influences the health of surrounding environment and ecosystems by enhancing biodiversity, habitat preservation, soil restoration and watershed protection (WEHAB, 2002). Secondly, the production and use of biofuels improve human health and safety. For example, in Brazil, sugarcane bagasse is used in ethanol production which otherwise would be burnt in the field releasing several harmful air pollutants that affect human health (Phalan 2009). Additionally, improved cooking fuels can alleviate health problems related to indoor air pollution from traditional ways of cooking with biomass (Cabraal et al 2005). Thirdly, biofuels which permit local energy security in rural households can provide access to food and nutrition by enabling people to prepare frequent meals and help reduce food contamination. Water pumps eliminate the need for water storage which otherwise lead to contamination or increased exposure to disease vectors (e.g. mosquitoes) (Ezzati et al 2004). Good energy supply can also lead to high agriculture productivity through increased irrigation. Finally, increased income through the biofuels production enable people to purchase daily goods and services and also able to afford good health care system. All of these factors contribute directly to improvements in the health of local people.

4) Increase in Productivity and Local Quality of Life

The increase in household income generation, energy in homes and businesses, and improvements in the health of physical environment (leading to that in the health of individuals) will collectively enhance the local quality of life and productivity of rural masses. There are several ways in which access to modern energy services contributes to the productivity of rural population particularly in developing countries. For example, improvements in education and health for instance result in increased knowledge, skills and physical capacity to carry out productive work (Cabraal et al 2005). Similarly, with limited or absence of efficient, clean energy services, people must spend a significant amount of time and physical energy on basic activities and are undermined in their efforts to engage effectively in productive activities (Kartha and Larson 2000; WEHAB, 2002). With energy access, poor people could utilize their time and physical energy to earn income and more importantly, hardship of women and children searching for firewood will be relieved. The increased income of an individual or household will lead to better access to very many human development services such as education, health, transportation, communication, energy etc to help enhance their quality of life.

Policy Approches to Maximize Rural Development Benefit

As illustrated in preceding sections, modern biofuels are particularly promising in meeting rural development needs. However, embracing the option of implementing biofuels projects to enhance rural development will undoubtedly require effective measures primarily to enhance the benefits and also to avoid certain environmental and socio-economic risks that could emerge in the process. It is important that the local biophysical and socio-economic conditions are assessed as it helps identify the efficient and cost-effective mix of measures for each specific rural area (Rossi and Lambrou 2009). Various policy measures

that promote biofuel development are being used in different countries reflecting their different socio-economic and environment conditions (Dufey and Grieg-Gran 2010). In general, however, some approaches have been advocated that ensure these projects to link more closely to rural development benefits. These measures include: better financing; establishment of small-scale bioenergy units; local needs assessment and stakeholder involvement; capacity building and policies to govern food security issues. These are discussed further.

Financial Assistance

Financial investment is an essential ingredient to successfully implement biofuel initiatives to enhance rural energy provision and development. Two types of funding assistance could be provided. One, obtaining funding and technical support from national and international development institutions (WWI 2006; UNDESA 2007). This type of funding would be helpful where the public sector is unable to bear all the investment costs to implement bioenergy / biofuel projects (UNDESA 2007). Governments and public sectors, on the other hand, help promote biofuels and their products creating required market environment and ensuring reasonable prices for farmers to help improve rural livelihoods (WWI 2006). In this respect some harmonization of policies of the national and state level governments is very important. Two, funding from financial institutions with an expertise in microcredit (UN-Energy 2007). Some examples include Grameen Banks of Bangladesh and The Bank Rakyat of Indonesia. These financial institutions have demonstrated that local micro-financing can be self-sustaining (Kartha and Leach 2001).

Small-scale Bioenergy Units

Establishment of small-scale bioenergy systems, mostly locally owned, are more promising for rural development by providing employment and poverty alleviation opportunities as opposed to large-scale bioenergy systems which are basically export-oriented and globally competitive (Dufey et al 2007). Further, several case studies of international small-scale bioenergy initiatives have revealed that small-scale bioenergy projects can be successful in achieving both natural resource efficiency and providing new livelihood choices for rural communities (Practical Action Consulting 2009). Government should provide support to small-scale biofuel production facilities through tax structures that give preference to small-scale operations for fuel production (WWI 2006).

Assessments of Local Needs and Stakeholder Involvement

Strong community involvement and participation of local stakeholder is important in implementing bioenergy projects for two reasons. First, to appropriately design a bioenergy / biofuel system that accommodates local agricultural current and expected crop yields and residue availability (Kartha and Larson 2000). The dynamic nature of local stocks and flows of biomass resources would require involvement of the community to obtain authentic data which reflect local values, practices and perceptions of resource opportunities and constraints (Kartha and Leach 2001). Second, to identify the local needs in terms of energy, employment or development of the community (UN-Energy 2007). The capacity of locally-produced biofuels to meet the energy needs of rural populations require the capacity and skill set at the local and community level (UN-Energy 2007). Any under or over estimation of resources and improper demand- supply ratios would affect the sustainability of bioenergy project (Kartha and Larson 2000; Practical Action Consulting 2009). Hence, community and stakeholder involvement is an important step in the development of such projects.

Capacity Building

Educating the public on all aspects of biofuels has been cited as the most crucial measure to the success of biofuel project (Dufey et al 2007; UNDESA 2007; Kartha and Leach 2001). Capacity building activities involve imparting skills and abilities on both specific and broad levels. Some specific level capacity building include educating farmers on feedstock selection, new suitable high yielding crops; access to inputs (e.g., seeds, fertilizer etc.) and sustainable agricultural techniques; technical skills training for artisans and blacksmith in order to maintain equipment; financial skills and train rural women (UNDESA 2007). On the other hand, broad level training might include educational initiatives, public outreach, and training for prospective entrepreneurs and policy-makers to acquire the necessary information, conduct economic analysis, design a biomass energy initiative, organize communities, and mobilize the necessary actors to design, manufacture, market, provide quality control

and service, and promote appropriate policies (Kartha and Leach 2001)

Policies to Safeguard Food Security Issues

Bioenergy projects could add to the problems of food security as the current agriculture systems are already suffering due to unsustainable practices in certain regions (e.g. low irrigation efficiency) and adopting sustainable agriculture practices that improve resource base, food production and quality of life is an urgent need for all developing countries to support their growing population and to protect agriculture resources such as freshwater, soil etc. (Sheelanere and Kulshreshtha 2012). To address these considerations, appropriate policies and programs that enhance awareness and accessibility to use sustainable practices and investment in water control measures (e.g. drip irrigation, switching to production of less thirsty crop), and in equipping farmers and non-farm community with appropriate information and skills would prove appropriate (Sheelanere and Kulshreshtha 2012).

Conclusions and Prospects

In this paper, we have provided an outline of rural development implications of sustainable biofuel projects with a general account on the processes involved in the production of biofuels. By exploring the interactions of various features of modern biofuel production on rural development, we have illustrated that modern biofuels have the potential to contribute to the development of rural areas, particularly in developing countries. This rural development potential of sustainable biofuel production is attributed to its capacity to enable energy services to the rural community, present jobs and livelihood options and create good local heath environment. Further, measures to improve the rural development benefits of biofuel projects were also reviewed. Clearly, the strategies to establish a biofuel projects to deliver rural development outcomes differ from one region to another based on local energy needs, environmental resource base and other socio-economic priorities of the region. For this reason, it is advisable not to assume all biofuel projects will yield expected results in all cases and in all regions. Proper design and analysis of these is very important.

In conclusion, we emphasize that the modern bioenergy will certainly make a meaningful strategy, although it is not the only solution, to address energy and development problems of rural regions. Comparison of costs and benefits of biofuel projects against those from other alternative means of improving rural areas need to be considered as an important pre-requisite to their development. Bioenergy projects will prove promising in the current context where there is a need to diversify energy supplies in order to be able to meet the increasing energy demands, minimize climate concerns and alleviate poverty.

Two important research needs could be addressed in reaping the rural development benefits of biofuel projects. First, to fully determine suitable crops to different biofuel applications, soil types, farming techniques and social contexts (UNDESA 2007) and to identify suitable locations for biofuel production. Second, developing technologies in order to improve the efficiency of conversion of biomass to biofuels is essential. This not only improves the energy yield of biofuels but also reduces the overall environmental costs and economic burden on the society, and hopefully could provide sufficient quantities to satisfy the energy needs of the society.

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