Chapter 9
Impacts of sugarcane bioethanol towards the Millennium Development Goals

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1. Introduction

At the Millennium Summit in September 2000 the largest gathering of world leaders in history adopted the United Nations Millennium Declaration. They committed to a new global partnership to reduce extreme poverty by 2015 in line with a series of targets that have become known as the Millennium Development Goals (MDGs). The MDGs are crafted around eight themes to promote sustainable development addressing extreme poverty in its different dimensions including hunger, health, education, the promotion of gender quality and environmental sustainability (see Box 1).

At the same time, during the last five years or so, the world has witnessed the global emergence of a new sector – the biofuels sector. Biofuels potential for achieving simultaneously economic, poverty reduction and environmental goals have combined and placed biofuels at the top of today's most pressing policy agendas.

This chapter argues that sugarcane bioethanol can be supportive of sustainable development and poverty reduction, thus contributing to the achievement of the MDGs. In some contexts there might be synergies between the pursue of different goals but there may be

Box 1. The Millennium Development Goals.

The eight Millennium Development Goals were agreed at the United Nations Millennium Summit in September 2000. The eight Millennium Development Goals are:
- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empower women
- Reduce child mortality
- Improve maternal health
- Combat HIV and AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

Source: http://www.un.org/millenniumgoals/

also risks and serious trade-offs over food security, small farmers inclusion, environment and the economy.

Much of the available evidence comes from Brazil, which has the main longstanding experience with the launching of the PROALCOOL Programme in 1975 to replace imported gasoline with bioethanol produced from locally grown sugarcane. Today Brazil is the second bioethanol producer after the United States and the main exporter. In addition, there have been other smaller initiatives with different rate of success. These include African and East Asian countries such as Zimbabwe, Malawi, Kenya, Pakistan and India that have promoted bioethanol from sugarcane molasses, some of them since the early eighties. More widely, at present, many countries around the world, in their search for development and poverty reduction opportunities are trying to replicate the Brazilian experience with sugarcane bioethanol. Their vast majority are developing countries in tropical and semitropical areas in the Caribbean, Africa, Latin America and East Asia in which sugarcane is traditionally grown.

The chapter is organized as follows. After this brief introduction, Section 2 argues that sugarcane bioethanol may offer some genuine opportunities for sustainable development and poverty reduction and identify the key potential benefits. Section 3 points out that benefits are not straightforward and identifies several challenges and trade-offs that need to be confronted in order to realize their full potential for achieving sustainable development and poverty reduction. Finally, section 4 concludes and provides some recommendations.

2. Opportunities for sugarcane bioethanol in achieving sustainable development and the Millennium Development Goals

Sugarcane bioethanol can contribute to sustainable development and poverty reduction through a varied range of environmental, social and economic advantages over fossil fuels. These include: (a) enhanced energy security both at national and local level; (b) improved social well-being through better energy services especially among the poorest; (c) improved trade balance by reducing oil imports; (d) rural development and better livelihoods; (e) product diversification leaving countries better-off to deal with market fluctuations; (f) creation of new exports opportunities; (g) potential to help tackling climate change through reduced emissions of greenhouse gases (h) reduced emissions of other air contaminants; and (i) opportunities for investment attraction through the carbon finance markets. This section briefly addresses each of these aspects.

2.1. Enhanced energy security

Enhanced energy security has become a universal geopolitical policy concern and it was a key policy driver behind the first attempts to introduce sugarcane bioethanol at a massive scale in the mid-1970s in Brazil (Dufey *et al.*, 2007b). Current increasing energy costs and uncertainty regarding future energy supply are giving many governments incentive to encourage the production of petroleum substitutes from agricultural commodities. Indeed, the volatility of world oil prices, uneven global distribution of oil supplies, uncompetitive structures governing the oil supply and heavy dependence on imported fuels are all factors that leave many countries vulnerable to disruption of supply, imposing serious energy security risks which can result in physical hardships and economic burden (Dufey, 2006). For instance, crude oil imports to African, Caribbean and Pacific countries were expected to increase to 72 percent of their requirements in 2005 (Coelho, 2005).

Energy diversification makes countries less vulnerable to oil price shocks, compromising macro-stability affecting variables such as the exchange rate, inflation and debt levels (Cloin, 2007). Sugarcane bioethanol is a rational choice in countries where sugarcane can be produced at reasonable cost without adverse social and environmental impacts (Dufey *et al.*, 2007b). For remote places, locally produced sugarcane bioethanol can offer a highly competitive alternative to other fuels. This might be the case of several sugarcane producing countries in Pacific island nations and land-locked countries in Africa where the high costs of fossil fuel transportation and the related logistics make them prohibitive.

2.2. Benefits at the household level - improved social well-being

A large part of the poor, mostly in rural areas, do not have access to affordable energy services which affects their chances of benefiting from economic development and improved living standards. In this context the use of bioethanol and other renewable sources can directly or indirectly lead to several MDGs including gender equality, reduction of child mortality, poverty reduction, improvement of maternal health and environmental sustainability. Firstly, they can reduce the time spent by women and children on basic survival activities (gathering firewood, fetching water, cooking, etc.). Women in least developed countries may spend more than one third of their productive life collecting and transporting wood. Additional help needed from children often prevents them from attending school (FAO, 2007). Secondly, the use of bioethanol (and other liquid biofuels) for household cooking and heating could help to reduce respiratory disease and death associated with burning of other traditional forms of fuels usually used in the poorest countries (e.g charcoal, fuelwood and paraffin solid biomass fuels indoors), to which women and children are especially vulnerable (UN-Energy, 2007; Woods and Read, 2005). In some African countries charcoal and woodfuel account for over 95 percent of household fuel (Johnson and Rosillo-Calle, 2007). As Box 2 suggests, experiences promoting the use of sugarcane bioethanol in stoves at the household level are expected to report important socio-economic and environmental benefits. Finally, the use of biofuels can improve access to pumped drinkingwater, which can reduce hunger by allowing for cooked food (95% of food needs cooking) (Gonsalves, 2006a). However, adaptation of bioethanol for domestic uses would of course require a cultural shift away from the traditional hearth, plus attention to safety in fuel storage, as liquid biofuels are highly flammable (Dufey *et al.*, 2007b). Overall, electricity through transmission lines to

Box 2. Bioethanol stoves to condominium residents in Addis Ababa in Ethiopia

In Ethiopia the Municipality of Addis Ababa EPA (Environmental Protection Authority) and a Sub-City district are working closely with Gaia Association, Dometic AB, Makobu Enterprises, and Finchaa Sugar Factory to develop a project whereby initially 2000 CleanCook (CC) stoves will be installed in newly built condominium apartments. Wood and charcoal stoves are not permitted in these condominium buildings.

The CC stove is financed within the condominium unit price. Financing is provided by the condominium association with the assistance of the Municipal EPA, the Sub-City Administration and a financing entity. The finance rate is regulated by the government and is kept low. The bioethanol used in the project is produced at one of three state-owned sugar factories at a contractual price by Makobu Enterprises and delivered to the condominium. The fuel storage and distribution infrastructure will be financed by the condominium association. The Ethiopian EPA will work with one Sub-City Administration to package the stove financing into the condominium financing through the national bank. As a result, 2000 CC stoves will be financed in 2008 and approximately 360,000 liters of domestically produced bioethanol will supplant kerosene, charcoal and firewood use. The other nine Sub-City administrations could replicate the model.

Since the CC stove is clean burning, its introduction will improve indoor air quality and, consequently, household health. Another advantage of this model lies in the potential for Clean Development Mechanism (CDM) financing. It is important to note the government has had a central role for the development of a domestic bioethanol industry in Ethiopia, as well as for building a local market for bioethanol as a household cooking fuel. Indeed, after considering allocating bioethanol for fuel blending in the transport sector in 2006, the Government got convinced that the most significant socioeconomic and environmental benefits would stem from prioritizing the use in the domestic household sector.

Source: adapted from Lambe (2008).

many rural areas is unlikely to happen in the near future, so access to modern decentralized small-scale energy technologies, particularly renewables are an important element for effective poverty alleviation policies (Gonsalves, 2006a). In this context, bioethanol can be directed towards high value added uses such as lighting or motors, which can lead to income generating activities.

But the effectiveness of using sugarcane bioethanol for these uses would need to be assessed against those of other energy crops or renewable sources such as small hydropower.

2.3. Improved trade balance

Heavy reliance on foreign energy sources means countries have to spend a large proportion of their foreign currency reserves on oil imports. Oil import dependency is especially acute in Sub-Saharan and East Asian countries, where 98 percent and 85 percent of their oil needs are met by imports, respectively (ESMAP, 2005a). Changes in oil prices have devastating effects in these countries. For instance, the 2005 oil price surge reduced Gross Domestic Product growth of net oil importing countries from 6.4 percent to 3.7 percent, and, as a consequence, the number of people in poverty rose by as much as 4-6 percent, with nearly 20 countries experiencing increases of more than 2 percent (ESMAP, 2006).

Domestically produced bioethanol offers oil importing countries an opportunity to improve their trade balance. In Brazil, for instance, the replacement of imported gasoline by sugarcane bioethanol saved the country some US$ 61 billion in avoided oil imports during the last eight years – equating the total amount of the Brazilian external public debt (FAO, 2007). In Colombia, the implementation of the bioethanol programme would result in foreign exchange savings of US$ 150 million a year (Echeverri-Campuzano, 2000).

2.4. Rural development and creation of sustainable livelihoods

Biofuels provide new economic opportunities and employment in the agricultural sector, key aspects for poverty reduction. They generate a new demand for agricultural products that goes beyond traditional food, feed and fibre uses, expanding domestic markets for agricultural produce and paving the way for more value-added produce. All of these aspects enhance rural development, especially in developing countries where most of the population live in rural areas. For instance, Echeverri-Campuzano (2002) estimates that every Colombian farming family engaged in bioethanol production will earn two to three times the minimum salary (US$ 4,000/year). In South Africa meeting targets of E8 and B2 would contribute 0.11 percent to the country's Gross Domestic Product. Most of the positive effect would take place in rural areas characterized by unemployment and rising poverty (Cartwright, 2007).

Compared to other sources of energy, biofuels are labour intensive. Their production is expected to generate more employment per unit of energy than conventional fuels and more employment per unit investment than in the industrial, petrochemical or hydropower sector (UN-Energy, 2007). Creation of rural employment and the related livelihoods are all key aspects for rural development and poverty reduction. In Brazil estimations of direct employment associated with sugarcane bioethanol production ranges from 500,000 and 1 million (Worldwatch Institute, 2006; FAO, 2007) with indirect employment in the order of 6 million. Although most of them are filled by the lower-skilled, poorest workers in rural areas (Macedo, 2005), average earnings are considered better than in other sectors as the average family income of the employees ranks in the upper 50 percentile (FAO, 2007). In India, country that houses 22 percent of the world's poor, the sugarcane industry including bioethanol production is the biggest agroindustry in the country and the source of livelihood of 7.5 percent of the rural population. Half a million people are employed as skilled or semi-skilled labourers in sugarcane cultivation (Gonsalves, 2006a).

The highest impact on poverty reduction is likely to occur where sugarcane bioethanol focuses on local consumption, involving the participation and ownership of small farmers in the production and processing (FAO, 2007; Dufey *et al.*, 2007b) and where processing facilities are near to the cultivation fields.

2.5. Product diversification and value added

International sugarcane market is one of the most distorted markets. It is highly protected, in general countries manage to negotiate quotas, a limited access to different markets, and because it is a commodity, it has important price fluctuations (Murillo, 2007). In this context, sugarcane bioethanol is an opportunity to promote agricultural diversification leaving producers in a more favourable situation to deal with changes in prices and other market fluctuations. In Brazil, for instance, besides the pursue of enhanced energy security, the government promoted the PROALCOOL programme in order to deal with the fall in international sugar prices preventing thus the industry of having idle capacity (FAO, 2007). Moreover, the production of both sugar and bioethanol gives the Brazilian industry flexibility in responding to the changing profitability of sugar and bioethanol production worldwide. In most cases, sugar and bioethanol are produced in the same mills (Bolling and Suarez, 2001).

Sugarcane bioethanol can also reduce vulnerability through diversification. The changes in the European Union's sugar regime will imply that many African, Caribbean and Pacific countries will see their market access preferences eroded generating negative impacts on poverty levels. In the Caribbean, for instance, the associated possible loss of export revenues is expected to be 40 percent with a heavy contraction in the industry. The resulting sugar surpluses therefore could be accommodated for biofuels production thus helping the industry to diversify, avoiding or mitigating the expected contraction (E4Tech, 2006).

Another element to consider is the fact that sugarcane bioethanol production provides value added to sugarcane production. For instance, Murillo (2007) notes for Costa Rica that if the molasses and sugar producers substitute their production by those of bioethanol the price received would be much more than what they would get if they were to continue producing molasses or sugar for the surplus market.

2.6. Export opportunities

Although at present very little bioethanol enter the international market (about 10%), international trade is expected to expand rapidly, as the global increase in consumption (especially countries in the North) will not coincide geographically with the scaling up of production (countries in the South) (Dufey, 2006). The geographical mismatch between global supply and demand represents an opportunity for countries with significant cost advantages in sugarcane production to develop new export markets and to increase their export revenues. These are invariably developing countries in tropical and semitropical areas.

Brazil, the main global bioethanol exporter, increased its exports considerably over the last few years and today supplies about 50 percent of international demand. (Dufey *et al.*, 2007b). The Brazilian government expects that by 2015 about 20 percent of the national production to be exported (Ministerio da Agricultura *et al.*, 2006). Countries from the Caribbean Basin Initiative are developing export-oriented sugarcane bioethanol industries taking advantage of preferential market access provided by the trade agreement with the United States. Other exporters include Peru, Zimbabwe and China. As them other Latin American, African and East Asian countries are exploring the benefits of export-oriented sugarcane bioethanol sectors.

In absence of trade distorting policies and where effective distributional and social policies are supportive, the development of a successful sugarcane bioethanol export-oriented industry could effectively reduce poverty.

2.7. Reduced greenhouse gas emissions

At present global warming is considered one of the key global threats facing the humanity (Stern, 2006). Biofuels alleged reduced greenhouse gas emissions compared to fossil fuels are one of the main policy rationales for their promotion especially in Northern countries. There are two ways in which biofuels can reduce carbon emissions. First, over their life cycle, biofuels absorb and release carbon from the atmospheric pool without adding to the overall pool (in contrast to fossil fuels). Second, they displace use of fossil fuels (Kartha, 2006). However, biofuels production does, in most cases, involve consumption of fossil fuels.

Compared to other types of liquid biofuels and under certain circumstances, Brazilian sugarcane bioethanol and second generation biofuels show the higher reductions in greenhouse gas emissions relative to standard fuels. IEA (2004) estimates that greenhouse emissions from sugarcane bioethanol in Brazil are 92 percent lower than standard fuel, while wheat bioethanol points to reductions ranging from 19 percent to 47 percent and reductions from sugar beet bioethanol vary between 35 percent and 53 percent. In addition to Brazil's exceptional natural conditions in terms of high soil productivity and that most sugarcane crops are rain fed, a key factor behind its great greenhouse emissions performance is that nearly all conversion plants' processing energy is provided by 'bagasse' (the remains of the crushed cane after the juice has been extracted). This means energy needs from fossil fuel are zero and the surplus bagasse is even used for electricity co-generation. In 2003, Brazil avoided 5.7 million tonnes CO_2 equivalent due to the use of bagasse in sugar production (Macedo, 2005). Moreover, new developments in the sector such as the commercial application of lignocelulosic technology that will allow the use of bagasse for bioethanol production and the increased generation of electricity from bagasse will improve their greenhouse emissions balance (Dufey *et al.*, 2007a).

However the Brazilian experience is not necessarily replicable in other contexts. For example, efficiency gains and the greenhouse emissions reductions associated with co-generation are an option for those countries whose electricity sectors regulation allows power sale to the grid (E4Tech, 2006).

Finally, these estimations do not include the emissions resulting from changes in land use and land cover induced by sugarcane plantations for bioethanol production. For example, the evaluation of greenhouse emissions from Brazil for the 1990-1994 period points out the change in land use and forests as the factor accounting for most of the emissions (75%), followed by energy (23%). This implies that if additional land use for sugarcane production leads (directly or indirectly) to conversion of pastures or forests as suggested later in this chapter, the greenhouse emissions may be severe and could have a major impact on the overall greenhouse emission balance (Smeets *et al.*, 2006). Overall, the land use issue requires further attention and is addressed in another chapter of this book.

2.8. Outdoor air quality

Road transport is a growing contributor to urban air pollution in many developing country cities. One of the greatest costs of air pollution is the increased incidence of illness and premature death that result from human exposure to elevated levels of harmful pollutants. The most important urban air pollutants to control in developing countries are lead, fine particulate matter, and, in some cities, ozone. Sugarcane bioethanol, when used neat, is a clean fuel (aside from increased acetaldehyde emissions). More typical use of bioethanol is in low blends. Bioethanol also has the advantage of having a high blending octane number, thereby reducing the need for other high-octane blending components such as lead that cause adverse environmental effects. Venezuela, for instance, began importing Brazilian bioethanol as part of the effort to eliminate lead from gasoline. Bioethanol can be effective for cutting carbon monoxide emissions in winter in old technology vehicles as well as hydrocarbons emissions. The latter are ozone-precursors, in old technology vehicles (ESMAP, 2005b).

On the other hand, there is air pollution associated with the slush and burn of sugarcane and the burning of the straw, a common practice in developing countries to facilitate the harvesting. This issue is further addressed in Section 3.b on Environmental Impacts.

2.9. Opportunities for investment attraction – including the Clean Development Mechanism

Developing countries can make use of the carbon finance markets for attracting investment into biofuels projects using the market value of expected greenhouse emission reductions. The Clean Development Mechanism (CDM) under the Kyoto Protocol is the most important example of the carbon market for developing countries. The CDM allows developed countries (or their nationals) to implement project activities that reduce emissions in developing countries in return for certified emission reductions (CERs). Developed countries can use the CERs generated by such project activities to help meet their emissions targets under the Kyoto Protocol. For instance, it is calculated the Colombian Programme on bioethanol would reduce CO_2 emissions by six million tons, offering opportunities to obtain financial resources for the project trough the CDM (Echeverri-Campuzano, 2000). For Costa Rica, Horta (2006) estimates that considering an avoided ton of carbon at a conservative price of US$ 5, in the scope of the Kyoto Protocol and the valid mechanisms of carbon trade, US$ 320,000/year can be obtained using a 10 percent of sugarcane bioethanol in the gasoline blend.

Although the CDM is a potential source of financing for biofuels projects, taking advantage of it can present a number of challenges for the developing country host. Firstly, so far there is no liquid-biofuels baseline and monitoring methodology approved. Calculation of greenhouse gases emissions is not straightforward and for many countries biofuels are still a relatively expensive means of reducing these emissions relative to other mitigation measures. An additional challenge is that the existing experience with CDM projects shows that approved projects are strongly concentrated in a handful of large developing countries, with over 60 percent of all CDM projects distributed across China, India and Brazil alone. While there are simplified procedures for small-scale projects, the current structure of the CDM tends to select for large-scale projects. The transaction costs associated with registering a CDM project are often prohibitively expensive for smaller developing countries, which imply that economies of scale are relevant (Bakker, 2006). For bioenergy projects specifically, the exclusion of all land use activities from the CDM except for afforestation and reforestation is another significant limiting factor, since in the poorest developing countries, land-use related emissions make up the bulk of greenhouse gases emissions from biomass energy systems (Schlamadinger and Jürgens, 2004). Overall, as FAO (2007) concludes, while carbon credits might be influential in the future, currently the carbon market does not have a large influence over the economics of bioenergy production.

3. Risks and challenges

Section 2 analysed a diverse range of benefits associated with sugarcane bioethanol in terms of its potential to support poverty reduction and environmental sustainability. However, as this section argues, these benefits are not straightforward. There is a range of challenges and trade-offs that need to be confronted in order to realize the full potential that sugarcane bioethanol offers to support the MDGs, which include: (a) impacts on food security; (b) environmental pressure; (c) small farmer inclusion and fair distribution of the value chain benefits; (d) land impacts; (e) employment quality; (f) need of government support; (g) existence of market access and market entry barriers and; (h) issues related to improved efficiency, access to technology, credit and infrastructure. These issues are addressed in the following.

3.1. The food versus fuel debate

Current food prices increases, the role that biofuels play on such rises and their related impacts on food security are, probably, one of the most controversial debates being held both at national and international fora. Indeed, food prices increased by 83 percent during the last three years (World Bank, 2008). The Food and Agriculture Organization of the United Nations (FAO) food index price rose by nearly 40 percent in 2007, from a 9 percent increase in 2006 (IFPRI, 2008). World prices rose much more strongly in 2006 than anticipated for cereals, and to a lesser extent for oilseeds, but weakened for sugar (OECD-FAO, 2007).

The understanding of biofuels impacts on food security is a wider and complex. It requires considering that the link between food prices increases and food security is not unique and necessarily negative. It needs to be analysed in the context that changes in food prices not only impact food *availability* but also its *accessibility* through changes in incomes for farmers and rural areas (Schmidhuber, 2007).

3.1.1. Impacts on food availability

The key question at the national level is whether the savings and gains from biofuels will outweigh additional food costs. Biofuels compete with food crops for land and water, potentially reducing food production where new agricultural land or water for irrigation are scarce (Dufey *et al.*, 2007b). For biofuels that are manufactured from food crops, there is also direct competition for end-use. To what extent sugarcane bioethanol creates competition for land and crowd out food crops is an issue that is not very clear. The limited available evidence would suggest a lesser impact compared to other feedstocks. Zarrilli (2006), for example, points out that sugarcane producing regions in Brazil stimulate rather than compete with food crops, which is done by two means. Firstly, through the additional income generated by sugarcane related agro-industrial activities which 'capitalises' agriculture and improves the general conditions for producing other crops. This is also noted by Murillo (2007) for Costa Rica, where under current weather conditions and land use, sugarcane bioethanol production is seen as a complement in income generation rather than a competition for basic products and vegetables. Secondly, the high productivity of cane per unit of land compared to other feedstocks enables a significant production of cane, with a relatively small land occupation (Zarrilli, 2006). Sugarcane's minimal land requirements but in the context of sub-Saharan Africa is noted by Johnson *et al.* (2006), but needs to be proven (Dufey *et al.*, 2007b). Moreover, in those countries where bioethanol is produced from sugarcane molasses there is no displacement of food crops (Rafi Khan *et al.*, 2007). In addition, in many African countries, cassava and maize are grown for subsistence purposes while cane is often grown for sugar export. Diversion to fuel production is therefore more likely to adversely affect food availability in the case of cassava (Johnson and Rosillo-Calle, 2007)

At the international level, the growing international demand for biofuels is expected to reverse the long-term downward trend in global prices of agricultural commodities. Several studies have been conducted linking increased global biofuels production with rising agricultural commodity prices. Estimations vary widely with most credible ones going up to 30 percent. Other contributing factors to price increases are the weather-related shortfalls in many key producing countries, reduced global stocks, increased demand from new emerging economies in Asia (OECD-FAO, 2007) and speculation (IFPRI, 2008). In that sense, the higher demand for biofuel feedstocks is viewed as increasing pressure on an already tight supply.

However, it is one issue trying to isolate how much biofuels, in overall, are responsible for the sector's inflationary pressure and, a different one, understanding to what extent sugarcane bioethanol is responsible for the price increase. Although the available evidence in this sense is also scant, it would suggest that, compared to other feedstocks, sugarcane bioethanol would have a slighter impact on food security. A key reason behind this is that sugarcane is not a principal food crop. Staple grains like maize and rice are often the main food source for the poorest people, accounting for 63 percent of the calories consumed in low-income Asian countries, nearly 50 percent in Sub-Saharan Africa, and 43 percent in lower-income Latin American countries (IFPRI, 2008). Rosegrant (2008) in an exercise in which biofuel production was frozen at 2007 levels for all countries and for all crops used as feedstocks, shows the smaller price reductions for sugarcane followed by wheat while the higher reductions are for maize (Figure 1). Another reason been argued is that sugarcane price would be relatively uncorrelated with other food crops (Oxfam, 2008).

3.1.2. Impacts on accessibility

The issue of how the gains and costs of biofuels to food security are distributed across society has been less explored in the literature. FAO and other commentators agree that hunger is largely a matter of access rather than supply, so that a focus on rural development and livelihoods makes more sense that trying to maximise global food supply, which for now at least is adequate for global needs (Murphy, 2007).

Higher agricultural commodity prices are good news for agricultural producers, but they have an adverse impact on poorer consumers, who spends a much larger share of their income on food (IFPRI, 2008). There are also differences depending on whether households are net food producers or buyers. For small farmers that are net food producers, overall gains in welfare and food security are expected due to rising revenues from biofuel crops and

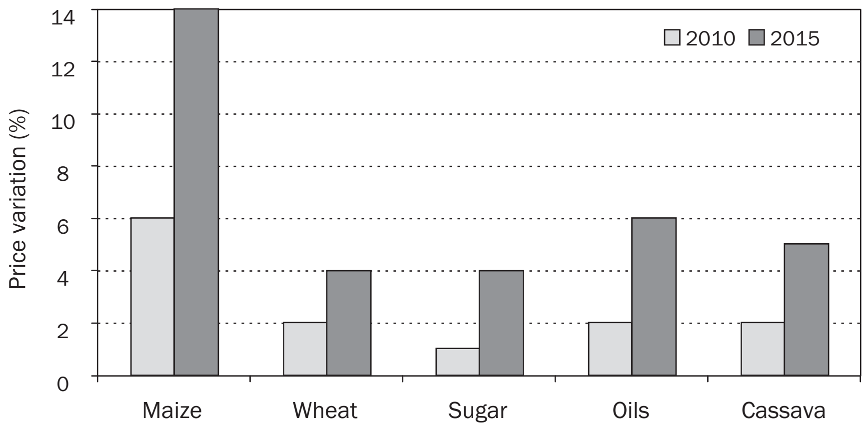

Figure 1. Change in selected crop prices if biofuel demand was fixed at 2007 levels. Source: Rosegrant (2008).

food crops (Peskett *et al.*, 2007). In overall, poor consumers in urban areas who purchase all their food are expected to be worst off. From this perspective and compared to other feedstocks, sugarcane bioethanol is likely to provide more limited opportunities to meet food security for small farmers. In Brazil, for example, sugarcane is a crop mainly grown under large-scale schemes, with limited participation of small farmers. In regions such as Asia, although small farmers participation in sugarcane cultivation is important, the need to use irrigation makes more unlikely to involve poorest farmers (ICRISAT, 2007). More widely, it is agreed that despite being producers of agricultural crops, most poor farming households in rural areas are net buyers of food (Dufey *et al.*, 2007b; IFPRI, 2008).

Finally, it should be noted that, historically, domestic food prices have not been tightly linked to international food or energy prices, as price transmission mechanisms are not straightforward (Hazell *et al.*, 2005). For instance, agricultural pricing policies such as price fixation, the remoteness of some rural areas, trade distortions and power structures governing agricultural commodity markets are key factors preventing world prices from reaching domestic markets. This may imply that farmers may not see the incentives to change feedstock production in tandem with changes in international prices.

3.2. Environmental pressure

Traditional environmental impacts associated with sugarcane appear when it comes to managing soil, water, agrochemicals, agricultural frontier expansion and the related biodiversity impacts. Among them, impacts on agricultural frontier and on water deserve especial attention. Regarding the former, it should be noted that the bulk of the sugarcane expansion in the last thirty years in Brazil has been concentrated in the central southern region of the country. Between 1992 and 2003, 94 percent of the expansion occurred in existing areas of agriculture or pastureland and only a small proportion of new agricultural borders were involved (Macedo, 2005). Often the sugarcane crop replaced cattle grazing and other agricultural activities (e.g. citrus crops), which in turn moved to the central region of Brazil where the land is cheaper (Smeets *et al.*, 2006). Land converted to agriculture in the sensitive area of the Cerrado savanna (which accounts for 25% of the national territory) has been used for cattle grazing and/or planted to soya, with only a small proportion for sugarcane. However, given the new phase of expansion experiencing the sector for bioethanol production, new areas are expected to be converted to sugarcane, including the Cerrado of Mato Grosso do Sul, Goiás and Minas Gerais (Dufey *et al.*, 2007a). This could further increase the pressure on the already affected biodiversity and produce greenhouse emissions. There is concern in this sense on the impacts that the substitution effect - sugarcane taking over existing pastureland or other crops that become less profitable which in turn advance into protected or marginal areas – may have on biodiversity. Indeed, in Brazil, substitution effect related impacts are considered more significant than the direct effects of sugarcane expansion (Dufey, 2007). In Africa, on the other hand, land constraints appear unlikely in any near-term scenario, and resources such as water, as explained in the next paragraph, may turn out to be the key limiting factor (Johnson and Rosillo-Calle, 2007).

Regarding water, sugarcane requires large amounts of water, both at the farming and processing level. Even in Brazil where most sugarcane is rain fed, irrigation is increasing. Energy cane, which is especially bred for energy production, requires more water and fertiliser than conventional sugarcane (Cloin, 2007). Water is likely to be a key limiting factor especially in dry and semi-dry areas in Africa and Asia. Bioethanol impact on water quality is another issue and not only at the farming level due to the use of agrochemicals but also at the processing level. Vinasse, - a black residue resulting from the distillation of cane syrup - is hot and requires cooling. In the mountainous areas of north-eastern Brazil, for instance, the costs of pumping storing vinasse were prohibitive, and it was therefore released into rivers, resulting in the pollution of rivers causing eutrophication and fish kills. Currently, vinasse is used for ferti-irrigation of cane crops, together with wastewaters. Moreover, legislation has been implemented in Brazil to avoid the negative impacts of vinasse applications, although its coverage is incomplete and its enforcement is rather weak (Smeets *et al.*, 2006). All in all, while steps have been taken in Brazil order to manage vinasse disposal, in countries such as Malawi it is still a major concern (Johnson and Rosillo-Calle, 2007).

Furthermore, the air pollution associated with the slush and burn of sugarcane and the burning of the straw, a common practice in developing countries to facilitate the harvesting, is an additional issue. Sugarcane burning emits several gases including CO, CH_2, ozone, non-methane organic compounds and particle matter that are potentially damaging for human health. Several studies were conducted in São Paulo in Brazil during the 1980s and 1990s to identify the impacts of sugarcane burning on human health. Although some studies did not found a link, others studies did confirm the relationship (Smeets *et al.*, 2006;

Dufey *et al.*, 2007a). Legislation has been passed in Brazil by which sugarcane burning is to be completely phased out in the São Paulo State by 2031. In Southern Africa efforts to reduce sugarcane burning pre-harvesting have also been reported (Jackson, 2004), but in other countries it still remain a major practice.

Overall, sugarcane bioethanol production poses some specific environmental challenges that need to be carefully identified and managed using a life cycle approach in order to achieve the MDG on environmental sustainability.

3.3. Small farmers inclusion and fair distribution of the value chain benefits

Addressing poverty means that biofuels should benefit poor and small farmers overall. An emphasis on small farmers would provide livelihoods across the greatest section of the populations (Johnson and Rosillo-Calle, 2007). But the competitiveness of a biofuels industry is highly dependent on gaining economies of scale. Often large-scale systems are more globally competitive and export oriented, while small-scale systems offer greater opportunities for employment generation and poverty alleviation (Dufey *et al.*, 2007b). In Brazil, the sugarcane business model is characterised by enormous concentration of land and capital, which highlights the need for a better inclusion of small-scale producers (Dufey *et al.*, 2007a). Increasing economies of scale and land concentration have meant that benefits of sugarcane bioethanol production for small land owners have so far been limited and large farmers and industrialists have benefited more from the expansion of the industry (Peskett *et al.*, 2007). In contrast, in countries such as India and South Africa small farmers are key players in the sugarcane sector. In India, they represent between 60 and 70 percent of the cane growers (Johnson and Rosillo-Calle, 2007). In Costa Rica, the proportion of small producers in the sugarcane sector increased by 97 percent between 2000 and 2005 (Murillo, 2007).

Small farmers face several obstacles in trying to access supply chains. They trade-off high transportation costs getting crops to processing plants with selling through middlemen (Peskett *et al.*, 2007; Rafi Khan *et al.*, 2007). In India, farmers must access to irrigation to be competitive, which is increasingly difficult and expensive due to growing water scarcity and cost (ICRISAT, 2007). At processing plants they have to time delivery to fit daily plant capacity and meet plant standards. Either way, small producers are price-takers (Peskett *et al.*, 2007). Box 3 highlights some of the challenges faced by sugarcane small farmers in Pakistan.

However, large-scale and small-scale systems are not mutually exclusive and can interact successfully in a number of different ways (Dufey *et al.*, 2007b). Some of the models for partnership between large-scale and small-scale enterprises include outgrower schemes, cooperatives, marketing associations, service contracts, joint ventures and share-holding by small-scale producers (Mayers and Vermeulen, 2002). Concerning sugarcane, in Brazil co-operatives operate in certain areas (Oxfam, 2008). In India some of the sugar mills are

Box 3. Unfair distribution of benefits against small farmers - middleman in Pakistan.

In Pakistan, where bioethanol is produced from sugarcane molasses, middlemen play a key role in sugarcane procurement and often end up exploiting small-scale farmers forcing them to sell at distress prices. In collusion with mill owners, they orchestrate delays at the mill gate; the problem becomes exacerbated during surplus years. The farmer has no option but to accept the price offered (lower than the support price) or face further delays. Large farmers are better placed as their crop represents a large proportion of the mill intake and they also have greater political clout. Small farmers are indebted to middlemen for their consumption and input needs, which also leads to under pricing. Further, a report by the Agricultural Prices Commission of Pakistan indicates that the scales installed to weigh sugarcane do not provide correct readings. However, given the high level of illiteracy among small-scale growers, such practices go undetected. Moreover, mills are also known to make undue deductions contending that sugarcane quality is low and contains high trash content.

Source: adapted from Rafi Khan *et al.* (2007).

cooperatives in which farmers also hold ownership shares in the factory (ICRISAT, 2007). The South African sugar industry distinguishes itself by operating a successful small-scale outgrower scheme, which supplies 11 percent of the country's sugarcane under contract farming arrangements to one of the three major mills (Cartwright, 2007).

The need for economies of scale to increase competitiveness constitutes a pressure to reduce costs. The main mechanisms for doing this – introduction of improved varieties, switch away from diversified production systems to monocropping, move to larger land holdings, and shift to increasingly capitalised production - are difficult or risky for small producers. For example, in Brazil, selection of improved cane varieties (e.g. energy cane) and investment in irrigation have helped to improve yields but the benefits of these have mostly been felt on plantations. Other mechanisms, such as increasing labour productivity without increasing wages, are likely to be detrimental to poor households (Peskett *et al.*, 2007). This presents a serious challenge to identifying pro-poor biofuels production systems.

Analysis by a UN consortium suggests that efficient clusters of small and medium-scale enterprises could participate effectively in different stages of the value chain (UN-Energy, 2007). The main challenge is how to provide appropriate policy conditions to promote value-sharing and prevent monopolisation along the chain (Dufey *et al.*, 2007b). Controlling value-added parts of the production chain 'is critical for realising the rural development benefits and full economic multiplier effects associated with bioenergy' (UN-Energy, 2007). In countries such as Thailand policy interventions are addressing the sharing of the earning between sugarcane growers and producers (70% and 30%, respectively). However, for bioethanol manufactured directly from sugarcane juice, producers argue the Government has to come with a better agreement as they have to invest on bioethanol plants (Gonsalves, 2006b).

At the international level this implies that the biofuels value chain must shift to the countries that produce the feedstock.

Overall, economies of scale are important and small-farmers will need to adapt and get organised towards that direction. Challenges and difficulties will be confronted and more research is needed to understand the role partnership schemes (Dufey *et al.*, 2007b).

3.4. Landlessness and land rights

The strength and nature of land rights are key determinants of patterns of land ownership under biofuel production. As the above point suggests, the need of costs reduction offers considerable incentives for large-scale, mechanised agribusiness and concentrated land ownership. This is turn can displace small farmers and other people living from the forests and depriving them from its main source of livelihoods. This may have devastating effects on rural poverty. Indeed, the primary threat associated with biofuels is landlessness and resultant deprivation and social upheaval, as has been seen for example with the expansion of the sugarcane industry in Brazil (Worldwatch Institute, 2006; Dufey *et al.*, 2007b) which is summarised in Box 4. Johnson and Rosillo-Calle (2007) also highlight land related problems in the African context, where the high proportion of subsistence farming and complexities of land ownership under traditional land regimes make large acquisition of land, for large-scale sugarcane operations, a highly controversial issue.

Box 4. Access, ownership and use of land in Brazil.

Biothanol production in Brazil has inherited problems faced by the sugar industry over the last 50 years, including violent conflict over land between indigenous groups and large farmers. Problems stem from weak legal structures governing land ownership and use which have increased land concentration, monoculture cropping and minimisation of production costs. Land occupation planning is carried out at municipal level, but not all municipalities have developed guidelines governing monocultures. Land concentration in Brazil is very high, with only 1.7% of real estate covering 43.8% of the area registered. Land concentration and subsequent inequality is increasing with expansion of monocropping areas, reduction of sugar mill numbers, growth in foreign investment and land acquisition. The need of economies of scale for efficient sugarcane production in part drives these effects.

Source: adapted from Peskett *et al.* (2007).

Rossi and Lambrou (2008) note some gender-differentiated risks. Marginal lands are particularly important for women. The conversion of these lands to energy crops might cause displacement of women's agricultural activities towards increasingly marginal lands, with negative effects in their ability to meet household obligations. This highlights the urgent need of a careful analysis of what the concept of 'marginal', 'idle' or 'unproductive' lands really entails. It is in these lands where most government are mandating biofuels to be grown.

3.5. Quality of the employment

Sugarcane bioethanol will generate a range of employment opportunities, mostly in rural areas, which is certainly good for poverty reduction. However there are limitations and trade-offs. Firstly, there is concern about the quality of employment, whether self-employment (small-scale farmers) or employment within large-scale operations (Worldwatch Institute, 2006; UN-Energy, 2007). Sugarcane harvesting is extreme physically demanding. Production is highly seasonal and, in Brazil, for example, the ratio between temporary and permanent workers is increasing. Low skilled labour dominates the industry and a high rate of migrant labour is employed. In southern Africa the sudden influx of seasonal workers has had negative effects on community cohesion, causing ethnic tension and disintegration of traditional structures of authorities. Migrants behaviour is also linked with higher rates of HIV infection around sugarcane plantations (Johnson and Rosillo-Calle, 2007).

Whilst over the latest years in some plantations in Brazil improvements in working conditions have been done, in other plantations, sugarcane cutters continue to work in appalling conditions. Cases of forced labour and poor working conditions within the sector are still reported (Oxfam, 2008). Other problems include a lack of agreed or enforceable working standards in many countries, and lack of labour representation (Dufey *et al.*, 2007b).

Moreover, compared to other feedstocks (e.g. palm oil, castor oil, sweet sorghum) sugarcane is less labour-intensive and thus provide less on-farm and off-farm employment (Dufey *et al.*, 2007b). The industry greater mechanisation in turn reduces labour demands. One harvester can replace 80 cutters and thus facilitate the whole harvesting process (Johnson and Rosillo-Calle, 2007). In Brazil mechanization of sugarcane harvesting has been driven by increasing labour costs and more recently by legislation to eliminate sugarcane burning. Total employment in the industry decreased by a third between 1992 and 2003 (ESMAP, 2005b). Indeed sugarcane related unemployment is expected to become the key social challenge faced by the sugarcane industry in Brazil (Dufey *et al.*, 2007a). This can have devastating effects on poverty levels as it is unemployment among the lower-skilled workers.

In order to balance trade-offs between environmental needs, mechanisation and unemployment, Johnson and Rosillo-Calle (2007) propose the use of half-mechanisation which was successfully used in Brazil as a transition towards full mechanisation. It consists in mechanical aid for the harvesting, in which a machine is used for cutting the cane and workers are used to gather the crops. As the cutting of the cane is the hardest part physically, the authors argue this system would also contribute to opening up the labour force for women.

All in all, although recognising that many of the above mentioned issues are not exclusive for sugarcane bioethanol, employment generation that leads to effective poverty reduction requires addressing these problems.

3.6. Government support

Experience suggests the biofuels sector requires some form of policy support, at the very least in the initial phases development. Even Brazil, the most efficient biofuel producing country, still maintains a significant tax differential between gasoline and hydrous ethanol to promote the sector (ESMAP, 2005b) and fixes a mandatory blend (between 20% to 25%). More generally, the PROALCOOL programme in the past required heavy support. Between 1975 and 1987 it produced savings for US$ 10.4 billion but it costs were US$ 9 billion (World Watch Institute, 2006). Moreover, with falling oil prices, rising sugar prices, and a national economic crisis the programme simply became too expensive and collapsed by end of 1980s.

In many countries, the main rationale behind biofuels production is to decrease the costs associated with imported fossil fuels. Among the costs of such a policy that need to be accounted is the foregone duty on fuel imports, which results in a decline in government revenues. For instance, in Brazil, the forgone tax revenue in the state of São Paulo, which accounts for more than one-half of the total hydrous ethanol consumption in the country, was about US$ 0.6 billion in 2005 (ESMAP, 2005b). In many developing countries a substantial portion of public revenues are derived from import duties. In addition, the diversion of sugar exports for bioethanol production for domestic markets means that countries may suffer reductions in their export earnings. All these pose significant challenges in poorest countries, where there are a multitude of urgent needs competing for scarce fiscal resources.

Another issue is that once granted and the biofuel industry has been launched, subsidies are difficult to withdraw. A major challenge to reduce policy support is the vested interests created in the domestic industry (Henniges and Zeddies, 2006).

On the other hand, the existence of contentious domestic policies and practices can undermine industry development. For instance, Rafi Khan *et al.* (2007) and Gonsalves (2006a) report the negative effects on bioethanol development of policy measures such as a high central excise duty and sales tax on alcohol that exist in Pakistan and India, respectively. The lack of policy provenance - reflected by the fact that the Pakistani government directed the Petroleum Ministry (who houses the oil lobby) to develop the bioethanol conversion plan also constitutes an additional policy constraint. Pricing issues - whether to use bioethanol international price or its cost of production - can also affect industry development (Rafi Khan *et al.*, 2007).

All the above suggest the promotion of a sugarcane bioethanol industry can become very expensive, not only due to the high up front investments that are required but also due to the financial resources that are needed to make it viable in the long term.

From a poverty reduction strategy point of view this means that governments should design their sugarcane bioethanol policies so as to reach the desired target group. As ESMAP (2005b) notes, resources that flow to agriculture all too often benefit politically powerful, large producers and modern enterprises disproportionately at the expense not only of the society as a whole, but of those that are supposed to be the main beneficiary group: smallholder farmers and landless workers. Examples include untargeted producer subsidies and distortionary subsidies for privately used inputs such as water and electricity. According to the same source, promoting biofuels for energy diversification can make sense if large government subsidies are not required. However, UN-Energy (2007) holds the view that if the large subsidies are targeting small producers this may be money well spent. Governments tend to get higher returns on their public spending by fostering small-scale production due to the lowered demand for social welfare spending and greater economic multiplier effects.

Overall, governments need to conduct a careful assessment of the pros and cons of promoting sugarcane bioethanol to support poor rural communities versus those of other alternatives. Similarly, from a climate change mitigation strategy, although sugarcane bioethanol may show the greatest greenhouse reductions compared to other first generation feedstocks, these should be assessed against the costs of other policy instruments to achieve the same goal.

3.7. Market access and market entry barriers

The strategic nature of bioethanol implies the existence of some degree of protectionism in almost any producing country. Protectionism is especially acute where energy security is equated with self-sufficiency or where biofuels are promoted to help domestic farmers in high-cost producing countries (Dufey *et al.*, 2007b). The use of tariffs to protect domestic biofuel industries is a common practice and, as Table 1 shows, these can be very high. However, these tariffs are only indicative as their actual level applied vary widely as both the European Union and the United States have trade agreements providing preferential market access to several developing countries. In particular, the extra US$ 0.14 to each litre (US$ 0.54 per gallon) of imported bioethanol on top of the 2.5 percent tariff applied by the United States, it is said to be targeting Brazilian imports as it brings the cost of Brazilian bioethanol in line with that produced domestically (Severinghaus, 2005). Tariff escalation, which discriminates against the final product, can also be an issue, for example, where there are differentiated tariffs on bioethanol and feedstock such as raw molasses (Dufey, 2006).

Table 1. Import tariffs on bioethanol[1].

Country	Import tariff
US	2.5% + extra US$ 14 cents/litre (46% *ad valorem*)
EU	€ 19.2/hl (63% *ad valorem*)
Canada	4.92 US$ cent/litre
Brazil[2]	20%
Argentina	20%
China	30%
Thailand	30%
India	186% on undenatureated alcohol

Source: adapted from Dufey *et al.* (2007b)
[1] Undenaturated alcohol.
[2] Temporarily lifted in February 2006.

On the other hand, the planning of an export-oriented bioethanol industry based on the rationale of preferential market access is a risky strategy. As Box 5 suggests for Pakistan, trade preferences can be withdrawn at any time with devastating effects on the industry.

Subsidies is another key concern. In industrialised countries, government support for the domestic production of energy crops, the processing or commercialisation of biofuels seems to be the rule (Dufey, 2006). Amounts involved are enormous. In the United States, Koplow (2006) estimated that subsidies to the biofuels industry to be between US$ 5.5 billion and US$ 7.3 billion a year. In the European Union, Kutas and Lindberg (2007) estimated that total support to bioethanol amounted € 0.52/litre.

The impacts these policies have on the developing countries competitiveness and on their potential for poverty reduction needs to be understood as domestic support in these countries is likely to be very limited. Moreover, subsidies impacts on environmental sustainability are also questionable as they promote bioethanol industries based on the less efficient energy crops and with the least greenhouse gases reductions such as maize and wheat (Dufey, 2006).

The proliferation of different technical, environmental and social standards and regulations for biofuels – without a system for mutual recognition – cause additional difficulties. For instance, at present not all biofuels are perceived as 'sustainable' especially those coming from overseas. As a consequence, several initiatives towards the development of sustainability certification for both bioethanol and biodiesel have started. Some of them are led by governments (e.g. the United Kingdom, Netherlands and the European Union); others by

Box 5. The elimination of Pakistan from the EU GSP.

Until recently, Pakistan was the second largest industrial alcohol exporter to the EU after Brazil, under the General System of Preferences (GSP). In May 2005, the Commission of Industrial Ethanol Producers of the EU (CIEP) accused Pakistan and Guatemala (the largest duty free exporters for the period 2002-2004) of dumping ethyl alcohol in the EU market, causing material harm to domestic producers. The Commission dropped proceedings a year later when full custom tariffs were restored on Pakistani imports. Later, following a complaint lodged by India at the World Trade Organization (WTO), a panel concluded that by granting tariff preferences to 12 countries under this special arrangement the EU was violating GATT/WTO preferential treatment obligations. The EU consequently removed Pakistan from the GSP. In the revised GSP regime, the anti-drug system has been replaced by GSP Plus, for which Pakistan does not qualify.
Elimination of Pakistan from the GSP had devastating effects on the local industry. Distilleries begun to suffer important losses and some had no option but to cease operations. Whilst between 2002 and 2003, the number of distilleries in the country increased from 6 to 21, the more stringent EU tariff measures together with a rise in molasses exports, the distilleries were soon running idle capacities. Currently, at least 2 distilleries have shut down, with another 5 contemplating that option.

Source: adapted from Rafi Khan *et al.* (2007).

NGOs (e.g. WWF); and also by Universities (e.g. Lausanne University). These schemes tend to focus on traditional environmental and social aspects of feedstocks production, with several of them including greenhouse emission issues and with some few of them expanding to food security concerns. Although environmental and social assurance is needed in the industry, where these schemes are developed by importing nations, with little participation by producing country stakeholders, insufficient reflection of the producing countries' environmental and social priorities and without mutual recognition between them, they are bound to constitute significant trade barriers. Moreover, the experience with assurance schemes in the agriculture and forestry sector indicates that the complex procedures and high costs usually associated with them have regressive effects in detriment of small and poorest producers in developing countries. All in all, sustainability standards for bioethanol trade are to become more and more important. Countries wanting to benefit from bioethanol exports need to invest in the development of robust and credible certification systems that satisfy importing countries requirements.

Overall, it is widely agreed that developing countries would benefit from enhanced bioethanol trade and therefore the need to eliminate trade barriers.

3.8. Improving efficiency, access to technology, credit and channelling investment

The development of a successful bioethanol sector goes beyond having available land, cheap labour and good climate. It crucially depends on countries' domestic capacity to expand production efficiently, accessing the technology and assuring best practice. Indeed, Brazil's success in developing an efficient bioethanol industry is in a large extent explained by the enormous endogenous efforts devoted to R&D, capacities building and infrastructure (Dufey *et al.*, 2007a). This implies that having a number of technical skills for research, technology transfer as well as access to credit are critical issues. Moreover, those countries wanting to develop an export oriented sector also need to be in compliance with the relevant technical standards in importing markets and to invest in suitable transport infrastructure (roads, water ways and ports) to reach exports markets. Countries also need to have sufficient capacity in policy implementation and project management to run biofuels production and processing effectively (Dufey *et al.*, 2007b).

At present, many countries foresee a major participation of the sugar industry in bioenergy production. However, the current low efficiency and productivity of the sector in many of them implies that major changes to the industry's structure will be needed to make sugarcane an important feedstock (FAO, 2007). In countries where bioethanol is produced from molasses and wanting a significant scale of production, efforts will need to be made to produce from sugarcane juice, which is a relatively more efficient source of bioethanol and capable of supplying larger volumes (Woods and Read, 2005). Other specific needs include adaptive agricultural research and extension development for enhanced transfer of bioethanol technologies. Investment is also important to bring agricultural practices up to the required level of technical capacity, scale of operations, and intensity of production (Johnson and Rosillo-Calle, 2007)

4. Conclusions

Sugarcane bioethanol can contribute to the achievement of several Millennium Development Goals through a varied range of environmental, social and economic advantages over fossil fuels. The highest impact on poverty reduction is likely to occur where sugarcane bioethanol production focuses on local consumption, involving the participation and ownership of small farmers and where processing facilities are near to the cultivation fields.

Realising the greatest potential of sugarcane bioethanol on poverty reduction implies that several challenges will need to be confronted and dealing with serious trade-offs. Especially tough will be those related to efficiency gains through large-scale operations, mechanisation and land concentration versus small farmers inclusion. Economies of scale are important and small farmers will need to adapt and get organised towards that direction. Likewise, the resulting unemployment among the lower-skilled workers is a key aspect to be addressed. Whilst the domestic use of sugarcane bioethanol may imply opportunities in terms of general well-being, the increasing use of marginal land for biofuels cultivation may imply negative impacts among the most vulnerable such as women. From a poverty reduction strategy this means that governments should explicitly design their sugarcane bioethanol policies to provide the right environment to promote business models that maximises rural development, small farmer inclusion and equitable access to ownership and value along the chain. One example in that direction can be the use of tax-breaks for companies that include small producers among their suppliers, which is already being used in the context of biodiesel in Brazil through the PROBIODIESEL programme.

The impacts of sugarcane bioethanol on food security are less clear. Regarding food availability and compared to other feedstocks, sugarcane bioethanol would provide better opportunities to meet food security as long as it creates less competition for land and crowd out other crops. However, from an accessibility point of view, it would provide more limited opportunities to the extent that its production is less likely to involve small or poorest farmers. Overall, more research is needed to understand these linkages.

From an environmental sustainability perspective, compared to other first generation biofuels, sugarcane bioethanol offers opportunities to achieve one of the greatest reductions in greenhouse emissions under certain circumstances. However, available estimations need to be revised to include the emissions directly and indirectly associated with changes in land use and cover. Similarly, biodiversity impacts linked to changes in land use and cover especially those associated with the substitution effect appear as crucial environmental aspects to be addressed and more research to understand them is needed. Likewise, impacts on water, especially in the context of dry and semi-dry lands, are other key aspects that deserve better analysis. Only the adequate understanding and management of these impacts, using a life cycle approach, will help to improve the environmental sustainability of sugarcane bioethanol and thus achieving the Millennium Development Goal on environmental sustainability.

In some contexts, the promotion of a sugarcane bioethanol industry can be a very expensive means of achieving poverty reduction and promoting environmental sustainability. Governments need to conduct a careful assessment of the pros and cons of promoting sugarcane bioethanol to support poor rural communities versus those of other policy choices. Similarly, from a climate change mitigation strategy, although under certain circumstances sugarcane bioethanol shows the greatest greenhouse reductions compared to other first generation feedstocks, these should be assessed against the costs and benefits of other policy instruments for achieving the same goal.

Another crucial issue involved in realising the full potential of sugarcane bioethanol is the building of an adequate set of national capabilities on technical skills, policy implementation, project management and development of R&D programmes. These should come hand in hand with promoting access to technology, credit and finance as well as the provision of some minimum transport infrastructure. For those countries wanting to take advantages of an export oriented industry, capacities building on standard setting and compliance as well as the negotiation of favourable terms of trade constitute other key aspects.

Policy coherence is another issue. The promotion of a sugarcane bioethanol sector that contributes to sustainable development and poverty reduction should be aligned with existing relevant national and international policies and frameworks such as Sustainable Development Strategies, Poverty Reduction Strategies, Environmental and Social Impact Assessments, the Kyoto Protocol or the Convention on BiologicalBiodiversity. Coordination therefore is required among different government bodies (e.g. Ministry of Agriculture, Energy, Environment, Industry, Trade, etc.), levels and actors.

Finally, at the international level, cooperation is also crucial for the development of a sugarcane bioethanol industry oriented towards poverty reduction and environmental sustainability. South-South cooperation can play an important role in overcoming many of the technical challenges. Countries can benefit from the technical and scientific knowledge of Brazil, which is at the forefront of the industry. One example in that sense is the illustrated by the Brazil-UK-Africa Partnership for bioethanol development. International financial institutions can help, for example, by mitigating political risk for project development in developing countries. Elimination of trade barriers is another issue to be addressed by governments to enhance development opportunities associated with sugarcane bioethanol. This would be also aligned with the last Millennium Development Goal that calls to 'develop a global partnership for development'.

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