# Prospects and Challenges of Biofuels in Developing Countries

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## Abstract

Two driving forces of global change will have a decisive influence on the future of world agriculture and forestry, and therefore on poverty reduction, the environment and economic growth in developing countries. These are the on going climate change, and our increasingly pressing need to switch to renewable, i.e. sustainable energy. Progress towards substituting fossil fuels with renewable energy sources will mitigate the risk of severe climate change. Biomass will provide one principal source of future renewable energy, in addition to wind, solar, water, and other sources. This paper focuses on biomass from agriculture and forestry, with the objective of reviewing the current situation and probable future trends in developed and developing countries concerning the production of biofuels, i.e. energy produced from biomass. Biofuels hold a number of promising prospects, but also present challenges, especially for developing countries. A review of these potentials and challenges is presented, which lead to the conclusion that the production and use of biofuels in developed and developing countries could potentially provide a win-win-win proposal for economic growth, poverty reduction and environmental sustainability, if the appropriate policies and related institutional and technological innovations are promoted. The important challenges that biofuels represent are identified and discussed, most importantly the exclusion of smallholders in producing biomass for biofuels, the issue of food security and rising food prices in global and local markets. We conclude that in order to master the challenges and capitalize on the promising prospects biofuels hold for sustainable development, massive investments in agricultural research and appropriate institutional and policy frameworks are required.


## 1. Introduction

The Stern report estimates that developing countries will be more severely affected by climate change, especially those situated in the tropics and subtropics (Stern, 2007). One key causal factor of global warming is the emission of carbon dioxide and other greenhouse gases (GHGs) from human use of fossil energy resources such as coal and oil. At present, fossil energy accounts for about 80 % of the worldwide total primary energy supply. The per-capita consumption of energy widely differs from country to country. Residents of the United States of America use more than double the energy than a comparable European. The Europeans use about ten times more energy than Africans (IEA, 2006). Yet, economic growth and increasing incomes in countries like China and India will result in significant increases in energy demand in the developing world. To address the global problem of climate change, as well as the finiteness of fossil energy resources, new carbon neutral and sustainable solutions for world's energy supply and use need to be found. Probably the most important approach is to save energy through more efficient energy use, supported by appropriate policies for the taxation of the energy amounts used, or taxed by the amount of pollution itself. However, policy and institutional frameworks for fostering research and development of alternative sources of energy are equally important.

A number of technologies for alternative energy are being tested or are already in use. One of these is the development of bioenergy technologies for the production of ethanol, diesel, and biogas produced from biomass. Biofuels offer a number of important prospects for development but also pose some challenges.

There is a large amount of variation in energy efficiency, the cost of production, as well as the cost of greenhouse gas abatement between the different types of biofuels (Brower et al., 2006; Henke, 2005). The efficiency and costs are largely a function of the type of feedstock and the agro-ecological and socio-economic conditions of production, the conversion technology used, and the agro-ecological as well as the socio-economic conditions of the production of biomass and the use of biofuel. Currently, the major biofuels produced are ethanol, diesel, and methane.

In the following sections, an overview of the present status and trends in worldwide biofuel production will be presented. We further review the major prospects of, as well as the challenges of biofuel expansion, as it concerns rural employment, agricultural development and research, world food markets and prices, food insecurity, and the mitigation of climate change.

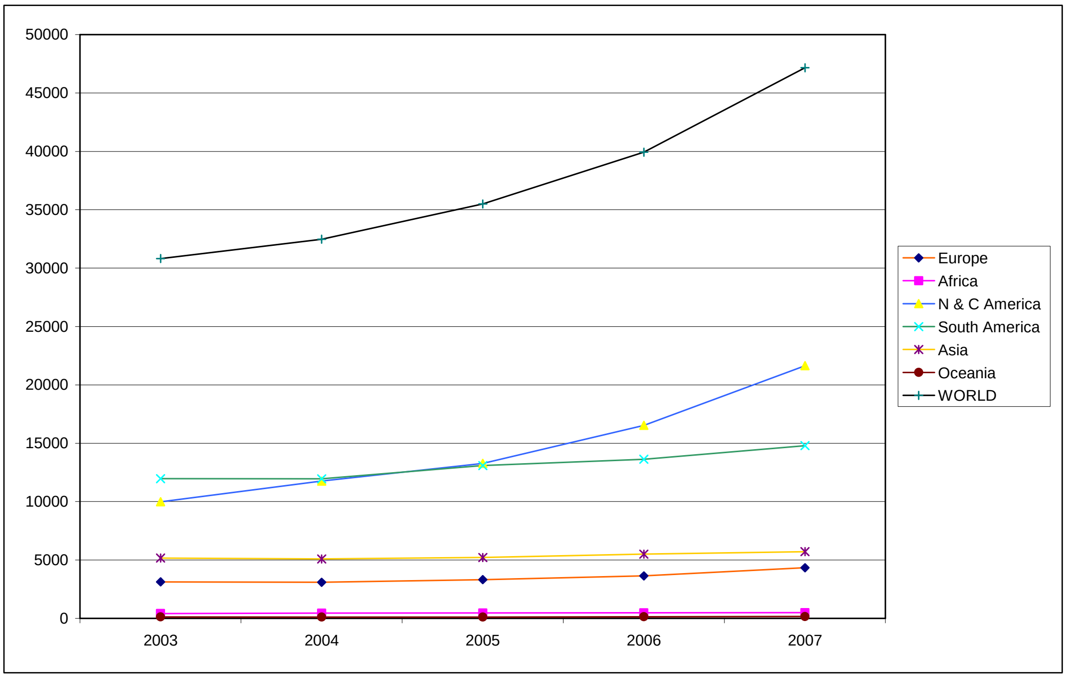
## 2. Trends in production of biofuels

### 2.1. Major types of biofuels

Biomass can be used as a primary or secondary energy source. Primary energy sources such as plants, organic waste and manure can be transformed into secondary energy sources, which can be liquid, gaseous or solid. The base for liquid biofuels are alcohols or vegetable oils. The most commonly used alcohol is ethanol and to a lesser extent methanol. Both are produced through the fermentation of biomass by micro organisms and enzymes. It is estimated that the world production of ethanol amounted to 47.156 million tons in 2007 (FO Licht´s, 2006). Major feedstocks used for ethanol production are corn (USA) and sugar cane (Brazil). Ethanol itself can be used as biofuel or as an additive to blend in with fossil fuel.

Figure 1 shows the growth of ethanol production between 2003 and 2007. During the past five years, ethanol production has increased by more than 50 % and exhibits rising annual growth rates. The major biofuel producing continents are North and Central America. In North America the major biofuel producer is the United States, which supports the production and use of ethanol for the transportation sector through a mix of subsidies to ethanol producers, as well as by environmental legislation. It is expected that the strong production trend seen for North America will continue in the near future as current U.S. policy foresees a significant expansion of U.S. production capacity. The second largest ethanol producing continent is South America, with Brazil as the leading producer. As illustrated in Figure 1, the world ethanol production has grown strongly, with high energy prices driving the growth. USA and Brazil currently account for 70 % of the global ethanol production, followed by China, which is the third largest producer (Henke, 2005). In Europe, ethanol production is also increasing, with France and Germany as the leading countries.

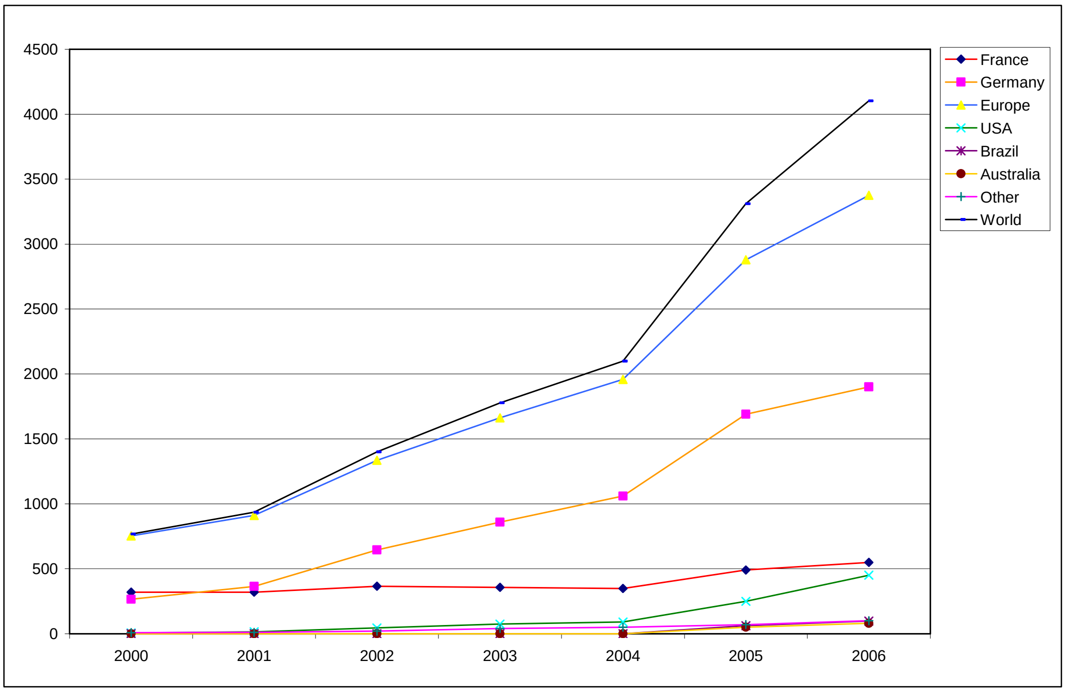
**Figure 1: World ethanol production outlook, by continent (in 1000 tons)**




**Source:** Graph by author, based on data published by FO Licht`s 2006, Vol. 5, No. 5.

Biodiesel is the second important liquid biofuel. It is produced from vegetable oil, for example from rapeseed oil in Europe. In 2006, the world's production of biodiesel reached 4.1 million tonnes worldwide (FO Licht´s, 2006). Figure 2 shows that most of world's biodiesel production occurs in Europe, produced mainly by Germany and France. The United States, Brazil and Australia are producers newly entering the market. Since any vegetable oil can be used for the production of biodiesel, there has been a resulting increase in demand for cheaper vegetable oils such as palm oil. The Major exporters of palm oil are Malaysia and Indonesia.

**Figure 2: World biodiesel production (in 1000 tons)**




**Source:** Graph by author, based on data published by FO Licht`s 2006, Vol. 5, No. 5

The trends in the production of bioethanol and biodiesel outlined above indicate that an increasing amount of world's production of sugar, corn, and vegetable oil will be used in energy production. Below, in Table 1 and Table 2, we show the projections for the use of feedstock in the EU for 2006 through 2013, and in the U.S. from 2006 to 2016.

**Table 1: EU-Biofuel feedstock balances for the European Union 2006-2013 (Million tons)**

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|
| **Cereals** | | | | | | | | |
| Usable production | 242.5 | 285.9 | 286.6 | 287.9 | 291.6 | 295.3 | 297.8 | 301.1 |
| Consumption | 246.8 | 270.1 | 269.8 | 270.3 | 272.4 | 274.7 | 276.8 | 278.9 |
| Of which bioenergy | 1.9 | 5.5 | 7.1 | 8.9 | 10.7 | 13.6 | 16.5 | 18.6 |
| **Oilseed** | | | | | | | | |
| Usable production | 20.1 | 27.8 | 28.8 | 28.9 | 30.0 | 30.5 | 31.5 | 32.3 |
| Consumption | 44.3 | 50.9 | 53.6 | 55.1 | 58.8 | 60.3 | 64.3 | 66.4 |
| Of which bioenergy | 7.9 | 10.1 | 11.0 | 12.9 | 15.5 | 16.6 | 18.4 | 18.8 |
| **Sugar** | | | | | | | | |
| Usable production | 17.4* | 16.7 | 16.4 | 16.5 | 16.7 | 16.7 | 15.2 | 15.6 |
| Consumption | 17.4* | 18.6 | 19.2 | 19.4 | 19.8 | 20.1 | 20.5 | 20.8 |
| Of which bioenergy | 1.0* | 1.1 | 1.3 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 |

* The analysis assumes a 12 month campaign year 2006/07. In fact, the campaign has been exceptionally prolonged to 15 months, i.e. 01.07.06-30.09.07. Therefore, figures for 2006 should be interpreted with care

** The year 2006 exclude Bulgaria and Romania.

**Source:** EU Commission, in F.O. Lichts 2007, Vol.5, Nr. 12, Page 249

Table 1 indicates that by 2012, more than half of the EU's production of oilseeds and more than ten percent of the EU's cereal and sugar production are expected to be used in the production of biofuel.

Similar production trends for biofuels are forecast in the United States. The U.S. Department of Agriculture predicts the increased use of corn in ethanol production, as well as an increasing share of the U.S. soybean crop being used for the production of biodiesel. The baseline projection in Table 2 assumes that the tax credit for domestically produced ethanol and biodiesel, as well as the import tariff for these products will be maintained. Both the U.S. and the EU use tax credits and other subsidies, as well as trade barriers, to protect their domestic biofuel industry from more competitive producers in developing countries.

**Table 2: Projections for hectarage and utilization of USA corn and soybean**

| | 2007/08 | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Corn plantings** (million ha) | 34.80 | 36.02 | 36.02 | 36.42 | 36.42 | 36.42 | 36.42 | 36.42 | 36.42 | 36.42 |
| Fuel alcohol use (%) | 29.22 | 32.67 | 33.99 | 34.26 | 34.39 | 34.58 | 34.57 | 34.55 | 34.54 | 34.59 |
| Feed & residual (%) | 53.20 | 50.99 | 49.89 | 49.25 | 48.73 | 48.33 | 48.15 | 47.97 | 47.79 | 47.51 |
| Exports (%) | 17.58 | 16.34 | 16.12 | 16.49 | 16.88 | 17.08 | 17.28 | 17.48 | 17.67 | 17.89 |
| **Soybean plantings** (million ha) | 28.73 | 28.13 | 27.92 | 27.92 | 27.92 | 27.92 | 27.92 | 27.84 | 27.84 | 27.84 |
| Biodiesel use, soybean oil (%) | 20.54 | 21.17 | 21.89 | 22.42 | 22.87 | 22.57 | 22.27 | 21.99 | 21.73 | 21.48 |
| Food use soybean oil (%) | 74.92 | 74.80 | 74.90 | 74.41 | 73.69 | 74.04 | 74.37 | 74.70 | 75.10 | 75.49 |
| Exports soybean oil (%) | 4.54 | 4.03 | 3.21 | 3.16 | 3.44 | 3.40 | 3.35 | 3.31 | 3.17 | 3.03 |

(%) percent points of total use, without taking into account ending stocks
**Source:** Based on USDA Agricultural Projections into 2016 (USDA, 2007)

The considerable increase in the use of cereals, oilseeds and sugar by the major traditional surplus producers, the EU and the U.S., will have a large impact on the world trade of cereals, sugar and oilseeds. Moreover, as reviewed later, the ambitious policy objectives in the U.S. as declared by President Bush in his State of the Union speech in early 2007, as well as the similar ambitious objectives in the EU to increase the use of biofuels in the transportation sector, will lead to a surge in demand for biofuels by consumers. The USDA estimates that more than 30 % of corn produced in the U.S. will be used to produce ethanol by 2009/10 (USDA, 2007). However, Kamalick and Gibson (2007) estimate that already by the year 2008, half of the U.S. corn production will be used for ethanol. Despite this increase in ethanol production, the U.S. cannot fulfil its target goal of greatly reducing the U.S. dependence on crude oil imports. In 2006, U.S. ethanol production (5 billion gallons) could only substitute 1.5 % of U.S. crude oil imports. Thus, the U.S. may need to import increasing quantities of ethanol and biodiesel, most likely from Latin American countries. It is therefore expected that the trade in biodiesel and bioethanol will increase significantly during the next few years, allowing low cost producers such as Brazil (ethanol) or Indonesia and Malaysia (palm oil) to either export feedstock or the refined biofuel to the U.S., Japan and the EU. At present, ethanol imports into the EU and the U.S. are relatively low due to prohibitive import tariffs, set for the protection of the domestic industry. Imports, as a percentage of the domestic production, account for only 4 % in the US and only 0.5 % in both the EU and China (Dimopoulos, FO Licht´s, 2006).

## 2.2. Major feedstocks for biofuels – Is the competition with food sustainable in the long run?

Biomass, as form of stored solar energy, is used to produce biofuel. Internationally traded biomass feedstocks are molasses, sugar from sugar cane or sugar beet, tapioca chips, rapeseed oil, palm oil, soy oil and cereals such as corn, feed wheat and feed rye. But other feedstocks can also be used. Research is currently exploring the use of sweet sorghum, cassava, sweet potato, wood, switch grass, edible and non-edible oil, animal fats, jatropha oil, palm oil, coconut, cotton, cellulose, manure and other biomass generators.

By far the largest cost component in the production of biofuels is the cost of the feedstock itself. Thus, the yields and the cost of producing the biomass are a critical factor in determining the overall competitiveness of the biofuel sector. With respect to biodiesel production, the yields for different feedstock crops range from 375 liters of biodiesel per hectare of soybeans, 1,000 liters for rapeseed, 1,300 liters for mustard and 1,590 liters per hectare of Jatropha[1]. Among conventional oil crops, palm oil exhibits the highest yield, with 5,800 l/ha (USDA, cited from a website at Market Analysis Division, Canada).

In a nutshell, as the energy market is much larger than the market for food, the demand for biofuels may create a huge demand for cereals, sugar and oilseeds. This would certainly drive up the prices for food crops. In the long run, it would be desirable to find more energy efficient biofuels that use biomass sources not directly in competition with human food and feed crops. The future policy and technological developments in the biofuel sector may create high level of uncertainty in agricultural markets (OECD-FAO, 2007). For example the politically driven increase in the use of first generation biofuels, i.e. cereals, sugar, and oilseeds, will create upward pressure on food prices, and therefore also for feedstock prices. The future of biofuel as an important source of carbon neutral renewable energy will therefore lie in reducing the direct competition with the food sector, and instead use feedstock with lower agricultural production costs compared to food and feed crops. This strategy is being pursued through the development and use of so-called second generation biofuels from cellulosic materials. The Fischer-Tropsch process allows the production of liquid fuels out of biomass (BTL), by which biomass is gasified and synthetic fuels are produced. On-going research seeks to improve the energy efficiency and the carbon balance, as well as lowering the production costs of biofuels produced from cellulosic materials. The result would be that any type of cellulosic plant material, such as cornstalks, fast growing trees such as poplar, switch grass, as well as waste left over from the forest products industry, could be used in the production of liquid biofuels (Ortiz et al., 2006; Ragauskas et al., 2006).

The OECD-FAO report further raises the question of whether this observed increase in energy and related food prices during recent years is a long term phenomena caused by changing market structures (i.e. link between energy and food). Moreover, they question whether the observed relationship between food and energy prices will increase uncertainty and result in higher price variability in the food market. In our view the answer to both questions should be affirmative. Modelling approaches, such as those of IFPRI seek to provide a more thorough analysis and provide an answer to this and to other questions.

Using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) at IFPRI, Rosegrant et al. (2006) investigated the interaction between the demand for biofuel feedstock crops, and the demand and production of crops used for both food and feed. The IMPACT model uses three different scenarios and estimates how projected growth in biofuel production could affect food availability, and the prices and consumption at global and regional levels, between now and 2020. Scenario I investigates how the increasing use of actual feedstock, driven by the increasing replacement of gasoline (10% in 2010 and 20% in 2020), affects the world prices of these feedstocks. Scenario II takes into account possible large scale conversion of cellulose to biofuel in 2015. Scenario III is similar to scenario II, but additionally considers the effect of investments in crop technology, that would result in increased productivity of biomass over time. The results of the scenarios are shown in Table 3.

[1] We agree with von Urff (2007) that there is quite some variation and sometimes even contradictions regarding the yield potential for Jatropha. For India we have seen figures published in the range of 400 l/ha to 3,000 l/ha.

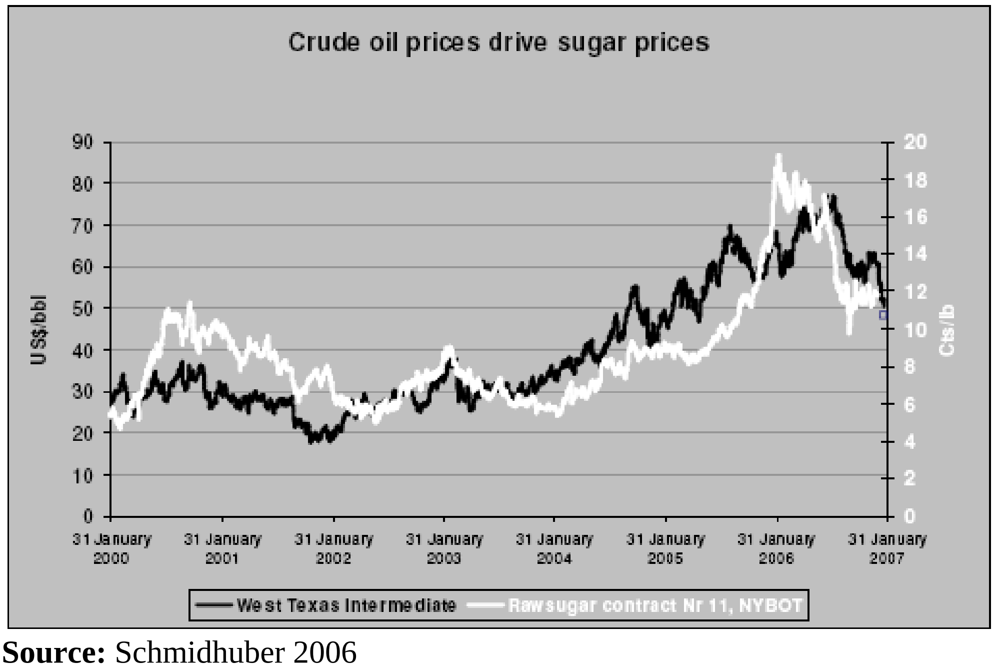
**Table 3: Percentage changes in world prices of feedstock crops under three scenarios, compared with baseline**

| Feedstock crop | Scenario I: Aggressive biofuel growth without technology improvements | | Scenario II: Cellulosic biofuel | Scenario III: Aggressive biofuel growth with productivity change and cellulosic conversion |
|---|---|---|---|---|
| | **2010** | **2020** | **2020** | **2020** |
| Cassava | 33 | 135 | 89 | 54 |
| Maize | 20 | 41 | 29 | 23 |
| Oilseeds | 26 | 76 | 45 | 43 |
| Sugar beet | 7 | 25 | 14 | 10 |
| Sugarcane | 26 | 66 | 49 | 43 |
| Wheat | 11 | 30 | 21 | 16 |

**Source:** Rosegrant, M.W. et al. 2006

The scenario I seeks to predict the situation in 2020 if the current aggressive policy decisions and strategies in regards to the expansion of biofuels, using first-generation feedstocks, are implemented in developed as well as developing countries. The resulting impact on food prices is astounding from the perspective of biofuel producers, and it will be certainly devastating from the perspective of poor consumers. The expected rise of food prices by 2020 will be in the range of 25 % to 135 %, depending on the crop. In scenario II, with the use of cellulosic biofuel, the impact of biofuel expansion on food prices is less dramatic. Cellulosic biofuel will not compete so strongly with the production of food and feed, as much of it can be supplied by the forestry sector from non-arable land or from byproducts of the agricultural sector. Even in scenario III, which assumes rapid technological progress in agricultural production as well as energy conversion, food prices are estimated to rise in the range of 10 % to 54 %. These scenarios indicate that the good old days of the past 200 years, where food and energy prices were only loosely connected, are finally over. We are returning to the basic Malthusian type of economic relationship between food and energy that has influenced human kind during much of our existence. Figure 3 indicates that this relationship has already started to emerge with the high oil prices during recent years.

**Figure 3: Futures prices for oil and sugar (2000-2007)**

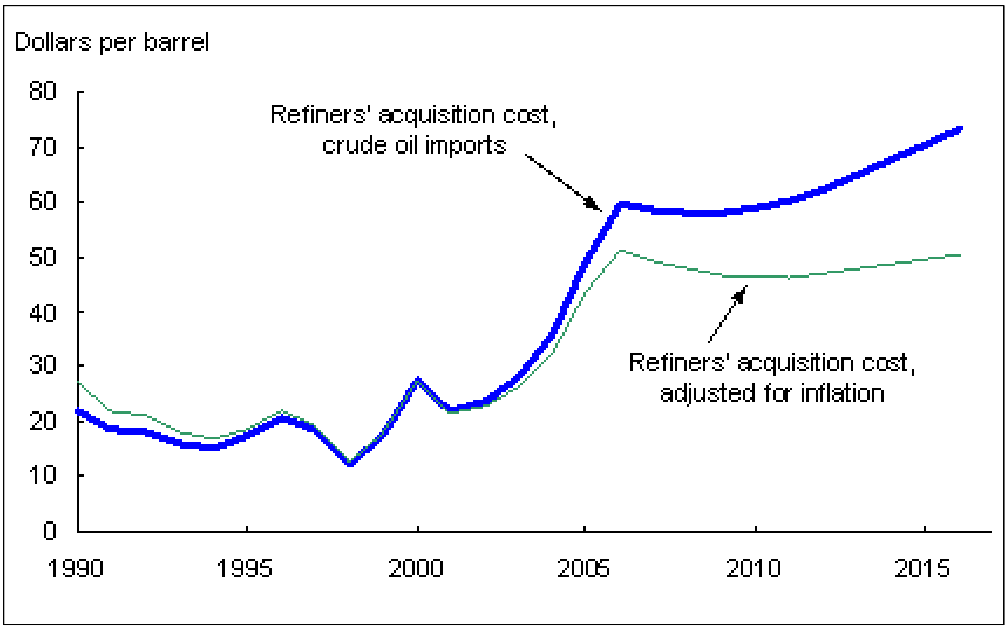



**Source:** Schmidhuber 2006

### 2.3 Growth in biofuel production

The future expansion of biofuel production is partially driven by policy decisions that are motivated by a host of political factors. In the long run, however, the main driving factor will be the price of oil and other fossil fuels. Oil prices above 45 US$ to 50 US$ per barrel are seen as favourable for biofuel production (Ugarte, 2006), as low cost producer countries like Brazil can profitably produce significant amounts of biofuels at such oil price levels.

**Figure 4: Crude oil price estimations until 2015**




**Source:** USDA Agricultural Projections to 2016, (2007)

Figure 4 shows the prediction of oil prices by the Economic Research Service of USDA. Taking into account the present conversion technologies for biofuel production, Ugarte (2006) estimates the potential demand for sugarcane and corn that would be created if biofuel were to fully replace the use of fossil fuels. Based on the data that each day worldwide, 21 million barrels of gasoline and 21 million barrels of diesel are consumed, Ugarte (2006) extrapolates these figures into a potential demand of roughly 30 million barrels of ethanol and 23 million barrels of biodiesel per day. To answer the question regarding the amount of land that must be reallocated to biofuel production in order to fill this demand for ethanol, Ugarte (2006) calculates that 300 million ha of sugarcane or 590 million ha of corn (maize) must be planted for energy production. This means an increase by a factor 15 and 5 times, respectively, in comparison with the current world hectarage of those crops. To replace all fossil diesel with biodiesel, the potential demand would necessitate an additional 225 million ha of palm, 20 times the current world plantings. These figures show that the expansion of biofuels with the aim of totally replacing fossil fuels for transportation will not be reached without significant improvements in technology, and appropriate policy and institutional frameworks that take into account the high environmental costs of fossil fuels (and potentially also biofuels if produced in unsustainable ways).

## 3. Policy settings for biofuel production

To support domestic biofuel sectors, governments have introduced a mix of policy instruments. The main instruments used are the introduction of mandatory quotas for blending gasoline or diesel with biofuels to reach certain fuel standards, the exemption from value added tax in the production of biofuels, and the introduction of prohibitive import policies to protect the domestic industry. The latter policy may be justified in the short run, allowing necessary technology developments and industry growth to occur in the domestic economy (i.e. the so-called infant industry argument), but runs the risk of building up a sector that is highly dependent on subsidies in the long run, at least in high cost production countries such as the EU and the USA. However, in all major production countries, government interventions are critical for expansion of biofuels. The OECD report states: “Moreover, most biofuel policies are new and it is not clear which measures are most effective in achieving the mix of objectives” (OECD-FAO, 2007).

### 3.1 Brazil as pioneer

In Brazil the production of ethanol is strongly related to the Brazilian sugar production and history. Since 1931 several phases of governmental regulations took place. To promote the production of ethanol out of sugar cane, blending obligations as well as price regulations and subventions were developed early on. This interventionist policy was critical in building up the sugar and ethanol sector in Brazil in the past three decades. By the end of the 1990's, Brazil had a mature and highly competitive ethanol industry, and in 1999, Brazil dismantled its interventionist policy, and liberalized its domestic prices for sugar and alcohol (Henniges, 2006). Since 2006 there is a 20 % mandatory blending of fuel with ethanol (FO Licht´s, Vol. 5, No. 5, 2006). Brazil is implementing further expansions of the ethanol sector, and more recently in biodiesel, in order to increase the domestic use of biofuel and to build up its capacity for export (Junginger et al., 2006). In short, Brazil’s policy on biofuels was motivated early on by dependencia doctrines, but nowadays is motivated by strengthening national energy security, promoting rural development (including smallholders, for example President Lulas program in the Amazon), and enlarging the potential for export.

### 3.2 The protectionist high cost producers: EU, U.S., and Japan

Policies in the biofuel sector in the EU, the U.S. and Japan are guided by a mix of political motivations. First of all, the diversion of agricultural surplus into bioenergy is a very welcome strategy that reduces export subsidies long opposed by the WTO. As von Urff states: “Since land requirements will exceed the area under set-aside food exports will be lowered, a fact that will be exacerbated if the Doha-Round results in further liberalisation particularly a ban on export subsidies” (von Urff, 2007). Second, energy security is a frequently postulated argument. Third, the reduction in greenhouse gas emissions make biofuel an attractive option, albeit Henke (2005) shows that the costs of reducing green house gasses (GHG) are very high in comparison with other measures. Fourth, and perhaps most important for the short run, is the potential of biofuels for continuing to support farm income and rural area development.

With Directive 2003/30/EC, the EU–25 instituted mandatory biofuel blending and pure biofuel use targets. By end of 2010, the market share of renewable fuels should reach 5.75 %. In order to support the uncompetitive production of biofuels in the EU (compared to imported fossil fuels), the EU–25 allows its member states under the Directive 2003/96/EC, to defiscalize biofuels up to 100%, as long as such measures do not lead to overcompensation in the production costs of biofuels. Directive 98/70/EG set up a European Fuel Standard, which sets prescriptive limits for blending amounts and necessary labelling. Regulation (EG) 980/2005 governs import regulations for biofuels and possible biofuel feedstocks.

With the Energy Policy Act of 2005, the U.S. Congress defined a strategy for future energy use and production in the U.S. (Kaerger, 2006). The U.S. primarily offers financial incentives for biofuel production, but not nationwide mandatory blending. However, a number of states have introduced mandatory blending guidelines. The recent legislation has granted biodiesel a 1 US$ per gallon excise tax credit, and a 0.10 US$ per gallon small producer tax credit, as well a 0.51 US$ per gallon tax credit per gallon for ethanol (Collins, 2006). The USDA states: “Additionally, an import tariff of 54 US cents per gallon is assessed on imported ethanol, with duty-free status on up to 7 % of the U.S. ethanol market for imports from designated Central American and Caribbean countries. The ethanol tax credit is scheduled to expire at the end of calendar year 2010 and the ethanol import tariff was recently extended through the end of calendar year 2008. The biodiesel tax credit is scheduled to expire at the end of calendar year 2008.” (USDA, 2007) In 2005, about 91 million gallons of biodiesel were produced under the support of the so-called Commodity Credit Corporation Bioenergy Program (Collins, 2006). It is expected that the U.S. biodiesel production capacity will level in 2010/11 at a total production of 700 million gallons of biodiesel, because increasing soybean prices will gradually reduce the profitability of expanding the production of biodiesel from soybeans. However, even if about 23 % of soybean oil production in the U.S. is used for biodiesel, only less than 2 % of highway diesel fuel used in the U.S. can be substituted (USDA, 2007). In Canada the total fuel alcohol capacity will reach almost 900 million liters in 2007. However, this would still fall short of the 2.1 billion liters required under a nationwide strategy for blending 5 % of fuels with biofuels by 2010 (FO Licht´s, Vol. 5, No. 5, 2006; USDA, 2007).

Japan has introduced a law allowing for a 3 % ethanol mix in gasoline. However, the progress in implementation has been slow, and is entirely dependent on biofuel imports. Because of land scarcity, Japan has a strategic interest to produce biofuels from domestic waste wood and other cellulosic materials (FO Licht´s, 2006).

### 3.3. The newly emerging developing country producers

Following the example of Brazil, developing countries with a considerable potential in biofuel production have recently implemented supportive policies. Among them are a number of Latin American countries, Malaysia, China and India. With the exception of China, these countries aim to not only produce for the domestic market, but also eventually for the growing world market for biofuels.

As Licht reports: “In April, Argentina approved a biofuel law which will go into effect in 2010. This regulation will oblige all refiners to blend 5 % ethanol or 5 % biodiesel in all fuel sold domestically. For alcohol, this would mean a market of the order of 300 mio litres.” (FO Licht´s, Vol. 5, No. 5, 2006) Argentina has a system of differential export taxes that exhibits a lower tax rate for biofuel export, than the tax rate on exports of feedstocks such as corn or soybean oil. In turn, the export tax on soybean oil is lower than the tax on soybean exports. This provides an incentive for further investments in Argentina’s already large crushing industry. Argentina is projected to import soybeans from other South American countries in order to keep its crushing facilities running at near full capacity. (USDA, 2007)

Licht's states that: “In late 2005, Colombia successfully started its fuel ethanol program with several distilleries coming on line. … Currently, the alcohol produced is used to supply cities in the central and southern part of the country and equates to about 70 % of the national demand for E-10.” (FO Licht´s, Vol. 5, No. 5, 2006).

The Malaysian government has approved 14 biodiesel plants for the country, and 36 further proposals are under consideration that will use a share of Malaysian palm oil production. The major aim of these plans is to meet the demand from Europe. The Malaysian government will extend trials of the B-5 biodiesel to commercial vehicles by the middle of this year (FO Licht´s, 2006). The Indonesian Government plans to build pilot biodiesel plants in 2006 as a model to promote alternative energy. To meet the increasing demand for biodiesel, Indonesia’s government plans to develop 3 million ha of palm oil plantations in the next five years (FO Licht´s, 2006). In the Philippines, a Biofuel Act was passed in December 2006, where all gasoline products are required to have an ethanol content of at least 5 % within two years. All diesel vehicles would be required to use a minimum of 1 % biodiesel blend within three months of the law going into effect. For biodiesel the main feedstock used in this case will be Coconut oil. The mandated blend will rise to 2 % biodiesel after two years and to at least 10 % for bioethanol after four years. Apart from the ready market for biofuels that the law creates, the Biofuel Act of 2006 also provides incentives for the production, distribution and use of locally produced biofuels. (FO Licht´s, 2007)

In India, the Ministry of Non-conventional Energy Sources released in 2005 their “New and Renewable Energy Policy Statement”, which explains the further Indian policy route for renewable Energy. The announced priority for India is to develop substitutes for liquid, gaseous and solid fossil fuels, in that order. The future goal for India is to make the domestic renewable energy industry globally competitive, so that by 2022, it becomes a net foreign exchange earner. For Indian biofuel development aims, the biodiesel production is especially considered to be a great employment generator. Licht reports: “Vegetable oils demand in India could rise within the next years, if planned biodiesel production capacities are being built” (FO Licht´s, 2006). The Indian government will start with a 5 % blending and by 2012 will have a blending of 20 % (FO Licht´s, 2006).

China, due to its food security policy and rising demand for meat products, is assumed to eliminate a government subsidy for the production of fuel ethanol from corn. China will attempt to focus on ethanol production using non-grain feedstocks such as sweet potatoes and cassava (USDA, 2007). For biodiesel, China is highly dependent on imports of vegetable oils (FO Licht´s, 2006) and has been Malaysia´s top palm oil buyer for several years. China produced just under 100,000 tons of biodiesel in 2005 and no blends are sold as of yet in any of China´s service stations. To speed up the development of the industry, as with ethanol, China needs to set biodiesel standards and introduce incentive policies (FO Licht´s, 2006). China aims to use 6.7 million tonnes of ethanol and 11 million tonnes of biodiesel by 2010, meeting 10 % of its forecast transport fuel demand. The country’s emphasis will be to develop ethanol from cassava, sweet potato and maize, and biodiesel from animal and vegetable oils. The country has plans to reserve 44 million ha of land for growing biofuel feedstock (FO Licht´s, 2007).

In Sub-Saharan Africa, some countries such as Malawi, Madagascar, Tanzania and South Africa (USDA, 2007), are reported to be making initial investments in biofuel production capacity.

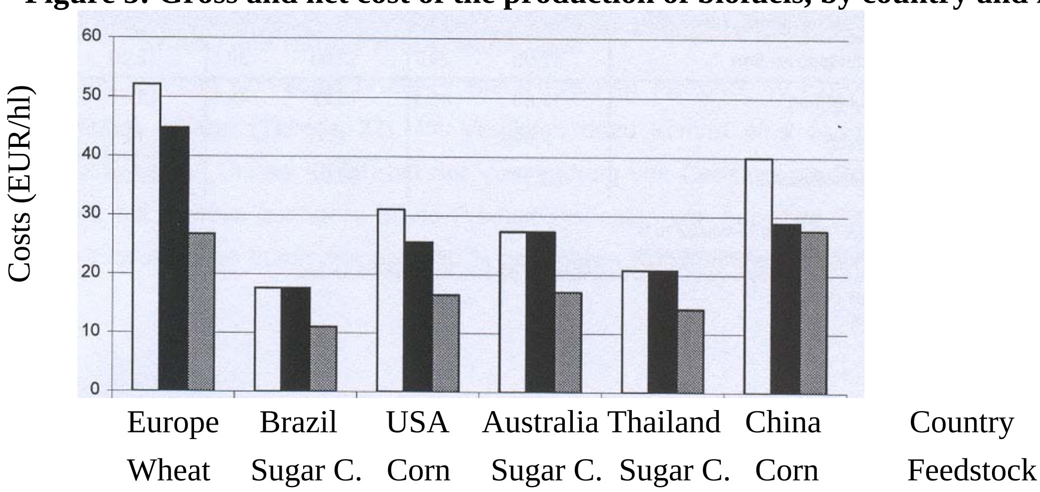
## 4. Future growth and equity perspectives for developing countries

The review of the policy frameworks for developed and developing countries showed that the latter group is mainly positioning itself to become major exporters of biofuels or its feedstocks, with the exception of China. There should be no doubt that with rising oil prices there will be also an increase in the production and international trade of biofuels. The major exporters of biofuels will be those with low production costs and considerable potential for expansion. In the following section, we review these production costs and compare them with those in developed countries.

### 4.1 Production costs across major producers

As illustrated in Figure 5, Brazil exhibits the lowest production costs when comparing net production costs and feedstock costs. Thailand comes in shortly after Brazil, and like China, faces a high domestic demand for biofuel. Production costs are found to be lower in the USA than in Europe.

**Figure 5: Gross and net cost of the production of biofuels, by country and feedstock**




gross costs of production (GCP)

net costs of production (= GCP – return of byproduct)

proportional feestockcosts

**Source:** Henniges 2006

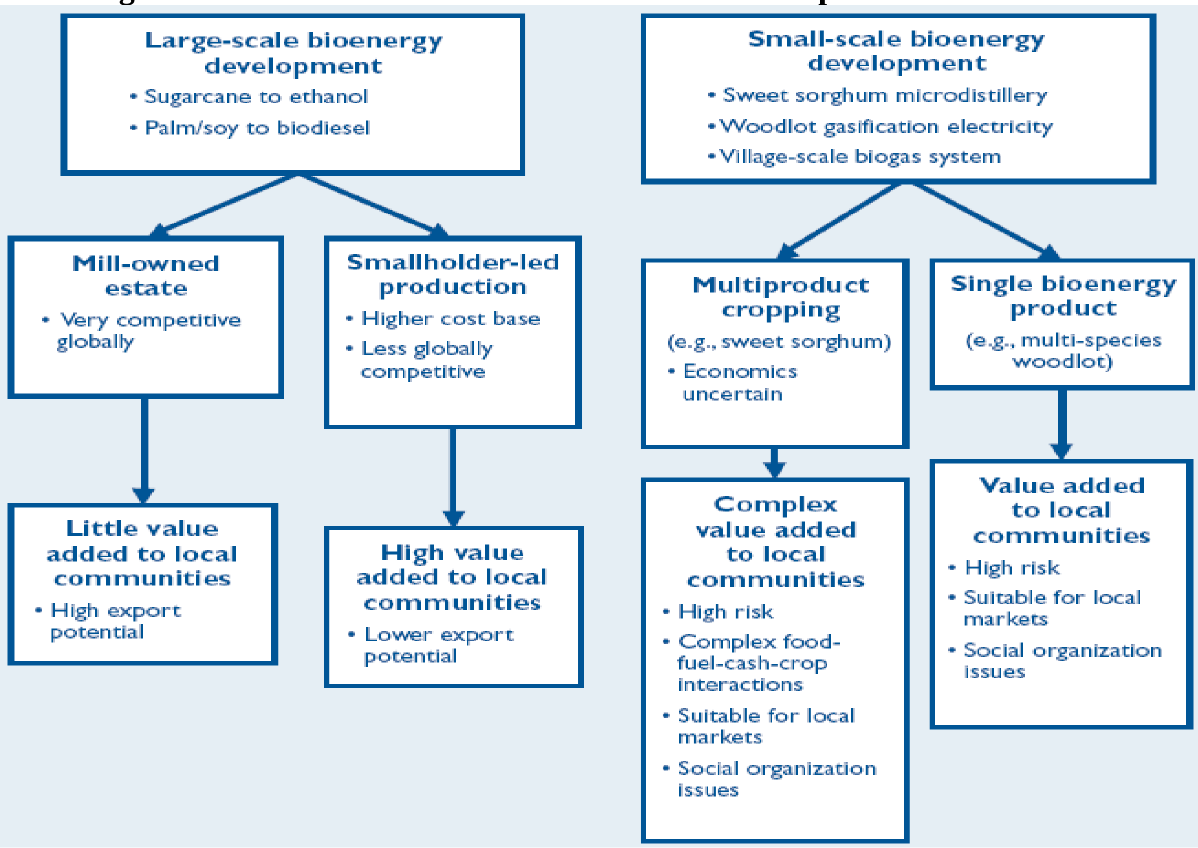
It is expected that the productivity of processing Brazilian sugar cane into ethanol will more than double by 2023 because of new technology. The capacity to convert sugar cane into ethanol will increase to 13,000 liters of ethanol per ha of arable land, from the present capacity of 6,000 liters. At present, sugarcane is grown on roughly 6 million ha of land, representing just 2 % of the total land used for agriculture and pasture and 0.7 % of the country's total land mass. According to a study commissioned by the Ministry of Science and Technology of Brazil: "For the past three decades, sugarcane plantations have been spreading north and west across Brazil's hinterlands, replacing coffee, citrus and pasture. Investors are planning to spend some $12.2 billion on 77 new ethanol plants over the next five years, as well as $2.4 billion to expand existing ones. By 2012, a total of 412 distilleries will be churning out 9.5 billion gallons of ethanol. Ultimately, Brazil would like to see ethanol traded as freely and widely as oil. In that case, it could potentially boost exports from the current 3 billion litres to as much as 200 billion litres by 2025. That would be enough to replace onetenth of the world's petrol consumption." … "Indeed, since sugarcane is grown throughout the region, most Latin American countries could benefit. A recent study from the Inter-American Development Bank argued that replacing 10 % of Mexico's petrol consumption with locally refined ethanol would save $2 billion a year and create 400,000 jobs. Several Caribbean governments hope that the ethanol boom could help revive their ailing sugarcane farms. The greatest lure would be access to the American market. Various Central American, Caribbean and Andean countries can already send ethanol to America tariff-free, thanks to concessionary trade agreements. Maple, an American energy investment group, plans to spend $120 million on an ethanol plant in Peru to take advantage of such a waiver. A pipeline running out into the nearby Pacific Ocean will deliver the plant's output directly to tankers bound for America. Proponents of the project say it will create 3,200 jobs. If all goes well, exports could reach 120 million litres a year by 2010, and perhaps as much as 400 million in the more distant future" (Economist, 2007)

Other countries likely to gain from biofuels are the large traditional exporters of agricultural products, mainly Argentina, Indonesia and Malaysia. In comparison with Brazil, Argentina has a comparative advantage in the production of oilseeds. As Gabriela Sustaita stated: "Argentina is one of the largest exporters of vegetable oil in the world, with over 90 % of our production sent abroad" (Gabriela Sustaita at FO Licht´s, 2006).

### 4.2 Institutional framework for biofuel production: Inclusion of the smallholder and poor?

Figure 6 shows alternative institutional frameworks for the production of biofuel. At present, large scale factories provide the dominant share of the world production of biofuel in developed and developing countries, in order to exploit the existing economies of scale in the production and distribution of biofuels. However, the production of biomass could be organized either through plantation estates, through contract farming with smallholders, or through using cooperative institutions.

**Figure 6: Alternative institutional frameworks in the production of biofuels**




**Source:** Woods 2006

The plantation model may have limited employment effects, and therefore negligible multiplier effects for the local economy. In comparison, the smallholder led production is more labour intensive and less capital intensive and thereby better adjusted to the production conditions in developing countries with more equalitarian land holding structures. In Brazil, with its highly unequal land distribution, the preferred institutional framework is the mill-owned estate. Figure 5 also shows a largely untested alternative in the form of small scale bioenergy development. There are a number of technological challenges, especially socio-economic issues with regard to social organization and profitability. More research and pilot experiments are urgently needed to further develop and test small scale production of biofuels for decentralized energy systems. These can be especially attractive for remote rural areas that face energy shortages or do not have access to public grids.

Overall, the current trends and technological and institutional development seem to be a pathway leading towards the large scale production of biofuels. However, appropriate policy frameworks could enable smallholders to take part in the production of biomass for biofuel, with positive effects on local employment, investment and income in rural areas. The small scale development of decentralized biofuel production faces a number of technological and socio-economic issues, and requires more (publicly funded) research and technological as well as institutional development.

## 5. Conclusions

Biofuels offer a number of important prospects for development. First, they are a renewable energy source. Second, they potentially can contribute to the reduction of greenhouse gases, as the production and use of biofuel is nearly carbon neutral. However, as argued by Henke

(2005), the greenhouse gas abatement costs of biofuel produced in Europe are prohibitively high, but further technological progress can greatly reduce these costs. Third, for countries with highly subsidized agricultural sectors, such as the EU and the United States, the promotion of biofuels are a very attractive political option as it can reduce or even eliminate the need for grain export subsidies, while enhancing national energy security and continuing to provide income support for farmers and rural areas. Fourth, biofuels create increased demand for agricultural raw materials, and therefore will have a positive influence on agricultural prices and the demand for agricultural products. This will benefit agriculture and rural areas in general, especially in countries with a strong comparative advantage in agriculture and forestry, provided that international trade in biofuel is not hindered by tariff and non-tariff barriers.

Biofuels however, also pose some important challenges. First, the effect on income and employment for the rural poor and smallholders, especially in developing countries, remains to be seen. Much will depend on how biofuels are eventually produced and distributed worldwide, and whether smallholders or rural labourers are able to find income or employment in the biofuel sector. Second, the expansion of biofuel production will create upward pressure on food prices. It is a well known fact that the effect of rising food prices on the rural population will depend on the net trading position of farm households. For the net sellers of agricultural produce, biofuels will provide the prospect of rising incomes. For the net buyers of food in rural and urban areas, especially for the poor, biofuel is likely to increase food insecurity and poverty. Third, a massive expansion of biofuel production may provide incentives for deforestation, soil mining and water logging, thus increasing the environmental pressure of agriculture and forestry. Fourth, there is a risk that the biofuel boom will be dominated by large scale agribusiness firms that produce biomass through mill owned plantations, rather than by involving smallholders. In the former scenario, the effects on local employment and investment in rural areas would be much weaker than in the latter scenario.

Thus, in order to reap the potential win-win-win biofuel offers for economic growth, poverty reduction, and the environment, it is clear that massive investments in agricultural research, conversion technology research, as well as research regarding appropriate policy and institutional settings promoting pro-poor and sustainable biofuel production is needed.

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