

Potential for Biofuels for Transport in Developing Countries

by Masami Kojima and Todd Johnson

This note is based on a longer report published by ESMAP in 2005. The report responds to the increasing number of requests from developing countries to help assess the commercial viability of biofuels for transport in the next 5 to 10 years. This brief draws from the successful Brazil experience and illustrates socioeconomic considerations for establishing biofuel programs in developing countries.

A Growing Biofuel Market

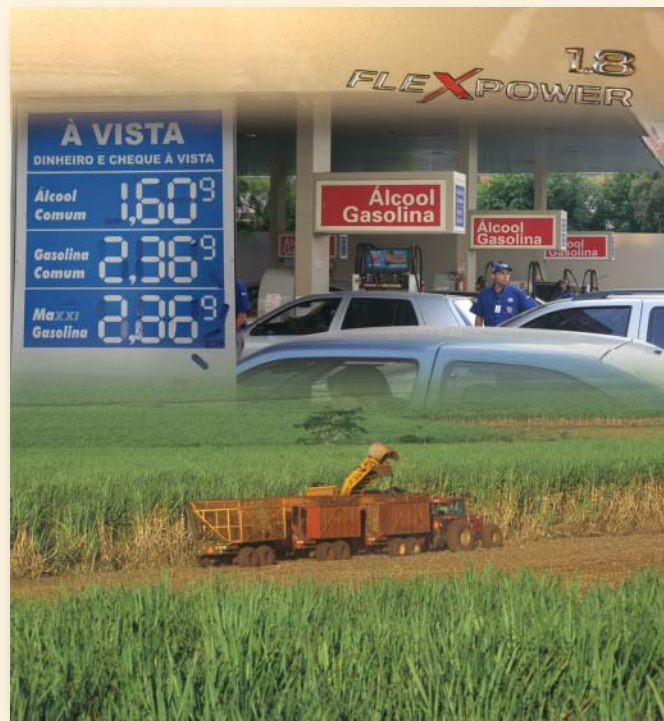
Liquid biofuels made from biomass are attracting increasing interest worldwide. Recent surges in world oil prices, concerns about energy security, and concerns about climate change from greenhouse gas (GHG) emissions have prompted industrial and developing countries alike to pursue avenues for commercializing biofuels. Developing countries also see biofuels as a way to stimulate rural development, create jobs, and save foreign exchange.

The transport sector has been the key area for large-scale efforts in biofuel use worldwide to date. The two primary biofuels consumed are ethanol and plant-oil-based biodiesel. Canada, Colombia, the European Union, India, Malaysia, the Philippines, Thailand, and the United States have all adopted targets—some mandatory—for increasing the contribution of biofuels to their transport fuel supplies.

Today, Brazil and the United States, which makes ethanol from maize, are the world's two largest biofuel markets. In Brazil, after a period of decline in ethanol consumption, new flex-fuel vehicles—capable of running on varying percentages of ethanol—are revitalizing the sale of ethanol, which now accounts for more than 40 percent of Brazil's gasoline-ethanol market. The global biodiesel market—although growing—is much smaller in size. Due to higher costs of biodiesel production, ethanol offers a better chance of commercial viability, with sugarcane being the most cost-effective and productive source at this time.

Despite the growing potential, there are still major barriers preventing widespread development of biofuels. This brief provides a snapshot of Brazil's bioethanol experience to illustrate factors that have contributed to that country's success, and, by so doing, help developing countries assess the social and environmental costs and benefits of biofuels and decide when, where, and how to embark on such programs.

ESMAP is a global technical assistance program managed by the World Bank Energy and Water Department (EWD) that promotes the role of energy in poverty reduction and economic growth in an environmentally responsible manner. Its work applies to low-income, emerging and transition economies and contributes to the achievement of internationally agreed development goals.



Motivation behind Biofuels

Developing country interest in biofuels is motivated by several factors:

- ▶ **Diversification of energy sources and lower exposure to the price volatility of the international oil market.** Diversification is attractive for oil-importing countries, especially those that have high delivered costs of petroleum (such as land-locked countries).
- ▶ **Rural development.** Biofuels hold the promise of contributing to rural development by creating jobs in feedstock production, biofuel manufacture, and the transport and distribution of feedstock and products.
- ▶ **Reduction in harmful pollutants from vehicle exhaust.** Where vehicles are important contributors to poor urban air quality, biofuels may be environmentally preferable to petroleum-based fuels. Ethanol has the greatest air-quality benefits where vehicle fleets are old, as is often the case in developing countries. It helps to reduce the exhaust emissions of carbon monoxide and hydrocarbons, especially in cold climates. Ethanol can replace harmful lead additives for raising the octane of gasoline, and all biofuels are sulfur-free. Biodiesel reduces emissions of carbon monoxide, hydrocarbons, and particulate matter, but can slightly increase emissions of nitrogen oxides.

- ▶ **Net reductions in lifecycle GHG emissions.** The prospect of bilateral or multilateral aid transfers for climate change mitigation is generating significant interest in biofuels. Developing countries do not currently have binding GHG reduction targets under the Kyoto Protocol, but they can sell carbon credits to countries with reduction commitments under the Clean Development Mechanism component.

Risks Involved

On the other hand, developing countries are also concerned with the potential social and economic costs of biofuel programs. These include the historical need for significant and ongoing government subsidies to the industry, the capturing of biofuel program subsidies by large-scale farms and agribusiness, fiscal and equity impacts of reducing government revenues from tax exemptions for biofuels, implications for agriculture and agricultural trade policy, and potential environmental damages associated with feedstock production and biofuel manufacture.

The greatest barrier to widespread development of the biofuel industry is economics, which is closely linked to the world price of oil. In this context, it is useful to see how Brazil overcame this challenge and to explore the factors that contributed to Brazil’s successful bioethanol industry.

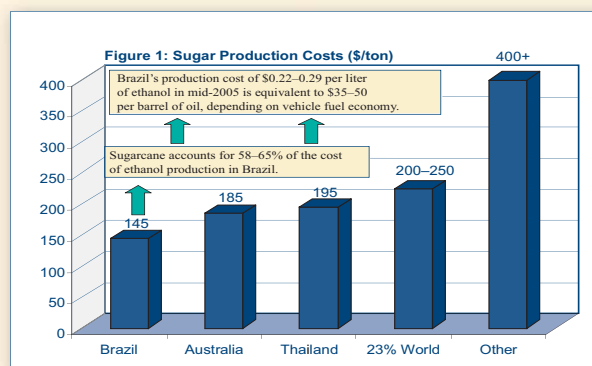
The Brazil Experience: Ethanol

Ethanol from sugarcane grown in the center-south region of Brazil is by far the cheapest biofuel today. The financial cost of ethanol production in Brazil is estimated to be in the range \$0.23–0.29 per liter.¹

The costs of ethanol production in other countries, or using other feedstocks, are significantly higher than from sugarcane in Brazil. Biodiesel production costs are considerably greater—at least \$0.50 per liter (or \$79 per barrel of biodiesel) or, in many cases, higher.

In Brazil, feedstock costs account for 58 to 65 percent of the cost of ethanol production, and so the commercial viability of ethanol is critically dependent on the cost of cane production. The center-south region of Brazil is virtually unmatched in its productivity and low production costs for the following reasons:

- 1) Cane cultivation is water-intensive, but nearly all cane fields in this region are rain-fed, in contrast to irrigated sugar production in countries such as Australia and India.
- 2) Sugarcane and other activities do not have to compete for land because there is still plentiful unused land in this region of Brazil for expanding cane production.



Source: Macedo 2005, Nastari 2005.

- 3) Productivity in Brazil has also been boosted by decades of research and commercial cultivation. To cite one example, cane growers in Brazil use more than 500 commercial cane varieties that are resistant to many of the 40-odd crop diseases found in the country.
- 4) Most distilleries in Brazil belong to sugar mill/distillery complexes, capable of changing the production ratio of sugar to ethanol. This capability enables plant owners to take advantage of fluctuations in the relative prices of sugar and ethanol, as well as benefit from the much higher price that can be fetched by converting molasses into ethanol.
- 5) Flex-fuel vehicles have further increased the attractiveness of building hybrid sugar-ethanol complexes and allayed consumer fears about potential ethanol shortages.

A critical question for replication of Brazil’s experience in other developing countries is at what point on Brazil’s historical cost “learning curve” will they be able to enter the ethanol market (see box 1).

Taking It Global

Close to 100 countries around the world are growing sugarcane, but none have been able to match Brazil’s sugarcane cost structure. In mid-2005, sugar production costs in the three lowest cost countries were estimated to be \$145/tonne in Brazil, \$185/tonne in Australia, and \$195/tonne in Thailand. About one-quarter of the total worldwide sugar production is at \$200–250/tonne, above which the cost jumps to \$400/tonne and higher; these high-cost sugars in turn account for about one-half of total world sugar production (see figure 1). Ethanol as an automotive fuel is estimated to be economic in Australia in the long run only if world oil prices remain at 2005 levels (Biofuels Taskforce 2005). In other countries, this breakeven point will likely be higher.

Given these cost figures, it is likely that subsidies—indirect, direct, or both—would be needed to launch and maintain a biofuels industry in most developing countries. However, the economics of biofuel production are site- and situation-specific, and each country will produce different results.

¹All dollar figures cited in this brief are U.S. dollars. For conversion from the Brazilian real to the U.S. dollar, the exchange rate prevailing in mid-2005 of R\$2.40 to the dollar is used.

Tax exemptions, administered pricing, and restrictive trade policies have all been used to assist biofuel manufacturers. Every country with a biofuel program has provided subsidies to the industry, and none has yet removed government fiscal support entirely. Brazil is the only country to have achieved a commercially competitive ethanol industry, and this was preceded by more than 20 years of government support. Even today, Brazil continues to maintain a significant tax differential between gasohol (80 percent gasoline/20 percent ethanol) and hydrous ethanol.

One universal instrument for supporting biofuels has been tax waivers. There are both equity concerns and practical difficulties for using tax exemptions to support biofuels in developing countries. Gasoline taxes are often a significant source of tax revenue in developing countries and are also progressive in that gasoline consumption is greatest among high-income groups. The provision of tax exemptions to ethanol results in a loss of tax revenue from gasoline, revenue that could have been used for other social programs. Diesel fuel is either taxed at very low levels or is subsidized in many developing countries. In these circumstances, tax exemptions would not be able to support biodiesel, and alternative means of support would need to be found.

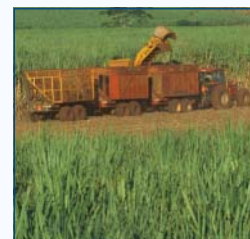
Government Interventions

Where biofuels are entirely commercially viable, government involvement can be limited to regulating the industry to ensure a level playing field; consumer protection; and compliance with environmental, health, safety, and technical standards. Under all circumstances, governments should improve the investment climate wherever possible by establishing a clear, stable, and transparent legal and fiscal framework supported by efficient administration.

Where biofuels are not commercially viable on their own, a case for government intervention must be made: fostering rural development, accounting for poorly priced externalities, or enhancing energy diversification.

- ▶ **Rural development.** Biofuel programs should be integrated within a broader context of investment in rural infrastructure and human capital formation. Low-income countries should assess whether the underlying conditions for a successful biofuel program exist or could be developed in the near term, including infrastructure and essential public services.
- ▶ **Unaccounted externalities.** The environmental benefits of biofuels, such as lower emissions of local or global pollutants, should be considered when assessing the economics of biofuels. Carbon market payments can serve as an imperfect proxy for the benefits of reducing GHG emissions. Using a carbon price range between \$3 and \$20 per tonne of carbon dioxide equivalent, this would provide only \$0.005–0.07 per liter, even if 100 percent of the lifecycle GHG emissions of petroleum

Box 1: Ethanol—What Conditions Foster Success?



1. **Do climatic conditions favor sugarcane production?** Is there plentiful rainfall, or a good irrigation system that is sustainable without large subsidies, and is soil fertility adequate for cane production?
2. **Is there good road and communications infrastructure?** Fertile land with good rainfall must be accessible in order to minimize the costs of moving cane to processing plants and ethanol to consumption centers.
3. **Is there good agricultural research and extension, or a high probability of strengthening it?** The Brazilian experience underlines the benefits of developing new cane varieties to stay ahead of cane diseases and pests, identifying the right variety for each microclimate, disseminating knowledge through agricultural extension services, and ensuring that farmers implement the findings and recommendations.
4. **Are farmers provided with adequate primary education?** Especially in low-income countries, farmer education is often lacking. Farmers need to be able to absorb and apply advice provided by extension services so as to be able to respond to new technical, marketing, organizational, and financial opportunities.
5. **Is there a functioning credit market?** Farmers need access to credit in order to implement the advice of extension service officers on soil improvement; select and plant the right cane varieties; and adopt adequate pest, weed, and disease control methods. Such measures are needed to improve cane yield to make ethanol production economic.
6. **Is there a cadre of managers that can be called upon to manage the industry?** Managerial skills, including technical management, are needed across the supply chain, from optimizing seed selection and harvest timing to processing plant operations.
7. **Is the sugar industry organized to foster cooperation across the supply chain for ethanol production?** Conflicts between sugar and ethanol producers, or between cane growers and distilleries, have slowed the growth of the ethanol industry in some countries.
8. **Is there a mechanism for capturing poorly priced externalities?** In some cases, the commercial viability of ethanol will depend on charging for externalities such as urban air pollution and GHG emission reductions that are not financially accounted for.

fuels are assumed to be offset by biofuels. For local air pollution benefits, one set of calculations suggests that the incremental value of ethanol compared to gasoline may not be much higher than \$0.02 per liter, and \$0.08 for biodiesel. Biofuel feedstock production and biofuel processing may also carry environmental costs: water and air pollution, soil depletion, and habitat loss associated with the conversion of forests to cropland.

- ▶ **Energy diversification.** Biofuels can provide energy diversification, but this should be weighed against the cost of biofuels production. What is important for energy diversification via biofuels is that there be alternative, reliable, and inexpensive sources of fuels from suppliers that are not traditional oil producers. As substitutes, the

prices of biofuels and petroleum products will equilibrate in a free trade regime on the international market and biofuels will be price takers, as long as biofuel production remains a small fraction of total petroleum fuel production.

Because the feedstock currently used for commercial biofuel production is agricultural crops, no discussion of biofuel programs is complete without addressing global distortions in agricultural products, especially the domestic subsidies and trade barriers in high-income countries. The world sugar market is one of the most distorted. Complete trade liberalization, which would dramatically reduce the production of sugar in high-production-cost countries, is forecast to raise the world price of sugar by about 30–40 percent according to most estimates (ESMAP 2005). This in turn would raise the cost of ethanol production until supply expansion responds to the much higher world sugar price.

Removing barriers to biofuel trade would be helpful for a number of reasons. First, the most efficient biofuel producers could expand their market share beyond their borders. Second, the political pressure to maintain large implicit and explicit subsidies in favor of biofuels in any given country could lessen or even disappear if, in addition to or instead of domestic producers, imported biofuels benefited from these subsidies. Both effects would provide a stimulus to increase efficiency and close inefficient manufacturers. Growth of the most efficient biofuel manufacturers in turn would strengthen the industry and contribute to energy source diversification worldwide.

In Summary

In the near term, ethanol from sugarcane is likely to offer the best chance of commercial viability.² Other feedstocks for producing ethanol increase the cost of production markedly and are unlikely to be financially viable without government support. Biodiesel remains expensive even against the backdrop of rising world oil prices, thus raising similar concerns over financial viability in the near term.

² Historically, world sugar prices have been as volatile as oil prices. World sugar prices reached a 25-year high in early 2006, causing the plant gate price of ethanol to far exceed that of gasoline and prompting the government of Brazil to reduce the required ethanol content in gasohol from 25 percent to 20 percent in March.

In the medium term, biofuel production costs will come down and other feedstocks may become attractive, expanding feedstock options and enabling countries not suited for growing sugarcane to enter into biofuel production. Particularly interesting is the potential for cost reduction in biodiesel manufacture from plants not requiring much rainfall and nutrients, such as *Jatropha*. An added benefit could be to reclaim land and provide other environmental benefits such as carbon storage.

In the long run, one of the areas with the greatest promise to become commercially viable is manufacture of ethanol from cellulose: forest products, wood wastes, crop residues, and energy crops such as switch grass. Their widespread availability, abundance, low cost, and significant lifecycle GHG emission reductions make them suitable and attractive for biofuel production. At the same time, world oil prices as well as the price of carbon may rise appreciably, altering the comparative economics of biofuel manufacturing greatly in their favor.

References

Biofuels Taskforce. 2005. **Report of the Biofuels Taskforce to the Prime Minister**. Australian Government. www.dpmmc.gov.au/biofuels/final_report.cfm.

ESMAP. 2005. **Potential for Biofuels for Transport in Developing Countries**. Report 312/05. Washington, DC: World Bank.

Macedo, Isaías de Carvalho, ed. 2005. **Sugar Cane's Energy: Twelve Studies on Brazilian Sugar Cane Agribusiness and Its Sustainability**. São Paulo: UNICA. São Paulo: Sugarcane Agroindustry Union.

Nastari, Plinio Mário. 2005. Personal communication.

Copyright 2006

Photo Credits: ©Todd Johnson and Carlos Goldgrup, Reflexo

Production Team: Marjorie K. Araya, Douglas F. Barnes, and Samantha M. Constant

This note is part of the forthcoming report "Potential for Biofuels for Transport in Developing Countries." Masami Kojima works as Lead Energy Specialist for the World Bank's Energy and Mining Anchor. Todd Johnson works as Senior Energy Specialist in the World Bank's Latin American Region.

The findings, interpretations, and conclusions expressed in this paper are entirely those of the author (s) and should not be attributed in any manner to the World Bank, or its affiliated organizations.

To order copies of the full publication and for more information, please visit us at our website: <http://www.esmap.org>.

The Knowledge Exchange Series is issued by ESMAP to disseminate the results of significant work in the energy sector for the benefit of the development community in the most effective and most accessible way possible.



<http://www.esmap.org>

