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It's Not About Ethanol, It's About Sugarcane

Innovations Case Discussion:
The Brazilian Experience with Biofuels

Brazil's decision to integrate sugar production with its energy system makes an interesting case study in optimization and economic flexibility. Dr. Goldemberg's first-hand experience with Brazil's policy of incorporating ethanol into the transport fuel mix offers important insights into the steps Brazil took to change fuel blends and encourage consumers' adoption of them. Dr. Goldemberg argues that an ethanol export industry could power development in other countries. While ethanol is part of an important Brazilian story, export-led development was not the driver. Rather, in finding multiple uses for sugarcane and its by-products, Brazil systemically transformed its energy mix. This success in optimizing resources offers a rare example of low carbon growth.

Can other countries replicate Brazil's experience with low carbon growth and/or become ethanol exporters? The answer is not yet clear. To illustrate the challenges, this commentary briefly explores the experiences that Brazil and the U.S. have had with ethanol as a transport fuel, the choices made by industry and policy makers and the economic and political forces that shaped decisions.

BRAZIL'S ETHANOL EXPERIENCE

Domestic economic policy was the original impetus behind the ethanol experiment in Brazil. When the military assumed political control in Brazil in 1964, it

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sought to expand the productivity of Brazil's major export products—coffee, sugar ,and citrus—and to protect the development of a modern industrial sector. Two of these markets, coffee and sugar, were highly distorted and Brazil was vulnerable to volatile prices. The success of the command-and-control economy was illustrated by 10 percent annual growth rates in the early years of the military regime, backed by high tariffs and domestic programs that supported the development of a new industrial sector that produced steel, autos, cement, and other products; meanwhile, agroindustry developed and the middle class expanded. Like most emerging markets of the mid-sixties, Brazil fueled much of its post-war expansion with cheap energy, primarily imported petroleum, to the extent that by 1974 it was importing 85 percent of its primary energy supply. In 1973-74, however, two events coincided to refocus the attention of Brazil's ruling elite on the potential of ethanol: (1) oil prices jumped sharply with the Arab oil embargo of 1973; and (2) sugar prices fell, leaving Brazilian producers with growing supplies and few markets.

> In finding multiple uses for sugarcane and its byproducts, Brazil systemically transformed its energy mix. This success in optimizing resources offers a rare example of low carbon growth. Can other countries replicate Brazil's experience with low carbon growth and/or become ethanol exporters? The answer is not yet clear.

In 1974, Brazil's oil import costs jumped from $769 million to $2.8 billion; the large oil import bill threatened the continued expansion of the economy.[1] Brazil had a long history, starting before World War II, of blending ethanol with gasoline as a thrift measure. Now sugar producers needed a new market, and the military dictatorship was concerned about the balance of payments and energy security. They seized an opportunity to expand blending requirements and stimulate a new domestic industry at the same time. One of the more ambitious features of this program was a decision to promote the manufacture of alcohol-only cars, an option few other sugar-producing countries had, or now have.

The government actually bought cars and retooled the engines to prove that 100 percent alcohol engines would work. They also established price parity with gasoline to ensure that ethanol would remain competitive as petroleum prices fluctuated. This approach enabled policymakers to adjust the ethanol price to offset the petroleum producers' economies of scale when gasoline prices were low, and to provide a smaller subsidy when gasoline prices were higher. The Brazilian government was responsible for the price mechanism and for establishing blending ratios, while Petrobras, Brazil's national oil company, played, and continues to play, a central role in blending and distributing both gasoline and ethanol. These early decisions, made under a program known as *Pro-Alcool*, were consistent with the "Brazil first" philosophy of the ruling junta, which involved direct government intervention and large subsidies. Within five years, ethanol was an accepted consumer product; sales of alcohol-only cars grew through the late 1980s, especially in the State of São Paulo.

With the restoration of democracy in the mid-eighties, Brazil began the painful process of liberalizing a highly protected economy. Foreign and domestic debt incurred by the military regime weighed heavily on the economy. Domestic subsidies, including those for ethanol production and blending requirements, were eliminated. Initially, this shift posed only minor problems for sugar producers, who were selling sugar in more profitable international markets; still, ethanol was an important option given the long-range volatility in sugar prices.

In the 1990s, sugar producers, ethanol processors, and Brazil's new economic team began to reassess whether it would make economic sense to maintain an ethanol option in the domestic market. This review prompted consultations with Brazil's auto industry, which had virtually stopped producing alcohol-only cars by early 1992, due to a sharp decrease in the domestic ethanol supply and the consequent decline in consumers' confidence in the availability of fuel for their vehicles. In addition, as the international prices of oil eroded and the price parity with ethanol was eliminated, consumer preference shifted quickly toward gasoline vehicles because of their higher engine performance and lower costs. Still, the experience of producing alcohol-only vehicles had paid off in expertise about ethanol engines. Volkswagen Brazil engineers offered a simple solution when the government asked them if they could develop a low-cost engine modification that would permit the use of any combination of ethanol and gasoline. The flex-fuel modification proved commercially viable, and most Brazilian manufacturers began adopting it. The Brazilian government helped offset manufacturing costs through consumer incentives, which gradually declined over time and encouraged consumers to opt for flex-fuel vehicles. Dr. Goldemberg has noted the success of this strategy, which has resulted in flex-fuel vehicles now comprising more than a third of the current fleet.

This policy secured the ethanol market, but sugar producers, who no longer had price supports for ethanol, realized that efficient processing systems would be essential to their long-term competitiveness, no matter the product. They had already started using bagasse, a waste product of sugar extraction, to fuel the processing plants. The next step they took was to cogenerate electricity. Then, the public utilities arranged to feed spare power into the grid. This systemic innovation created a win-win formula for sugar producers and Brazil's power sector, which gained a new domestic source of electricity. The contribution to power generation tipped the economic scale in favor of ethanol production (see Figure 1).

Whether by chance or design, Brazil's sugar industry has become a "strategic optimizer," and this market flexibility has encouraged a continuous search to

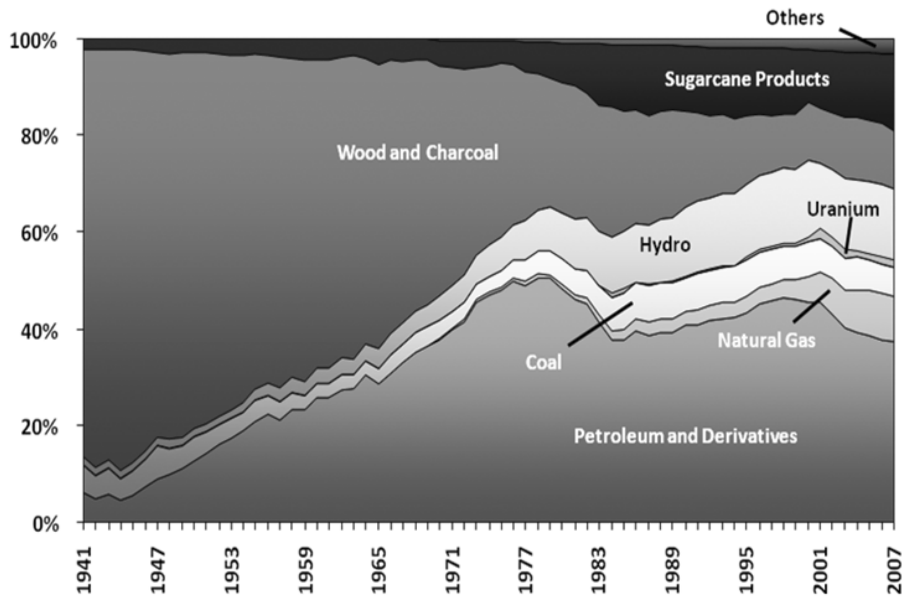

Figure 1. Brazil Energy Mix, by Percentage, 1941-2007.
Source: Ministry of Mines and Energy, Brazil, Balanco Energetico Nacional, 2008.

increase efficiency, productivity, and profits. This process of improving productivity through public-private research partnerships and systematic review of agricultural practices has extended to Brazil's other major agriculture crops, including citrus and coffee.

U.S. ETHANOL POLICY

As in Brazil, the U.S. experience with ethanol has been shaped exclusively by domestic agricultural production and energy consumption. While the U.S. does export vast quantities of agricultural goods, ethanol was always envisioned as a domestic market, driven by domestic interests.

As the auto industry developed in the U.S. at the beginning of the 20th century, Henry Ford thought the most reasonable fuel would be grain alcohol. But that calculation changed as petroleum was discovered and John D. Rockefeller consolidated the petroleum industry. Rockefeller recognized that he needed a variety of markets for this new product, as the initial use for lighting was insufficient to sustain the investment required to exploit this resource. The new markets for electricity and personal mobility were ideally suited to creating demand for petroleum, and the control Rockefeller exercised over supply made it possible to establish prices that many could afford and still remain competitive with alternative fuel options. By about 1920 the fortunes of the oil and automotive industries were firmly linked. As the U.S. was the largest producer of petroleum until after World War II, its actions suggested a lack of concern about long-term energy supply.

This calculation prompted U.S. policymakers to ignore any potential renewable and alternative fuels, even though gasoline rationing had been imposed during WWII. After the war, major U.S. oil companies discovered far more oil in the Middle East, reinforcing the belief that supplies would be abundant and cheap. U.S. policy continued to reflect these early assumptions until the 1973 Arab oil embargo led to a rapid jump in global oil prices to levels far above the historical trend, and touched off a global recession.

In response to new energy concerns, the Carter administration launched a variety of programs to improve domestic energy supply, including a corn ethanol program. It put in place both a processing subsidy and a tariff on ethanol imports that remains in effect today. As with sugarcane, ethanol served as an outlet for an oversupply of corn. While the costs of producing corn ethanol were similar to Brazil's during its early efforts, they were much higher than for the recently optimized Brazilian sugar-based ethanol. And U.S. ethanol, suffering from high production costs and lower energy density, could not compete with inexpensive gasoline in the 1981-2000 period. Unlike Brazil, the U.S. made no significant attempt to retool vehicle engines for ethanol.

Oil producers contended that oil was plentiful and would continue to be available, even though U.S. oil companies were producing much of the oil in the sensitive Middle East. By 1979, state-owned oil companies had control of reserves and supply in Iran, Iraq, Saudi Arabia, and Kuwait, with international oil companies reduced to production contracts. Despite warnings that the U.S. or U.S. oil companies would have less and less control over international petroleum reserves, Congress found it too difficult to build a consensus on an energy policy that would promote conservation, efficiency, and alternative fuels.

In 1987, Ronald Reagan joined Margaret Thatcher in establishing the Intergovernmental Panel on Climate Change (IPCC) to examine the environmental implications of growing fossil fuel use and its impacts; still, few policymakers were convinced that a shift from conventional fossil fuel was either necessary or possible. These attitudes were generally reinforced in the 1990s, as oil prices hit a low point for most of the decade. Even with the expertise of Vice President Al Gore on emerging environmental issues like climate change, the Clinton administration was unable to build a legislative consensus to revamp domestic energy policy significantly (see Figure 2, next page).[2]

In 1997, the President's Committee of Advisors on Science and Technology (PCAST) made the energy security case again. It estimated that by 2015, 70 percent of internationally traded oil would come from the Persian Gulf region, and it argued that U.S. access would not necessarily be assured, especially given the rising consumption of gasoline.[3] In that report, the PCAST experts argued that an aggressive program using cellulosic biofuels from perennial crops could replace 2.5 million barrels of oil a day by 2030 (38 billion gallons of oil a year). The panel also cautioned against a continued focus on corn ethanol as too costly and inefficient.

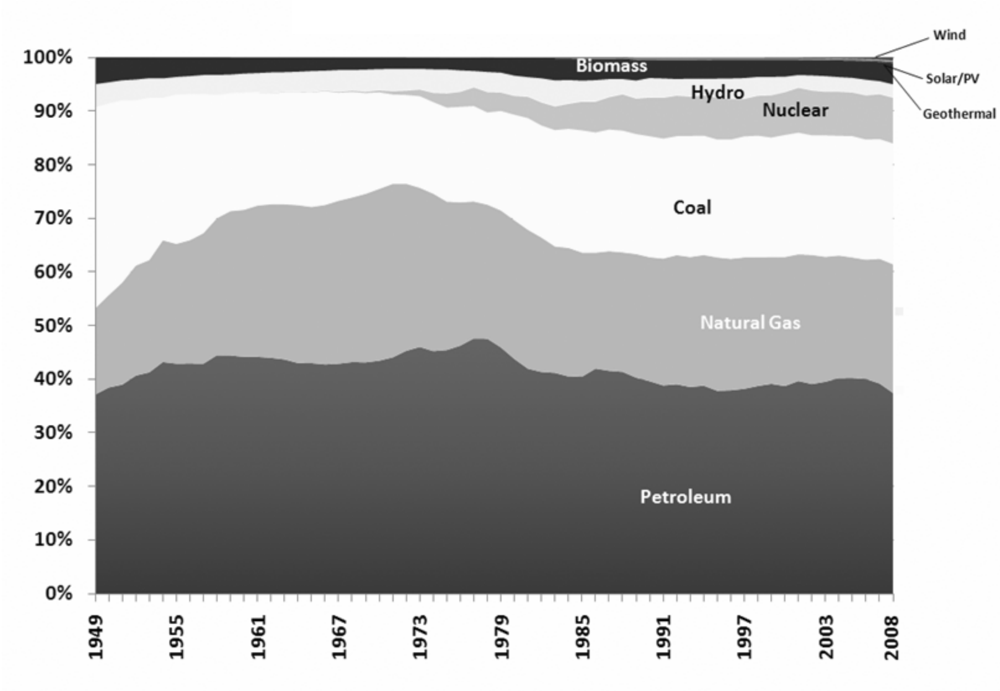

Figure 2. U.S. Energy Mix, by percentage, 1949-2008.

Source: Energy Information Administration (EIA) Annual Energy Review, 2008.

In 1999, recognizing the need to understand how alternative fuels might affect greenhouse gas (GHG) emissions, Michael Wang of the Argonne Laboratory published his work on the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) fuel model, estimating the GHG balance for several fuels.[4] He demonstrated that ethanol produced from various feedstocks was less carbon intensive than gasoline and had a lower lifecycle GHG balance. In these assessments, cellulosic and sugarcane ethanol produced the greatest reductions in GHG emissions, and corn ethanol had a 20 percent lower carbon profile than gasoline, keeping it within a viable range for an incremental low-carbon transformation of the U.S. energy mix. These research results set a useful benchmark, but the study had limited impact until the September 11, 2001, terrorist attacks again raised the specter of dependence on Middle Eastern oil and reignited the ethanol discussion (see Figure 3).

In 2002, two bipartisan coalitions formed to examine energy, environmental and energy security issues. One, the Energy Future Coalition, published an article in *Foreign Affairs* arguing that revamping U.S. energy use would transform long-term energy access in the U.S., strengthen the U.S. economy by accelerating and diffusing new technology, and speed international efforts to address the impacts of climate change.[5] This report was reinforced by the National Commission on Energy Policy, which called for a cap-and-trade system to price carbon emissions throughout the economy and use market forces to advance the transformation to

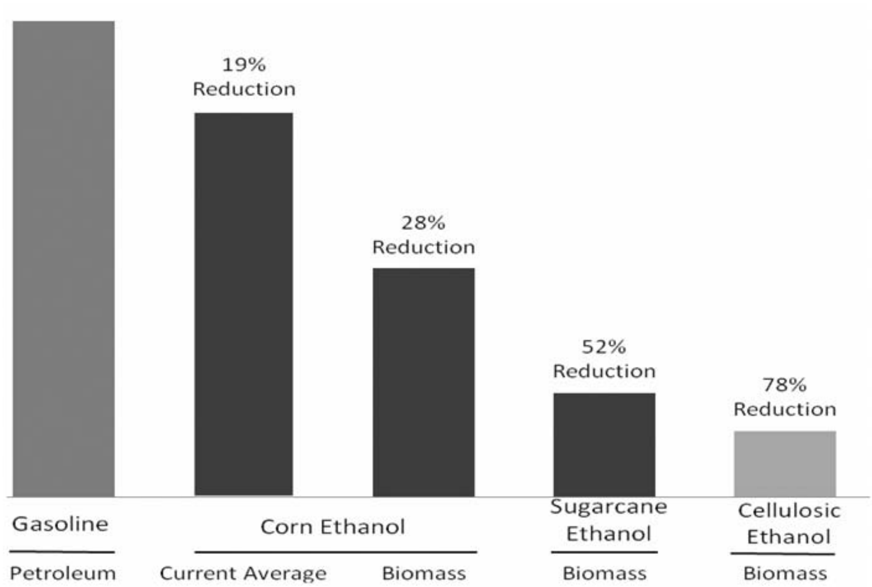

Figure 3. Lifecycle GHG Emissions Associated with Different Fuels, compared to Gasoline.
Source: John Ferrell, U.S. Department of Energy, 2008.

cleaner energy sources. The stage was set to revisit ethanol alternatives when yet another unexpected driver emerged.

Studies showed that MTBE (methyl tertiary butyl ether), a common fuel oxygenator widely used in the U.S., was contaminating soils and groundwater, prompting a number of U.S. states to ban MTBE from their fuel supply, beginning in 2004. Federal regulations required that gasoline be oxygenated for air quality reasons and ethanol replaced MTBE in a variety of gasoline blends in order to meet these standards. Individual states adopted different fuel blends within the larger federal air quality framework, using more or less ethanol depending on local circumstances. For example, California was concerned about nitrogen oxides (NOx) emissions and unsuccessfully sought to eliminate MTBE without substituting ethanol. Despite this patchwork approach, MTBE bans did increase the use of ethanol nationally. While a federal ban on MTBE stumbled, Congress refused to provide MTBE distributors with liability protection against pollution damage suits, prompting the remaining distributors to switch to ethanol voluntarily in 2005 in order to limit their risk.

In 2005, driven primarily by concerns about energy security, Congress established the first federal renewable fuel standard, requiring that 2.78 percent of the U.S. fuel supply come from renewable sources (two decades after Brazil had started its effort). Lacking second-generation fuels made from cellulosic feedstocks, these mandates depended universally on corn ethanol and demanded increasing portions of the U.S. harvest. These moves led farm organizations to see ethanol as

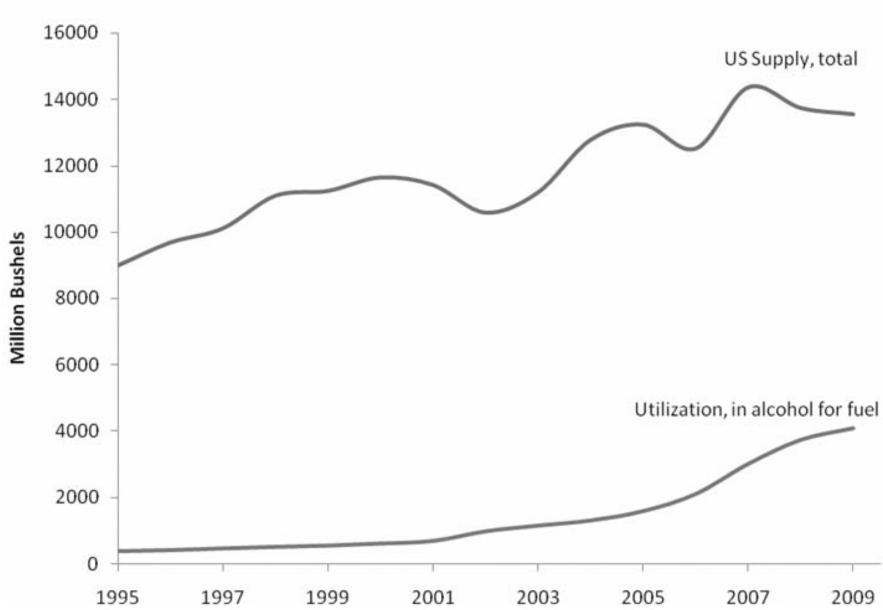

Figure 4. U.S. Corn Supply and Ethanol Demand, 1995-2009.

Source: Feed Grains Database, Economic Research Service/USDA.

a new opportunity to restore prosperity in rural areas. They strongly backed efforts to create a market for renewable fuels. Despite the earlier recommendations of PCAST, corn ethanol production in the U.S. climbed to five billion gallons by 2006, up 20 percent from 2005.[6] U.S. corn farmers responded to the new demand by planting significantly more corn (see Figure 4).

In 1998, with little fanfare, U.S. automakers had begun selling flex-fuel vehicles that could run on gasoline or a mixture of gasoline and up to 85 percent ethanol.[7] Up to 2006, they mainly promoted these vehicles in markets like Iowa, where state policy had encouraged the use of higher ethanol blends. Recognizing a new marketing opportunity, Ford and GM quickly expanded their marketing of flex-fuel cars, stressing first and foremost the opportunity for energy independence, and secondarily, the technology. Response proved limited, however, especially as U.S. gasoline refiners and distributors were not prepared to offer higher blends of ethanol on a national scale. In 2006, despite the very rapid growth, ethanol still only represented 3.5 percent of motor vehicle gasoline supplies in the U.S..[8] As in Brazil, the U.S. focus was strictly domestic and the country retained its duties on imports and subsidies to processors.

The rapid increase in production of both corn and ethanol drew renewed attention to questions of sustainability. Environmentalists contended that the rapid increase in U.S. corn production had negative domestic impacts: increased use of both fertilizers and water for irrigation, pollution of water with both nitrogen and phosphorus, and significant reductions in the acreage of conservation

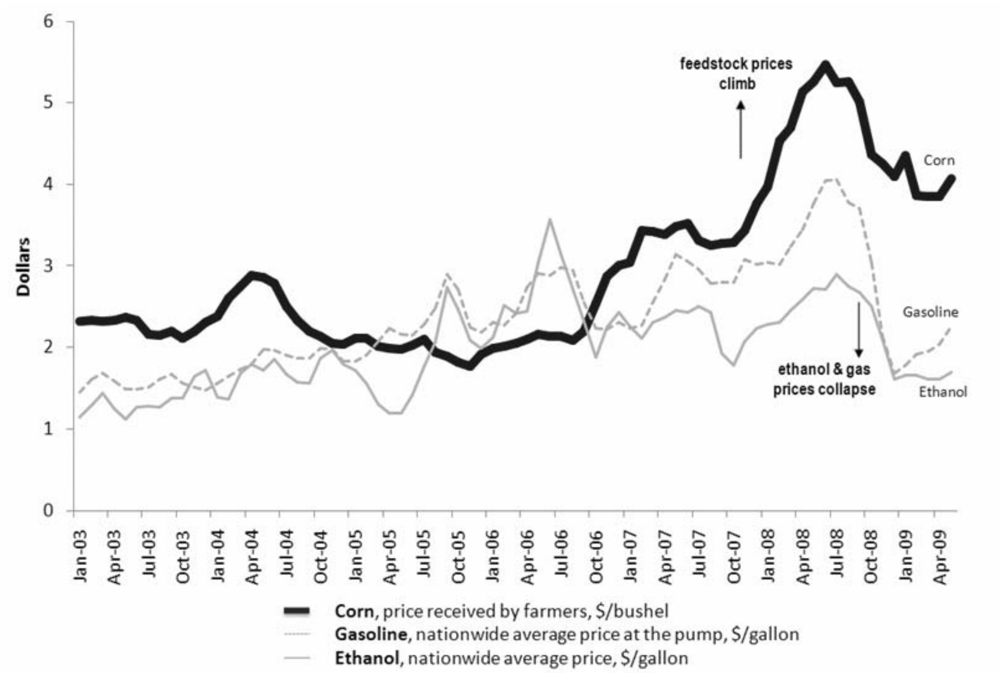

Figure 5. Ethanol, Corn, and Retail Gasoline Prices, 2003 through Present.
Source: EIA, Government of Nebraska, and USDA.

reserves.[9] However, the key charge was that corn ethanol had no GHG advantage if lifecycle analyses included indirect land use changes. In studies published in *Science*, researchers argued that using ethanol as a transport fuel would have no GHG benefits as long as deforestation in Brazil and other countries was driven by the diversion of U.S. corn acreage for ethanol.[10] This argument is often summarized simply: "U.S. corn production drove Brazilian soy producers to expand the agricultural frontier into the Amazon."

One of these researchers, Timothy Searchinger, estimated that, including direct and indirect land use changes amortized over 30 years, corn ethanol would produce 93 percent more GHG emissions than gasoline. He also challenged the positive assessment of sugarcane ethanol, by arguing that the expansion of sugarcane had displaced livestock producers, who also pushed into the Amazon. This research remains controversial, and Dr. Goldemberg addresses its results from the Brazilian perspective, arguing that sugarcane expansion occurs so far from the Amazon that it is impossible to assume it has indirect impacts on deforestation. Searchinger's work, however, raised serious doubts in policymakers' minds about whether GHG reductions could be achieved with liquid biofuels, tempering the early enthusiasm.

But the environmental debate was quickly overshadowed by the economic debate. In mid-2007, global grain prices rose sharply and much of the increase was immediately blamed on biofuels, despite clear evidence that much of the increase in food prices resulted from a combination of factors, including Australia's drought, increased global demand for meat, and controls on grain exports. The rising commodity prices made grain feedstocks, especially corn and wheat, more costly for ethanol producers and ate into their already slim margins. Humanitarian experts, nongovernmental organizations, and environmentalists called for a moratorium on biofuel mandates in the E.U. and the U.S. to relieve pressure on grain supplies.

As regulatory mandates became less certain, investment in the corn ethanol industry started to slow. The increase in production costs and decline in investments was just the beginning: petroleum prices declined in the second half of 2008, further eroding the economics of corn ethanol, and the financial crisis further constrained investment and credit. Over the winter of 2008, many U.S. plants were idled and some large producers went bankrupt. Meanwhile, sugarcane ethanol retained its market position in Brazil. Sugar prices spiked only briefly and cane-based ethanol remained competitive, even at lower oil prices (see Figure 5).

DEVELOPING COUNTRY PRODUCERS

Dr. Goldemberg highlights the ethanol export potential for developing economies based on legislative mandates in the U.S. and the European Union, particularly given the U.S. plan to expand renewable fuel use to 36 billion gallons annually by 2022. However, the size of the U.S. market for imported ethanol is constrained, particularly by a Congressional preference to protect corn ethanol production. Other nations may find opportunities to enter this market if blending mandates outstrip domestic production, but past practice suggests that Congress would adjust the mandate rather than open the market to imports. Brazil will likely dominate any opportunities to supply the U.S. market, as it remains the high-volume, low-cost producer. Under the current trade regime, Caribbean and Central American producers are importing Brazilian ethanol and re-exporting it to the U.S. These countries can supply up to 7 percent of U.S. ethanol consumption and remain exempt from import duties under the Central America and Free Trade Agreement (CAFTA)[11] regime. Considering its fleet structure, the European market is primarily focused on biodiesel and is less likely to present major opportunities for ethanol exporters.

One cannot underestimate the scale of Brazil's investment to build the modern, highly efficient, and flexible sugar and ethanol industry it has today. Few other developing countries have the finance, infrastructure, agricultural expertise, car industry, or strong central government required to duplicate Brazil's experience. However, each country can center its innovation and low-carbon growth around its own assets and unique national circumstances. Sugarcane ethanol for domestic or export markets may or may not be the best opportunity; for example, palm oil may be a much more important feedstock in Africa, given the preference for diesel in Europe, Africa's traditional export market.

Ethanol may be part of the solution for countries with major gasoline requirements, large distances to cover, urban areas with traffic congestion, and appropriate resources. But ethanol is far from a perfect substitute for gasoline. It supplies less energy by volume and takes on water from the atmosphere, so it requires high-quality blending and careful storage. Processing must be done close to feedstock sources, and sugarcane, in particular, must be processed within a few hours after it is harvested. Creating an efficient ethanol production system demands careful placement of multiple local processing facilities. Most importantly, ethanol is highly volatile and its transport requires careful handling.

One option for developing countries, particularly smaller producers, may be to create regional markets for a single ethanol-gasoline blend and establish policies to support these initiatives. For example, they might require gasoline refiners and distributors to meet a common fuel standard. A Central American and Caribbean regional policy could combine the elimination of subsidized petroleum and expand the use of domestic ethanol. That would encourage national sugar industries to become more efficient, generate local employment, and reduce dependence on imported oil. A regional market in southern Africa could take advantage of South Africa's refining capacity and market and the agricultural potential of its neighboring countries.

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Given the complexities of using ethanol as a transport fuel, it may not be the optimal energy investment choice for countries where less than half of the population has adequate access to modern energy services (energy services include lighting, cooking, heating and cooling, water pumping, refrigeration, transportation, and communications). Instead, investments in renewable energy, including modern biomass fuel options, and in alternative energy technologies (solar, wind), are much more likely to expand energy access at the village level and to have greater impacts on livelihoods and on sustainable low-carbon growth. For example, in West Africa, more than 70 percent of the population has no access to electricity; their primary energy source is unrefined biomass, which is both inefficient and unsustainable.[12]

African countries could assess the potential to cogenerate electricity at sugar production facilities, sending it either to local communities or the national grid. They may also see opportunities to process some of the sugar wastes as high-protein animal feed, a practice that is common in Brazil. In the African context,

Indirect Land Use Change (iLUC)

Heated exchanges on indirect land use change (iLUC) have occurred in the U.S. as the Environmental Protection Agency has undertaken life-cycle analyses of biofuels in compliance with the 2007 Renewable Fuel Standard. The California Air Resources Board has also recently published its analysis of fuels under California's low carbon fuel standard. Brazilian producers of sugarcane ethanol may have been frustrated to see analysts attribute Amazonian deforestation to their expansion, but U.S. corn growers were furious when they saw Amazonian deforestation via changes in soybean production attributed to their corn ethanol. The debate about how to accurately attribute indirect land use changes to particular biofuel feedstocks is somewhat intractable at this stage, critical though it might be to meeting the larger challenge of climate change mitigation in the transport sector. Data are scarce, methodologies diverse, and results are considered highly political. Pending the widespread availability of economically viable second-generation or cellulosic biofuels (and potentially even after their arrival, given global limitations on biomass production), the debate will continue to rage on how to best account for the full GHG impact of biofuel feedstocks.

To address findings about emissions from iLUC, Brazilian ethanol producers and academics have collaborated on their own research into this issue. They report that sugarcane production is so efficient that it limits the amount of new land that must be brought into use. Furthermore, they find that meat production is becoming more efficient on a per-hectare basis, reducing its encroachment on forests. Finally, the rate of annual deforestation is now slowing, compared to the recent past. These analyses, while important, would be significantly buttressed by a full national accounting of greenhouse gas (GHG) production.

A national accounting system, includings sinks and sources, would eliminate the need to track or estimate the indirect impacts of the decisions by farmers or policymakers in the U.S., E.U., or elsewhere. As Michael Obersteiner and others have argued, a full carbon accounting that covered all carbon-related components of terrestrial ecosystems would mirror "what the atmosphere sees."[13] In this model, international annual or bi-annual reports would track the flow of GHGs, both into sinks and out of sources. If Brazil were already producing a full carbon accounting on a regular basis, it would be significantly less open to accusations of rogue emissions. Brazil has fulfilled its commitments under the U.N. Framework Convention on Climate Change, producing a single National Communication with emissions data from agriculture, forestry and land use change up to 1994. A second National Communication is underway. This lack of firm data creates the opportunity for wide-ranging estimates of emissions and emission trends and attribution to a diverse set of drivers.

As sustainability criteria are established for biofuels, through regulatory or voluntary processes, Brazil and other larger producers would find that increased transparency is in their own interest, protecting both the larger biofuels market and their own reputations within it.

ethanol gel cooking stoves are an attractive replacement for unsustainably harvested wood and charcoal. Many African countries could find it useful to adopt Brazilian agricultural practices, not just for sugarcane, but for a variety of crops. Optimizing the management of biomass to improve productivity and sustainable production and use could make the transition to modern energy services a foundation for the rest of the economy.

CONCLUSION

Dr. Goldemberg has advised developing countries to examine their current development and energy paradigm in light of potential opportunities and Brazil's historical experience. That experience is clearly relevant to any sugar-producing country. But the more important lesson is Brazil's overall investment in its agriculture sector, which is among the most efficient in the world. While Brazil remains a major exporter of agricultural commodities, it continues to expand its value-added processing systems. Much like the U.S. in the 1960s, Brazil is not only a major agricultural producer, but also an industrial powerhouse. Few countries, however, have a domestic market that can support initiatives like *Pro-Alcool,* and the start-up costs would likely be prohibitive.

The U.S. had many opportunities and the scientific research base to use various "oil shocks" to drive changes in its energy mix, but the status quo politics proved too powerful for such a shift to occur. This underscores how difficult the transition to lower carbon alternatives will be without resources and policies to underpin it.

Still, Dr. Goldemberg's examination of the role ethanol played in Brazil's economic course is important as it highlights the necessity of making new energy choices in this century. As the world moves from fossil energy to more sustainable and less carbon-intensive options, there are a range of choices. It is easy for sugar producers to also produce ethanol, but it may not optimize potential benefits unless other factors are in place, including a domestic market and refining capacity. It is vital that countries be able to analyze the options rather than pursue a single course of action. There are many lessons to be learned from Brazil's experience, but they are centrally about market flexibility and resource optimization rather than ethanol alone.

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