Maintaining Brazil's ethanol fuel momentum

Arthur L. Robinson

The 1973–1974 First Energy Crisis was a cloud with a silver lining for Brazil. A severe negative balance of payments, as oil prices more than quadrupled, stimulated the birth of a bioethanol initiative based on fermented sugarcane, which vaulted the country into today's position as a world leader in the quest for renewable energy that promises to be green, affordable, and secure.

Around 1930, Brazil began experimenting with sugarcane-derived ethanol as a fuel supplement for the then newly introduced automobile. But the first in a series of oil crises provided the crucial push, resulting in the 1975 creation of the National Alcohol Program (Pró Álcool), with multiple strategies to develop a homegrown ethanol industry and to phase out fossil fuels for transportation in Brazil. Confidence in the ethanol option rose with a 1978 article in *Science* by José Goldemberg, a physicist at the University of São Paulo, and several others, whose calculations demonstrated that ethanol from sugarcane could be a renewable, clean, and profitable transportation fuel.

Today, Goldemberg told the 2009 "Ethanol Summit," an international meeting in São Paulo, that Brazil is the world's most efficient and second-largest ethanol producer (after the United States). Brazil's domestically produced ethanol accounts for about 50% of its gasoline use and is equivalent to 1% of the world's vehicle fuel needs. Brazil exports about 16% of its ethanol to countries around the world. "Brazil will be the giant in the ethanol field for the foreseeable future," said Chris Somerville, director of the Energy Sciences Institute at the University of California, Berkeley, where advanced bio-energy technologies are being explored.

But comparatively speaking, Brazil's ethanol production is still only a drop in the world's energy bucket. Blessed with a huge unused land area for planting crops for both food and fuel and an equatorial climate with both rain and sun for growing high-energy-density sugarcane, Brazil has been looking at how to make a bigger splash as a competitive player in the world energy economy while meeting its own needs. Both the Ministry of Science and the Ministry of Agriculture, Livestock, and Food Supply are intimately involved.

A larger government-industry worry is that, in general, Brazil lacks a science culture, and, in particular, that domestic science, technology, and innovation must play a more decisive role in the country's sustainable development, which motivated the science ministry to initiate its "Action Plan 2007–2010 for Science, Technology and Innovation (STI)." The plan spans a wide range of programs, including the research and development (R&D) of clean, efficient, and renewable energy technologies, particularly ethanol and its companion, biodiesel. Brazil's agriculture ministry has a companion and equally wide-ranging initiative, the Brazilian Agroenergy Plan 2006–2011, with the mission to produce and transfer knowledge and technologies that contribute to the sustainable production of energy from agriculture.

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Quite a lot can be done before more advanced technologies are needed, according to Goldemberg. He predicts that by combining genetic improvements (e.g., by cross-breeding) to double the ethanol yield of sugarcane with increasing the area planted to 10% of its arable land, Brazil could ramp up ethanol production sufficiently to displace 10% of world gasoline consumption.

A government-sponsored study led by Rogério Cezar de Cerqueira Leite from the Interdisciplinary Center for Energy Planning (NIPE) at the State University of Campinas, which was published in 2008, analyzes in detail the requirements for a 5% world penetration by 2025. Its favorable but caveat-loaded conclusion provides some support for Goldemberg's view, while it also looks to future technology challenges.

Fernando Galembeck of the Institute of Chemistry at Campinas points to one particularly demanding test: The distillation step in which the water is removed after fermentation of the harvested and milled sugarcane produces ethanol. Distillation is an energy-intensive process, although, at present, burning the sugarcane stalks—remaining after fermentation (bagasse)—and other waste products can be used to provide this energy while exporting the excess to the electricity grid, a by-product accounting for about 3% of the nation's total electricity. However, a lower-temperature dehydration process based on separation membranes would save energy, as well as prevent the respiratory problems reportedly associated with burning bagasse. Though lots of work is focused on these membranes, "we're not even close," said Galembeck.

As the alleged respiratory effects suggest, biofuels from sugarcane and other raw materials are not universally seen to be as environmentally and socially benign, as often portrayed. Critics frequently bring up the specters of deforestation in the Amazon and competition for land for food and fuel. In contrast, Leite's study found no need to intrude on the environmentally precious rain forest nor on massive irrigation, but both land and water use, nonetheless, remain among several issues calling for careful oversight. Galembeck at Campinas points out that 2009 zoning laws forbid sugarcane plantations in any native biomass, including the Amazon forest, the floodplains in the west (Pantanal), and the remnants of the eastern tropical forest (Mata Atlântica).

Galembeck also argues that a synergy between fuel, food, and raw materials for other types of products is possible, while Esdras Sunfeld, the deputy head of R&D at the soon-to-open Agricultural Research Center for Agroenergy of the Brazilian Agricultural Research Corporation (EMBRAPA), part of the agriculture ministry, said that "the sugarcane sugar/ethanol/electricity plants that exist in Brazil are the precursors of the modern bio-refineries of the future." In bio-refineries, sunlight and biomass of several types would be converted in a sustainable, closed system to fuels, heat, electricity, and materials, and waste products would be recycled.

To remain competitive, Brazil is preparing for a future that is likely to include increased use of bio-diesel fuels and the introduction of so-called second-generation technologies, such as cellulosic ethanol and, ultimately, genetically engineered and synthetic organisms.

Bio-diesel technology based on fatty esters from soybeans and other oil-bearing plants, for example, already exists, and the products are used in blends with diesel fuel. To ramp up production, transesterification and hydroesterification processes need to be much more efficient, explains Donato Aranda of the Green Technology Laboratory at the Federal University of Rio de Janeiro. At the International Conference on Advanced Materials in 2009 he reviewed progress in heterogeneous catalysts, based, in part, on molecular modeling, and he described several pilot plants now in operation.

Sugarcane plantation in Brazil. © Elder Vieira Salles.

Cellulosic processes for bioethanol enable use of the entire sugarcane plant and are also the key to making other crops, such as grasses, that grow well in many parts of the world, more important biofuel sources. In addition to the raw sugar, polysaccharides in plant cell walls of sugarcane (and other plants) are rich sources of sugars, but so far, no way has been found to efficiently break them down to extract the sugars, and it takes more energy to convert the raw material than what is gained. If extraction could be done efficiently for bagasse and sugarcane trash, for example, the acreage required could drop by 35% or so, according to the Leite report.

Current research focuses on enzymes as catalysts for the key hydrolysis process. Some are optimistic, including Steen Riisgaard, CEO of Novozymes, a Danish company active in Brazil. Riisgaard told the Ethanol Summit that Brazil's cellulosic ethanol production potential from sugarcane biomass is between 2.5 and 4.3 billion gallons by 2020. Catalyst designers might also profitably take a cue from the chemical industry in designing novel synthetic organic catalysts that can depolymerize biomass or convert sugars to fuels, suggests Berkeley's Somerville, who adds that synthetic organisms could also be programmed to produce fuels other than ethanol, such as petroleum look-alikes that would be more compatible with current industrial technology.

In Brazil, new laboratories are sprouting up, in part, to explore cellulosic biofuels. In addition to the EMBRAPA Agroenergy Center, the Bioethanol Science and Technology Center (CTBE), headed by Marco Aurélio Lima, is a recently dedicated national laboratory founded by the Ministry of Science and Technology in Campinas. The center's projects include a pilot plant for the transformation of lignocellulosic biomass into ethanol on a semi-industrial scale.

In the end, Brazil's ethanol represents just one path toward weaning the world away from its reliance on fossil fuels with their increasingly dire economic, environmental, and national security consequences. Brazilian scientists agree with their confreres around the world that it will take the combined contributions of many renewable technologies, each tailored for regional resources and needs, to carve out this future. □

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