

# Bio-refineries of the future

Studies reveal forecasts about the share of ethanol in agriculture and the fuel matrix

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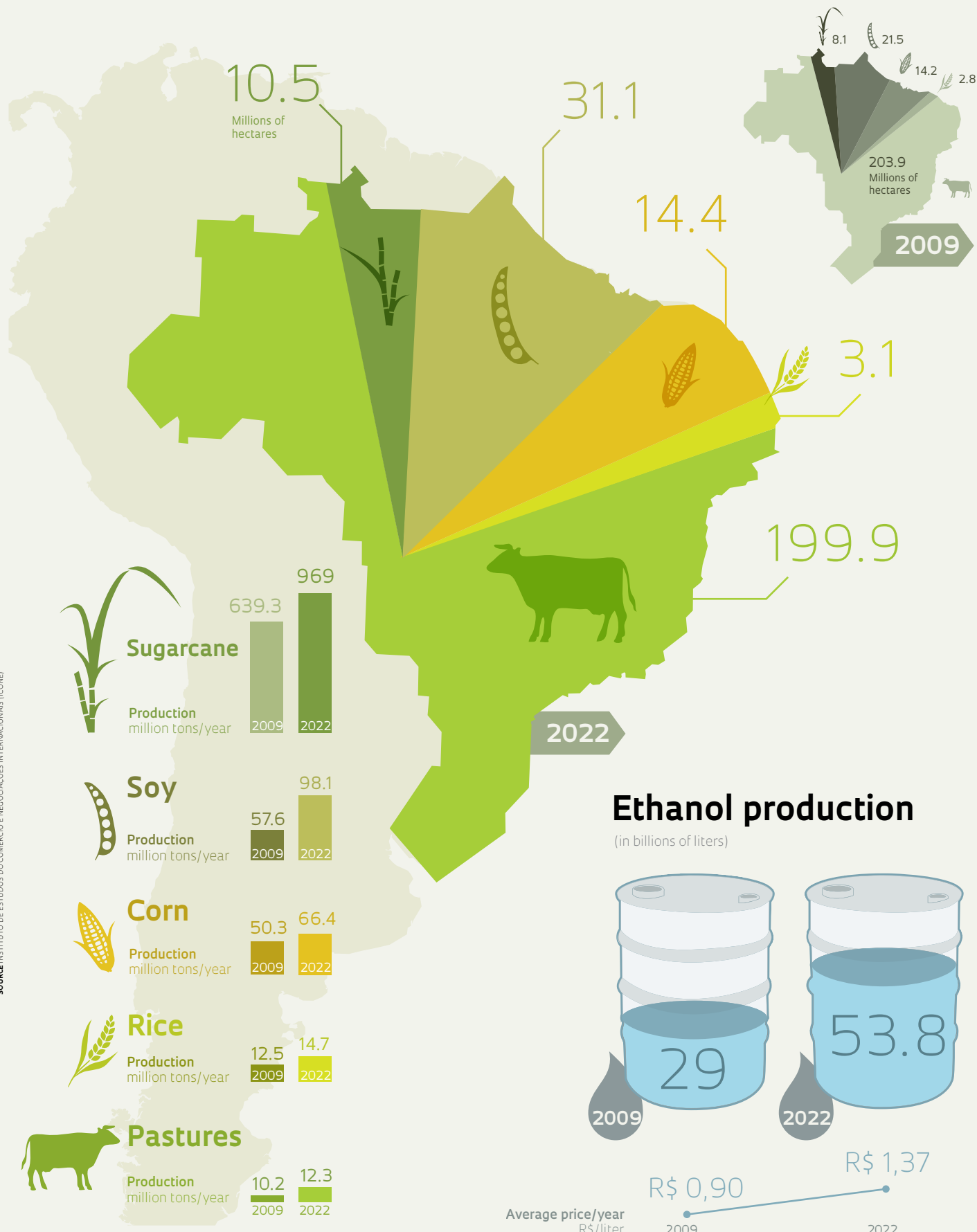
The future of ethanol production appears to be more promising than the forecasts have indicated. According to a study by researchers from the University of São Paulo (USP), in 20 years, it will be possible to supply the entire world's automobile fleet using ethanol and electricity produced in sugarcane mills. "This can be done by using the ethanol and electricity more efficiently, with more economical vehicles," says Sergio Pacca, a professor from the School of Arts, Sciences and Humanities at USP Leste, in São Paulo. Professor Pacca and Professor José Roberto Moreira from USP's Institute of Electronics and Engineering are the authors of the article "A biorefinery for mobility?", which was published in October 2011 in the journal *Environmental Science & Technology*.

The conclusion that these authors reached is based on the automobile fleets of Brazil and the United States. For sugarcane to supply both ethanol and electricity, they calculated that the ideal proportion of electric automobiles to hybrids in 2030 would be 33% to 67%. The hybrids should have highly efficient engines that achieve 15 km per liter of alcohol, and the electric engines should be powered using energy generated by the ethanol engine and vehicle braking, akin to Toyota's Prius system. Under this scenario, if each American automobile is assumed to travel 20,000 km a year and each Brazilian vehicle is assumed to travel 12,000 km, a single hectare of sugarcane would be sufficient to supply 9.2 vehicles in the USA and 11.6 vehicles in Brazil, provided that the ideal proportion of automobile types is maintained.

As an alternative, all of the automobiles in both countries could be of the hybrid plug-in type, with batteries recharged using power plugs and an ethanol engine that starts when the batteries discharge, as for GM's Volt. The study considers the current production technology that could be used by all mills to increase bioelectricity generation. Pacca and Moreira also forecast that 50% of the straw that is currently left in the field will be used to generate electricity. They believe that it would be possible to achieve 90 liters of ethanol per ton of sugarcane (l/TC) - the average is currently 83 l/TC - and use just 4% of the cultivated area of the planet. The scenario that the USP researchers outline does not consider the prospects of the second generation of biofuels currently under development, including those that use bagasse and straw along with the sugarcane juice currently used to make ethanol.

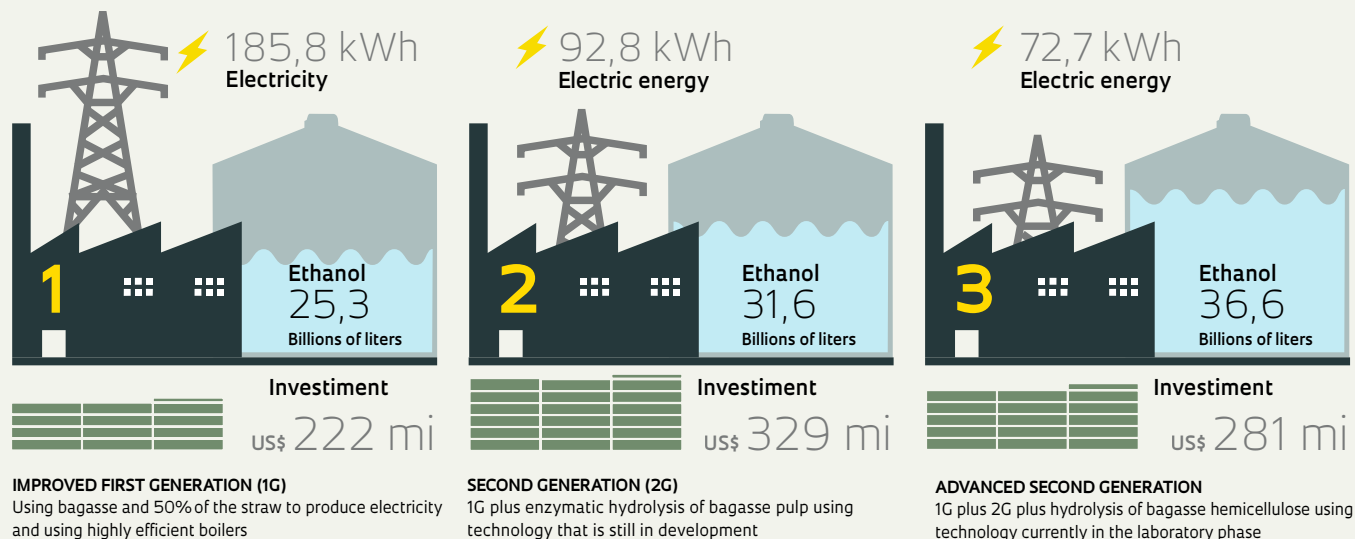
The authors' calculations for the ethanol production sector in Brazil in 2030, with the ideal proportion of 33% electric automobiles (approximately 12 million vehicles) and 67% hybrid vehicles (20 million), forecast the use of 2 million hectares of sugarcane to produce alcohol in comparison with the current 8 million (one half used to produce ethanol and the other half for sugar). These 2 million hectares will produce 16.3 billion liters of ethanol, approximately 8 billion less than the 25 billion liters produced using the 2010/2011 crop. The area used to cultivate sugarcane will decrease because the production efficiency will increase and the automobiles that depend on ethanol will become more efficient. Within the scenario described, 23 terawatt-hours (TWh) per year would be produced

# Probable agricultural production scenario in 2022



SOURCE: INSTITUTO DE ESTUDOS DO COMÉRCIO E NEGOCIAÇÕES INTERNACIONAIS (ICONE)

# Three scenarios for biorefineries



SOURCE CTBE

from the burning of bagasse and straw to power the country's electric cars. However, there would no longer be any surplus electricity, which is currently sold.

## EFFICIENT PROPOSALS

Pacca believes that public policy plans would be necessary for this scenario to work, including tax incentives for those who buy hybrid, electric or plug-in hybrid vehicles and tax penalties for those who drive vehicles that consume a lot of energy. "These policies benefit the most efficient cars." Pacca and Moreira's calculate that 66 million hectares of land worldwide would be needed to cultivate sugarcane (in 2010 there were 23.8 million) to supply the entire world's fleet of vehicles with ethanol and electricity.

"The calculations are reliable, but for this scenario to occur, it will also be necessary to improve the ethanol productivity per hectare, utilize second-generation fuels and new cane varieties, and increase the number of efficient vehicles," is the analysis of Professor Lee Lynd from The Thayer School of Engineering at Dartmouth College in the United States. Professor Lynd is the executive coordinator of the Global Sustainable Bioenergy (GSB) Project, a group of international researchers in bioenergy.

The researchers from the Brazilian Bioethanol Science and Technology Laboratory (CTBE) in Campinas (SP) are less optimistic. In collaboration with the

Faculty of Chemical Engineering of the State University of Campinas (Unicamp), they wrote the article "Second generation ethanol in Brazil: can it compete with electricity production?", which was published in the scientific journal *Bioresource Technology* in October 2011. In this article, the influence of the second generation on ethanol production was analyzed using three projections, including the use of electricity generated at mills and the future hydrolysis of pulp and hemicellulose, both of which are components of bagasse. "We developed computer simulations to monitor the different methods for taking advantage of the production. We prepared spreadsheets that calculate the risks and values that are most probable," explains Antonio Bonomi, the CTBE's director of technological assessment.

One of the scenarios proposed by the researchers as a model for an existing cane-based biorefinery is an improvement in the first generation, which currently produces alcohol without using bagasse. "The initial reaction would be to take advantage of 50% of the straw. Currently, almost all cane leaves remain in plantations during the harvest. In the past, all of the leaves were burned off before this stage, but now excess straw is left in the field. This straw forms a cushion that makes it difficult for the machine [harvester] to enter the sugar plantation. It is estimated that at least 50% can be removed, but part of the

straw needs to remain in the field to protect the soil from erosion, maintain humidity and recycle nutrients" explains Bonomi.

In addition to producing electricity from straw, Bonomi forecasts an increase in the production of electricity using highly efficient boilers with pressures up to 90 bar instead of the current 22 bar. This change would enable greater production of electricity, which would be used to power the mill itself, with any excess being sold to the national grid. If all of the mills exchanged their boilers and used 50% of the excess straw, electricity generation would increase to 185 kilowatts an hour per ton of cane (kWh/TC) - an increase of 620% over the current 30 kWh/TC. According to the Sugarcane Industry Union (Unica), 8774 gigawatt-hours (GWh) were pro-

## THE PROJECT

Simulating land use and agriculture expansion in Brazil: food, energy, agro-industrial and environmental impacts - n° 2008/56156-0

**MODALITY**  
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R\$ 67,886.54 (FAPESP)

duced from cane in Brazil in 2010, representing just 2% of the 509 TWh of total electricity consumption in the country. With the suggested improvements to the first-generation mills, the researchers are forecasting production of 89.3 liters of ethanol per ton of cane (l/TC).

In a second scenario, the researchers also include second-generation fuel production, the hydrolysis of pulp, representing 40% to 60% of bagasse, which also contains hemicellulose (from 20% to 40%), and lignin (from 10% to 25%). This procedure, which uses part of the cane straw, will increase production to 110.7 l/TC; however, electricity production will fall to 92.8 kWh/TC, half of that in the first scenario. In this case, biofuel is more profitable than electricity, even though the enterprise has a smaller financial rate of return because the investment grows with the adoption of the second generation. "In a study carried out by our group, we calculated that the return on production of the second generation is almost five times greater than the return on cogeneration electricity," says Lynd.

The CTBE estimate of the investment in first- and second-generation etha-

nol production units is US\$ 329 million. In contrast, the investment is US\$ 222 million the first scenario, with only improvements to the first generation. "The investment carries considerable weight. It is higher than the production costs and decreases the rate of return in the second-generation scenario compared to improving the first-generation facilities."

One way to improve the return for the mill owner and make such business more attractive is to ferment the pentose sugars produced by hemicellulose, as these sugars can also be made into alcohol. However, this conversion process is not yet a commercially viable technology. "Were it to become possible to use the hemicellulose and other advanced hydrolysis technologies, ethanol production would grow to 131.5 l/TC, the weight of the investment would decrease as more ethanol was sold, and the cost to the mill-owner would decrease, thus increasing the rate of return" says Bonomi. With the use of hemicellulose, biorefineries would generate less electricity, from 185.8 kWh/TC to 72.7 kWh/TC. "In Brazil, mill-owners will never stop using part of the bagasse and straw to generate electricity for use in their own mills. This is the great Brazilian advantage," says Bonomi.

#### USE OF THE LAND

However, the fact that Brazil is strong in agriculture for food production and is using suitable food-producing land to plant sugarcane is being questioned abroad. However, according to a study by the group led by economist André Nassar from the Institute of Trade Studies and International Negotiations (Icône), with funding by FAPESP (São Paulo Research Foundation) within the Bioenergy Research Program (Bioen), this problem is non-existent. In the scenario outlined by the institute, sugarcane cultivation is likely to occupy 10.5 million hectares in 2022, as compared with 8.1 million hectares in 2009.

This 30% growth in sugar plantations is likely to occur in the Southeast region, particularly in the pasture areas currently used for cattle-rearing and in the Midwest region where it is likely to substitute areas traditionally used for pasture or grain cultivation. "Today, livestock farmers produce more meat per

hectare. In 1996, 6 million tons of meat were produced on 184 million hectares. Ten years later, production had reached 9 million tons on 183 million hectares. The herd in this same period went from 158 million head to 206 million," explains researcher Leila Harfuch from Icône. "Between 2009 and 2022, pastures area is likely to decrease by approximately 5 million hectares, accommodate part of the grain and sugarcane expansion."

The conclusion is based on a model created by the Institute called the Brazilian Land Use Model, which describes supply and demand for agricultural products and the use of land in the country. This model indicates that expansion into native areas will not occur because of biofuel production but for food production. "The area where there is more competition for land and the yield is better for the farmer is the *Cerrado* [tropical savanna], which may have an impact on native forests. However, intensification of agriculture and livestock farming in the future should lead to smaller demand for new area relative to in the past."

The model predicts an increase in ethanol production from 29 billion liters in 2009 to 53.8 billion in 2022 without considering second-generation production. "We assume that exports to the United States are likely to reach 9 billion liters per year in 2022." This survey was performed before the announcement of the end of the import tax in the US announced in December. "We calculated 9 billion liters in this scenario because the Americans will have to reduce their consumption of fossil fuels and the greenhouse gases they emit, and ethanol from Brazilian sugarcane and US corn should fulfill part of that mission" says Leila.

"Projections for the energy potential of biomass must be very cautious, particularly in a world motivated for sustainable energy and development of rural economies, which biofuels can offer if carefully implemented," adds Lynd. ■

#### Scientific articles

1. Pacca, S.; Moreira, J.R. A biorefinery for mobility? *Environmental Science & Technology*. v. 45 (22), p. 9498-505. online, October 3, 2011.
2. Dias, M.O.S.; Bonomi, A. *et al.* Second-generation ethanol in Brazil: Can it compete with electricity production? *Bioresource Technology*. v. 102, n. 14, p. 8964-71. Oct. 2011.

