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In Search of A Biofuel El Dorado: The Quest for Brazil's Energy Independence Future is one in a series of papers published by Advanced Biofuels USA exploring the technologies, products and policies related to the development, deployment and use of advanced biofuels.

"and though you came with sword held high
you did not conquer, only die"

Conquistador by Procol Harum, written by Keith Reid

In Search of A Biofuel El Dorado:

The Quest for Brazil's Energy Independence Future

by Robert Kozak

El Dorado

In 1568, a Spanish Conquistador by the name of Pedro Maraver de Silva led his men on a mission to capture Incas who had escaped with their gold. Journeying north of Peru, they encountered the headwaters of the Amazon and the great plains (*gran llano)* of what is now Brazil. Almost to a man they were killed or driven mad by the diseases of the rivers, the droughts of the grasslands, or the arrows of the tribal warriors. One who did survive, Juan Martin de Albujar, returned not with Inca gold but with something much grander, the story of El Dorado.[1]

"Gold on the skin of a great chief; gold on the glistening bodies of his warriors; gold gleaming from the arms and legs and breasts of the Indians, from the temple vessels and statues; gold that seemed to throb from the rocks beneath his feet."[2]

When word of El Dorado reached the great English explorer, poet, and philosopher Walter Ralegh (known in the US for the 1587 "Lost Colony" settlement in North Carolina) it was enough to overcome his rationality and inflame his soul with a fever. It would be Ralegh who would conquer El Dorado and offer the gold to his queen and unrequited love, Elizabeth I.

With his maps, sailors and soldiers he would land on the coast and venture upriver into the wilds of the Americas twice in search of El Dorado. Instead of presenting his monarch with gold, he would provide his head. Elizabeth's successor, James I, was not pleased with either Ralegh's costs or results. On October 29, 1618 he was beheaded.

El Dorado fever did not end with Ralegh. "Over the mountains and up the rivers went expedition after expedition; Spanish, Flemish, and German (working for the banking house of the Welsers), each wrecked in its own way, some broken as they tried to ride the churning falls, others patiently roasted on the scalding aridity of the llano, other still smothered in velvet darkness as the creeping forest closed about them."[3]

In the writings of the European El Dorado explorers and mystics, their destination is described as an unspoiled Eden to be reclaimed by them. *"...nature is perfect till man deforms it with care"*[4] wrote naturalist Alexander von Humboldt who explored the Orinoco and Amazon River headwaters in 1800 and had an arrest warrant issued by Brazilian authorities for his efforts.

In this incredible environment inhabitants of the Amazon and Orinoco basins were seen as either barriers to El Dorado or near mystical creatures, "[*the women were] very young and excellently favored which came to us without deceit starke naked*" (Ralegh) that could lead to Eden and the gold. Never were the warriors and women of the tribes seen as people who had rights to their lands who were trying to survive in their environment, much as herders and farmers in Europe did.

"The Road to the Future Runs Through Brazil"
(*Biofuels Digest,* 2011 Article Headline)

For many people in biofuels, there is thought to be a new El Dorado in Brazil. Instead of gold, there will be an unlimited supply of biofuel sugar ready for export. It will be available for biofuel production in Brazil or as a feedstock for the US, Asia, or Europe. The sugar will be cheap. It will never cost more than $.10/lb (US dollars). It will be available without research costs or the need to negotiate with individual growers. Any additional acreage needed will magically appear, rainfall will always be abundant and the waters of the Amazon basis will never run low.

As for the approximately 203 million people who live in Brazil, what role would they play in this modern El Dorado quest? We could ask the *"biofuel conquistadors"* or we could try to learn about the energy challenges confronting the people who live there and will have to solve them long after the *biofuel conquistadors* have moved on.

Coming Into Country

Before we begin our journey up river to search for El Dorado, let's find out something about Brazil and how Brazilians are currently dealing with energy. Since Brazil covers about the same amount of land as the US (92%) and both countries produce large quantities of agricultural products, including ethanol, some basic comparisons with the US might be a good place to start.

Some people may find it surprising that the same percentage of people in both countries live in urbanized areas (87% and 83%) and the population growth rates are virtually identical (1.13% and .96%). Three significant differences do pop up though.

- One, the poverty rate in Brazil is over twice that of the US.
- Two, the agricultural sector in Brazil requires significantly more labor. While less than 1% of the US workforce produces food and biofuel for domestic use and export, 20% of the workforce in Brazil is needed to produce about 50-60% of the US agricultural output.
- Three, the cost of borrowing money in Brazil is astronomical (the prime rate is 44% per annum versus about 3% in the US).

Brazil and the United States: Basic Comparisons

(Information from CIA-The World Fact Book Website)

	Brazil	USA
Area Km^2	8,500,000	9,200,000
Population	203,000,000	304,000,000
Population Density (/km^2)	23.88	33.04
% Urbanized Population	87.0%	83.0%
Population Growth Rate	1.13%	0.96%
Percent Population Below Poverty Line	26.0%	12.0%
Agriculture % GDP	6.0%	1.2%
% Work Force in Agriculture	20.0%	0.7%
Public Debt % GDP	60.8%	58.9%
Loan Prime Interest Rate	44.0%	3.0%

Producing Energy

Current energy production in Brazil is split almost evenly between renewable and non-renewable sources.[5] Renewable energy production includes:

- Approximately 90% of electricity is from hydroelectric installations. The waterfalls that stopped Ralegh have been harnessed to turbines.
- 5% of electricity is from biomass combustion (primarily sugar cane bagasse).
- 40-45% of fuel produced is sugar cane ethanol.

At the same time the Brazilian national petroleum entity Petrobras processes approximately 2 million barrels of oil a day into both gasoline and diesel fuel. Additional refining capacity is not scheduled to come on-line until 2013.

Brazil has recently discovered large offshore petroleum deposits estimated at 14.2 billion barrels. The deepsea drilling required to access these deposits has been moving ahead slowly because of reduced international investments meaning significant additional production is probably at least five to ten years away.

Brazilian Energy Use Requires Imports

Despite the large oil deposits, 400 ethanol producers, and large hydroelectric projects, Brazil is currently an energy importer. Salient current energy imports include:

Petroleum: 1.5 million barrels/day of refined fuels, gasoline and diesel, are currently imported. Because refined products instead of crude oil are imported, Petrobras has recently been losing money since the spot market purchase price for gasoline and diesel has been higher than the controlled selling prices for gasoline and diesel in Brazil. For every $.10 (US)/gallon the spot price is above the $(US) 3.19/gallon Brazilian price, Petrobras loses approximately $6 million dollars (US) per day.

Ethanol: In 2010, Brazil imported 17.9 million gallons of ethanol from the US.[6]

Electricity: Approximately 10% (42 KwH of 438 Kwh) is imported annually from Paraguay[7]

Natural Gas: 8.4 billion meters^3 of 18.72 billion meters^3 (45%) were imported annually in the last available data.[8]

These figures say very clearly that in order for Brazil to be energy independent, fuel as well as electricity production must be increased even to meet current needs. As Brazil moves forward to improve the economic conditions of its people, what does future energy use look like? In a recent report[9] on building a low-carbon, sustainable economy the following estimates of future total energy needs were reported.

ENERGY CONSUMPTION (POWER AND FUEL) FORECAST IN BRAZIL, 2010–2019
SOURCE: EPE (2010)

TECHNOLOGY	2010	2014	2019
Consumption – w/o conservation (103 toe)	184,110	235,628	309,229
Conserved energy (103 toe)	1,467	5,481	13,325
Conserved energy (%)	0.80%	2.30%	4.30%
Consumption – with conservation	182,644	230,148	295,904
(%) Increase -with conservation		**26.0%**	**62.0%**
Annual Increase (%)		**6.5%**	**6.9%**

Even with some energy conservation in place, projected population increases and more important, improvements in the economic conditions of Brazilian people, will produce percentage increases in energy use well above those projected for most developed countries.

Three energy questions therefore confront Brazil:

- How much of this increased demand can be met with renewable energy?
- How fast must the 14.2 billion barrels of oil deposits be used?
- How many nuclear plants are needed to be built?

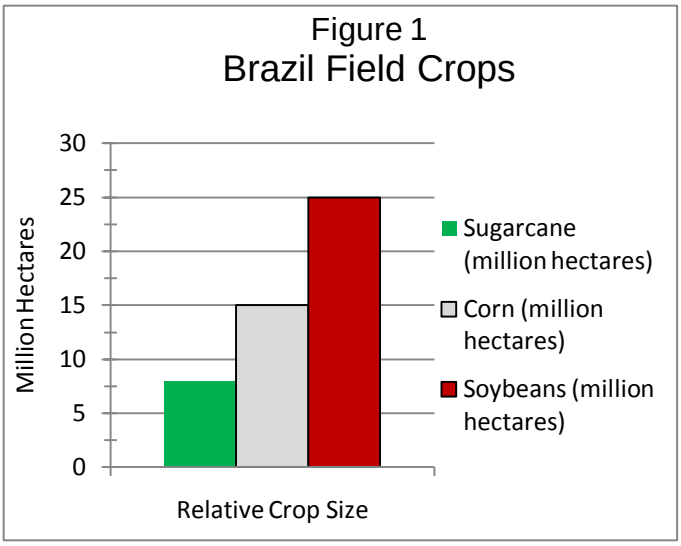
Given the much talked about potential of expanded biofuels and biomass electrical production in Brazil (or is it El Dorado?) in many ways the future of Brazil's energy independence turns on the question:

Is there or isn't there
a new bioenergy El Dorado?

It is time to get to the get the heart of the matter, or as Walter Ralegh would have said, "time to go up river."

Biofuel Futures (1): Sugar Cane Ethanol

Current sugarcane production comes from 8 million hectares (1 hectare=2.47 acres) of land. This is approximately 1.5% of total agricultural land. Even with ethanol production growing at 18%/year from 2006 to 2009, this sugarcane acreage is currently a distant third behind corn and soybean cultivation (Figure 1).[10]The significant acreage devoted to corn and soybeans is in large part due to increased agricultural exports. Between 2000 and 2008, Brazil increased its global participation in agribusiness exports from 4.1% to 7%, having grown to a rate of 19% in the period, behind only Indonesia. Today Brazil is the 3rd major agricultural sector exporter in the world, after the U.S. and the 27-member group of countries in the European Union (FAO, 2010) FGV report.)[11]

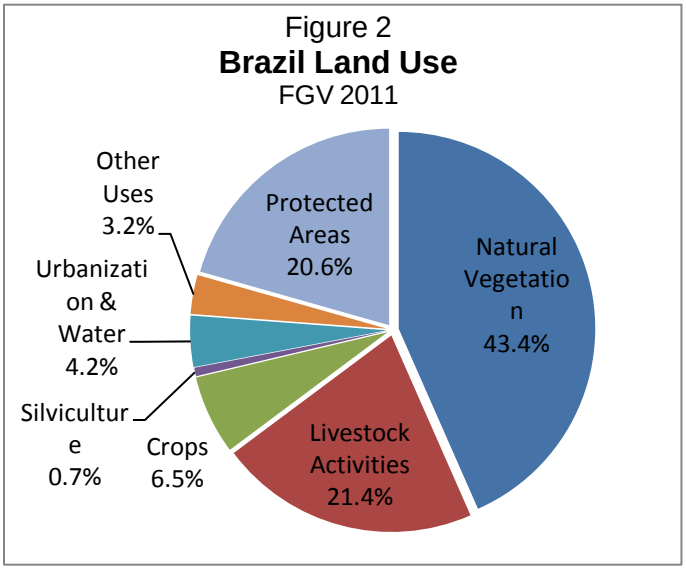


A potentially large increase in Brazilian ethanol production could occur since under current Brazilian Federal agricultural land use plans, up to 62 million hectares could be used for sugar cane. This significant increase of 54 million hectares is greater than current soybean and corn croplands (54 million hectares vs 40 million hectares) combined. Federal plans envisioned that additional sugarcane acreage would come primarily from pastureland (74%), with only a small amount (.5%) from natural lands.[12] However, is this increase in sugarcane cultivation realistic?

Figure 2[13] shows current land use. It appears that the 58 million new sugarcane hectares would probably reduce Livestock Activity land by several percentage points (6.5% for Crops is equal to about 100 million hectares.) So, while improved livestock and pasture practices are a goal of Brazil, additional land for livestock could be needed. The only source of this land would be in Natural Vegetation areas. Yes, expansion of sugarcane cultivation to the maximum allowed limit would most likely cause an indirect land use change that would result in some portion of Brazil's natural vegetation being converted into pasture land.

Large scale intrusions into natural vegetation areas for new pasture land or other livestock activities are taken seriously in Brazil. In addition, if the increases in sugarcane were planted for export, additional "local use versus export" conflicts would be created.

It is probably safe to say therefore, that while a total of 68 million hectares are allowed for sugar cane, that amount of sugar cane



cultivation will probably never be reached, especially if some smaller amount could provide for Brazil's needs. The sugar cane El Dorado that the *Biofuel Conquistadors* are looking for may not be around the next bend.

Biofuel Futures (2): Biomass Biofuels

The greatest renewable transportation fuel challenge for Brazil is diesel fuel. According to the National Agency for Petroleum, Natural Gas, and Biofuels figures, forty-eight percent (48%) of total fuel use is for diesel powered vehicles. Much diesel fuel also has to be imported because of a lack of refining capacity.[14]

Biomass sugars from agricultural residues would be a very good feedstock for renewable diesel production. Currently in Brazil, three buses are running on a "drop-in" B-10 mixture produced from the Amyris yeast sugar fermentation process.[15] Novozyme has also been working with the biomass residue (bagasse) from sugar cane to produce biofuel sugars.

The large quantities of bagasse produced from the current 8 million hectares of sugar cane and the even larger quantities that would be produced from the projected 62 million hectares are among the ***El Dorado Sugars*** the *Biofuel Conquistadors* are searching for.

But, when the *Biofuel Conquistadors* landed they were met with a government policy that was hard to understand. Brazil was not investing in 2nd generation (cellulosic) biofuel research.[16] Why, they wondered? Is it to preserve sugar cane sucrose prices? Is it because of some political opposition to government R&D spending?

No, there is instead a very simple answer. **Sugar cane bagasse is an important Brazilian electricity production fuel.**[17] As mentioned above, 5% of the country's electricity is currently produced from biomass. And, with investments being made to replace bagasse boilers and processing equipment with state-of-the-art systems, increases have already been built into national system plans. In the immediate to mid-term future, any **additional bigasse produced from new sugar cane cultivation will be used for electrical production**.

How Sustainable is Brazil's Renewable Energy Supply?

The 2010-11 Drought

> *"The reaction of the pollution chain transformed the burning and destruction of the Amazon forests into a problem in the South and Southwest of Brazil. The scientific experiments that took place in the last years by the LBA [Large Scale Biosphere-Atmosphere Experiment in the Amazon, under the scientific coordination of INPA] revealed that a reduction of rains in the South and Southwest regions is intimately linked to the existing environmental in the northern region of the country." (Ottoboni, 2004)*[18]

In 2010 and 2011, the effects described above happened. The reduction in rains in the south and southwest regions were so significant that large parts of Brazil, including the sugar cane growing areas suffered what is called a "one-hundred year" drought. For some areas of Brazil, this was the second "one-hundred year" drought of the decade. The effects of the 2010-2011drought on sugar cane harvests were dire. According to the Superintendent of the Union for Sugar and Ethanol Industry of Pernambuco State, ethanol production fell by 18% and electrical production fell 32% in his region.[20]

Media outlets have covered the cascading effects of this decrease in ethanol production. In April 2011, ethanol prices, which are not

controlled, rose to $1.73/liter ($6.75/gallon). This immediately increased gasoline sales, which are controlled at $3.19/gallon. Petrobras had to increase gasoline imports, bought at spot market prices that were above the controlled selling price, to meet this demand. This meant Petrobras lost money on most of the increased imports. [20]
Government response was two-fold.

First, the minimum quantity of ethanol allowed to be mixed in gasoline was lowered to 18% (and some ethanol imported from the US was used as well).

Second, in a move that will become significantly more important in the coming years, in April 2011, the Brazilian government began to regulate the ethanol industry. The first step was to define ethanol as a fuel instead of an additive. By taking this action the National Petroleum, Natural Gas and Biofuel Agency (ANP) was given similar regulatory power for ethanol that it exercises over petroleum and natural gas.

Initial ANP ethanol actions (as of May 2011) have included interventions in ethanol exports and financial actions based on biofuel stocks.

Also in response to ANP being given regulatory authority over ethanol, the government owned petroleum entity Petrobras announced they were increasing their ownership of ethanol production from 5% to 15% over the next four years.[21]

As can be expected, reactions to the government decree have ranged from anxiety to alarm. Even though no one at ANP or elsewhere in the Brazilian government has said anything about nationalizing the ethanol industry, the red flag of nationalization is being brought to the pole planted in the *llano* by some of the *Biofuel Conquistadors.*

Future Renewable Energy Yields in Brazil

While some people see the 2010-2011 drought as a one-off event, the fact that it tracks with environmental models should cause a serious consideration of what level of renewable energy Brazil can produce in the future. Will there be sufficient water in the rivers to run the electric turbines? Will there be sufficient rainfall to grow the crops that will produce biofuels and biomass electricity?

There have been studies performed on the future water flows of Brazilian rivers based on Climate Change models and changes in South American land use. Brazilian decisionmakers and industry leaders are aware of what the results of these studies mean.

The following table is from a 2011 study (***Public Policy Proposals by the Business Sectorfor a Low Carbon Economy in Brazil: Energy, Transportation, and Agriculture***,)[22] commissioned by a coalition of twenty-eight Brazilian companies to provide a policy road-map for the country's energy future.

WATER FLOW IN THE MAIN BRAZILIAN RIVER BASINS SOURCE: Margulis & Dubeux (2010)							
			A2-BR SCENARIO				
	1961-1990		2011-2040		2041-2070		2071-2100
Tocantins	13,264		9,945		9,091		6,434
Amazon	131,047		123,238		111,609		91,930
Paraguay	2,368		2,145		2,169		3,470
Oriental Atlantic NE	779		133		83		2
Atlantic East	1,492		423		375		88
Paraná	11,453		10,764		9,649		12,669
Parnaiba	763		261		150		75
Sao Francisco	2,850		1,223		1,227		1,504
Atl antic South	4,174		4,659		4,496		4,599
Uruguay	4,121		4,435		4,511		4,342
Southeast Atlantic	3,179		3,174		2,674		3,036
Occidental Atlantic NE	2,683		1,915		1,670		1,250
Total	178,173		162,315		147,704		129,399
(%) Reduction			**8.9%**		**17.1%**		**27.4%**

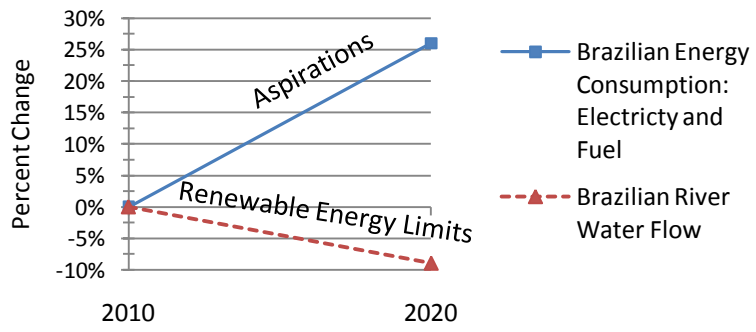
One could quibble about the numbers for each river, but the overall trend seems clear. **The water for hydroelectric power, sugar cane, and other crops is decreasing**. The eternal rivers of Walter Ralegh will be running lower for the next generation of Brazilians.

No matter what laws or regulations may say about how much land may be cultivated or used for animal pastures, or how efficient new hydro-generators may be, the great rivers of South America will put a limit on how much energy can be extracted.

Figure 3

The Brazilian Energy Dilemma

FGV 2011 Data



For Brazilians, their energy future may be expressed by the following graph (Figure 3).

Just as Brazil foresees a bright economic and social future powered by increased renewable energy, the very source of that power has been reduced by the actions of humans, present and in the past. This is the dilemma confronting Brazil.

Brazil, like every country on the planet has important energy decisions to make. As the FGV policy report points out, energy efficiency is the first place to start. After that, hard investment decisions on solar, nuclear, petroleum, and biofuels will have to be made.

As for the *Biofuel Conquistadors*? If you can help Brazilians, that should be your quest. If not, you know how the song goes.

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