Artigo

Developments of biofuels in Brazil and East Asia: experiences and challenges[1]

Desenvolvimento dos biocombustíveis no Brasil e no Leste Asiático: experiências e desafios

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Introduction

Interest in biofuels is growing worldwide for economic, environmental and energy-security reasons (Mathews 2007). It is increasing not only in Brazil and the United States, which are the largest producers, but also in China, Japan and South Korea, which are the potential largest consumers of this energy source.[2] East Asian countries remain the most dependent on oil and other traditional energy sources (including coal) to keep their economies running. These countries are becoming interested in the development of biofuels as means of diversifying their energy consumption sources, curbing greenhouse-gas emissions and contributing to rural development.[3]

Brazil is a pioneer in developing ethanol as an economically viable alternative to fossil fuels. As part of the government's efforts to diversify the nation's energy sources and to overcome the threat of future oil price shocks, the country developed the first industrial-scale production of cars to operate with ethanol as fuel in 1979. Brazil has grown to become one of the world's top producers of biofuels and today has one of the highest proportions of renewable energy sources in its energy matrix. Goldenberg, one of the most notable scholars in the energy sector including the Brazilian ethanol program, has underscored the fact that the sector is based on indigenous technology (both in the industrial and agricultural areas), and, in contrast to wind and solar photovoltaics, does not depend on imports, and the technology can be transferred to other developing countries.[4]

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2 For a recent and thorough discussion on energy and its sustainable development for China, see the November 2010 Special Issue of the journal *Energy*, edited by Hongguang Jin, Xiliang Zhang, and Noam Lior.

3 A helpful discussion on the development of these markets and the implications for developing countries can be found in Faaij and Domac (2006).

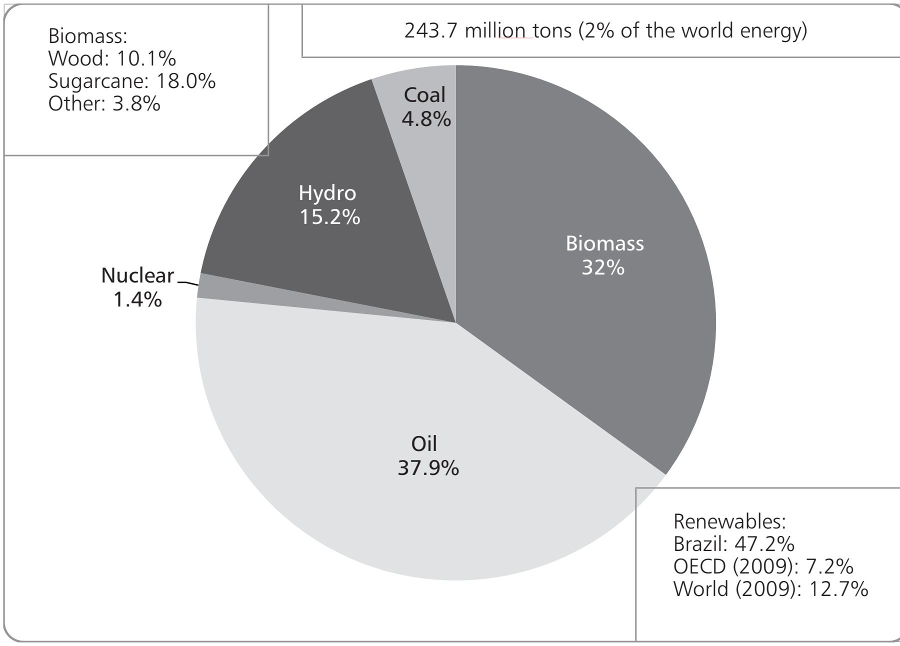
4 An example of this author's work on biofuels can be found in Goldemberg (2007) and Goldemberg et al. (2004).

According to the Brazilian Oil Agency, by 2007, 492 tons of sugarcane were produced, and a portion of this feedstock was used to produce 8.4 billion liters of anhydrous—also called pure—ethanol and 13.9 billion liters of hydrated ethanol. By 2010, 2,397,272 cubic meters of biodiesel were also produced, a level that increased from 736 cubic meters in 2005 when the Biodiesel Program was implemented (ANP 2011). Brazil is also at the forefront of developing biofuels as an alternative renewable energy source and prospecting more cooperation with other Latin American as well as Asian countries (Masiero 2007).

In order to outline the development and challenges of this emerging industry, this paper begins by describing the role of new technologies and governmental policies in the evolution of Brazil's biofuels industry. It then briefly assesses the technological and policy environment in the three most dynamic and energy-hungry economies of East Asia: China, Japan and South Korea, to show that the biofuels industry in these countries is in an incipient stage. For the three East Asian countries, it then assesses the extent to which trade and cooperation on biofuels exists with Brazil. It argues that Japan has furthered its cooperation with Brazil on biofuels much more. Some new important linkages between Brazil and South Korea have also emerged. In contrast, there are few links between China and Brazil in biofuels. To explain this variation, it argues that the growth in trade and cooperation between East Asia and Brazil on biofuels is best understood within the context of the stage of development of biofuels in each of these countries. The final section reviews these developments and suggests that multilateral forums may be an important mechanism for expanding Brazil-China cooperation on biofuels, as well as furthering existent cooperation with Japan and South Korea.

The Brazilian experience on biofuels

Brazil has one of the most diversified energy matrices in the world. Graph 1 shows that the values of renewable and non-renewable energy generation are 47.2 percent and 52.8 percent in Brazil, respectively. Data published by the Ministry of Mines and Energy (MME) show that total non-renewable energy consumption in 2009 was divided as follows: 37.9 percent from petroleum and its derivatives, 8.8 percent from natural gas, 4.8 percent from coal, and 1.4 percent from uranium (MME 2010). The remaining sources responsible for the 47.2 percent of Brazil's renewable energy sources were hydroelectricity, representing 15.2 percent; sugarcane, representing 18 percent; wood, representing 10 percent; and other types of biomass fuels, totaling 3.8 percent. These sources totaled 243.7 million tons of oil equivalent (Mtoe), which was 2 percent of total world energy supply. Since 2005, Brazil has sought to deepen exploration of its extensive pre-salt oil reserves, while at the same time continuing to pursue its alternative energy promotion policies. In the same year, it launched an ambitious national biodiesel program to expand its renewable energy sources.



Graph 1. The Brazilian energy matrix in 2009.
Source: Ministry of Mines and Energy.

The search for oil-alternative sources of energy has a long history in Brazil. Governmental policy and technological innovations have been critical to the successful adoption of biofuels. The nation's first experience using ethanol as a transportation fuel took place in 1925 (Nass, Pereira, and Ellis 2007). Some years later, in 1931, the Institute of Sugar and Alcohol was created. These early efforts were reinforced in the early 1970s. When the world economy experienced two great shocks caused by the abrupt rise in the oil prices, the Brazilian government began the Brazilian Ethanol Program called *Pró-Alcool*. The program, which was implemented when the country's sugar exports were declining, consisted of the development of technologies and incentives to increase production and to encourage the widespread use of ethanol, or ethyl alcohol. The initiative also sought to replace methyl tert-butyl ether (MTBE) as an additive to gasoline and encourage the use of ethanol in its pure form as a fuel for car engines.

From the onset, this type of technological innovation has been instrumental. Manufacturers began to sell 100 percent hydrated ethanol-powered cars in 1979. Sugarcane growers and private industrialists founded the Cooperative of Sugar, Alcohol, and Sugarcane Producers (Copersucar) in 1979. This cooperative established the Copersucar Center of Technology, which rapidly became the local focus and coordinator of subsidized research in breeding and processing of sugarcane for sugar or ethanol production.

The Brazilian government played an active role in the *Pró-Alcool* program during the 1970s and early 1980s through measures to stimulate both supply and demand. The evolution of the sugarcane-ethanol industry in Brazil has been strongly supported by subsidies introduced and sustained by successive governments. Tax incentives have reduced the prices of ethanol-powered cars, making them highly attractive to Brazilian consumers. From 1979 to 2007, nearly 5 million ethanol-powered cars were produced in Brazil, and from 2003 to 2009, 8,294,291 flex fuel cars replaced a great amount of the Brazilian automobile fleet. The production of flex fuel cars reached 2,241,820 by 2009, while only 322,868 gasoline-only vehicles were produced (ANP 2010).

Brazil produces two basic kinds of ethanol from sugarcane. Anhydrous ethanol (8.5 percent of Brazil's total energy consumption in 2007) presents a 99.30 percentage of alcohol and is used to mix with pure gasoline (type A) to produce mixed gasoline (type C). Since its introduction, Brazil has gradually increased the proportion of ethanol in gasoline. By 2003, the mix was fixed by the Brazilian government to be from 20 percent to 25 percent. Hydrated ethanol (8.4 percent of total Brazilian energy consumption in 2007) is produced and used in Otto-cycle engines as a substitute for gasoline. Since 2005, as will be discussed in the next section, Brazil has also been increasing the mix of another renewable source of energy—biodiesel—in fossil diesel.

Brazil's trajectory suggests that it will continue to pursue an energy strategy based on the development and adoption of alternative fuels. New plants and larger pipelines to transport biofuels are being constructed. Brazil has also passed legislation allowing blends of ethanol in gasoline (gasohol) to be increased to 40 percent (E40). Most of the new and refurbished older plants that have been modernized can produce sugar and ethanol as well as electricity.

The growing reliance on ethanol has raised concerns that Brazil's sugarcane-based ethanol program could directly or indirectly increase the loss of high biodiversity areas in the Cerrado and the Amazon rainforest. For critics, ethanol production has been a cause of the Amazon rainforest's devastation. The distribution of sugarcane production in the five regions of Brazil clearly shows that this argument is not substantiated by the data, since the main sources of the nation's ethanol production are the states of São Paulo and Minas Gerais, located in the Southeast, a region that is 2,500 kilometers away from the Amazon rainforest. Moreover, Brazil's harvested sugarcane area is not increasing at the same rate as the sugar and the ethanol production growth.

In addition, while the area devoted to sugarcane production rose by 85 percent between 1990 and 2008, ethanol and sugar production increased by 130 percent and 350 percent, respectively. In addition, Brazil still has 91 million hectares of uncultivated land that can be used for agriculture without needing to rely on the 360 million hectares of the Amazon forest. Statistics of the Ministry of Mines and Energy (MME 2010) show that there remains almost half of the land area dedicated to agriculture that could be used for ethanol or biodiesel feedstock production, and the dislocation of traditional crops that could occur is predicted to not be at a significant scale. Moreover, if the land area available becomes further restricted in the future, 220 million hectares currently used for pasture could be transformed to grow oilseed crops.

Even though biofuels are considered a successful experience in Brazil, it is important to bear in mind that this type of fuel can be produced almost everywhere in the world. Yet, few countries will become large-scale producers able to supply domestic and external markets. The processing of biofuels has the potential to be a more diffused industry compared with fossil oil, which was the main energy source for transportation in the 20th century. The fossil oil business has been dominated by a few countries endowed with oil reserves and a concentrated group of extraction and distribution companies. The rise of fossil oil prices has been the leading factor blamed for generating inflation and geopolitical conflicts around the world. Thus far, biofuels, albeit on a small scale, have been the first fuel used to replace fossil fuels.

The development of ethanol in Brazil was driven by economic considerations. In contrast, the introduction of biodiesel has been justified by citing economic, social, and environmental aspects. In addition to biodiesel being a response to the high prices of crude oil, governmental and private sector biodiesel development efforts have been motivated by demands for job creation, the permanent settlement of families in the countryside, and the introduction of additional renewable and environmentally friendly fuels in the domestic market. Biodiesel was introduced into the Brazilian market in 2005, and 3 percent of biodiesel (known as B3) has been blended with diesel fuels for commercialization since March 2008. Brazilian law mandates that a minimum blend of 5 percent will be required by 2013 (Biodiesel Magazine 2010).

There has also been an exponential rise in the supply of biodiesel since the program began. Statistics reported by Brazil's National Petroleum Agency (ANP) indicate that 736 cubic meters (0.74 billion liters, equivalent to 4,630 barrels) of biodiesel were being produced in 2005, the program's first year. Four years later, total production reached 1,608,448 cubic meters in 2009 (ANP 2010).

Castor beans, sunflowers, soybeans (the most commonly used), palm oil, and cotton are the main Brazilian feedstocks being tested and used in biodiesel production. Brazil has the ideal climate and land conditions for oilseed production. Different species of oilseed are better cultivated in a diverse-climate environment, ranging from the cool region of the South and Southeast of the country for soybeans, rapeseed, sunflowers, and cotton to the tropical hot weather in the North and Northeast for castor beans, palm, and babassu. Note, however, that the share of these crops used in energy production is relatively small compared with the production of ethanol.

The mass production of biodiesel has raised concerns echoing the criticisms that have been made about the use of ethanol as a fuel source. In response, critics point out that biofuels require a relatively small proportion of Brazil's land. Currently, 3 million hectares are used to cultivate sugarcane. This is equivalent to 0.35 percent of Brazil's total area, or just 0.8 percent of its land area devoted to agriculture. In the case of oilseeds that would be cultivated to produce biodiesel, the estimated amounts are also minor. Indeed, it has been estimated that 0.4 percent of the country's agricultural land would be required to fully blend all diesel to B2 (2 percent of biodiesel blended with diesel fuels). If the nation's total diesel consumption were blended at B5, the estimated area required to meet this level of demand would be 1 percent of Brazil's total area.

East Asian experiences: policies, technologies, production and trade of biofuels

Today, the largest consumers of biofuels are also the largest producers. In the case of ethanol, the United States and Brazil dominate, whereas Germany and France are notable producers of biodiesel. Although domestic demand is far greater than available supply in these economies, trade of biofuels in world markets has been insignificant thus far. Generally, trade is concentrated in the different feedstocks that are used for processing the fuel in the final consumer markets. Such is the case with respect to the ethanol exported to the United States via Caribbean countries by Brazil as part of the Caribbean Basin Initiative. The high trade barriers and subsidies for feedstocks in the United States and Europe have been the main stumbling block to the trade of this commodity (which is still not yet standardized) in world markets.

The development of a biofuels industry in East Asian countries is motivated by some key drivers. The first and most important one consists of the need for these economies to acquire security in their energy supply sources. It is becoming clear that issues concerning energy may become a threat to the continuous development of the region. East Asia is growing rapidly and its future energy needs are predicted to escalate proportionally especially because of the expansion of the transportation industry. In addition, these countries see biofuels as an alternative to poverty alleviation in rural areas. They are also becoming concerned about the environmental issues and perceiving this new industry as an alternative to reduce their emissions of greenhouse gasses (Yan and Lin 2009).

Historically, East Asian countries have tried to diversify their energy sources and steer their economies to be less dependent on fossil oil. To this date, however, these efforts have been unsatisfactory. China, Japan, and South Korea remain highly dependent on the fossil oil supplied from different producing countries, including those from "distant" Latin American countries such as Venezuela and

Mexico. China is the only one of the three East Asian giants that has fossil oil reserves and produces some amount of diesel and gasoline from domestic sources. Japan and South Korea are net importers of fossil oil and their dependence, even though declining, is still among the highest in the world. Indeed, the Asia-Pacific Economic Cooperation (APEC) statistics show that Japan and South Korea import 100 percent and China 50 percent of their crude oil requirements (APEC 2010). Figures 1, 2, and 3 provide an overview of the mix of energy consumed in each country. It should be noted that China's energy consumption matrix indicates that, while 18 percent of total energy consumption is derived from renewable and waste sources, none is derived from the consumption of liquid biofuels.

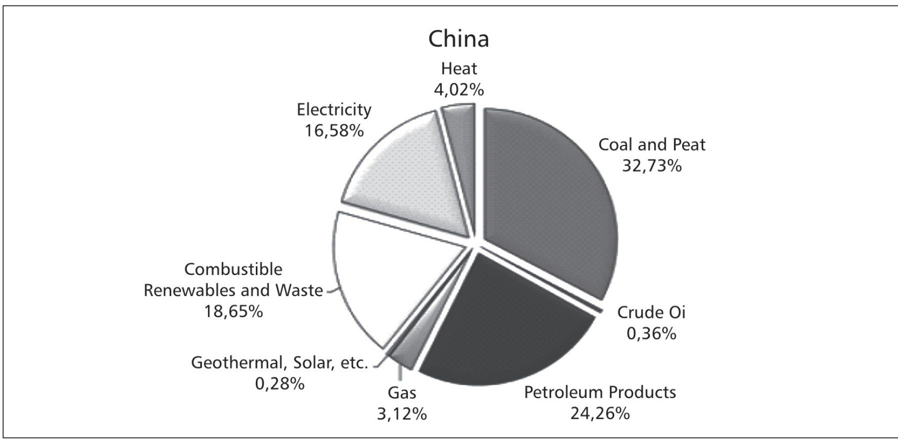


Figure 1. Energy matrix for China.

Source: IEA (2010).

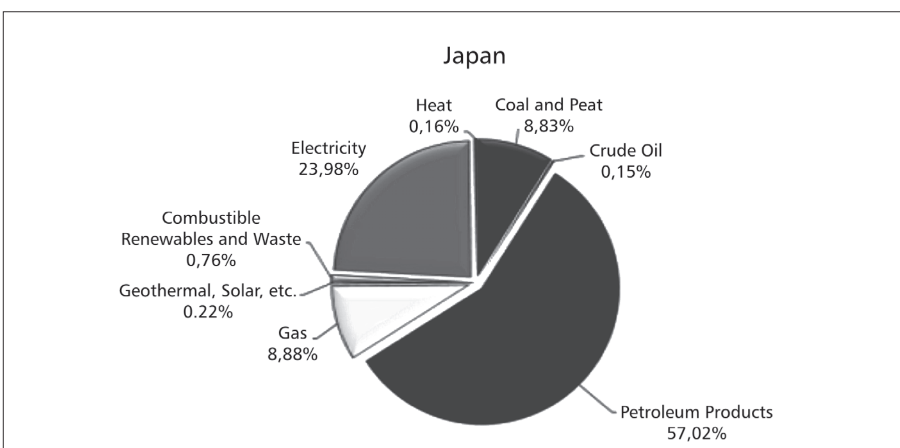


Figure 2. Energy matrix for Japan.

Source: IEA (2010).

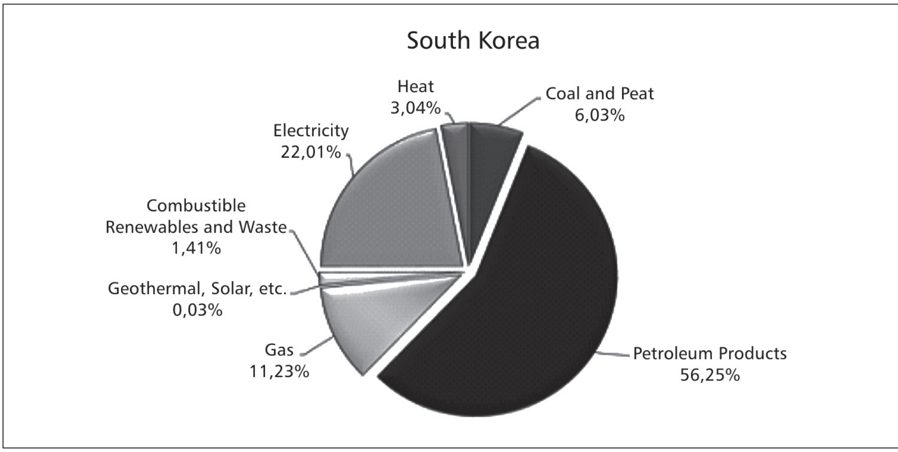


Figure 3. Energy matrix for South Korea.
Source: IEA (2010).

Through direct or indirect trade, East Asian countries are exploring opportunities with other potential large biofuels producers in the Southeast Asia, like Malaysia, Indonesia, Philippines, and Thailand. They are planning to produce and guarantee reliable supplies of feedstock and biofuels for their increasing needs of renewable energies. They are also looking for suppliers from Brazil. Brazilian exports of ethanol have increased significantly since the turn of century and most significantly after 2004. As shown in Table 1, ethanol has increased in terms of total value and volume: exports amounted to almost US$2.4 billion in 2008 and nearly 4.1 billion liters.

Table 1. Brazilian ethanol exports, 1996–2008 (select years).

Year	Total	
	Liters	US$ FOB
2008	4,094,957,145	2,390,109,630
2004	1,926,633,608	497,740,226
2000	181,806,324	34,785,662
1996	209,046,315	95,420,391
Total (1996–2008)	**16,101,450,428**	**7,440,720,385**

Source: MDIC.

By 2008, Brazil was exporting more than one third of its total ethanol exports (31.67%) to the United States. Japan and South Korea have been relevant importers of Brazilian ethanol as well. Japan was Brazil's third largest destination for ethanol exports between 1996 and 2008. On the other hand, in the same period, South

Korea ranked in sixth place. On the other hand, and in stark contrast to the share of natural resources exported to China from Brazil more generally, the exported volumes of ethanol to China has been insignificant. By 2008, China imported 0.07% of ethanol from Brazil. From 1996 to 2008, the United States purchased 29.53% of all Brazilian ethanol exports. During the same period, Japan imported 8.95%, while South Korea purchased 4.67% of the total. For the remainder of this section, we focus on the development of the biofuels sector in each country, which helps explaining why there has been greater cooperation in the cases of Japan and South Korea with Brazil.

Chinese initiatives

Statistics of the International Energy Agency (IEA) shows that China will continue increasing its energy demand and consumption needs until 2020. Hydro, wind, petroleum as well as CO_2 emissions present an accentuated growing trend since the beginning of this century. According to the Agency, coal, oil, and gas are the main energy sources to supply about 60 percent of the country's total energetic needs. The remainder sources break down as follows: 18 percent from renewable and waste, 16 percent from electricity, and approximately another 4 percent from heat. The renewable energy structure in China in recent years breaks down with 59 percent as household stove fuel, 30 percent as hydro and wind power, 9 percent as solar, geo, and ocean energy, and 2 percent as modern bioenergy. Table 2 shows the demand of Chinese energy transportation for 2005–2020 (ECLAC 2008).

Table 2. China's estimated transportation demand (in Mtoe), 2005–2020 (select years).

Fuel	2005	2010	2020
Gasoline	40.0	47.0	66.0
Bioethanol/ETBE	0.6 (1.4%)	2.6 (5.1%)	15.0 (15.0%)
Diesel oil	37.0	49.0	86.0
Biodiesel	0.0 (0.4%)	2.0 (3.8%)	15.0 (15.0%)

Note: the numbers in parenthesis indicates the percentage of biofuels as a share of the total.
Source: ECLAC (2008).

The shortage of water, land, food, and energy sources is a common feature of almost all Asian countries. However, the high economic growth rates of China, which is the most populous country in the world and which have fueled its demand for ever-growing supplies of energy and food, have potential impacts at a global scale. The effect on air pollution from its increase in energy consumption, which is partially due to the nearly 15 percent annual increases in the automobile fleet in congested cities, is just one example. China has begun to awaken to these problems and in response is starting to develop a biodiesel industry. This energy-hungry country has established as a target a biofuel participation of 15 percent of transportation energy sources by 2020. In the case of ethanol, China has been producing this fuel mainly from corn (50 percent), cassava (30 percent) and sugarcane (20 percent), and it has introduced a trial to test the impact of 10 percent blending in some regions.

China produced 1.45 million tons of ethanol in 2007. About 80% of this amount was made with corn, while the rest was produced from wheat. A small percentage was produced from cassava and sweet sorghum on an experimental basis. Using these crops for fuel production has contributed to an increase in food prices which may limit access to food by an expressive number of the Chinese population. Regarding biodiesel, the Chinese industry is yet to be greatly developed: the sector has a small amount of 300,000 metric tons installed capacity, and the biodiesel is produced from animal fat and vegetable waste, considered low-quality sources (Zhou and Thomson 2009).

Ethanol technologies were already available in 1986. Three years later, four ethanol factories were approved and they began operations in 2001. A year later a first test of blending ethanol into gasoline (E10) in Henan and Heilongjiang was carried out. In that same year, the distribution of this fuel was extended to Anhui, Jilin, Liaoning, and to Hubei, Jiangsu, and Shandong in 2003. The government made clear its intentions to promote new bioenergy research and development in China in 2004, the year in which biofuel policies were included in the National Long and Medium Science and Technology Plan. By 2005, the government launched a National Renewable Energy Development Strategy which was later developed into the Long and Medium Renewable Energy Development Strategy. Studies regarding the biomass energy have been carried out by the Ministries of Agriculture and Science & Technology, the National Development and Reform Commission (NDRC), and the Forest Bureau as well as the State Environmental Protection Administration (SEPA). The NDRC has been the leader in the biofuel development arena, guiding future energy production and consumption in China (Rothkopf 2007).

Regarding sugarcane production, China has achieved constant increases in productivity. Average tons of sugarcane per hectare increased from sixty in 1997 to sixty-nine in 2008, a rate of growth of 1.4% per year on average. In addition, the state has been investing greatly in biotechnology research centers, such as the Guangdong Sugarcane Research Institute, which employs 200 researchers who have worked to develop fifteen new varieties of sugarcane in past decades (Kosta, Polzin, and Scharrer 2009).

In the case of ethanol production, the Chinese government has been showing great enthusiasm. The industry counts on the benefit of receiving increasing subsidies and monetary payments for a multiple supply chain of actors. Having reached US$114 million in 2006, it is expected that government support will increase to US$616 million by 2020. The Chinese government has also made it clear that it will prioritize the production of non-food crop based ethanol, which means that it will seek to produce this fuel source from sugarcane, cassava, sweet potatoes, and sweet sorghum (Li and Halbrendt 2009).

China is the world's third largest ethanol producer (most of it for the pharmaceutical and beverage industries) and the fifth largest producer of biofuels. It began its biofuels production from corn, sugar, sorghum, and wheat as a way to reduce its high stocks of grains at the turn of the 21st century. In the next three five-year national plans, a roadmap for the further development of the industry has been outlined. In the 11th five-year development plan (2006–2010), the commercialization of biofuel-related technology was established a target goal. In the 12th plan (2011–2015), the aim is to achieve large-scale production and in the 13th (2016–2020) the goal is to replace 15% of fossil-based transportation fuel with biofuels and build an industry that is globally competitive.

In 2007, a renewable energy law was enacted to encourage clean and high efficient utilization of bioenergy and the development of energy crops. The government is encouraging the introduction and use of liquid biofuels in the market and mandating that national fuel standards must be met. The new law establishes that biofuels should not compete with food for people or for land used to grow crops to provide nutrition to the population. It also demands that current producers switch to non-food feedstocks and stresses the need to develop cellulosic biomass-to-liquids (BTL) fuels. Currently, the main feedstocks for biofuels produced in China are corn, sugarcane, cassava, and sweet sorghum. Sugarcane is by far the most important feedstock in terms of productivity (6–8 tons of bioethanol per hectare), two times higher than corn. Sugarcane is a suitable crop to be grown in southern China as this region is located below the Tropic of Cancer and close to the Equator in latitude—this area is most suitable for production.

China has come to view biodiesel as a valid alternative to sustain its fast-paced, dynamic economic growth. The country consumed 140 million tons of diesel in 2005. About 40 million tons, or 30%, was imported. By developing and motivating the domestic biodiesel industry, the country seeks to lower its dependence of external sources of energy (Wang, Xiong, and Liu 2009). In fact, according to Zhang Yongguang, the Biodiesel Blending Fuels (B5) National Standards will be effective February 1st, 2011. For him, the technology for biofuel blending is already mature in China and the government must roll out the rules as well as the fiscal and taxation policies to encourage the development of the biofuel sector (China Chemical Reporter 2010).

As mentioned above, the level of imports of ethanol from Brazil to China have been insignificant. By 2008, China imported 0.07% of ethanol from Brazil. The biofuels industry is at an early stage in China and thus far the emphasis has been on the development of a domestic industry in China. These factors in part may explain why there had been such limited growth of links with Brazil on biofuels. However, Brazil signed a cooperation memorandum on energy and mining with China in 2009 that has sparked interest in new initiatives to further develop the biofuels industry, as well as to turn ethanol into an energy commodity and promote its use in the international market (MRE 2011).

More recently, Governor Jacques Wagner (PT-BA) announced that the Chongqing Grain Group would invest US$200 million in a soy processing center in Barreiras, in the state of Bahia, during the Brazilian President Dilma Rousseff's visit to China. According to non-official sources, other Chinese companies and entrepreneurs are buying land in the same state and in the state of Goiás in order to produce food or fuel to supply the Chinese market. An official government study has presented mixed evidence on the overall significance of the growing Chinese presence in the Brazilian land market. On the one hand, official data indicate that non-Brazilians own 5.5 million hectares of land. On the other hand, unofficial statistics indicate that 7 million hectares are owned by Chinese—well above the official estimate for all foreigners (Acioly, Costa Pinto, and Cintra 2011). Due to unreliable data, it is nearly impossible to know the exact share of Chinese or other foreigner investments in the Brazilian agriculture sector.

Japanese experiences

Global warming and other issues related with oil prices and the development of innovative technologies for producing low-cost fuel ethanol have been at the core of the Biomass Nippon Strategy implemented in late 2002. This strategy was reformulated at the beginning of 2006 emphasizing the utilization of biomass for the transportation sector. By that same year, six biorefineries responsible for the production of thirty kiloliters of ethanol were operating experimentally (Tatsuji and Keiji 2007). They were using sugar molasses, wheat, sorghum, and wood residues as the raw materials to produce ethanol. Biodiesel from rapeseed and used cooking oil in a small scale also began to be produced and used for transportation.

Since the signing of the Kyoto Protocol, Japan has been working to reduce CO_2 emissions by 60 percent by 2010 from 1990 levels. In order to reach this target, the government is hoping to replace 500,000 kiloliters of fossil fuels by ethanol in the transport sector. The new National Strategy formulated in 2007 by the Ministry of Economy, Trade and Industry (METI) aims to reduce the present 100 percent oil dependence to 80 percent by 2030.

To increase its biofuels industry, Japan is following some specific strategies. The Ministry of Agriculture, Forestry and Fisheries has developed the Biomass Nippon Strategy, considered the first national plan to approach biomass resources. These guidelines focus on mitigation of global warming, development of a recycle-based society, incubation of a new industry, and revitalization of rural economies.

In addition, the Japanese Ministry of Economy, Trade and Industry has established specific numerical targets regarding energy security in the country, by exploring new alternatives in the transportation industry that include the use of biofuels to achieve these targets.

Also, Japan has been investing significant amounts of resources in biofuels research and development. Currently, eight ethanol pilot projects are being developed, including sugar beets, corn, rice, and food waste ethanol. It is important to note that while these projects focus on ethanol production, Japan is also considering the development of biodiesel, although investments in this type of research are being made by local governments and nongovernmental organizations (NGOs) (Matsumoto, Sano, and Elder 2009).

The development of biofuels is now being advanced through research in producing ethanol from cellulose with nanotechnology. The method is being developed by Professor Takashi Endo at the Hiroshima University. This proves the yet undiscovered potential of biofuels, which will surely contribute to the future of this incipient industry (Endo 2009).

Japan currently has a noncompulsory target of 3 percent ethanol in gasoline and is considering increasing that to a 10 percent blend. This would create a Japanese market of 6 billion liters of ethanol a year, which is equivalent to about 22% of the 27.512962 billion liters of the Brazilian production in 2008. The demand for biofuels is estimated to increase 1.8 million liters per year and replace 5 percent of gasoline and 1 percent of diesel oil by 2020. Table 3 shows the estimated evolution of the fuel demand in the Japanese transportation sector from 2005 to 2020.

Table 3. Japan's estimated transportation demand (in Mtoe), 2005–2020 (select years).

Fuel	2005	2010	2020
Gasoline	45.5	50.2	58.0
Bioethanol/ETBE	0.2 (0.4%)	0.3 (0.5%)	3.1 (5.0%)
Diesel Oil	27.9	29.3	32.0
Biodiesel	0.0 (0.0%)	0.0 (0.0%)	0.3 (1.0%)

Note: the number in parenthesis indicates the percentage of biofuels as a share of the total.
Source: ECLAC (2008).

Among the countries reviewed in this study, Japan has been the one that has sought most actively to partner with Brazil in developing its biofuels industry. In 2005 the Japan Bank for International Cooperation signed an agreement with Brazil's Ministry of Agriculture to export Brazilian ethanol and biodiesel to Japan. The Brazil-Japan Working Group on Biomass was also established to share information and explore opportunities for bilateral cooperation.

In addition to government and academic initiatives, the Brazilian petrochemical company, Petrobras, and the Japanese conglomerate, Mitsui, are also trying to strengthen cooperative ties to develop the ethanol and biodiesel industry. They are studying the viability of new production facilities in Brazil dedicated to the Japanese market, including a focus on the logistics of how biofuels would be transported, transformed, and distributed. Petrobras also formed a joint venture with Japan Alcohol Trading, called the Brazil/Japan Ethanol Company, to import and distribute ethanol in the Japanese market.

The Japanese transportation industry is investing in research and development of hybrid cars and new energy sources. In 2006, Nippon Oil and Toyota Motors, for example, developed a new palm oil-based fuel removing the oxygen from the palm oil. Honda Motors is also researching new technologies to use renewable energies and in March 2009 its Brazilian subsidiary started commercializing the first flex fuel motorcycles in the local market. These factors help to explain why Japan is now the third largest destination for ethanol exports for Brazil, a trend which is likely to increase in the near term.

South Korea

In the first decade of the 21st century, energy has risen to the top of the policy agenda in South Korea. In November 2006, the National Energy Committee was created to address energy issues and to advocate budget increases for three key policies: strengthen energy supply security through overseas resource development, create a society in which less energy is consumed by improving energy efficiency, and establish a sustainable energy system through more investment in new and renewable energy.

As part of this agenda, South Korea has established targets for its energy policy for the next decade. However, these targets do not suggest that biofuels will play a major role as a fuel source. South Korea will seek to increase the share of overseas production from imports of oil and gas from 3.7 percent to 5.8 percent in 2005 and 15 percent and 30 percent in 2013. According to the president of the Korean Energy Economics Institute, Bang Ki-yual, the government has also sought to reduce energy intensity as measured by the share of consumption relative to gross domestic product from 0.36 tons of oil equivalent per US$1,000 in 2005 to 0.30 tons of oil equivalent per US$1,000 by 2012.

The awakening of Korea to its energy and economic constraints was rightly addressed by President Lee Myung-bak's "low carbon, green growth" vision outlined in his August 15th Liberation Day address in 2008. The president called for selecting green technology and clean energy as the new economic engines of sustainable growth and development. This vision contrasts, however, with the emphasis on the expansion of atomic power generation in South Korea. The country already has twenty reactors in operation; six more are under construction, and two more reactors are planned to be opened by 2016. In comparison, the targets aimed at increasing new and renewable energy consumption by 2030 are timid. Moreover, if these were reached, Korea's strong dependence on fossil oil and its other sources of energy, including atomic energy, will remain.

Plans have been introduced to increase the share of renewable energy from 2.1 percent of total energy consumption in 2005 to 5 percent by 2011 (Bang 2007). These efforts, however, are concentrated on renewable energies such as the development of solar power using photovoltaic cells for residential use based on the domestic semiconductor industries, wind power based on the development of wind turbines through the adaptation of advanced technologies, and H_2 fuel cells for residential and building use. The drive to secure energy sources has gained momentum as South Korea has introduced measures requiring a compulsory mixture of 3 percent of biodiesel in diesel by 2012.

Bae (2007) from the Korean Energy Economics Institute and Kang (2006, 2007, 2008) from the Samsung Economic Research Institute have begun describing the initial steps toward the adoption of biofuels as Korea's alternative-energy source and evaluating the implications. Arguing that Korea will have strong needs for transportation fuels in the coming years, Kang predicts biofuels will be 20 percent of gasoline and diesel consumption by 2030 and that the supply of biodiesel will grow at 30 percent annually. A four-year pilot project to introduce 20 percent biodiesel (BD 20) into the Korean market took place between 2002 and 2006. Because of technological requirements, however, BD 20 is limited to fleets of vehicles that can be repaired in their own facilities.

Between 2006 and 2007, an agreement between the Korean government and oil companies introduced a 0.5 percent mixing rate for biodiesel (BD 05) into gas stations throughout the country. As a result of these efforts, total consumption of biodiesel nearly doubled, reaching 90,000 kiloliters in 2007. The estimates indicate that biodiesel will increase to 3 percent of diesel supply in 2012. At the moment, eleven biodiesel refinery companies are registered, and only licensed oil distributors are allowed to supply this fuel, which is derived mainly from soybeans imported from the United States and Argentina (77 percent) and recycled waste oil (23 percent).

Several initiatives are being implemented in South Korea in order to achieve the expansion of the biofuels industry. The Korea Research Institute of Bioscience and Biotechnology relies on funding from the Ministry of Education, Science and Technology to research the CO_2 fixation through microalgae from 2002 to 2012. The Ministry of Land, Transport and Maritime Affairs is investing US$200 million in research to develop a method to produce biofuel from algae and microalgae. The Korea Institute of Industrial Technology will research, from 2008 to 2011, the production of bioalcohol from red algae, a groundbreaking technology in the sector (Yang 2010).

A pilot project using ethanol is testing the technical feasibility and acceptability of this fuel in the Korean market between 2008 and 2011. Efforts to produce ethanol domestically from rapeseed are being explored. Analyses of these proposed domestic supply sources clearly show that a major challenge will be the limited area of arable land available to grow this feedstock. As Table 4 illustrates, the supply of ethanol was projected to begin in 2010 and reach 1,881,000 kiloliters by 2030.

Table 4. South Korea's transportation energies, 2005–2030 (in thousands of kL).

	2005	2010	2015	2020	2025	2030
Diesel	16,301	18,635	20,016	22,437	24,531	25,942
Biodiesel	8	373	1,001	2,244	3,680	5,188
% Biodiesel	**0.05**	**2**	**5**	**10**	**15**	**20**
Gasoline	7,512	7,818	8,945	9,001	9,158	9,403
Ethanol	-	78	447	900	1,374	1,881
% Ethanol	**0**	**1**	**5**	**10**	**15**	**20**

Source: Kang (2008).

Given the scarcity of arable land available in South Korea, its companies are seeking to produce biofuels elsewhere. In July 2008, Samsung, the electronics, engineering, construction and shipbuilding *chaebol*, announced plans to invest US$1.63 billion to produce biodiesel from oil palms in Indonesia (Jakarta Post 2008). The company also has invested in the Philippines in collaboration with the Philippines National Oil Company in a jatropha-based biodiesel production plant. In 2007, Petrobras and Samsung signed a memorandum of understanding calling for joint technical, financial, and trade studies on biofuels.

In addition to being a significant consumer of Brazilian ethanol (Korea as previously mentioned is the sixth top importer of ethanol), there are some emerging signs that cooperation between South Korea and Brazil will also become more extensive. Reports have confirmed plans for investments by a Korean consortium for the production of biodiesel in the state of Paraná, Brazil (Valor Econômico 2008). Twenty Korean companies will invest US$30 million in a mill to produce biodiesel from soybeans. Given that South Korea is one of the largest ethanol importers from Brazil, there is potential for much greater levels of trade. Until now, Brazilian ethanol imports have been used in the food and beverage industry, but they could also be used as a clean fuel for transportation.

Final remarks

In a recent study, IEA estimated that world production of biofuels will grow from twenty Mtoe in 2005 (1 percent of world road-transport fuel demand) to ninety-two Mtoe in 2030 (4 percent of total road-fuel consumption) in the reference scenario in which there is no change in government policies (IEA 2006). In the alternative policy scenario, production could reach 147 Mtoe in 2030 (7 percent of road-fuel consumption). In this alternative scenario much cooperation between suppliers of feedstock or fuel and consumers is needed.

One of the biggest challenges that most countries are facing is not to produce biofuels, but to secure their large-scale and long-term supply. Renewable energy sources including biofuels can play an important role in mitigating global warming and the securing of an alternative to fossil fuel for industry and transportation uses. As this paper has reviewed, Brazil has been successful in developing its ethanol industry in large scale since the 1970s thanks to government policies and technological development. Brazilian ethanol production based on sugarcane is the most efficient in the world. Moreover, forecasts predict that Brazilian production of biodiesel will increase at a larger scale than ethanol in coming years.

Historically, Brazil has been the world's largest producer of ethanol. However, the U.S., China, the European Union, India, and Russia are also big ethanol producers. Relatively to its competitors, Brazil's production is cheaper. Brazilian sugar production from sugarcane is more efficient than from beet or wheat used as a feedstock in the European Union, from corn in the United States, from cassava in Thailand, or even from other species of sugarcane in India. For example, the energy output to input ratio is between 1.2 and 1.8 from corn production in the United States and between 8.0 and 9.0 from Brazilian sugarcane. Besides ethanol, Brazil's modern sugar and ethanol mills are also producing bioelectricity for their own use and selling the surplus to the national electricity grid.

More efficient technologies for bioethanol and biodiesel demand the adoption of technological developments and a sizeable amount of investments. Aware of these difficulties and in order to support the international trading of biofuels as a commodity, Brazil, China, the European Union, India, South Africa, and the United States established an International Biofuels Forum. The Forum is open to new partners because its aim is to bring together both biofuel producers and consumers. For Brazil, the Forum is one more arena for the country's steadfast efforts to transform biofuels in a commodity to be traded in a liberalized world market (Teixeira 2005).

At the multilateral level, Brazil and the U.S. are cooperating to promote greater compatibility of standards and codes via the International Forum of Biofuels. Moreover, there is a desire to build on these nascent efforts of "ethanol diplomacy" to broker agreements on biofuels with other countries (Wright 2008). China, the third largest producer of ethanol and a hungry consumer of renewable and non-renewable energy, is a strong candidate for a future partnership. As China's economy has been growing at rates more than twice the world average, its energy demands rose 47 percent since 2000 and there are estimates that it will rise by a 3–5 percent annual rate between 2005 and 2020.

The three countries of East Asia—Japan, China and South Korea—are some of the world's largest potential consumers of renewable transportation energies. Pressured by their domestic needs and commitments to reduce greenhouse-gas emissions, countries throughout Asia have introduced important technological and policy initiatives to develop biofuels and to position themselves as a potential source of ethanol and biodiesel. A few countries are pursuing multilateral and bilateral initiatives. There is strong potential to speed up these initiatives regionally owing to the strategic imperatives of energy security, the need to maintain economic dynamism, and the necessary reduction in the damage to the atmosphere caused by burning fossil oil. To date, however, the biofuel efforts of Asian countries remain in an early development stage.

In part due to the early stage in which biofuels have been developed in these countries, the level of trade and cooperation with Brazil has also advanced slowly. Japan has advanced in its cooperation with Brazil on biofuels more significantly. It is also the country that has adopted more advances introducing biofuels as an important source of energy in domestic consumption. Some new important linkages between Brazil and Korea have also emerged, but the limited extent to which the industry has been adopted suggests that these links will remain limited in the short term. In contrast, few links between China and Brazil in biofuels have emerged. Multilateral forums may be an important mechanism for expanding Brazil-China cooperation on biofuels, as well as for furthering existent cooperation with Japan and South Korea.

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Abstract

This paper summarizes the role that new technologies and government policies have played in the evolution of the biofuels industry in Brazil and East Asia. It documents the factors that contributed to Brazil, China, Japan, and South Korea becoming producers and consumers of biofuels, as well as the extent to which this energy source has been effectively adopted in each of these economies. For the three East Asian countries, it then assesses the extent to which trade and cooperation on biofuels exists with Brazil. It argues that Japan is much more far advanced in its cooperation with Brazil on biofuels and asserts that there is strong potential to improve cooperation with China and South Korea.

Keywords: biofuels; Brazil; East Asia.

Resumo

Este artigo resume o papel que as novas tecnologias e as políticas governamentais têm desempenhado na evolução da indústria dos biocombustíveis no Brasil e no Leste Asiático. Ele documenta os fatores que contribuíram para que o Brasil, China, Japão e Coreia do Sul se tornassem produtores e consumidores de biocombustíveis, bem como a extensão em que essa fonte de energia tem sido efetivamente adotada em cada uma dessas economias. Em seguida, avalia a extensão do comércio e da cooperação em biocombustíveis entre os três países do Leste Asiático e o Brasil. Argumenta que o Japão é muito mais avançado em sua cooperação sobre biocombustíveis com o Brasil e que nas demais economias asiáticas existe grande potencial para maior cooperação.

Palavras-chave: biocombustíveis; Brasil; Leste Asiático.