Korea Economic Institute
Academic Paper Series

December 2008 • Volume 3 • Number 10

Ethanol and Biodiesel:
The Role of Brazil and South Korea in the Emerging Alternative-Energy Market

by Dr. Gilmar Masiero

Around the globe, government and private ventures in the ethanol and biodiesel industry are booming on the basis of their potential to replace fossil oil, to reduce carbon emissions, and to raise incomes in rural areas. The two most common biofuels are (bio) ethanol and biodiesel.[1] Sugarcane is the most efficient feedstock for producing ethanol and is the predominant feedstock for ethanol-producing and -exporting countries, most notably Brazil, Thailand, South Africa, and Australia. Several plants, such as rapeseed in Europe; soybeans produced in Argentina, Brazil, and the United States; palms in Indonesia and Malaysia; and jatropha, more common in India, the Philippines, and Thailand, are considered the main feedstocks for producing biodiesel. Some estimates predict that these alternative fuels will grow at 7 to 9 percent annually in the coming decades and displace one-third or more of road transportation fuels by the 2050–2100 time frame.[2]

To meet the increasing demand for energy, the burgeoning biofuels industry will need to develop significantly in the short and medium term. According to the International Energy Agency, global energy needs are likely to be about 50 percent higher than today by 2030. Between 2006 and 2030, energy demand in the Asia-Pacific region is estimated to grow by about 2.75 percent per year, or 32 percent faster than the world average.[3] In a recent study, the UN Economic and Social Commission for Asia and the Pacific (ESCAP) estimated that energy demand under the most "sustainable" (improving savings and renewables) energy scenario will be equivalent to 6,919.8 million tons of oil equivalent (Mtoe) for the region's 58 economies by 2030. According to this same report, energy demand for the Republic of Korea, which is the world's fifth-largest importer of oil, is expected to reach 312.0 Mtoe.[4]

To date, South Korea has made scant progress in shifting its dependence away from fossil oil. The limited efforts that have been implemented to introduce biofuels into the transport sector have thus far concentrated on the development of biodiesel, as two-thirds of its transportation industry relies on diesel as a fuel source. As the other one-third relies on gasoline, experiments with ethanol as a fuel source have just begun. Korea has a long tradition of alcohol production geared toward the food and beverage industry. For this use, it also has become a large importer of this commodity from its neighboring countries, and it imports significant amounts from Brazil as well. Despite familiarity with alcohol technologies and uses, Korea has only recently become interested in exploring their potential as an alternative fuel source for the transportation sector.

Brazil was 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 produced the first cars to operate with ethanol as fuel—the *carro a álcool* in 1979. Brazil has grown to become one of the world's top producers of biofuels and today has one of the highest renewable energy matrices in the world. 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. Indeed, it is estimated that more than $33 billion will be invested in the sector in Brazil by 2011. Brazil is also at the forefront of developing biofuels as an international trade commodity.

Gilmar Masiero's paper is the twentieth in KEI's Academic Paper Series, which began in December 2006. As part of its Academic Paper series, KEI commissions and publishes 9 to 10 papers per year on original subjects of current interest to Korea watchers, which KEI distributes to over 2,000 government officials, think tank experts, and scholars around the United States and the world. A public discussion at KEI with the author generally follows publication. In February 2008, KEI published its first collection of KEI Academic Papers in *On Korea*, Volume 1. To order a hard copy of *On Korea*, please visit KEI's website at www.keia.org; where PDF-versions are also available for download.

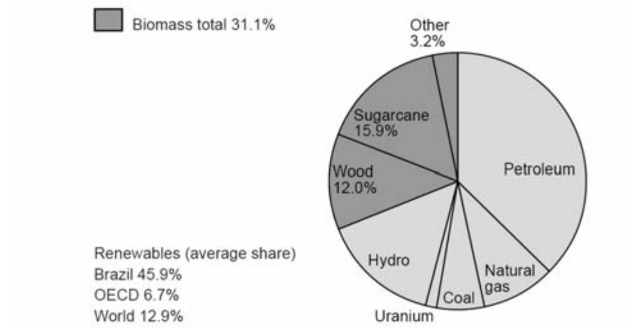
To change the energy consumption features of any country, new technologies and government policies are decisive. This paper reviews the role each of these factors has played in the evolution of Brazil's biofuels industry. It then briefly assesses the technological and policy environment in Asia before focusing on this "new" emerging industry in South Korea. It shows that South Korea has made scant progress in the development of biodiesel relative to its counterparts in the Asia-Pacific area. In the case of ethanol, Korea is farther behind. In addition to policy measures, it shows that some countries, including India, Japan, South Africa, and the United States, are joining efforts with Brazil to further develop the biofuels industry on an international scale. The study concludes that South Korea could increase the effectiveness of its biofuel development by partnering with countries that have a demonstrated expertise and capacity to be reliable suppliers.

The Biofuel Industry and Brazil's Pioneering Leadership

Because of the rising prices of oil as well as energy security and environmental concerns, a great number of public and private authorities are encouraging the development of a new breed of energies and technologies more suitable to the needs of the twenty-first century.[5] Biofuels—fuels produced from a renewable biomass to be used in internal combustion engines or in other types of energy generation—have emerged as an important energy source given their capability to partially or totally replace fossil fuels. As a result of Brazil's large expanses of idle land, a significant share of which is used to raise cattle, and its favorable climate, Brazil has searched to develop a more renewable energy development model, and it has become a benchmark case for other countries.[6]

Brazil has one of the most diversified energy matrices in the world. While the percentage of consumption divided between renewable and nonrenewable fuels for the world is 13 percent and 87 percent, respectively, for Brazil these values are 45.9 percent and 54.1 percent.[7] Data published by the Ministry of Mining and Energy show that total nonrenewable energy consumption in 2007 was divided as follows: 37.4 percent from petroleum and its derivatives, 9.3 percent from natural gas, 6 percent from coal, and 1.4 percent from uranium. As ***Figure 1*** shows, the remaining sources responsible for the 45.9 percent of Brazil's renewable energy sources were hydroelectricity representing 14.9 percent, sugarcane representing 15.9 percent, wood representing 12 percent, and other types of biomass fuels totaling 3.2 percent. These sources totaled 238.8 Mtoe, which was 2 percent of total world energy supply.[8]

Figure 1: **Brazil's Energy Matrix, 2008**



Source: Ministry of Mining and Energy, Brazil

The search for oil-alternative sources of energy has a long history in Brazil. Government policy and technological innovations have been instrumental to the successful adoption of biofuels. The nation's first experience using ethanol as a transportation fuel took place in 1925, and some years later, in 1931, the Institute of Sugar and Alcohol was created.[9] These early efforts were buttressed in the early 1970s. When the world economy experienced two great economic shocks caused by the abrupt rise in the price of petroleum, the Brazilian government launched the Brazilian Ethanol Program, also called Pró-Alcool. The program, which was developed at a time of growing reductions in the country's sugar exports, consisted of the development of technologies and the introduction of incentives to increase production and 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 ethanol in its pure form as a fuel for car engines.

From the onset, 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, or Copersucar, in 1979. This cooperative established the Copersucar Center of Technology that rapidly became the local focus and coordinator of subsidized research in breeding, milling, and fermentation of sugarcane for sugar or ethanol production.[10]

At the policy level, the Brazilian government played an active role in the Pró-Alcool program during the 1970s and early 1980s through measures directed at stimulating both supply and demand.[11] The evolution of the sugarcane-ethanol industry in Brazil has been strongly supported by a series of significant subsidies that have been introduced and sustained by successive governments. Tax incentives and subsidies have reduced the prices of ethanol-powered cars, making them highly attractive to

Brazilian consumers. From 1975 to 2000, nearly 5.6 million ethanol-powered cars were produced in Brazil. The introduction of a mix of alcohol in the fuel of gasoline-powered cars (1.1 percent to 25 percent of ethanol per liter of fuel) also played an important role. It has been estimated that, as a result of the adoption of ethanol in automobile transportation, the emission of 110 million tons of carbonic gas in the atmosphere has been avoided and the importation of 550 million petroleum barrels at an expenditure of $11.5 billion has been saved.

Brazil produces two basic kinds of ethanol from the fermentation of moist 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 mixing share was fixed by the Brazilian government to be any amount 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.

Future plans suggest that Brazil will continue to pursue a strategy based on the rapid and widespread use 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) of up to 40 percent (E-40). Most of the new and refurbished older plants that have been modernized can produce both sugar and ethanol as well as electricity. The 2007 sugarcane harvest was split, with 55 percent of the total used for ethanol sugar and the remaining 45 percent for sugar. In the same year, Brazil exported 66 percent of its sugar and 15 percent of its ethanol production. In the case of ethanol exports, 50 percent was converted into fuel, and 50 percent was used in the food and beverage industry. In Brazil's domestic market, a record 90 percent was used for fuel consumption and only 10 percent as input in other industries. The growing use of ethanol as a fuel was due not only to the oscillations of petroleum prices but also to the launch of flex fuel vehicles in 2003. Flex fuel cars may operate with any proportion of gasoline and ethanol, ranging from 0 to 100 percent, and drivers have the power to constantly decide the best fuel alternative depending on the costs of alcohol and oil. A record 1.7 million flex fuel vehicles were produced in Brazil; this is equivalent to 71.9 percent of the total automotive fleet manufactured in 2007.[12]

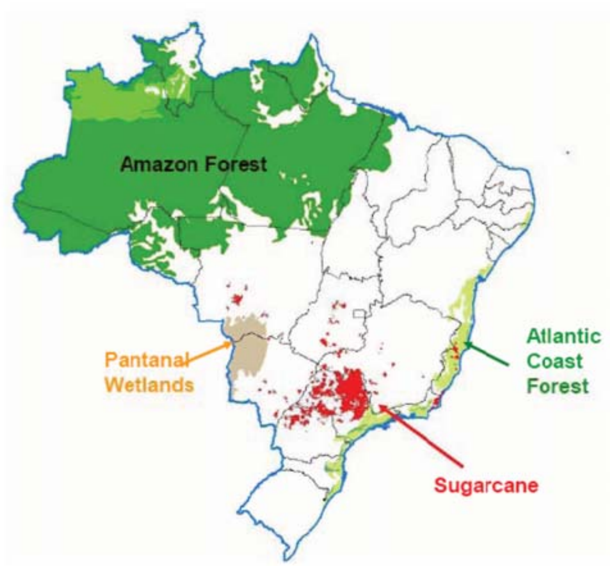
Historically, Brazil has been the largest producer of ethanol. However, U.S. production is growing at a faster rate than any other country owing to recently implemented large subsidies for corn producers and ethanol end users. China, the European Union, India, and Russia are also large producers of ethanol, but Brazil's production is comparatively more efficient. Brazilian production of energy from sugarcane is more efficient than from beet or wheat used as a feedstock in the European Union, from corn in United States, from cassava in Thailand, or even from other species of sugarcane in India. For example, the energy output to energy 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 of energy in the national electricity grid.

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. Some have even suggested that ethanol production has been a cause of the Amazon rainforest's devastation. The distribution of sugarcane production in the five regions of Brazil presented in ***Figure 2*** below shows that this argument is not substantiated by the data, as 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 sugar and ethanol production.

While the area devoted to sugarcane production rose by 85 percent between 1990 and 2008, ethanol and sugar production increased 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 Mining and Energy show that there remains about half (24 percent of the 45 percent) 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.

A second concern that has been raised and has become important more recently has to do with the rise in world food prices that could be caused by the increase in ethanol production. Although the price of oil dropped to an average of $20 per barrel in the 1980s and 1990s, oil

Figure 2: **Sugarcane Production in Brazil and Location of Production by Region, 2007**



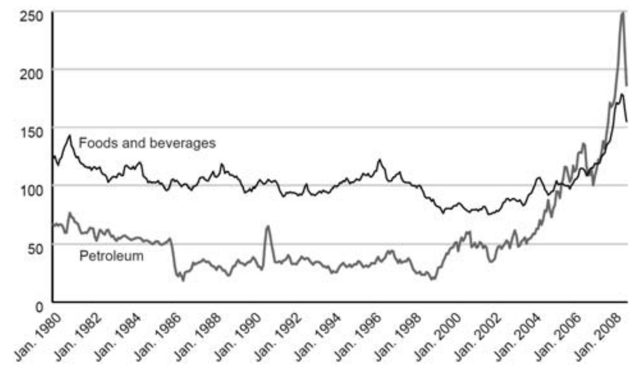
Regions in Brazil	Cubic meters (in thousands)
North	47
Northeast	1,901
South	1,923
Center West	2,902
Southeast	15,782
Total	22,555

Source: National Petroleum Agency of Brazil, 2008.

prices have been rising since the beginning of 1999. Food and commodity prices have also risen, but, as ***Figure 3*** shows, the International Monetary Fund (IMF) petroleum price index increased by 137.8 percent between 1998 and 2008, while the IMF food and beverage price index (which includes cereal, vegetable oils, meat, seafood, sugar, bananas, oranges, coffee, tea, and cocoa) has risen by only 52.15 percent. This apprehension, however, may abate somewhat in the near term. With the current financial crisis and an expected worldwide recession, oil and perhaps even food prices will fall.

Nevertheless the oil-versus-food debate remains ongoing, and consensus has not been reached.[13] Jacques Diouf, director-general of the Food and Agriculture Organization, has argued that "if we get it right, bioenergy provides us with a historic chance to fast-forward growth in many of the world's poorest countries, to bring about an agricultural renaissance and to supply modern energy to a third of the world's population." On the other hand, Jean Ziegler, the UN special rapporteur on the Right to Food, has warned that "it is a crime against humanity to convert agriculturally productive soil into soil which produces foodstuffs that will be burned into [*sic*] biofuel."[14] Reflecting on this ongoing discussion, Ban Ki-moon, UN secretary-general, at a recent world conference on the topic demanded a historical revitalization of agriculture and a greater level of international consensus on biofuels.[15]

Figure 3: **Indices of Food and Petroleum Prices, 1980–2008**



Source: Indices of Primary Commodity Prices, International Monetary Fund, 5 June 2008, http://www.imf.org/external/np/res/commod/table1a.pdf. Note: 2005 = 100.

A New Renewable Energy Fuel: Biodiesel

Biofuels can be produced almost everywhere in the world, but few countries will become large-scale producers able to service 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 twentieth 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.

One of the biggest challenges that most countries are facing is not to produce biofuels but to secure a large-scale and long-term supply. This includes obtaining not only economies of scale but also learning economies. To help different countries overcome adversities of developing a large-scale production of a new energy source, first- and second-generation technologies for biomass feedstock and production processes of biofuels are already being developed and tested in different countries.

The 2006 report, “Biofuels in the European Union: Vision for 2030 and Beyond,” reviews these first- and second-generation technologies.[16] The report shows that the first generation of technologies includes conventional bioethanol, pure plant oil (PPO), biodiesel from energy crops, rapeseed methyl ester (RME), fatty acid methyl/ethyl ester (FAME/FAEE), biodiesel from waste (FAME/FAEE), and upgraded biogas. The second generation includes cellulosic bioethanol, biomass-to-liquids (BTL), Fischer-Tropsch (FT) diesel, synthetic (bio)diesel, biomethanol, heavier (mixed) alcohols, bio-dimethyl-ether (Bio-DME), NExBTL, and SNG (synthetic natural gas).

Each of these technologies demands time and large amounts of investments to be fully developed. 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 the International Biofuels Forum in March 2007. The Forum is open to receiving other interested countries 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 into a commodity to be traded in a liberalized world market.[17]

In 2007 the two largest ethanol producers also signed an agreement to advance bilateral, regional, and multilateral cooperation. The U.S.-Brazil Memorandum of Understanding on Biofuels includes provisions for both countries to work together to advance research and development of the next generations of biofuels. With respect to regional initiatives, both countries agreed to encourage production and consumption of biofuels in third countries. Feasibility studies by representatives of the two countries working in partnership with the Organization of American States, Inter-American Development Bank, and UN Foundation have been started in the Dominican Republic, El Salvador, Haiti, and St. Kitts and Nevis. At the multilateral level, both countries 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.[18] Recently, Brazil and the United States agreed to expand their bilateral biofuels agreement to include Guatemala, Honduras, Jamaica, Guinea-Bissau and Senegal. In October 2008, the two countries also established a joint effort to develop 2nd generation biofuel technologies through Cenepes (Petrobrás Center for Research & Development) and NREL (National Renewable Energy Lab).

Brazil and the United States also have a strong potential to be the largest producers of biodiesel in a short period of time. In Brazil the ethanol program has not been the only attempt to develop renewable fuels. In 1983, the Brazilian government started the National Program of Vegetable Oils Production for Energetic Ends (also called Pro-óleo). This program concentrated efforts on the development and production of biodiesel from vegetables—including the castor-oil plant, colza, sunflower, soybean, African palm, and peanut—that would then be mixed with diesel oil. The program was deactivated in 1985 owing to the fall in oil prices and was restarted in 2002 by the Ministry of Science and Technology as part of the Brazilian Biofuels Program.

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 friendly fuels in the domestic market. Biodiesel was introduced into the Brazilian market in 2005, and 3 percent of biodiesel has been blended with diesel fuels for commercialization as B3 since March 2008. Brazilian law provides that a minimum blend of 5 percent will be required by 2013.

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) indicated that 736 cubic meters (0.74 million liters, equivalent to 4,630 barrels) of biodiesel were being produced in 2005, the program’s first year. Two years later, total production reached 402,152 cubic meters (402 million liters, equivalent to 2,529,475 barrels). In the first six months of 2008, production had already reached 557,670 cubic meters (559 million liters, equivalent to 3,514,680 barrels), a 268 percent growth as compared with the total produced in the same six first months of 2007.[19] By September 2008, ANP, which is the agency that authorizes the commercialization of biofuels, estimated that installed capacity could be used to produce 2,818,646 cubic meters per year (300 days).[20]

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, three 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.

Asia-Pacific Ethanol and Biodiesel Initiatives

The countries in the Asia-Pacific 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 supply 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.

The cost-benefit rationale of undertaking investments to develop biofuels in the short-term horizon must be weighed against other geopolitical factors. These include the potential effects that could be caused by food shortages, food price inflation, and agricultural land and water constraints as well as climate improvements. Initiatives to develop the promising second generation of biofuels from the lignocellulosic biomass sources, such as agricultural and forest residues and nonedible vegetable oils, as well as the visionary third-generation experiments, such as those based on the extraction of biodiesel from marine feedstocks like algae, have yet to achieve the industrial and commercial scale necessary for domestic or international trade. Indeed, in some developed countries the second generation of biofuel technologies has surpassed the laboratory, and the technologies are being tested on an industrial scale.

The enactment of a new energy bill in 2007 requiring 130 billion gallons (492.1 billion liters) of biofuels to be produced by 2022 in the United States and President-elect Barack Obama's promise of a $150 billion investment to "green" the country's use of energy in the next 10 years have served as wake-up calls encouraging countries to secure their sources of ethanol and biodiesel internally or externally. Japan, which is the world's second-largest economy and a leader in the development of clean-energy technologies, has sought to reduce greenhouse gases by 6 percent of 1990 levels by 2012 in compliance with its Kyoto Protocol commitments. As part of these efforts, the country is working to enter into cooperative partnerships with Brazil and other leading ethanol and biodiesel suppliers.

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 biofuels a year, which is equivalent to 37 percent of Brazil's 2007 production of ethanol. Japan has also been the country in Asia 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 in Brazil dedicated to Japan, 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. After the United States (importing 858 million liters) and the Netherlands (808 million liters), Japan was the third-largest importer of Brazilian ethanol in 2007. Although the majority of these resources are used in the industrial and beverage industries, the country also imported 364 million liters of ethanol from Brazil.

Several other Asian countries are important, albeit relatively small, producers of biofuels. Indonesia is potentially the most important producer of ethanol and biodiesel in Asia.[21] The fact that the country will become a net oil importer sometime between 2010 and 2015, as will Malaysia, has encouraged the nation to make significant efforts to secure the supply of biofuels. It is developing special biofuel zones and self-sufficient energy villages as well as improving local government and community participation in its nascent biofuel industry.[22]

Traditional technology to produce biofuels from palm oil or molasses and starch are available, but thus far the experiments to use these technologies to develop the most promising jatropha plants have not been as successful as expected. Many countries in Asia have been undertaking efforts to produce biodiesel from this plant, as has been the case of the company Embrapa in Brazil. Indonesia is also trying to develop a new coastal natural plant, calophyllum inophyllum, as a new feedstock for biodiesel. Indonesia and Malaysia are the two largest producers of palm oil in the world. However, the land for expanding palm plantations is limited. In these countries, most of palm oil is exported, and the channeling of these feedstocks to produce biofuels will surely result in skyrocketing domestic prices.[23]

In addition, Thailand, which has been exploring cassava as the main feedstock to produce ethanol, and the Philippines, which is using sugarcane for ethanol and coconut and jatropha for biodiesel production, are also seeking to increase biofuel production. Since the beginning of 2008, Thailand has been enforcing nationwide a requirement that 2 percent of biodiesel produced mainly from palm oil be used in all diesel vehicles. The Philippines has been mandating a minimum blend of 1 percent biodiesel in all diesel since March 2007, and 5 percent bioethanol in gasoline will be mandatory by January 2009.[24] As in Malaysia, in Thailand and the Philippines biofuel crops are fast displacing food crops in productive lands; hence, they are compromising food security. Moreover, these efforts are also expanding deforestation in the region that in the past 25 years has been averaging a 1 percent loss of forests each year.[25] Some have even asserted that the "forests in Indonesia and Malaysia are being filled so quickly that 98 percent could be gone by 2022."[26]

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 and India, which are the two most populous countries in the region and which have fueled their demand for ever-growing supplies of energy and food, have potential impacts on a global scale. The effects on air pollution, partially owing to the nearly 15 percent annual increase in the automobile fleet running in congested cities in these two countries, is just one example. China has begun to awaken to these problems and in response is beginning to develop a biodiesel industry. This energy-hungry country has established a target of biofuel share of 15 percent for transportation energy 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.

At the beginning of 2008, before the onset of the current worldwide financial and economic crises, the Indian economy was projected to grow between 8 to 10 percent a year during the next two decades.[27] The fifth-largest energy consumer in the world currently imports 70 percent of its total oil needs, and by 2030 this share is expected to increase to 94 percent. India has also introduced measures to develop its own biofuels industry. The government has been trying to encourage the production of biodiesel from jatropha since 2003 but without much success. Some states now blend 5 percent of ethanol in gasoline, and the implementation of a mandatory 10 percent blend is presently under discussion. In 2002 India signed a memorandum with Brazil for technological cooperation in the field of blending of ethanol in transport fuels and created the Trilateral Task Force on Biofuels to work on concrete areas of common interest in the context of the India, Brazil, and South Africa Forum that began in 2006.

In the Asia-Pacific region the future of biofuels was succinctly summarized by the Energy Working Group of the Asia-Pacific Economic Cooperation, which stated that "the question today is no longer whether or not biofuels will be a part of the energy mix, but rather what are the economic, social, and environmental implications to their large-scale adoption."[28] Asian economies have a high potential to develop the biofuels industry. Mature technologies have already been developed. Effective policy options to increase the incorporation of biofuels as an energy source are available. These could include the introduction of direct or indirect subsidies, tax relief, and mandatory requirements to blend biofuels into gasoline and diesel. The greatest uncertainties for the development of the biofuels market in the region are the volatility of oil prices and insufficiency of feedstock supply for production.

South Korea's Needs for Energy for Transportation

Increasing dependence on oil imports, which increased from 73.5 percent of the country's needs in 1980 to 96.5 percent in 2006 in South Korea, is a common phenomenon of all fast-growing industrial economies with few natural resources. At the same time, during the past 25 years, oil and coal have decreased as shares of South Korea's energy matrix. By 2006, fossil fuels represented 43.8 percent and coal 25.4 percent of energy consumption. Liquid natural gas and nuclear energy, which were zero or almost zero in 1980, represented 13.3 percent and 16 percent, respectively, of energy demand by 2006. In that same year, the share of hydro energy was just 0.6 percent, and renewables and other sources were 1.8 percent.

During this same period, the industry and transport sectors increased their shares from 44.9 percent to 55.4 and 9.6 percent to 21.1 percent, respectively. The share of resources directed for residential, commercial, and public uses has decreased from 45.5 percent to 23.5 percent. Even though the type of energy and the amount of consumption in different sectors have changed considerably in the last quarter century, South Korea remains highly dependent on energy imports. In 2007, energy represented 27.7 percent of its total imports.[29]

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, biofuels are not being considered for a major role. The country has resolved to increase the share of overseas production from imports of oil and gas from 3.7 percent and 5.8 percent in 2005 to 15 percent and 30 percent, respectively, in 2013. According to 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 $1,000 in 2005 to 0.30 tons of oil equivalent per $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 15 August 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 20 reactors in operation; 6 more are under construction, and 2 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, they would not change significantly Korea's strong dependence on fossil oil and other sources of energy, including atomic energy.

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.[30] These efforts, however, are concentrated on new and renewable energies that prioritize the development of solar power using photovoltaics 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 H2/fuel cells for residential and building use.

Although biomass resources are scarce, Korea has begun investing in new and renewable energies. Like Japan, South Korea does not have a large territory and does not have a good climate for producing any of the most efficient feedstocks for biofuels. The drive to secure energy sources has risen because South Korea has introduced measures requiring a compulsory mixture of 3 percent of biodiesel in diesel by 2012. Thus far, efforts have been focused on developing a biodiesel industry for the two-thirds of the transportation sector that runs on diesel. The other one-third runs on gasoline, and plans to introduce ethanol were initiated in 2006. In the absence of large domestic supplies of the feedstocks necessary to produce biofuels, an important concern has been and will continue to be focused on securing an external supply of either raw materials or biodiesel and ethanol. In addition, both the national government and the private sector are developing second- and third-generation biofuels, which include the production of biodiesel from algae and hydro fuels from biomass.

Bae from the Korean Energy Economics Institute[31] and Kang from the Samsung Economic Research Institute[32] 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 provision 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, a voluntary agreement between the Korean government and oil companies introduced 0.5 percent biodiesel (BD 05) into gas stations throughout the country. As a result of these efforts, total consumption of biodiesel nearly doubled, reaching 90 thousand kiloliters in 2007. The estimates made by these researchers indicate that biodiesel will increase to 1 percent of diesel supply in 2008 and 3 percent in 2012. At present, 11 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 waste oil (23 percent).

A pilot project using ethanol will test 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. Analysis of these proposed domestic supply sources clearly shows that a major challenge will be the limited available quantity of arable land that can be used to grow this feedstock. As ***Table 1*** illustrates, Kang forecasts that the provision of ethanol will begin in 2010 and reach 1,881 thousand kiloliters by 2030.

Given the scarcity of arable land in South Korea, companies are seeking to produce biofuels elsewhere. In July 2008, Samsung, the electronics, engineering, construction, and shipbuilding *chaebol*, announced plans to invest $1.63 billion to produce biodiesel from oil palms in Indonesia.[33] 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.

Recent media reports have confirmed plans for an influx of investment by a Korean consortium for the production of biodiesel in the state of Parana, Brazil.[34] Twenty Korean companies will initially invest $30 million in a mill to process biodiesel from soybeans. Given that 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.

Conclusion

Renewable energy sources including biofuels can play an important role in mitigating the warming of the stratosphere owing to carbon emissions and the securing of an alternative to fossil fuel for industry and transportation uses. This study has shown that 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 of any in the world.

Since 2005 the country has also introduced a biodiesel program, and production in the first six months of 2008 rose by an average of 268 percent as compared to the same semester in 2007. Soybeans, which Brazil produces on a large scale, are being used as inputs. In addition, other feedstocks are being used to produce biofuels in different parts of the vast Brazilian territory. Production and processing technologies for a large array of oil plants are under investigation to improve their energy efficiency. There are hopes that Brazilian production of biodiesel will reach a larger scale than ethanol in the coming years.

Table 1: **South Korea's Needs for Energy Transportation, 2005–2030 (est.), in thousands of kiloliters and percentage**

Types of energy	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
Percentage of 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
Percentage of ethanol	0	1	5	10	15	20

Source: Heechan Kang, "The Current Status of Bio-Fuels in Korea, 2008" (Seoul: Samsung Economic Research Institute, 2008).

Those countries that have advanced the most in promoting biofuels have implemented policies to encourage the adoption of these alternative fuels in their transport sector. They have also invested in research and development efforts regarding feedstocks, processes, and advanced initiatives based on bilateral and multilateral agreements. Some countries and companies have sought to partner with Brazil in the effort to learn about and develop the biofuels industry. These partnerships are driven by desires to secure supplies of feedstock as well as the pure fuel. They have involved technology transfers, exchanges of experts, and joint ventures.

Although South Korea has a demonstrated record of selecting and rapidly developing strategic sectors of its dynamic economy, it has not yet focused a significant share of its resources on the development of biodiesel and ethanol. Because of Korea's increasing needs for energy and lack of natural resources, efforts to develop the second generation and the promising third generation of renewable biomass energies and the introduction of fuel blends are important and much needed. This study has shown that Korea should not wait to develop its green engines of growth. The country is at risk of falling behind its neighbors and also failing to be part of strategic partnerships that will define the renewable energies paradigm. By acting strategically, the country of "a great people with new dreams" can shorten the needed time to reach its hopes of a more sustainable economy.

Gilmar Masiero is a Professor in the Department of Management of the School of Economics, Management, Accounting, and Information Sciences at the University of Brasilia — UnB.

Endnotes

[1] Biofuel is defined as a fuel compounded of alkyl ester of long chain fatty acids, derived from vegetal oils or animal grass and ethanol (C2H5OH), and used as a fuel in engines of the Otto cycle in the transport sector. Nicolaus Otto in 1876 demonstrated how a four-stroke cycle engine works; this became the most common type of engine used in cars and lightweight trucks.

[2] *Biofuels for Transport: An International Perspective* (Paris: International Energy Agency, 2004), www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf.

[3] *World Energy Outlook 2007* (Paris: International Energy Agency, 2007), http://www.worldenergyoutlook.org/2007.asp.

[4] *Energy Security and Sustainable Development in the Asia Pacific Region* (Bangkok: U.N. Economic and Social Commission for Asia and the Pacific [ESCAP], 2008), www.unescap.org/esd/energy/publications/theme_study/themstudy.pdf.

[5] Nebojsa Nakicenovic, Arnulf Grubler, and Alan MacDonald, eds., *Global Energy: Perspectives* (New York: Cambridge University Press, 1998).

[6] Garten Rothkopf, "A Blueprint for Green Energy in the Americas: Strategic Analysis of Opportunities for Brazil and the Hemisphere" (Washington, D.C.: Inter-American Development Bank, 2007), www.iadb.org/biofuels/.

[7] "Resenha Energética Brasileira: Exercício de 2007," and "Resenha Energética Brasileira: Exercício de 2008," Ministry of Mining and Energy, Brazil.

[8] Ibid.

[9] Luciano Lourenço Nass, Pedro Antônio Arraes Pereira, and David Ellis, "Biofuels in Brazil: An Overview," *Crop Science* 47 (November–December 2007).

[10] There has been an intense sugarcane breeding program in Brazil, where 550 varieties of sugarcane were developed and 51 varieties have been released since 1995. Currently, 20 varieties account for 70 percent of the total planted area.

[11] Although the Brazilian government played a lead role in the growth of the biofuels industry, its activism has decreased. When the Brazilian economy was suffering from high external debt and high inflation in the 1980s, the Pró-Alcool program was discontinued and officially terminated in 1988 in response to its relatively high costs and the low world market prices for oil. Following the recovery of the Brazilian economy from its "lost decade," when inflation was brought under control after the Real Plan of 1994, government support for sugarcane producers was once again strengthened primarily through funding of research such as the sequencing of the sugarcane genome, a project that was started in 1999 and involved more than 200 scientists from 22 Brazilian research groups.

[12] *2007 Statistical Yearbook* (Brasília: Associação Nacional dos Fabricantes de Veículos Automotores (Anfavea), 2007).

[13] C. Ford Runge and Benjamin Senauer, "How Biofuels Could Starve the Poor," *Foreign Affairs*, May/June 2007.

[14] Edith M. Lederer, "UN Expert Calls Biofuel 'Crime against Humanity,'" LiveScience.com (Associated Press), 27 October 2007, http://www.livescience.com/environment/071027-ap-biofuel-crime.html.

[15] Ban Ki-moon (speech at the High-Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy, UN Food and Agriculture Organization, Rome, 3 June 2008).

[16] "Biofuels in the European Union—A Vision for 2030 and Beyond," Report no. EUR 22066 (Brussels: European Commission, Directorate-General for Research, Sustainable Energy Systems, 2006), http://ec.europa.eu/research/energy/pdf/biofuels_vision_2030_en.pdf.

[17] Suani Teixeira Coelho, "Biofuels—Advantages and Trade Barriers" Paper no. UNCTAD/DITC/TED/2005/1 (paper prepared for Expert Meeting on the Developing Countries' Participation in New and Dynamic Sectors of World Trade, Geneva, 7–9 February 2005), www.unctad.org/en/docs/ditcted20051_en.pdf.

[18] Alan M. Wright, "Brazil-U.S. Biofuels Cooperation: One Year Later" (Washington, D.C.: Woodrow Wilson International Center for Scholars, Brazil Institute, June 2008), www.wilsoncenter.org/topics/pubs/brazil.biofuels.wirec.pdf.

[19] Produção Nacional de Biodiesel Puro—B100 (metros cúbicos), Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, Brasília, www.anp.gov.br/doc/dados_estatisticos/Producao_de_biodiesel_m3.xls.

[20] "Capacidade Autorizada de Plantas de Produção de Biodiesel," Ministry of Mining and Energy, Brasília, www.anp.gov.br/biocombustiveis/capacidade_plantas.asp.

[21] A protocol between Brazil and Indonesia on technical cooperation in the areas of ethanol production was signed in July 2008.

[22] Hanafi Sulistyowati, "Bioenergy: Opportunity, Challenge, and Way Forward in Indonesia" (presentation at the Regional Forum on Bioenergy Sector Development: Challenges, Opportunities, and the Way Forward, ESCAP and Asian Pacific Centre for Ag-

ricultural Engineering and Machinery, Bangkok, 23–25 January 2008).

[23] Malaysia, for example, which is the world's largest exporter of palm oil, produced 15.82 million tons and exported 13.74 million tons to generate earnings of $13.7 billion; for further details, see Puah Chiew Wei and Choo Yuen May, "Palm Biodiesel Development and Its Social and Environment Impacts in Malaysia" (presentation at the Policy Dialogue on Biofuels in Asia: Benefits and Challenges, Beijing, 24–26 September 2008).

[24] *Biofuels Act of 2006,* Republic Act No. 9367, 12 January 2007, www.lawphil.net/statutes/repacts/ra2007/ra_9367_2007.html.

[25] Alan Dale C. Gonzales, "Overall Stocktaking of Biofuel Development in Asia-Pacific: Benefits and Challenges" (background paper for "Policy Dialogue on Biofuels in Asia: Benefits and Challenges," Beijing, 24–26 September 2008.

[26] Bae Jeong-hwan, "Opportunity and Challenge for the Evolution of Biofuels in the Asia and Pacific Region" (presentation at the Regional Forum on Bioenergy Sector Development: Challenges, Opportunities, and the Way Forward, ESCAP and Asian Pacific Centre for Agricultural Engineering and Machinery, Bangkok, 23–25 January 2008), www.unapcaem.org/ppta/0801Bio.htm.

[27] Paul Varghese, "India's Biodiesel Programme: Promises and Challenges" (presentation at the Regional Forum on Bioenergy Sector Development: Challenges, Opportunities, and the Way Forward, ESCAP and Asian Pacific Centre for Agricultural Engineering and Machinery, Bangkok, 23–25 January 2008).

[28] Asian-Pacific Economic Cooperation. *The Future of Liquid Biofuels for APEC Economies.* Energy Working Group. APEC#208-RE-01.8. May 2008.

[29] "Energy Statistics 2008" (Kyonggi-do: Korea Energy Economics Institute, 2008), www.keei.re.kr.

[30] Bang Ki-yual, "Energy Policy Directions towards Sustainable Development in Korea" (presentation at Challenge of Climate Change and the Role of the Renewables, Daesung Group World Energy Forum, 10 May 2007), http://daesungwef.korea.com/wef/Ki-YualBang.pdf.

[31] Bae Jeong-hwan, "Biofuel Promotion Policy and Economics in Korea" (presentation at the International Conference on Commercialization of Biofuels, 17 September 2007), www.keei.re.kr/keei/download/seminar/070917/4_Jeong-Hwan_Bae.pdf.

[32] Kang Hee-chan, "Biofuels as Korea`s Alternative Energy Sources" (Seoul: Samsung Economic Research Institute, 2006); "Evaluation and Implication for the Validity of Korean-type Biofuels" (Seoul: Samsung Economic Research Institute, 2007); and "The Current Status of Bio-Fuels in Korea 2008" (presentation at the Regional Forum on Bioenergy Sector Development: Challenges, Opportunities, and the Way Forward, ESCAP and Asian Pacific Centre for Agricultural Engineering and Machinery, Bangkok, 23–25 January 2008), http://www.unapcaem.org/ppta/0801Bio.htm.

[33] "Samsung Group to Develop Biodiesel in Indonesia," *Jakarta Post,* 22 July 2008.

[34] "Coreanos investirão na produção de biodiesel no Paraná," *Valor Econômico,* 7 August 2008.

The Korea Economic Institute is registered under the Foreign Agents Registration Act as an agent of the Korea Institute for International Economic Policy, a public corporation established by the Government of the Republic of Korea. This material is filed with the Department of Justice, where the required registration statement is available for public inspection. Registration does not indicate U.S. Government approval of the contents of this document.

KEI is not engaged in the practice of law, does not render legal services, and is not a lobbying organization.

The views expressed in this publication are those of the author. While this publication is part of the overall program of the Korea Economic Institute, as endorsed by its Board of Directors and Advisory Council, its contents do not necessarily reflect the views of individual members of the Board or the Advisory Council.