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A0005 Alternative Transportation Fuels: Contemporary Case Studies

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1. Introduction
2. General Overview
3. Case Studies: Ethanol Use Worldwide
4. Flex-Fuel Vehicles

Glossary

G0005 **biodiesel** An ester that can be made from substances such as vegetable oils and animal fats. Biodiesel can either be used in its pure state or blended with conventional diesel fuel derived from petroleum.

G0010 **ethanol** Ethyl alcohol (CH_3CH_2OH); one of a group of chemical compounds (alcohols) composed of molecules that contain a hydroxyl group (OH) bonded to a carbon atom. Ethanol is produced through the fermentation of agricultural products such as sugarcane, corn, and manioc. Most of the ethanol produced in the world is from sugarcane, mainly in Brazil. In the United States, ethanol is made from corn.

G0015 **gasohol** A mixture of 20–26% anhydrous ethanol (99.6° Gay-Lussac and 0.4% water) and gasoline; used in most vehicles in Brazil.

G0020 **methyl *tert*-butyl ether (MTBE)** A chemical compound that is manufactured by the chemical reaction of methanol and isobutylene. MTBE is produced in very large quantities (over 3.18×10^6 liters/day in the United States in 1999) and is almost exclusively used as a fuel additive in motor gasoline. It is one of a group of chemicals commonly known as "oxygenates" because they raise the oxygen content of gasoline. At room temperature, MTBE is a volatile, flammable, and colorless liquid that dissolves rather easily in water.

G0025 **Organization for Economic Cooperation and Development (OECD)** An international body composed of 30 member nations. Its objective is to coordinate economic and development policies of the member nations.

G0030 **transesterification** The reaction of a fat or oil with an alcohol in the presence of a catalyst to produce glycerin and esters or biodiesel. The alcohol, which carries a positive charge to assist in quick conversion, is recovered for reuse. The catalyst is usually sodium hydroxide or potassium hydroxide.

Alternative transportation fuels are those fuels not derived from petroleum. These fuels include not only those derived from renewable sources but also natural gas and its derived fuels. A general overview of the existing status of development of alternative fuels for transportation throughout the world is presented in this article. Long-term experiences, such as the Brazilian Alcohol Program and several programs in the United States, as well as those in other countries, are also discussed. P0005

1. INTRODUCTION S0005

The perspective that envisions exhaustion of the world's oil reserves is not the main reason for researching and developing alternative fuels; rather, it is for environmental and strategic reasons that alternative fuel technology is of importance. For example, big cities such as São Paulo, Mexico City, and Delhi (among others) currently face serious environmental problems due to the pollutant emissions from vehicles. Some countries have proposed and enacted solutions for these problems. Ambient concentrations of lead in the São Paulo metropolitan region dropped more than 10 times from 1978 to 1991, far below the air quality standard maximum, due to the mandatory use of either an ethanol/gasoline blend or straight ethanol in all cars, legislated through the Brazilian Alcohol Program (further details are discussed in Section 3.1). Strategic aspects of alternative fuel development are also significant due to the fact that most oil reserves are P0010

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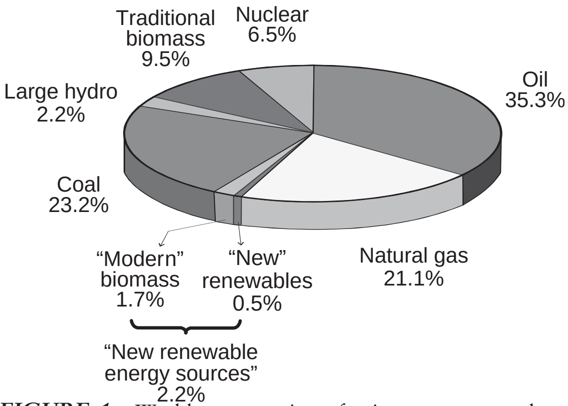

F0005 ***FIGURE 1*** World consumption of primary energy and renewables, by energy type, 1998.

in the Middle East, a region facing complex political conflicts. The current trends show that the world will continue to depend on fossil fuels for decades; however, because the largest share of the world's oil resources is concentrated in regions with potential or active political or economic instabilities, alternative fuels ease the complexity of worldwide distribution of necessary energy resources. Nuclear energy plants, although an alternative to fossil fuels, are also concentrated only in a few countries and nuclear technology raises numerous concerns on physical security grounds.

P0015 Organization for Economic Cooperation and Development (OECD) countries, which account for 80% of the world economic activity, are quite dependent on oil imports, with a 63% share of global oil consumption (expected to rise to 76% in 2020). Asian Pacific countries are expected to increase the external dependence of their energy requirements to 72% by 2005. Compared to fossil and nuclear fuels, renewable energy resources are more evenly distributed, although only 2.2% of the world energy supply in 1998 was from new renewable sources. New renewable sources include modern biomass, small hydropower, geothermal energy, wind energy, solar (including photovoltaic) energy, and marine energy. Natural gas accounts for 21.1% of this supply (Fig. 1).

S0010 2. *GENERAL OVERVIEW*

P0020 The alternative fuels being used in the world today include biodiesel, electricity, ethanol, hydrogen, methanol, natural gas, propane, and solar energy. In 1999, the U.S. Department of Energy finalized an amendment to the Energy Policy Act of 1992 that added certain blends of methyltetrahydrofuran (MeTHF), ethanol, and light hydrocarbons to the list of approved "alternative fuels." These liquid products for spark-ignited engines have come to be known under the registered trademark, "P-series." The discussion here is limited to the fuels already being commercialized.

2.1 Biodiesel S0015

Biodiesel is an ester that can be made from substances such as vegetable oils and animal fats. Biodiesel can either be used in its pure state or blended with conventional diesel fuel derived from petroleum. Vegetable oil was used as a diesel fuel as early as 1900, when Rudolf Diesel demonstrated that a diesel engine could run on peanut oil. For vegetable oils to be used as fuel for conventional diesel engines, the oils must be further processed, primarily because of their high viscosity. Transesterification (production of the ester) of vegetable oils or animal fats, using alcohol in the presence of a catalyst, is the most popular process. For every 100 units of biodiesel fuel produced using this method, there are 11 units of glycerin as a by-product. Glycerin is used in such products as hand creams, toothpaste, and lubricants. Another biodiesel production process in limited use involves cold-pressed rapeseed oil, but no glycerin by-product is produced. Alternatively, unprocessed vegetable oils can be used in modified diesel engines. Such engines have limited production and are therefore more expensive, although their numbers are increasing in Europe. P0025

The main benefits of biodiesel can be categorized as strategic (increased energy self-sufficiency for oil-importing countries), economic (increased demand for domestic agricultural products), and environmental (biodegradability and improved air quality, particularly lower sulfur emissions and almost null carbon balance). Exhaust emission improvements include substantial reduction in carbon monoxide, hydrocarbons, and particulates, although the production of nitrogen gases can be similar to that of regular diesel fuel (depending of the diesel quality). The United States, New Zealand, Canada, and several European Union countries have conducted extensive tests of biodiesel in trucks, cars, locomotives, buses, tractors, and small boats. Testing has included the use of pure biodiesel and various blends with conventional diesel. Among the developing countries, the Biodiesel Program started in Brazil in 2002 was notable for its goal to replace part of the diesel consumption in the Brazilian transportation P0030 sector. Presently, the major disadvantage of biodiesel is its high production cost. As discussed in Section 3.1, in the case of Brazil, biodiesel forecasted costs are higher than diesel costs.

S0020 *2.1.1 Biodiesel in the United States*

P0035 Interest in biodiesel in the United States was stimulated by the Clean Air Act of 1990, combined with regulations requiring reduced sulfur content in diesel fuel and reduced diesel exhaust emission. The Energy Policy Act of 1992 established a goal of replacing 10% of motor fuels with petroleum alternatives by the year 2000 (a goal that was not reached) and increasing to 30% by the year 2010.

S0025 *2.1.2 Biodiesel in Europe*

P0040 Two factors have contributed to an aggressive expansion of the European biodiesel industry. Reform of the Common Agricultural Policy to reduce agricultural surpluses was of primary importance. This policy, which provides a substantial subsidy to non-food crop production, stimulated the use of land for non-food purposes. Secondarily, high fuel taxes in European countries normally constitute 50% or more of the retail price of diesel fuel. In 1995, Western Europe biodiesel production capacity was 1.1 million tons/year, mainly produced through the transesterification process. This added over 80,000 tons of glycerin by-products to the market annually, creating created a large surplus. Germany thus decided to limit the production of biodiesel using the transesterification process. When it is not possible to market the glycerin by-product, one method of disposal of the excess is incineration; however, this creates an environmental risk and results in additional costs. Germany is now focusing on biodiesel production using the cold-pressed rapeseed method to avoid the problem of excess glycerin.

S0030 *2.1.3 Biodiesel in Japan*

P0045 In early 1995, Japan decided to explore the feasibility of biodiesel by initiating a 3-year study. Biodiesel plants using recycled vegetable oils collected in the Tokyo were planned; 10% of federal vehicles were expected to use alternative fuels to set an example for the private automotive and fuel industries. The 3-year study indicated production costs for biodiesel in Japan are 2.5 times that of petroleum diesel. The program has only recently reach its objectives.

S0035 *2.1.4 Biodiesel in Canada*

P0050 In the early 1990s, Canadian canola production increased in response to higher market prices relative to cereal grains and increased grain handling and transportation costs. Canola production peaked in 1994 and 1995, limited by suitable land base and crop rotational requirements. However, higher yield due to new *Brassica juncea* varieties and improved chemical weed control may further increase production in the medium term. There is a potential for the use of lower quality canola oils derived from overheated or frost-damaged seed without any ill effects on biodiesel quality.

2.1.5 Biodiesel in Brazil S0040

In 1998, several initiatives were implemented in Brazil, aiming to introduce biodiesel into the Brazilian energy matrix. The initiatives included (1) tests performed in South Brazil, using the so-called B20 blend (20% ester and 80% diesel oil), in specific fleets of urban buses, (2) the building of a small-scale pilot plant for biodiesel production from fat and palm oil (largely produced in North Brazil), and (3) laboratory-scale production and tests of biodiesel using soybean oil/sugarcane ethanol. The Brazilian federal government subsequently decided to establish a work group of specialists from all involved sectors, creating the National Biodiesel Program in 2002. This program will mainly analyze the use of surplus of soybean oil, which is produced on a large scale in Brazil and is presently facing, export barriers. P0055

The economic competitiveness of biodiesel and diesel oil has been evaluated; studies in Brazil show that biodiesel production costs are higher than diesel costs (Table I). P0060

TABLE I T0005

Production Cost for Methyl Ester (1 ton) from Soy Oil in Brazil[a]

	(Amount)			
Input	Kilograms	Tons	Price (R $/ton)	Cost
Soy oil	1015	1.015	169.64	172.19
Methanol[b]	140	0.14	93.57	13.10
Catalyzer[c]	12	0.012	125.00	1.50
Input cost				186.79
Production cost (115% of input cost)				401.59
Total cost (U.S. $/ton)				588.38

[a] Data from the Brazilian Reference Center on Biomass (CENBIO). Exchange rate, Brazilian real (R)/U.S. dollar, $2.8/1 (July 2002). Diesel price in São Paulo pump stations is around R $1.00/liter (about U.S. $350/ton).

[b] Methanol cost based on prices at pump stations in California (U.S. $0.88–1.10/gallon).

[c] Catalyzer cost based on Brazilian market price. AU:1

S0045 ## 2.2 Electricity

P0065 Electricity is not, technically speaking, a fuel, but it is used in existing alternative technologies for powering transportation. Electricity can be used to power electric and fuel cell (discussed later) vehicles. When used to power electric vehicles (EVs), electricity is stored in an energy storage battery, which must be replenished by plugging the vehicle into a recharging unit. The electricity for recharging the batteries can come from the existing power grid (from large hydroelectric or thermoelectric power plants), or from distributed renewable sources, such as biomass, small hydro, solar, or wind energy. The main benefits to electric-powered vehicles are the lower pollutant emissions at the point of use, although the emissions generated in the electricity production process at the power plants or from the fuel reform reaction (when the fuel cells use hydrogen produced by the reform reaction, as discussed later) can be indirectly attributed to EVs. Economic aspects of using EVs include the high initial capital cost, which can be partially offset by the lower maintenance costs. When compared to the cost of gasoline, the cost of an equivalent amount of fuel for an EV is lower. Maintenance costs for EVs are lower because EVs have fewer moving parts to service and replace.

S0050 ## 2.3 Ethanol

P0070 Ethanol (ethyl alcohol, CH_3CH_2OH) is one of a group of chemical compounds (alcohols) with molecules that contain a hydroxyl group (OH) bonded to a carbon atom. Ethanol is produced through the fermentation of agricultural products such as sugarcane, corn, and manioc, among others. Most ethanol produced worldwide is from sugarcane, mainly in Brazil. In the United States, ethanol is made from corn.

P0075 Ethanol is used as a high-octane fuel in vehicles. More than 4 million cars run on pure, hydrated ethanol in Brazil, and all gasoline in the country is blended with anhydrous ethanol (20–26% ethanol), as a result of a government program to make ethanol from sugarcane, in place since the 1970s. In the United States, there is a similar program being started and the number of vehicles using ethanol is increasing.

P0080 Ethanol makes an excellent motor fuel: it has a motor octane number that exceeds that of gasoline and a vapor pressure that is lower than that of gasoline, which results in lower evaporative emission. Ethanol's flammability in air is also much lower than that of gasoline, which reduces the number and severity of vehicle fires. Anhydrous ethanol has lower and higher heating values of 21.2 and 23.4 megajoules (MJ)/liter, respectively; for gasoline the values are 30.1 and 34.9 MJ/liter. Because ethanol in Brazil is produced from sugarcane, it has the lowest production cost in the world. This is due not only to high agricultural and industrial productivity levels, but also to the extremely favorable energy balance of the alcohol production. In the United States, ethanol is produced from corn and represents a large consumption of fossil fuels, with much lower energy balance, despite the existing controversy among specialists. Table II shows a comparison of the ethanol energy balance in Brazil (from sugarcane) and the United States (from corn). Ethanol can also be produced from cellulose feedstock (corn stalks, rice straws, sugarcane bagasse, etc.), through a process still under development.

In the United States, because of support from corn-growing states and the U.S. Departments of Energy and Agriculture, ethanol-fueled vehicle production is increasing. Auto manufacturers began in 1997 to produce cars and pickup trucks that could use either ethanol or gasoline. These flexible fuel (or flex-fuel) vehicles are discussed in Section 4. P0085

2.4 Hydrogen S0055

Hydrogen (H_2) is a gas that has considerable potential as an alternative fuel for transportation but, at this point, little market presence. The most important use of hydrogen is expected to be in electric fuel cell vehicles in the future. Fuel cell cars are in development by most major manufacturers, but hydrogen still lacks a wide distribution infrastructure. The current emphasis is on the use of hydrogen to supply the fuel cells that power electric vehicles. Fuel cells produce electricity. Similar to a battery, a fuel cell converts energy produced by a chemical reaction directly into usable electric power. However, unlike a battery, a fuel cell needs an external fuel source—typically hydrogen gas—and generates electricity as long as fuel is supplied, meaning that it never needs electrical recharging. Inside most fuel cells, oxygen and hydrogen from a fuel tank combine (in an electrochemical device) to produce electricity and warm water. As a simple electrochemical device, a fuel cell does not actually burn fuel, allowing it to operate pollution free. This also makes a fuel cell quiet, dependable, and very fuel efficient. P0090

An impediment to the use of fuel cells is the hydrogen production and storage. The predominant P0095

T0010 *TABLE II*

Energy Balance of Ethanol[a] from Sugarcane and from Corn

Product	Source	Fossil fuel consumption in ethanol production (MJ/liter of ethanol)[b]	Final energy balance[c]
Ethanol from sugarcane[d]	Macedo (2000)	1.89[h]	11.2:1
Ethanol from corn			
Existing plants[e]	Pimentel (1991)	42.6	Negative
Laboratory tests[f]	Pimentel (1991)	25.6	Negative
Existing plants[e]	Unnasch (2000)	11.8	1.8:1
With allocation to coproducts[g]	Unnasch (2000)	7.19	2.9:1

[a] Lower ethanol energy value: 21.2 MJ/liter.

[b] Fossil fuel consumption in ethanol production corresponds to diesel oil use in the agricultural phase and during transport, to coal and natural gas use in corn-based ethanol plants, and to natural gas use for fertilizer production.

[c] Final energy balance corresponds to the low energy content in 1 liter of ethanol divided by the total fossil fuel consumption to produce 1 liter of ethanol.

[d] Includes bagasse surplus production (Brazil); see footnote b.

[e] Large plants in the United States.

[f] Using membrane technology.

[g] Considering the coproduction of corn oil and animal feed products, the allocation of energy inputs corresponds to 1096 kcal/liter of ethanol.

[h] In sugarcane-origin ethanol plants, there is no fossil fuel consumption in the plant (all fuel consumed in the plant is sugarcane bagasse, the by-product of sugarcane crushing); fossil fuel consumption corresponds to the agricultural phase and fertilizer production.

method of making hydrogen today involves using natural gas as a feedstock. Petroleum-based fuels, including gasoline and diesel, can also be used, but this may compromise a major objective behind alternative fuels, i.e., to reduce oil consumption. Hydrogen production is through the "reform reaction" of an existing fuel (natural gas, methanol, ethanol, or naphtha), a chemical reaction that "extracts" the hydrogen from the fuel, producing a gas mixture of carbon monoxide (CO) and hydrogen. The hydrogen must be separated from the CO to be fed into the fuel cell. This reaction can be performed in a stationary system (and the vehicle will carry a high-pressure hydrogen storage tank) or in an on-board reformer/fuel cell system (and the vehicle will carry a conventional fuel tank to feed the system). Both possibilities are now under study in several countries. According to some specialists, ethanol should be the fuel of choice for fuel cells due to its lower emissions and because it is produced from a renewable source (biomass).

P0100 Though fuel cells have been widely publicized in recent years, they are not new: the first one was produced in 1839. Fuel cells powered the Gemini spacecraft in the 1960s, continue to power the Space Shuttle, and have been used by the National Aeronautics and Space Administration (NASA) on many other space missions. Although their operation is simple, they have been quite expensive to make. Extensive research and development have promised the widespread use of fuel cells in the near future. All major auto companies have fuel cell-powered vehicles in the works, and a nascent fuel cell industry is growing rapidly. By the kilowatt, fuel cells still cost more today than do conventional power sources (from $1000 upto $5000/kW, U.S. dollars), but an increasing number of companies are choosing fuel cells because of their many benefits, and large-scale production is expected to make fuel cell costs decline.

According to the U.S. National Renewable Energy Laboratory, hydrogen prices vary widely, depending on the transport distance and the type of hydrogen (from 17 to 55 cents/100 cubic feet), but cost figures for hydrogen use as transportation fuel are not yet available. P0105

2.5 Methanol S0060

Methanol (or methyl alcohol) is an alcohol (CH_3OH) that has been used as alternative fuel in flexible fuel vehicles that run on M85 (a blend of 85% methanol and 15% gasoline). However, methanol is not commonly used nowadays because car manufacturers are no longer building methanol-powered vehicles. Methanol can also be used to make methyl-*tert*-butyl ether (MTBE), an oxygenate that is blended with gasoline to enhance octane and reduce pollutant emissions. However, MTBE P0110 production and use have declined due to the fact that MTBE contaminates groundwater. In the future, methanol may be an important fuel, in addition to ethanol, to produce the hydrogen necessary to power fuel cell vehicles; such a process is now under development.

P0115 Methanol is predominantly produced by steam reforming of natural gas to create a synthesis gas, which is then fed into a reactor vessel in the presence of a catalyst to produce methanol and water vapor. Although a variety of feedstocks other than natural gas can and have been used, today's economics favor natural gas. Synthesis gas refers to combinations of carbon monoxide (CO) and hydrogen (H_2). Similar to ethanol vehicles, methanol-powered vehicles emit smaller amounts of air pollutants, such as hydrocarbons, particulate matter, and NO_x, than do gasoline-powered vehicles. However, the handling of methanol is much more dangerous compared to ethanol due to its high negative impacts on health.

P0120 World demand for methanol is around 32 million tons/year and is increasing modestly by about 2–3%/year, but with significant changes in the industry profile. Since the early 1980s, larger plants using new, efficient low-pressure technologies have replaced less efficient small facilities. Demand patterns have been changing in Europe; methanol was once blended into gasoline (when its cost was around one-half of that of gasoline), but now is not competitive with lower oil prices. Offsetting this was the phasing out of leaded gasoline in developed countries, mandating the use of reformulated gasoline. The United States promoted the use of MTBE derived from methanol. The United States produces almost one-quarter of the world's supply of methanol, but there is a significant surplus of methanol in the world. Figure 2 shows the world methanol supply, indicating this significant excess capacity.

P0125 The largest market for methanol in the United States is for the production of MTBE; there are nearly 50 U.S. plants. It is estimated that 3.3 billion gallons of MTBE was used in 1996 for blending into clean, reformulated gasoline serving 30% of the U.S. gasoline market. MTBE displaces 10 times more gasoline than all other alternative vehicle fuels combined.

P0130 Methanol prices in the United States have varied significantly since 1989; they doubled by 1994 and returned to the 1993 levels by 1996. In 2002, methanol prices reached 64 cents/gallon, slightly higher than European prices (61.7 cents/gallon) and Asian prices (55.9 cents/gallon).

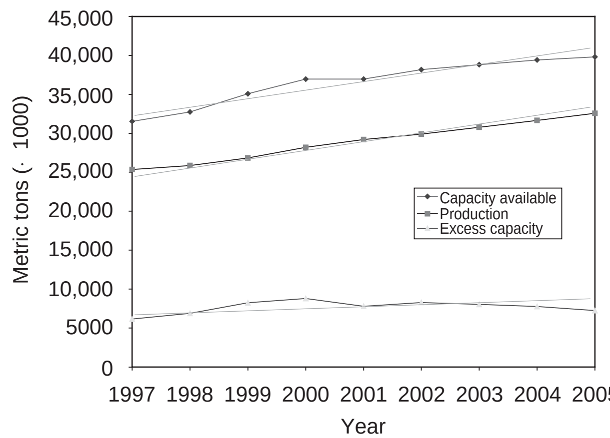

FIGURE 2 World methanol supply. Data from the Methanol Institute (www.methanol.org). F0010

2.6 Natural Gas S0065

Natural gas is a mixture of hydrocarbons, mainly methane (CH_4), but it also contains hydrocarbons such as ethane (C_2H_4) and propane (C_3H_8) and other gases such as nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapor. It is produced either from gas wells or in conjunction with crude oil production (associated natural gas). Natural gas is consumed in the residential, commercial, industrial, and utility markets. The interest in natural gas as an alternative fuel comes mainly from its clean burning properties, with extremely low sulfur and particulate contents. Also, carbon emissions from natural gas are lower compared to those from other fossil fuels, such as oil and coal. Because of the gaseous nature of natural gas, it must be stored on board a vehicle in either a compressed gaseous state (compressed natural gas) or in a liquefied state (liquefied natural gas). Natural gas is mainly delivered through pipeline systems. P0135

Natural gas reserves are more evenly distributed worldwide than are those of oil. According to BP Global, reserves at the end of 2000 totaled 5304 trillion cubic feet, with 37.8% of the reserves located in the former Soviet Union, 35% in the Middle East, 6.8% in Asia Pacific, 6.8% in North America, 4.6% in South and Central America, and 3.5% in Europe. By contrast, crude oil reserves are heavily concentrated in the Middle East, which alone held 65.3% of oil reserves at the end of 2000. Global proved natural gas reserves available in 2000 would last more than 60 years at the 2000 rate of production. Although production and consumption are likely to increase over time, past trends suggest that reserves will increase as well, especially with P0140 improvements to the technology employed to find and produce natural gas.

P0145 Consumption of natural gas for fuel increased more than consumption of any other fuel in 2000, with global consumption rising by 4.8%, the highest rate since 1996. This was driven by growth in consumption of 5.1% in the United States and Canada, which together represent more than 30% of world demand. Chinese consumption increased by 16%, although China still represents only 1% of world consumption. In the former Soviet Union, growth of 2.9% was the highest for a decade.

P0150 Gas production rose by 4.3% worldwide, more than double the average of the last decade. This growth is mainly due developments in the United States and Canada, where production rose by 3.7%, and the fastest since 1994. Growth exceeded 50% in Turkmenistan, Nigeria, and Oman, and 10% in 11 other countries. Russia, the second largest producer, saw output decline by 1.1%. North America produced and consumed in 2000 more than 70 billion cubic feet (bcf)/day. The former Soviet union produced about 68 bcf/day and consumed about 53 bcf/day. Europe produced less than 30 bcf/day but consumed about 1.5 times more. The balance is practically even in South and Central America (with a little less than 10 bcf/day) and is almost even in Asia Pacific (about 30 bcf/day; consumption higher than production) and the Middle East (about 20 bcf/day; production a little higher than consumption). Africa produced more than 10 bcf/day but consumed less than half of it.

P0155 In the U.S. market, natural gas prices are about \$1.5/million British thermal units (MMBtu) above oil spot prices, which ranged from \$2.1 to \$3.5/MMBtu by the end of 2002 (according to the U.S. Department of Energy; information is available on their Web site at www.eia.doe.gov).

S0070 2.7 Propane

P0160 Liquefied petroleum gas (LPG) consists mainly of propane (C_3H_8) with other hydrocarbons such as propylene, butane, and butylene, in various mixtures. However, in general, this mixture is mainly propane. The components of LPG are gases at normal temperatures and pressures. Propane-powered vehicles reportedly have less carbon build-up compared to gasoline- and diesel-powered vehicles.

P0165 LPG is a by-product from two sources: natural gas processing and crude oil refining. When natural gas is produced, it contains methane and other light hydrocarbons that are separated in a gas-processing plant. The natural gas liquid components recovered during processing include ethane, propane, and butane, as well as heavier hydrocarbons. Propane and butane, along with other gases, are also produced during crude refining as a by-product of the processes that rearrange and/or break down molecular structure to obtain more desirable petroleum compounds.

The propane market is a global market. Approximately 1.3 billion barrels of propane are produced worldwide. Although the United States is the largest consumer of propane, Asian consumption is growing fast. According to the World LP Gas Association, during 1999 China achieved a growth rate of over 20% in their consumption of propane, largely in the residential/commercial sector. Other notable increases were recorded in India, Iran, and South Korea, which are rebounding from the Asian economic crisis. P0170

2.8 Solar Energy S0075

Solar energy technologies use sunlight to produce heat and electricity. Electricity produced by solar energy through photovoltaic technologies can be used in conventional electric vehicles. Using solar energy directly to power vehicles has been investigated primarily for competition and demonstration vehicles. Solar vehicles are not available to the general public, and are not currently being considered for production. Pure solar energy is 100% renewable and a vehicle run on this fuel emits no pollutants. P0175

3. CASE STUDIES: ETHANOL USE WORLDWIDE S0080

3.1 The Brazilian Experience S0085

The Brazilian Alcohol Program (PROALCOOL) to produce ethanol from sugarcane was established during the 1970s, due to the oil crises, aiming to reduce oil imports as well as to be a solution to the problem of the fluctuating sugar prices in the international market. The program has strong positive environmental, economic, and social aspects, and has become the most important biomass energy program in the world. In 1970, some 50 million tons of sugarcane were produced, yielding approximately 5 million tons of sugar. In 2002, sugarcane production reached 300 million tons, yielding 19 million tons of sugar and 12 billion liters of alcohol (ethanol). In 2002, the total land area P0180 covered by sugarcane plantations in Brazil was approximately 4.2 million hectares (60% in the state of São Paulo, where sugarcane has replaced, to a large extent, traditional coffee plantations). The average productivity of sugarcane crops in Brazil is 70 tons/hectare, but in São Paulo State there are mills with a productivity of 100 tons of cane per hectare.

P0185 Ethanol production costs were close to $100/barrel in the initial stages of the program in 1980. After that, they fell rapidly, to half that value in 1990, due to economies of scale and technological progress, followed by a slower decline in recent years. Considering the hard currency saved by avoiding oil importation through the displacement of gasoline by ethanol, it is possible to demonstrate that the Alcohol Program has been an efficient way of exchanging dollar debt for national currency subsidies, which were paid by the liquid fossil fuel users.

P0190 The decision to use sugarcane to produce ethanol in addition to sugar was a political and economic one that involved government investments. Such decision was taken in Brazil in 1975, when the federal government decided to encourage the production of alcohol to replace gasoline, with the idea of reducing petroleum imports, which were putting great constraints in the external trade balance. At that time, sugar price in the international market was declining very rapidly and it became advantageous to shift from sugar to alcohol production. Between 1975 and 1985, the production of sugarcane quadrupled and alcohol became a very important fuel used in the country. In 2002, there were 321 units producing sugar and/or alcohol (232 in central–south Brazil and 89 in northeast Brazil). An official evaluation of the total amount of investments in the agricultural and industrial sectors for production of ethanol for automotive use concluded that in the period 1975–1989, a total of $4.92 billion (in 2001 U.S. dollars) was invested in the program. Savings on oil imports reached $43.5 billion (2001 U.S. dollars) from 1975 to 2000.

P0195 In Brazil, ethanol is used in one of two ways: (1) as an octane enhancer in gasoline in the form of 20–26% anhydrous ethanol (99.6° Gay-Lussac and 0.4% water) and gasoline, in a mixture called gasohol, or (2) in neat-ethanol engines in the form of hydrated ethanol at 95.5° Gay-Lussac. Increased production and use of ethanol as a fuel in Brazil were made possible by three government actions during the launching of the ethanol program. First, it was decided that the state-owned oil company, Petrobrás, must purchase a guaranteed amount of ethanol; second, economic incentives were offered to agro-industrial enterprises willing to produce ethanol, in the form of loans with low interest rates, from 1980 to 1985; third, steps were taken to make ethanol attractive to consumers, by selling it at the pump for 59% of the price of gasoline. This was possible because the government at that time set gasoline prices.

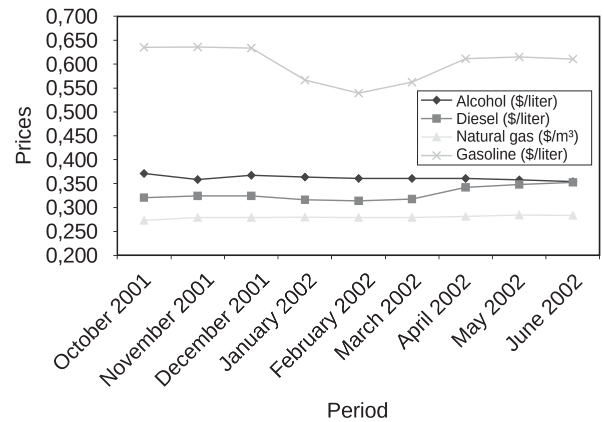

FIGURE 3 Transportation fuel prices in Brazil (in U.S. dollars). F0015

P0200 The subsidies for ethanol production have been discontinued and ethanol is sold for 60–70% of the price of gasoline at the pump station, due to significant reduction of production costs. These results show the economic competitiveness of ethanol when compared to gasoline. Considering the higher consumption rates for net-ethanol cars, ethanol prices at the station could be as much as 80% of gasoline prices. Fig. 3 shows a comparison of the different transportation fuels in Brazil.

3.1.1 Impact of Alcohol Engines on Air Pollution S0090

P0205 All gasoline used in Brazil is blended with 25% anhydrous ethanol, a renewable fuel with lower toxicity, compared to fossil fuels. In addition to the alcohol–gasoline (gasohol) vehicles, there is a 3.5 million-vehicle fleet running on pure hydrated ethanol in Brazil, 2.2 million of which are in the São Paulo metropolitan region. Initially, lead additives were reduced as the amount of alcohol in the gasoline was increased, and lead was completely eliminated by 1991. Aromatic hydrocarbons (such as benzene), which are particularly toxic, were also eliminated and the sulfur content was reduced as well. In pure ethanol cars, sulfur emissions were eliminated, which has a double dividend. The simple substitution of alcohol for lead in commercial gasoline has dropped the total carbon monoxide, hydrocarbon, and sulfur emissions by significant numbers. Due to the ethanol blend, ambient lead concentrations in the São Paulo metropolitan region dropped from 1.4 μg/m^3 in 1978 to less than 0.10 μg/m^3 in 1991, according to CETESB (the Environmental Company of São Paulo State), far below the air quality standard maximum of 1.5 μg/m^3. Alcohol hydrocarbon exhaust emissions are less toxic, compared to those from gasoline. They present lower atmospheric reactivity and null greenhouse emissions balance (9.2 million tons of carbon dioxide avoided in 2000 due only to the gasoline replacement by ethanol).

P0210 One of the drawbacks of the use of pure ethanol is the increase in aldehyde emissions as compared to gasoline or gasohol use. It can be argued, however, that the acetaldehyde from alcohol use is less detrimental to human health and to the environment, compared to the formaldehyde produced when gasoline is used. Total aldehyde emissions from alcohol engines are higher than emissions from gasoline engines, but it must be noted that these are predominantly acetaldehydes. Acetaldehyde emissions produce fewer health effects compared to the formaldehydes emitted from gasoline and diesel engines. Aldehyde ambient concentrations in São Paulo present levels substantially below the reference levels found in the literature. In addition, carbon monoxide (CO) emissions have been drastically reduced: before 1980, when gasoline was the only fuel in use, CO emissions were higher than 50 g/km; they went down to less than 5.8 g/km in 1995.

S0095 ### *3.1.2 Social Aspects of the Brazilian Alcohol Program*

P0215 Social considerations are the real determinants of the impact of the Brazilian alcohol program. Presently, ethanol production generates some 700,000 jobs in Brazil, with a relatively low index of seasonal work. The cost of creating a single job in the ethanol agroindustry is around $15,000 (U.S. dollars), according to recent studies by the São Paulo Sugarcane Agroindustry Union (UNICA). In Brazil, job generation in most other industries requires higher investments, as shown in Fig. 4.

P0220 Although Brazilian workers have low incomes relative to workers in developed countries, there has been a significant increase in agricultural mechanization, particularly in the São Paulo region. There are two main reasons for this trend: social changes such as urban migration have reduced the number of workers available to the sugarcane industry, promoting mechanization, and mechanization has proved cheaper than hand labor. Thus, the delicate balance between mechanization and the number and quality of new jobs created by the ethanol industry is likely to remain a key issue for several years.

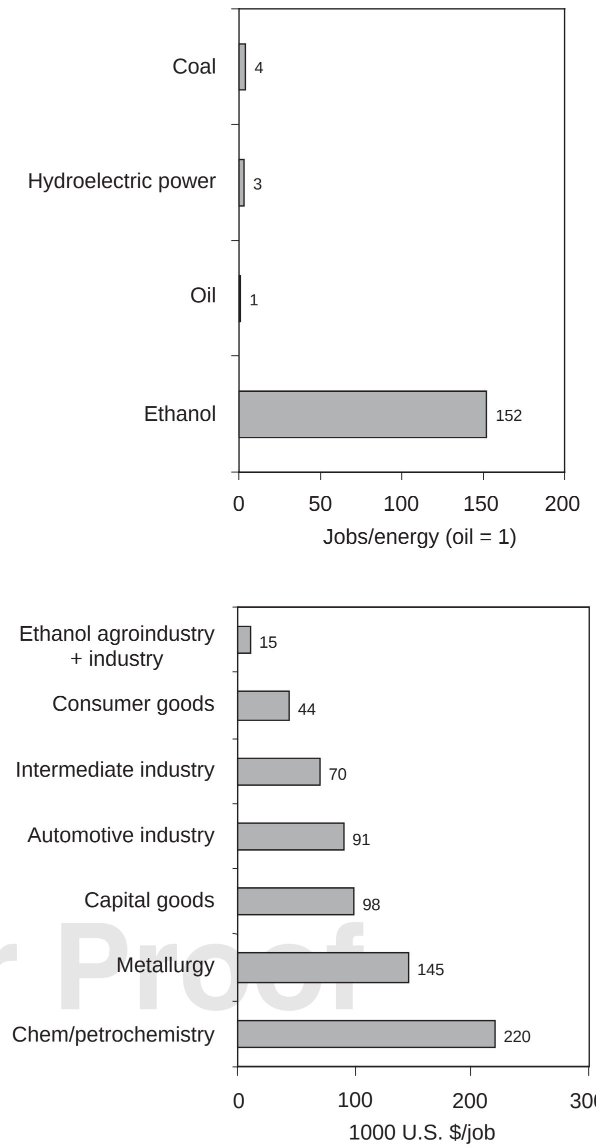

FIGURE 4 Employment numbers (2001) for the Brazilian Ethanol Program. Data from UNICA (2002). F0020

3.1.3 Outlook for the Brazilian Alcohol Program S0100

The use of alcohol as a fuel in Brazil was an extraordinary success until 1990. In 1988, sales of ethanol-powered cars represented 96% of the market; by the end of the decade, 4.5 million automobiles were sold. Since then, however, there has been a precipitous drop in the sale of new ethanol-powered cars, due to the following reasons: P0225

- The price of pure alcohol was set in 1979 at 64.5% of the price of gasoline but increased gradually to 80%, reducing the economic competitiveness.

- The tax on industrialized products (IPI), initially set lower for alcohol-fueled cars, was increased in 1990, when the government launched a program of cheap "popular cars" (motors with a cylinder volume up to 1000 cm^3) for which the IPI tax was reduced to 0.1%. According to the local manufacturers, the "popular cars" could not be easily adapted to use pure alcohol because this would make them more expensive and would take time. Competition between manufacturers required an immediate answer to benefit from the tax abatement.
- Significant lack of confidence in a steady supply of alcohol and the need to import ethanol/methanol to compensate for a reduction in local production due to the increase on sugar exports (high sugar prices in international market).

As a result, the sales of pure ethanol cars dropped almost to zero in 1996. However, in 2001, this scenario started to change: 18,335 units of pure ethanol car were sold, showing an increase in consumer interest. Use of blended ethanol–gasoline has not been affected due the existence of a federal regulation that requires addition of ethanol in all gasoline sold in Brazil.

P0230 Other countries adopt special taxes (mainly on gasoline) that are quite substantial (around 80% in Italy and France, around 60% in the United Kingdom, Belgium, Germany, and Austria, and around 30% in the United States). In addition, ethanol as an additive is made viable in some countries by differentiated taxes and exemptions. In the United States, federal taxes on gasoline are 13.6 cents/gallon (3.59 cents/liter). The addition of 1 gallon of ethanol leads to a credit of 54 cents/gallon, or $26.68/barrel (U.S. dollars). Some states have also introduced tax exemptions that are the equivalent of up to $1.10/gallon, or $46.20/barrel. The rationale for these subsidies and exemptions is the same as was used in Brazil in the past, such as the social benefits of generating employment and positive environmental impacts.

P0235 An interesting option regarding the future for the ethanol program is its expansion. To guarantee ethanol market expansion, there are two distinct alternatives: increase national demand or create an international alternative liquid fuel market. However, international trade of ethanol still faces several difficulties regarding import policies of developed countries. Finally, it is also important to consider the effect the use of ethanol has in the balance of payments made by Brazil. Since the beginning of the alcohol program in 1975, and until 2000, at least 216 million m^3 of ethanol have been produced, displacing the consumption of 187 million m^3 of gasoline. This means that around $33 billion (U.S. 1996 dollars) in hard currency expenditures were avoided.

The international alternative liquid fuel market is P0240
currently an interesting option if developed countries decide effectively to limit CO_2 emissions to satisfy the goals established in the 1992 Rio de Janeiro conference, in the Climate Convention adopted in the United Nations World Summit for Sustainable Development. There are also reasons to develop an alternative to fossil fuels for economic and strategic reasons while promoting better opportunities for farmers. Food production efficiency has improved so much in the past 30 years that around 40–60 million hectares (Mha) of land is now kept out of production to maintain food product prices at a reasonable level able to remunerate farmers in the OECD countries. With the introduction of biomass-derived liquid fuels, a new opportunity exists for utilization of such lands and preservation of rural jobs and employment in industrialized countries. Not all industrial countries have free agricultural areas to produce biofuels, and even those that do will not be able to satisfy fully the demand for biofuel, at a reasonable price and in an environmentally sound way. The total automobile fleet in Western Europe exceeds 200 million units, demanding more than 8 million barrels/day (bl/day) of gasoline. To satisfy such a level of demand with a 10% ethanol blend, production of 0.8 million bl/day is necessary, of which probably two-thirds would be imported. This means an international market of 530,000 bl/day for ethanol from sugarcane, which could be shared mainly by a few developing tropical countries, such as Brazil, India, Cuba, and Thailand. With the creation of such a market, some developing countries could redirect their sugarcane crops to this market instead of to sugar. Sugar is a well-established commodity with a declining real average price in the international market. This is not the case for gasoline, for which the average real price is increasing.

Finally it is worthwhile to add that the interna- P0245
tional fuel market option has the potential to increase ethanol demand to a level above the level presented here, because (depending on the seriousness of environmental problems) ethanol blends of up to 25% may be marketed in the future, as is already happening in Brazil, as well as the possibility that such a practice will be followed by the diesel oil industry. Brazil's sugarcane industry is recovering

Article Number: NRGY : 00177

T0015 *TABLE III*

Comparative Prices of Transportation Fuels in Brazil and the United States[a]

	Prices			
	Brazil		United States	
Fuel	Low	High	Low	High
Gasoline	20.92	24.69	11.49	20.38
Natural gas	7.63	7.94	6.21	6.48
Diesel	8.67	9.75	8.81	10.41
Ethanol[c]	16.39	17.76	17.92	21.90
Methanol	na[d]	na[d]	12.93	16.14

[a] Data from Brazilian Petroleum National, the Alternative Fuels Data Center, the U.S. Gas Price Watch, and the Ministry of Science and Technology. Calculations by the Brazilian Reference Center on Biomass.

[b] All prices in U.S. dollars ($/m^3); average prices taken between January and July, 2002. Exchange rate, Brazilian real (R)/U.S. dollar, 2.8/1.

AU:8 [c] Brazilian ethanol from sugarcane and U.S. ethanol from corn.

[d] na, Not available.

from a significant decrease in production in recent years; in 2002, a sugarcane surplus allowed Brazil to increase ethanol exports. Table III shows comparative prices of gasoline, natural gas, diesel oil, methanol, and ethanol in both Brazil and the United States. The low prices of gasoline in the United States are remarkable compared to Brazilian prices. It also must be noted that ethanol prices in Brazil, in contrast to the United States, do not include any subsidies.

S0105 3.2 The U.S. Experience

P0250 In 2000, 19.7 million barrels of crude oil and petroleum products were consumed in the United States per day (25% of world production); more than half of this amount was imported. The United States has the lowest energy costs in the world. In 2001, ethanol-blended fuels represented more than 12% of motor gasoline sales, with 1.77 billion gallons produced from corn. Corn is used as the principal feedstock, in contrast to practices in Brazil, where all ethanol is produced from sugarcane, which considerably less expensive than corn. The U.S. Congress established the Federal Ethanol Program in 1979 to stimulate rural economies and reduce the U.S. dependence on imported oil. In 1992, the Energy Policy Act established a goal of replacing 10% of motor fuels with petroleum alternatives by the year 2000, increasing this to 30% by the year 2010.

In 2002, the U.S. Senate passed an energy bill that includes a provision that triples the amount of ethanol to be used in gasoline in the next 10 years. This policy, combined with regulations requiring reduced sulfur content in diesel fuel and reduced diesel exhaust emission, also was designed to foster an interest in biodiesel. Ethanol blended fuel is now marketed throughout the United States as a high-quality octane enhancer and oxygenate, capable of reducing air pollution and improving vehicle performance. The federal administration denied California an oxygenate waiver in 2002, thus ethanol fuel production is expected to grow strongly. According to the Renewable Fuels Association, by the end of 2003, U.S. annual ethanol production capacity will reach 3.5 billion gallons (13.25 billion liters). P0255

California currently uses 3.8 billion gallons/year of MTBE, compared with total U.S. use of 4.5 billion gallons/year. MTBE, like ethanol, is an oxygenate that allows lower pollutant emissions from gasoline. Under federal law, in urban areas with the worst pollution (as in many California cities), gasoline must contain at least 2% oxygen by weight. This requirement applies to about 70% of the gasoline sold in California. The use of MTBE will be discontinued by 2003 in California, being replaced by ethanol, which does not present risks of contamination of water supplies. P0260

In the United States, fuel ethanol production increased from about 150 million gallons in 1980 to more than 1700 million gallons in 2001, according to the Renewable Fuels Association. In the period 1992–2001, the U.S. demand for fuel ethanol increased from 50 to 100 thousand barrels/day, whereas MTBE demand increased from 100 to 270 thousand barrels/day. According to the Renewable Fuels Association, ethanol production in the United States affords several advantages: P0265

- Ethanol production adds $4.5 billion to U.S. farm income annually.
- More than 900,000 farmers are members of ethanol production cooperatives; these cooperatives have been responsible for 50% of new production capacity since 1990.
- Ethanol production provides more than 200,000 direct and indirect jobs.
- Ethanol production reduces the U.S. negative trade balance by $2 billion/year.

In June 2002, ethanol and MTBE prices in the United States were practically equivalent ($1/gallon). Gasoline prices were $0.8/gallon. P0270

S0110 3.3 Other Countries

S0115 *3.3.1 Europe*

P0275 In the European Union, currently only about
AU:2 0.01 billion m^3 of ethanol is used as fuel. In 1994, the European Union decided to allow tax concessions for the development of fuel ethanol and the other biofuels, and as result a number of ethanol projects have been announced in The Netherlands, Sweden, and Spain. France has one of the most developed fuel alcohol programs in the European Union. A 1996 law requires the addition of oxygenate components to fuel, and ethanol was given an early exemption from the gasoline excise tax.

P0280 The European Commission (EC) is currently drafting a directive that could force member states to require 2% biofuels in all motor fuels. The directive, if eventually confirmed by the European Parliament and Council, could be enforced as early as 2005. France, Austria, and Germany have already experimented with biodiesel, and other countries, including Sweden, Spain, and France, use ethanol or ethyl *tert*-butyl ether (ETBE) in gasoline. Sweden is the first country in Europe that has implemented a major project introducing E85 fuel and vehicles. Approximately 300 vehicles have been in use in Sweden since the mid-1990s and 40 E85 fueling stations have been established from Malmo, in the south, to Lulea, in the north. In 1999, a consortium composed of the Swedish government, many municipal administrations, companies, and private individuals contacted over 80 different car factories inquiring about the production of an ethanol-fueled vehicle for use in Sweden. A major criterion was that it should not be much more expensive than a gasoline-powered vehicle. Car manufacturers are presently marketing these vehicles. The ethanol fuel will be produced and distributed by all major gasoline companies in Sweden. The production of the blend, 4–5% ethanol in gasoline from the first large-scale plant, will occur at the oil depots in Norrköping, Stockholm, and Södertälje. In the region near these depots, all unleaded 95-octane gasoline will contain ethanol. In 1998, Swedish gasoline consumption was 5.4 million m^3; a 5% ethanol blend means consumption of 270,000 m^3 ethanol annually, i.e., more than five times the capacity of the plant in Norrköping.

S0120 *3.3.2 Australia*

P0285 There is a plan under development in Australia that will enable Australia to produce 350 million liters of ethanol annually by 2010. The increase in production, equivalent to approximately 7% of the current petrol market, would total 1% of the liquid fuel market. The Agriculture Minister also intends to ensure that biofuels contribute to 2% of Australia's transportation fuel use by 2010. Under the new plan, a capital subsidy of A$0.16 for each liter of new or expanded biofuel production capacity constructed would be presented to investors. This is equivalent to a subsidy of about 16% on new plant costs. At least five new ethanol distilleries are expected to be set up under the new program, generating a possibility of 2300 construction and 1100 permanent jobs.

The Australian Environment Ministry recently P0290
announced that the federal government is trying to determine an appropriate level of ethanol in fuel and would not enforce mandatory levels of ethanol. The federal government has been asked by Australian sugarcane growers to create a plan that would develop a variable and sustainable ethanol industry throughout the country. A producers' working group would assist the government in the production of the plan. The sugarcane growers have also announced plans to launch an educational campaign that will focus on the benefits of ethanol. The cane growers hope to win the support of other farmers throughout the country. Manufacturers announced they would build a 60-million gallon/year ethanol plant in Dalby, Australia, making it the country's largest. The project is expected to be completed by the end of 2003. The plant will process sorghum, wheat, and maize into ethanol that will be blended with petrol sold through 40 or more of the company's service stations.

3.3.3 New Zealand S0125

The Queensland Government has announced that its P0295
vehicle fleet will switch to petrol blended with ethanol. Although the switch was welcomed by the Queensland Conservation Council, concerns were expressed about the environmental risks and problems associated with sugarcane farming. The Council noted that they would work to ensure that sugarcane growing is environmentally sound. The Cane Growers' Association believes it is unlikely that the sugar industry will expand due to the government's decision. The Association will not encourage the planting of more cane, because it is likely that the ethanol will be made from the by-product molasses or that it will be sourced out of cereal crops.

3.3.4 South Africa S0130

There are four major ethanol producers in South P0300
Africa. The largest ones produce up to 400 million

AU:3 liters/year of ethanol from coal. This capacity was developed during the 1950s to reduce South Africa's dependence on oil imports during the apartheid era. Synthetic ethanol production can top 400 million liters/year, but usually fluctuates with demand on the world market in general, and on the Brazilian market in particular. Since the mid-1990s, the efforts to introduce coal-derived ethanol into gasoline have repeatedly failed because of petroleum and automobile industry complaints about the low quality of the ethanol. Coal-derived alcohols are not pure ethanol. The original alcohol additive contained only 65% ethanol, which caused significant engine problems. In 1990, the quality issues seem to have been resolved through development of an 85% ethanol blend, and the coal-derived ethanol is used in South Africa as a 12% blend with gasoline. South Africa also produces ethanol from natural gas, about 140 million liters/year, and it is quite expensive. In addition, there are other plants that use molasses as a feedstock.

S0135 *3.3.5 Thailand*

P0305 In 2000, Thailand launched a program to mix 10% ethanol with gasoline. Ethanol would be produced from molasses, sugarcane, tapioca, and other agricultural products. The goal was the production of
AU:4 730 million liters/year by 2002. One of the major sugar groups in Thailand announced that it would invest Bt800 in an ethanol plant in 2002. This group would apply for a license to produce ethanol as an alternative fuel for automobiles. On approval from the National Ethanol Development Committee, the building of the plant was scheduled to begin immediately and it was expected to take 12 to 18 months to complete. The group expects to use molasses, a by-product supplied by the group's sugar mills, to produce 160,000 liters of ethanol/day.

S0140 *3.3.6 Japan*

P0310 In order to reduce automobile emissions, Japan is considering introducing a policy that will support the use of blending ethanol with gasoline. The policy is a result of pressures to cut greenhouse gas emissions that lead to global warming. As the second largest consumer of gasoline in the world, Japan has no extra agricultural produce to use for fuel output. Thus, the use of biofuels could create a big export opportunity for ethanol-producing countries. The trading house of Mitsui & Co. is backing ethanol use in Japan. Mitsui estimates Japan's ethanol market at approximately 6 million kiloliters/year at a blending ratio of 10%. Due to an ample supply of low-cost gasoline produced by imported crude oil, the Japanese have yet to use ethanol as a fuel. Japan's interest in green energy increased with the 1997 Kyoto Protocol, which went into effect in 2002. The Kyoto Protocol aims to cut carbon dioxide emissions by 5.2% by 2012.

In order to implement mandatory use of ethanol in P0315
Japan, the Environment Ministry must win the support of the oil-refining industry as well as the energy and transportation arms of the government.

3.3.7 Malawi S0145

Malawi has very favorable economic conditions for P0320
ethanol. Like Zimbabwe, Malawi was on the forefront of fuel alcohol development; Malawi has blended ethanol with its gasoline continuously since 1982, and has thereby eliminated lead. Because of high freight costs, the wholesale price of gasoline is about 56 cents/liter retail. Moreover, Malawi's molasses has a low value because the cost of shipping it to port for export typically exceeds the world market price. Malawi's Ethanol Company Ltd. produces about 10–12 million
liters/year, providing a 15% blend for gasoline. AU:5

3.3.8 China S0150

China is also interested in introducing an alcohol P0325
program. A pilot program was introduced in the Province of Jilin in 2001, and, in 2002, a Chinese delegation from the Province of Heilonjiand visited Brazil. The Chinese government is concerned about the increase in oil consumption in the country (around 7–7.5%/year between 2000 and 2005) and the alcohol–gasoline blend appears to be an interesting option due to job generation and to the potential for reducing the pollution in large Chinese cities. China finds itself short on fuel and producing only 70% of the nation's demand, and the country is also faced with a sagging economy for farmers. In order to fight both problems, China is considering a new program to launch its first ethanol plant. Despite the numerous projected benefits, the program is not expected to be implemented right away. Although ethanol is environmentally friendly, it is still expensive to produce in China and there are difficulties in transporting it. China hopes that the cost will come down in the next 5 years, making ethanol a viable option for the country.

Despite no laws mandating the use of greener P0330
fuels, China has continued to phase out petroleum products since 1998. China is encouraging the use of alternative fuels in their "Tenth Five-Year Plan," which includes trial fuel ethanol production (2001–2005).

S0155 ### *3.3.9 India*

P0335 India is one of the largest producers of sugarcane in the world (300 million tons of sugarcane, similar to Brazilian production) and has vast potential to produce ethanol fuel, which would significantly reduce air pollution and the import of petroleum and its products. The Indian distillery industry has an installed capacity of over 3 billion liters (Brazilian production is in average 13 billion liters of alcohol per year), but operates only at 50% capacity. Also, the Indian sugar industry currently faces an uncertain future, with high stock valuations, unattractive export balances, and narrow operating margins. There are also the issues related to the balance of payments due to oil imports. Therefore, there is a growing interest in ethanol as major business opportunity, mainly to produce anhydrous ethanol to be used in a 5% ethanol–gasoline blend.

P0340 The New Delhi government is currently reviewing the excise duty structure on ethanol. The government hopes to make ethanol more attractive to oil companies that blend ethanol with petrol. Government officials are currently concerned about India's sugar farmers, who have found it difficult to sell their crop. As the demand for ethanol-blended petrol increases, so will the demand for sugarcane increase. India produced 18.5 million tons of sugar in the past year. It is expected that, if a trial run proves successful, ethanol-blended petrol (5% ethanol) will be sold throughout the country. The government plans to free all market pricing of petrol.

S0160 ## *4. FLEX-FUEL VEHICLES*

P0345 Flex-fuel vehicles are vehicles that can operate with multiple fuels (or fuel blends). Such technology was created 1980 and there are around 2 million flex-fuel vehicles in the United States today. The main fuels used include gasoline and several alternative fuels, such as pure ethanol (already used in Brazil in automotive vehicles) and blends of ethanol and gasoline. Already in use in Brazil is an ethanol–gasoline; blend at a percentage of 20–26% ethanol. Another blend of ethanol–gasoline (E85), with 85% ethanol, is used in the United States; a blend of methanol–gasoline also used in the United States has 85% methanol. The methanol–gasoline blend has a limited potential for widespread use, because most automobile manufacturers do not build fuel systems compatible with methanol blends. Flex-fuel vehicles have a small processor placed inside the fuel system; the processor detects the fuel blend being used and automatically adjusts the ignition time and the mixture of air and fuel. The greatest advantage of the flex-fuel vehicles is that they can operate with regular gasoline when alternative fuels are not available or are not economically competitive.

Flex-fuel cars in the United States are built to utilize natural gas, pure gasoline, and gasoline blended with a small percentage of ethanol. In Brazil, flex-fuel motors have to be built to accept a much larger percentage of ethanol; the larger percentage of ethanol does negatively affect the life span of the fuel tank and other parts of the engine system, and the design requirements and shortened system life span add to the overall expense of the vehicles. P0350

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17-18	230	425	790	1,120	1,410	1,665	1,875	2,050	2,185	2,285	2,345
19-20	250	455	855	1,210	1,525	1,795	2,025	2,210	2,355	2,460	2,520
21-22	260	465	880	1,250	1,575	1,855	2,095	2,290	2,440	2,545	2,605
23-24	265	475	905	1,290	1,625	1,920	2,165	2,365	2,520	2,630	2,690
25-26	275	485	930	1,325	1,675	1,980	2,235	2,440	2,600	2,715	2,780
27-28	285	490	955	1,365	1,730	2,040	2,305	2,520	2,685	2,800	2,865
29-30	295	500	980	1,405	1,780	2,100	2,375	2,595	2,765	2,880	2,950
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