The steam engine reigned supreme from the early 18th to the mid-19th century as man’s best invention for producing useful power. It replaced not only animals – used for millennia in milling, transportation and industry – but also the power of the wind, used in maritime transportation. The innovation was so important that it was proudly hailed as a symbol of progress and economic development. The steam engine made commercial navigation faster and more efficient, popularized rail travel and delivered the industrialization sought by governments of all persuasions. To this day, references to the industrial era conjure in our minds the image of the famous “London fog” – symbol of the unchecked use of steam engines – itself a mixture of coal smoke with steam pouring forth from thousands of boilers. In 1698, Thomas Savery, an Englishman, invented his wood or coal-fired external combustion “fire engine” wherein water was superheated inside a closed container. A number of different models were produced in various sizes, but there remained the limitation that the power obtained was direct-

1 President of the Environmental and Energy Committee at the National Association of Motorized Vehicles Fabricants (ANFAVEA).

All images in this article were provided by the author.
ly proportional to boiler size, and the larger the boiler the more heating it required. Furthermore, the furnace needed constant stoking with coal or wood to maintain those high temperatures. Because of these limitations, the steam engine never replaced animal power for individual transportation, urban collective transportation or even cartage over small distances. Its application, albeit widespread, was always as a stationary motor in industry or agriculture or as a prime mover for smoke-belching locomotives, steamboats or ships. There were several experiments with tractors and even over-land vehicles, but these applications were few and limited compared to conventional stationary use.

The first internal combustion engine was invented and built by Belgian engineer Jean Joseph Étienne Lenoir. Born in Luxembourg in 1822, Lenoir emigrated to France in 1838 and waited tables in Paris. He began working as a mechanic...
in 1852, and six years later tried his hand at building a stationary explosion engine running on a mixture of coal gas and air. After two years he patented the so-called “Lenoir gas-engine,” the first practical application of an internal combustion engine, fueled by illuminating gas and using a storage battery ignition system. Some 400 of these motors were built, mainly for operating lathes and printing presses. Lenoir then had the idea of using the motor in a vehicle by transforming its reciprocating movement into rotational motion. In 1860 he was able to assemble a motorized tricycle powered by coal gas or light (shale) oil sprayed in a crude precursor to the carburetor. His vehicle, however, was a failure because the motor did not compress the fuel-air mixture, and its output was only 1.5 hp. Remembered as the inventor of the internal explosion engine, Lenoir died in France in 1900.
Despite the failure of Lenoir’s effort to power a vehicle with an internal combustion engine, the idea was taken up by several followers. Such an engine offered many significant advantages over external combustion engines. The energy yield from burning the fuel within a closed chamber is much greater. Using a gas or evaporated liquid allows for quick and effective air dilution, which in turn increases efficiency. Directly converting the energy released by fuel combustion into mechanical energy greatly increases the thermal yield and makes for a better ratio of engine size to power output. Burning a fluid fuel in a closed environment makes the process easier to control by allowing one to manage the rate of combustion and, consequently, the engine cycles. It also makes it easier to start up and shut down the engine, and to control its power output. The combination of all of these factors augured well for the application of an internal combustion engine to a vehicle, and it’s significance was not lost on military technologists at the close of the 19th century.

Among the enthusiasts for the idea of mounting an internal combustion engine on a vehicle was Nikolaus August Otto. Born in Germany in 1832, Otto was a traveling salesman who made his rounds through a number of cities in Germany and neighboring countries selling sugar, tea and kitchenware. During a visit to Paris he learned of Étienne Lenoir’s internal combustion engine and its application on the three-wheeled vehicle. Undaunted by its poor showing as a vehicle engine, Otto believed he could improve that invention and began devising experiments. He accidentally stumbled upon the importance of compressing the fuel-air mixture before its ignition in the combustion chamber, and the resulting increase...
in power output. The idea of a four-stroke piston movement – the Otto cycle – quickly emerged. He built his first gas engine in 1861 and formed a partnership with German industrialist Eugen Langen. He started his first factory in Deutz, a suburb of the German city of Cologne. There, thanks to prizes won in technology expositions, he was able to raise capital and hire specialized personnel, among them, a highly qualified technician named Gottlieb Daimler, whose name would become a legend in automotive history. A second plant was eventually added in Philadelphia, USA. Originally named N.A. Otto & Co, the company is still doing business under the name Deutz AG. Beginning in 1876, by applying Daimler’s technological input to the four-stroke concept, production of the new Otto engine was soon underway. His patent, No. DRP 532, the basic patent for the modern engine, became the most widely-challenged patent in the world.
Gottlieb Daimler was also born in Germany, in 1834. After acquiring some experience building machinery during a stay in France, he attended Stuttgart Polytechnic. In late 1863, he hired on as an inspector at a machine factory, where he met Wilhelm Maybach. In 1872, he transferred to Otto & Langen, where he learned of the four-stroke Otto engine. Following disagreements with company management, Daimler left Deutz in 1882. Soon afterward he purchased a villa in Cannstatt, with a greenhouse in the garden, to which Daimler added a testing workshop, then invited Maybach to work with him. Daimler proposed to use gasoline as engine fuel, and to install motors on all possible vehicles – on land, sea and air. He relied on the four-stroke Otto cycle which, due to its complicated ignition mechanism, could not achieve high rpms. Intensive testing convinced Daimler to patent a motor using an electric heat ignition system controlled by a resistor. The patent was a masterpiece in its design, since it included the four-stroke workings of the Otto cycle engine, and became the focus of considerable legal dispute over patents with Deutz. The federal court, however, was persuaded by Daimler’s arguments that the technology was his own and in late 1883 the first test engine, cast by a bell factory, was cranked up. Thanks to its spark ignition and exhaust valve, the engine revved to 600 rpm – a higher rotation than any previous engine had ever attained. The next motor was dubbed the “Grandfather Clock” (Standuhr), and in 1884 it developed 1 hp. With its lightweight and highly compact construction, Daimler and Maybach had met the basic requirements for mounting the engine on a vehicle. The first test was made on a wood-frame bicycle. The single-cylinder engine was mounted beneath
the seat. Early in 1886, Daimler ordered a carriage made in Hamburg and assembled in Stuttgart. In darkness and secrecy the vehicle was delivered on the night of August 28 as a present to Mrs. Daimler. The engine, mounted close to the steering drawbar, was a belt-drive “Grandfather Clock” model. This odd horseless carriage was thus the world’s first four-wheeled automobile.

The fine-tuning between fuels and engines was of paramount importance in the development and growth of the internal combustion engine market. The first efforts relied on illuminating gas for fuel. Its ready availability, due to its use in gaslight public lighting systems at that time, made it a very handy fuel for running stationary motors. Yet the small and lightweight engines, which the requirements of small vehicles for individual transportation dictated, pretty much ruled out the use of illuminating gas as fuel.
The glimpsed opportunity to install explosion engines on light vehicles caused a number of inventors to set themselves to the task of developing systems for running internal combustion engines on liquid fuels. Their greater energy density and ease of transportation clearly made them the fuels of choice for small vehicles. The discovery of oil wells around 1854 in the United States, with sizable reserves readily accessible, was another factor driving this development.

Born in 1839, John D. Rockefeller was one of the first men with the foresight to understand the commercial importance petroleum derivatives would have as liquid fuel for these newly-emerging motorized vehicles. At age 22, having only a basic education, Rockefeller acquired a small company which made him a captain of industry engaged in refining, hauling and selling oil products. He founded his first refinery in 1863, and added a second in 1866. Quick to monopolize the business, Rockefeller built his own pipelines, took over a host of companies, created distribution networks and developed quick negotiating methods. By 1879, his Standard Oil Company controlled 95% of the oil market. His attempts to get along with the world of politics were, however, rebuffed and, in 1892, under the Antitrust Law, his company was ordered broken up into smaller enterprises in which Rockefeller was but a minority shareholder. Rockefeller personified the industrial capitalist, leading a Puritan lifestyle and spreading around his profits as a patron of the arts and sciences.
Siegfried Marcus, of Austria, is credited with the invention of the carburator – without which liquid fuels could not be used in internal combustion engines. Because of the difficulty inherent in achieving a good fuel-air mixture, the invention was a milestone in the application of gasoline as engine fuel. Yet the consolidation of gasoline engines did not come until 1883, when Gottlieb Daimler and Wilhelm Maybach built a workable carburator and devised an ignition system to go with it. The result was a quantum leap in the development of internal combustion engines. Daimler’s engine turned over at 900 rpm, at a time when 200 rpm was considered high for vehicles running on gas. This, resulted in the union of combustion engines and petroleum derivatives, which in turn contributed to the development of the automobile.

Concurrent efforts were underway to produce an internal combustion engine with the greatest possible yield by Rudolf Diesel, engineer and German national, albeit born in Paris in 1858. Diesel’s attempt made use of a mechanical configura-
tion similar to that of Otto: a four-stroke cycle with intake and exhaust valves. In Diesel’s engine, however, combustion was brought about by injecting fuel into the combustion chamber during the final stage of compression. The high air temperature within the cylinder, due to compression, caused the injected fuel to self-ignite. The idea was not original, but Diesel was the first to come up with a practical, high-yield engine, which was patented in 1892. The machine’s thermal yield was thrice that of a steam engine and 2.5 times what gasoline engines were turning out at the time. As conceived, diesel engine features recommended it for heavy load applications, and it was soon seen as a strong contender to replace the steam engine. In large-scale applications, it outperformed gasoline engines, yet was too heavy to competitively power road transportation and light-load applications.
In a sense, the Otto and Diesel internal combustion engines complemented each other over a broad range of applications within which each predominated in its own special area. Weight and price figured most heavily in the choices between them. In addition to the singular advantages offered by each engine, an additional factor worked effectively to preserve the equilibrium between them: the two drank from the same fountain, the oil well.

Because diesel fuel and gasoline are both obtained by fractional distillation of petroleum, the supply of either affected the demand for the other. This “symbiosis” enabled their competition to find a point of equilibrium as they evolved into their various fields of application. In practice, meanwhile, they brought the steam engine down off its throne. The reign of thermal engines was now divided into Otto-cycle and Diesel-cycle fiefdoms.

It would’ve remained a small fiefdom indeed, open only to a handful of multimillionaires, were it not for the enterprising spirit of America’s Henry Ford. Born a Northerner in 1863, the engineer understood that automobiles would appeal to everyone if they could be had at a reasonable price. To make the product cheaper, Ford invented the famous “assembly-line” along which the various stages of fabrication were distributed by a conveyor-belt arrangement, and each employee installed a standard component part. The idea was to do away with uncertainty and idle time among employees during vehicle assembly. Ford’s Model T sold for US$ 850 apiece in 1908, and was a tremendous success – with 15 million sold over 20 years. Unlike vehicles...
produced by other automakers, Ford cars were a far cry from handmade rich men’s toys, but rather, mass-produced goods designed for everyday use by ordinary citizens. Enterprising as he was, Henry Ford was a poor manager, more at home in the plant than in the office. He was bored by ledger sheets, despised bankers and kept his cash in the safe. For 19 years he only built black Model Ts, which hardly qualified him as a marketing innovator. Indeed, one of his sale pitches was precisely that you could have a Ford in any color you wanted, so long as it was black. It wasn’t until 1927 that Ford made the Model A available in different colors, but by then the company was being overtaken by General Motors.

The successes rung up by Ford and his host of competitors caused a multitude of auto parts dealers, car lots, mechanics shops, gas stations and highways to spring up. Automobiles meant that people could travel more often and live farther
away from urban centers. Pollution, noise, accidents and traffic jams elbowed aside other urban problems and became part and parcel of the image of urbanization and development.

Henry Ford’s assembly-line methods of mass production brought huge growth to the automobile industry at the dawn of the 20th century – not only in the United States but in England, Germany, Italy and France as well. In 1919, there were already 186 automakers scattered throughout the world, and in that year alone they produced 11 million vehicles.

Two very important changes came to the industry with the outbreak of World War I in Europe. Volume of production, which had been expanding, fell off sharply – especially in Europe. The war effort itself led to widespread application of internal combustion engines running on petroleum distillates in military cars and trucks, motorcycles, airplanes, boats, ships and anything else that would move, and led to enormous technological advances in efficiency and performance, along with size and cost reductions.

Between the wars, the number of automakers diminished, but the remaining companies – greatly enlarged by mergers and takeovers – put wartime technological innovation to work on a massive scale, making automobiles increasingly accessible and exporting them everywhere. The movie industry made the most distant hamlets familiar with individual use of automobiles, as cities were transformed, highways opened, oil fields discovered, refineries built and petroleum derivatives sold and distributed.

**In 1919, there were already 186 automakers scattered throughout the world, and in that year alone they produced 11 million vehicles.**
By the time World War II broke out, the automobile and other vehicles could be found on every continent, and demand for fuel, parts and maintenance items was very large. Supplies of these products were cut off as strategic trade routes were lost and rationing imposed. The seriousness of the situation led to the search for alternative fuels and production of replacement parts became an industry unto itself – an industry which later evolved as vehicle parts production plants spread all over Asia, Oceania and South America, where previously there had been no local production.

After the war ended, amid the reconstruction of the vanquished and economic rehabilitation of the nations most affected, the automobile industry reached its zenith. Automobile plants expanded into an international industry as automakers, truck builders and parts manufacturers set up shop in dozens of countries. By 1960, the world’s vehicle fleet had increased to 200 million units. Inasmuch as all of those vehicles were powered by gasoline or diesel fuel, oil consumption increased to 8 million barrels a day that same year, at prices averaging close to two dollars a barrel, estimated cost during this period. The fuel that went into those marvelous vehicles, which brought status, freedom and progress, was actually quite cheap.
Yet, before the close of the 1960s there came the first signs that not everything was rosy with automobiles running on petroleum fractions. Chronic visibility problems reported by aircraft making their landing approaches to the Los Angeles Airport in 1962 brought the issue of pollution caused by vehicle exhaust emissions in densely populated areas into the spotlight. As the causes of this phenomenon were studied more closely, it was found the damage from vehicle emissions went way beyond occasional fatalities from carbon monoxide poisoning suffered by drivers warming their engines in closed garages on cold mornings. There turned out to be a whole chain of chemical reactions between the oxides of nitrogen (NOx) and hydrocarbons (HC) given off by vehicles. When exposed to ultraviolet light from the sun, they formed a host of different chemicals able to seriously affect the health of humans, livestock and even plants. The resulting preoccupation with urban air pollution caused by vehicles led to passage of emission-control laws – first in California, then spreading throughout the United States and taken up by dozens of other countries. Despite local differences among measuring procedures, permissible limits and regulated pollutants, standards restricting vehicle emissions – including noise pollution – are currently in effect in every developed country in the world.

Conflicts in the Middle East – beginning with the Suez War of 1956 and profoundly worsened by the Arab-Israeli War of 1967 – signaled oil-importing countries of the serious possibility of shortages and price hikes, and brought home to them
Oil-producing nations in the war-torn region began to feel they held a trump card with which to impose their political will upon the international economic community. At the time, they provided over 70% of the world’s oil supply. U.S. production did not suffice America’s needs and deep water oil from the North Sea was too much expensive. Russia, then the head of the Soviet Union, supplied none of its oil to the Western world because of the Cold War. Mexico and Venezuela were content with catering to part of the United States’ requirements, and the remaining oil producers were not large enough to matter. The nations of the Middle East soon realized they were the ones supplying Western Europe, Asia, Oceania and much of the Americas. Because of the weight they carried within the Organization of Petroleum Exporting Countries (OPEC), until that time, an international organization of no great significance, they were able to persuade producer countries to adopt production quotas and jointly arrive at a price scale. Repercussions of this collective strategy were quickly felt everywhere. In 1973, in response to international support for Israel during the Arab-Israeli War, the world got its first taste of what was promptly dubbed the “Oil Crisis”. Acting in concert, the oil exporters cut back production and began charging absurdly high prices for oil. Within three months, a barrel of oil, as priced at the time, went from US$ 2.90 to US$ 11.65. The global economy was shaken and the United States and Europe were hit by strong recessions, the effects of which were felt everywhere. Countries like Saudi Arabia, Iran, Iraq and Kuwait, sitting
atop two-thirds of the world’s oil reserves, were able to control production and prices for the product.

The Second Oil Crisis, in 1979, was a result of the revolution in Iran which deposed Shah Reza Pahlevi and set up an Islamic regime. The country’s oil production was disrupted to the point at which Iran was no longer self-sufficient, so that one of the world’s largest oil exporters – second only to Saudi Arabia – was, in effect, out of the market. The drop in supplies sent oil prices skyrocketing to record levels, and the global recession worsened considerably in the early 1980s. Aside from the Soviet bloc countries, with their abundant supplies of Russian oil, all others – developed and developing – were severely affected by the crisis.

The rise of oil price levels in the wake of the two crises aggravated by joint action OPEC members, brought unexpected consequences. High prices drove oil producers to look for new sources or resume pumping from reserves hitherto known but uneconomical. Deepwater drilling in the North Sea, Gulf of Mexico, Caribbean basin and off the coast of Brazil were thus resumed, along with onshore exploration in Africa, Alaska and South America – and increased oil supplies considerably. Yet, for the international community, there was no escaping the second thoughts they were having about reliance on petroleum alone as feedstock for vehicle fuel. A number of experiments were made in different countries. Methanol, ethanol, vegetable oil, natural gas, MTBE, ETBE, FAME, FAEE, DME and other substances gained importance and interest in terms of research.
However, the most serious aspect of intensive reliance upon fuels derived from petroleum – not only as vehicle fuel but throughout the entire gamut of uses found for petroleum and coal – was the discovery that their combustion gases are directly related to the severe problem of global warming. As far back as the 1970s, the issue had been pointed out by a number of scientists, but it was only in the 1990s that people became convinced of the urgent necessity for changing the world’s energy mix as a way of dealing with the problem.

In summary, it was found that burning oil and coal causes the carbon within them – which was deep within the earth – to react with atmospheric oxygen and form carbon dioxide ($CO_2$). This inert, non-toxic substance is also given off by living creatures as they breathe. Under ordinary circumstances the $CO_2$ would be absorbed by nature. But because of the absurd amounts released by human action, it is accumulating in the atmosphere at a rate greater than nature’s capacity to reabsorb it, thereby forming a layer which blocks the outward reflection of incident sunlight and increasing the temperature of the Earth’s surface in a phenomenon known as the greenhouse effect. If nothing is done to stop global warming, the consequences will be grave indeed, for humanity is at stake.

Added to the above problems of urban pollution, high costs, unsteady supplies and global warming, the intensive reliance on petroleum has another drawback: it is a finite resource, the available amount of which is decreasing. Cur-
rent world petroleum consumption is on the order of 85 million barrels per day, while estimated reserves amount to 1.4 trillion barrels. If this situation persists, we will only have oil available for another 45 years — this by a fairly simple calculation.

The world’s rolling stock is quickly approaching the fantastic figure of one billion vehicles, that is, there are a billion automobiles, vans, pickups, station wagons, trucks and buses being driven in all countries on the planet. There are one billion vehicles with Otto or Diesel-type internal combustion engines burning gasoline, natural gas or diesel fuel. Every day, over 165,000 vehicles are produced and added to that fleet — a rate of over two vehicles per second. Eighteen billion passengers and 30 billion metric tons of cargo are transported over roads every day by automotive vehicles.

So how do we change this picture? How shall we replace this fleet? Can the fuel which powers it be replaced? And if so, replaced with what?

Several different studies currently being developed point to one approach, namely, replacing the internal combustion engine with electric motors that are efficient, quiet, powerful, nonpolluting and technologically simple. Yet, two nagging questions remain: how to safely generate the electrical power needed to power the motor? And how to carry enough of that energy on board to give the vehicle a reasonable range? Safe and nonpolluting methods for generating energy are subject to risk analyses much the same as nuclear or thermal power plants. Carrying sufficient energy aboard calls for...
for something other than batteries made from lead or other heavy metals. Right now it appears that the best way to generate that power would be through ion exchange obtained by passing hydrogen through a set of electrolytic membranes (the fuel-cell), combined with a catalytic fuel reformer able to extract hydrogen from a substance rich in hydrogen – such as natural gas (rich in methane) – or, better still, from a liquid such as alcohol (methanol or ethanol), which is easier to handle and transport. The transportation of bottled hydrogen gas aboard the vehicle is something to be avoided due to hydrogen’s very low density and potential for explosion.

These issues are certainly not trivial. Hundreds of researchers have spent two decades working on the electric vehicle + fuel cell concept and the results so far have been pitiful. Compared to conventional vehicles powered by internal combustion engines, those arrangements are technologically complex, have very little range, poor performance and low cargo capacity, all of which add up to their being too expensive for mass production. Although a number of prototypes have been devised, no automaker has produced any such model on the assembly line.

So far, all we have seen by way of commercial use of electric motors – leaving aside special-purpose vehicles such as golf carts and neighborhood electric vehicles, or warehouse tractors and forklifts – is the recent appearance of so-called hybrid vehicles equipped with two engines. Harnessing an internal combustion engine side-by-side with an electric motor allows one to use electric propulsion while the conventional motor recharges the batteries. The first hybrid applications were heavy vehicles (buses, garbage trucks, etc.) equipped with the two different motors. Recently, however, some light-
weight hybrids have emerged in which the two designs are combined in a single engine, making the arrangement much more compact and efficient. Yet, this is still complex and expensive technology, that limits its commercial use to a small number of units in high-income countries.

Someday, overland vehicles will doubtless leave behind internal combustion engines and move on to electrics. What we do not know is how long this process will take and what we should do in the meantime.

Brazil has found its own solution, and is now reaping the benefits.

Brazil’s automobile industry currently produces 1.5 million light vehicles a year, all equipped with internal combustion engines, much like other countries. These cars, however, have been tailored to run on pure ethanol or a gasohol mix consisting of 20% to 25% ethanol. So, although we are turning out conventional vehicles, we are in fact creating a fleet that is less dependent on petroleum, and that has brought significant savings in hard currency and better prepared us to face the future. As the international scientific community struggles to develop and produce the car of the future, Brazil is investing in fuels made from biomass.

Our advantageous situation did not come cheaply or quickly. Thirty years ago, suddenly faced with an international oil shortage, we embarked upon a radical change in our fuel mix and have stuck to that decision through thick and thin as researchers, alcohol producers, automakers and parts manufacturers have worked together to get us where we are.
The standardized, responsible addition of ethyl alcohol (ethanol) to our energy mix was given a consistent and systematic push in the 1970s by both versions of the National Alcohol Program (Proálcool I & II) passed by Executive Decrees in 1975 and 1979. Since the early days of the 20th century, however, ethanol – a byproduct of the sugar industry – had been added to gasoline. World War II, with its rationing and curtailment of imports, greatly increased the blending of alcohol with gasoline to good effect.

With the advent of the National Alcohol Program, Brazil’s automobile industry began adapting technology to the new fuel. In the absence of international experience with ethanol, Brazilian automakers embarked upon a development that gave the nation’s automotive engineering efforts a huge boost.

With the combined support of several state and federal agencies, a number of institutions and research centers, several universities, parts manufacturers and even fuel producers themselves, automakers managed to quickly modify gasoline-fired vehicles to run on gasohol with a high (20% to 25%) ethanol content and design vehicles and engines capable of running on 100% fuel alcohol. Along the way, they overcame such setbacks as corrosion, chemical degradation of plastic and rubber, cold-weather starting, handling and performance problems.

During those heady years from 1979 to 1993, over 5 million alcohol-fired vehicles were produced. In 1986, the 700,000 such units sold amounted to 89% of total light vehicle sales, but consumer interest waned soon afterward. By 1995, sales had fallen to
under 50,000 units, and, in 1997, were a mere 0.1% of total light vehicles sold.

Although there was no single cause, several factors contributed jointly toward loss of consumer interest in ethanol vehicles: global oil prices dropped, and with them the cost of petroleum derivatives; sugar prices increased worldwide, leading producers to shift to producing sugar for export. The Brazilian government offered incentives for the manufacture of affordable cars, with no special exemptions for ethanol-fired engines, and automakers responded by producing only cars which ran on gasoline.

The advent of dual-fuel vehicles in March of 2003 was a milestone event and a turning point for Brazil’s alternative fuels market. Beginning with the launching of these vehicles, popularly dubbed flex-fuel cars, Brazilian automakers manufactured 3 million dual-fuel vehicles over a four-year period. Nine manufacturers are currently offering over 60 different models of flex-fuel cars on the Brazilian market – at the same prices charged for similar conventional vehicles.

Flex-fuel vehicles were not really invented in Brazil. The first automobiles able to run on different kinds of fuel were unveiled in the United States back in the 1980s. The technology used by U.S. automakers, however, was based on a sensor that identified which fuel was being used and instructed the onboard computer to adjust the fuel injection and ignition systems to make better use of that particular fuel. Efficient as it is, that technology is expensive, complicated,
and entirely dependent on the useful life of that identifying sensor. The cost was such that it could only be used on expensive vehicles without unduly impacting showroom prices. The technology gained acceptance in the United States only to the extent that automakers were able to take advantage of tax exemptions for producing alternative-fuel vehicles.

Because Brazil’s automobile market is geared predominantly toward compact, low-cost vehicles, there was no way to make expensive American flex-fuel technology work here. However, as automakers in Brazil began to discuss the possibility of building a local version of such a vehicle, the first requirement was to avoid using a fuel-identification sensor.

At that point, the vast experience acquired over 25 years of producing alcohol-fired vehicles combined with Brazilian ingenuity to yield a solution.

Taking as a starting point the physical and chemical differences between alcohol and gasoline (octane number and stoichiometric ratio) and using the various function sensors (air pressure and temperature, fuel flow, load, engine rpms and exhaust gas oxygen) that are stock equipment in all modern vehicles, Brazilian engineers developed an entirely new flex-fuel system. In the Brazilian system, fuel is first ignited in the combustion chamber. A fraction of a second later, sensor readings on that burnt fuel are matched against a database stored in the onboard computer memory which then identifies the fuel and adjusts engine parameters without the need for a fuel type sensor. You
thus have a flex-fuel vehicle for the same price as the alcohol-powered vehicles we already make so well.

Thanks to consumer acceptance of these vehicles and the competitive price of alcohol compared to gasoline, Brazil’s alcohol production – which had been dropping off by 11% per year – did a quick about-face and began increasing by 10% a year.

Renewable fuels are fuels made from agricultural products or from the fermentation of organic matter. Unlike fossil fuels (oil or natural gas), with their finite reserves, mankind will always be able to produce additional renewable fuels, as needed, by farming or fermentation.

One feature in particular has added considerable significance to the word “renewable”, and it points to renewable fuels as the long-awaited solution to global warming. Carbon dioxide gas – which is released by burning any fuel and is
the primary cause of atmospheric warming – is reabsorbed through photosynthesis by the very plants used to produce renewable fuels so that its use cancels out. The carbon dioxide released during combustion thus renews itself without harming the environment.

Because of such qualities as their ease of use with existing vehicle technology – obviating the trouble and expense of petroleum – and their lessened environmental impact, renewable fuels made from biomass have increased their market share and aroused in other countries a lively interest in trying them out.

Just as many countries are interested in using renewable fuels, others – able for geographic and climactic reasons to engage in the necessary agricultural production – are just as

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Legends:
1-Cold-start gasoline reservoir
2-Canister
3-Electric Fuel Pump
4-Solenoid Valve
5-Canister Purge Valve
6-Spark Plug
7-Relay
8-Throttle Body
9-Coil
10-Oxygen Sensor
11-Primary Catalytic Converter
12-Onboard Computer
13-Vacuum/Pressure & Air Temperature Sensor
14-Modular Fuel Pump
15-Fuel Line/Fuel Injector
16-Cam Position Sensor
17-Detonation Sensor
18-Crankshaft Position Sensor

Flex Engine Diagram
keenly interested in the economic advantages to be had by producing them for export.

It is, therefore, reasonable to expect the emergence of an international market in renewable fuels in the near future. Such a market would offer socioeconomic advantages to many countries and energy alternatives to others – at least until there emerges some new vehicle design which proves cleaner, more affordable and reliable while lending itself to mass production – to replace today’s internal combustion automobiles.