Alternative Vehicle Fuels

SIC 2861

INDUSTRY SNAPSHOT

Facing the long term effects of global warming and the shorter term consequences of extensive reliance on foreign oil supplies, U.S. automakers, researchers, environmentalists, and policy makers shared a common goal in the development of alternatives to the transportation sector's basis in gasoline and diesel fuels. Alternative fuels-including liquefied petroleum gas (LPG), methanol, ethanol, compressed natural gas (CNG), hydrogen, biomass (plant or animal waste), and mixtures of these with regular gasoline-gained increasing favor due to test results demonstrating their significantly more benign effects on the ozone layer and their reduction of pollutant emissions. But mass commercialization was another issue.

According to information released by the Energy Information Administration (EIA) in August 2006, approximately 890,281 alternative fuel vehicles (AFVs) cruised U.S. roads in 2005, an increase from 518,919 in 2002. The majority of these vehicles (885,341) were non-dedicated or hybrid AFVs. Vehicles capable of burning 85 percent ethanol comprised the largest AFV category (743,948), followed by hybrid gasoline-electric vehicles (139,595); compressed natural gas (3,304); electric (2,281); and liquefied petroleum gas (700). The number of vehicles powered by E85 is especially noteworthy, considering that only 12,788 such cars were on the road in 1998 and 82,477 in 2002. By vehicle type, the EIA indicated that there were 305,454 alternative fuel vehicle SUVs in 2005, followed by pickup trucks (278,096); automobiles (294,665); vans and minivans (8,055); buses (1,753); medium- and heavy-duty trucks (216); and other vehicle types (2,042).

The extensive resources, in terms of private investment and public policy, required to maintain the stability of the U.S. oil supply create an enormous incentive for the introduction of viable alternative fuel technologies on a mass level. Political factors, including skyrocketing concern-particularly following the terrorist attacks of 11 September 2001, and the U.S. military involvements in an unstable Middle East, which was home to 90 percent of the world's proven oil reserves-over the country's dependency on foreign energy sources, as well as evolving attitudes toward environmental stability, have played the leading role in the push toward alternative vehicle fuels.

The impact of a mass alternative fuel-based economic conversion is a sticky issue, both domestically and globally. The tenuous balance of geopolitical power and international governmental alliances is intricately tied to control over energy supplies, which has served as the backdrop to wars as well as less dramatic international tensions. On the domestic front, some of the nation's largest enterprises have staked their fortunes on traditional energy sources slated for replacement by alternative fuels. Power companies, electricians, coal companies, and oil firms are just a handful of the players throughout the economy that will need to scramble for a meaningful place in a dramatically changed market.

Market forces, as a result, are unlikely to be the primary motivating factor in the rollover from oil-based fuels to alternative vehicle energy sources. AFVs typically cost several thousand dollars more than conventional vehicles, and the fueling station infrastructure to accommodate alternative fuel vehicles (AFVs) has been sorely lacking. Compared with the 200,000 gasoline and diesel refueling stations in the U.S. in 2003, the 1,600 natural gas refueling sites looked conspicuously inadequate to inspire mass market penetration of AFVs. For perspective, the U.S. General Accounting Office (GAO) reported that in order to reduce gasoline and diesel fuel consumption by 30 percent between 2000 and 2010, the nation would require some 64,000 AFV fuel stations, which, at some $300,000 apiece, amounts to an enormous investment in infrastructure just to make the cars-themselves still expensive and developing-a viable commercial reality.

Thus, one of the biggest challenges facing the alternative fuels industry has been how to incorporate such fuels into vehicles and power systems on a mass scale cheaply and without sacrificing everyday conveniences and comforts. The question of how best to accomplish this task amidst the range of hurdles-logistic, economic, and environmental-is not so easily answered and remains the most nebulous aspect of the alternative fuels industry.

ORGANIZATION AND STRUCTURE

Because of the interrelationship and interdependency between transportation fuels and the national economy as well as national security, both the gasoline and alternative fuel industries are heavily structured, controlled, and regulated by federal and state interests. Control spills over into the user market in that private industry must not only produce alternative fuel vehicles that can compete with the price and efficiency of traditional gasoline-fueled vehicles but must also meet strict emissions and other environmental regulation standards.

The Energy Information Administration reports that the primary determinant of the choice and scale of alternative fuel production is governmental policy, noting that use of such technology takes off only following public policy initiatives, whereas incentive seems to be in short supply absent government spurs. Not surprisingly, then, federal funding remains a cornerstone of alternative fuels development programs.

Industry Regulation

To ease the pain of regulation as well as stimulate interest, numerous laws and tax incentives are directed toward both producers **and** users of domestically produced alternative fuels, giving them a chance to compete with the oil industry and its monopolized hold on the global market. Some of the more important federal legislation supporting bio-fuels includes the Energy Security Act (1978); the Energy Tax Act (1978); the Gasohol Competition Act (1980); the Crude Oil Windfall Profit Tax Act (1980); the Energy Security Act (1980); the Surface Transportation Assistance Act (1982); the Tax Reform Act (1984); the Alternative Motor Fuels Act (1988); the Omnibus Budget Reconciliation Act (1990); the Clean Air Act Amendments (1990); the Energy Policy Act (1992); the Building Efficient Surface Transportation and Equity Act (1998); and the Energy Conservation Reauthorization Act (1998). These acts are administered and overseen by the U.S. Department of Energy (DOE).

The manner in which these laws affect and interface with private industry can be summed up by the Alternative Motor Fuels Act of 1988. Its stated objective is to encourage the widespread development and use of methanol, ethanol, and natural gas as transportation fuels. Section 400AA requires the U.S. government to acquire the maximum number of alternative-fueled vehicles in its fleets as is practical. Importantly, the vehicles are to be supplied by original equipment manufacturers (OEMs), thus stimulating private industry. The act also mandates that the DOE must assist state and local governments in developing public transportation buses capable of operating with alternative fuels.

Concurrently, acts such as the Clean Air Act and its amendments continue to focus on reducing the amount of pollutants emitted from motor vehicles. The U.S. Environmental Protection Agency (EPA) also remains greatly involved in the monitoring of environmental effects caused by vehicular traffic and fuel byproducts. In the late 1990s, for example, the EPA ruled that particulates, microscopic specks of carbon emitted from diesel engines that can lodge in lungs and cause a host of medical complications (including death), constituted air quality health hazards.

To monitor progress under the Energy Policy Act of 1992 (EPAct), which extends the Alternative Motor Fuels Act by requiring the incorporation of AFVs into the fleets of federal and state governments, the DOE reports to Congress annually on the progress of the act's focus, which is to encourage use of alternative fuels. Field researchers, OEM markets, and fuel suppliers complete lengthy annual surveys that primarily address the number and type of alternative fuel vehicles available; the number, type, and geographic distribution of those vehicles in use; the amount and distribution of each type of alternative fuel consumed; and information about the refueling/recharging facilities. As the data builds from year to year, the DOE paces its monetary funding and program initiatives accordingly.

BACKGROUND AND DEVELOPMENT

It would be remiss not to begin the industry's history by emphasizing the enormous economic influence that gasoline has had over both Western and Eastern countries. In the United States, for example, a single dollar increase in the price per barrel of crude oil could lead to a $1 billion change in oil imports. In fact, gasoline supply disruptions between 1974 and 1984, such as those surrounding the 1973 Arab Oil Embargo and the 1979 Iranian Oil Embargo, cost Americans $1.5 trillion. In the late 1990s, petroleum imports accounted for nearly half of the U.S. trade deficit and were expected to rise to 60 to 70 percent within the next 10 to 20 years, even though Congress voted in 1990 that a dependence on foreign oil of more than 50 percent would constitute a "peril point" for the United States.

The additional expense in terms of military security and protection of foreign oil interests cost the United States an estimated $365 billion between 1980 and 1990. The Persian Gulf War alone cost $61 billion. Factoring in these energy security costs results in the astounding reality that the true financial cost of oil consumption in the late 1990s was approximately five dollars per gallon.

These factors helped stimulate efforts toward near total replacement of gasoline fuels with renewable alternative fuels. Henry Ford himself, back in 1908, well expected his Model T automobile to be fueled by ethanol, the most viable alternative fuel at that time. In fact, an ethanol-gasoline mix (25 percent ethanol) was rather successfully marketed by the Standard Oil Co. in the 1920s. When high corn prices, doubled with storage and transportation costs, made ethanol less feasible, federal and state initiatives were undertaken to keep interest alive. Ford again re-entered the picture and joined others to establish a fermentation plant in the Corn Belt capable of producing 38,000 liters per day. But the efforts could not effectively overcome the low petroleum prices, and ethanol production plants closed down in the 1940s.

Interestingly, at about the same time Ford was developing prototype vehicles, Rudolf Diesel was perfecting his diesel engines to run on peanut oil, with the intention that eventually they would be able to operate on several types of vegetable oils. It is unfortunate that both Ford's and Diesel's hopes were relegated to the back burners of a hot petroleum market with which these resourceful fuels could not then compete. It was not until the critical gasoline market in the 1970s that momentum was reestablished. Ethanol-gasoline blends were again re-introduced to the U.S. market in 1979. These blends, however, were marketed not as gasoline replacement fuels but as "octane enhancers" or "gasoline extenders." This may have diminished any sense of urgency in the public's mind to accelerate conversion of a transportation economy so comfortable with inexpensive gasoline.

Along the same lines, the federal government created the Strategic Petroleum Reserve (SPR) to stockpile nearly six million barrels of oil (about 75 days' worth of fuel at 1998 consumption rates) in an underground facility in Louisiana. Since 1993, no oil has been added to the reserves and the facility's $200 million annual operating cost ultimately prompted Congress to mandate selling the reserve oil at half price.

Complacency again reverted to a proactive attitude during the 1990s as Americans became more sensitive about environmental issues and economic dependency. The Clean Air Act Amendments of 1990 required that special fuels be sold and used in areas of the country with harmful levels of carbon monoxide. This resulted in the development and promotion of a cleaner burning and lighter gasoline product known as "reformulated gasoline." California had its own formula. Again ethanol blends and other alternative fuel choices caught the public's attention. Concurrently, the federal government continued to infuse money into numerous projects for bio-fuel development, also giving private industry a stake in the results. By the end of the 1990s, the alternative fuel industry had been resurrected.

The Clinton administration's Partnership for a New Generation of Vehicles (PNGV), established in 1993, created an industry-government consortium with the ultimate goal of phasing out gasoline engines over the next 20 to 30 years. The federal government pledged an annual investment of $500 million (half of which included direct federal funds) to help the industry. The University of Illinois received such a prize in 2000 to build a "bio-refinery" devoted to the production and commercialization of the Pure Energy Corp.'s P-Series ethanol-based fuel. Pure Energy Corporation, headquartered in Paramus, New Jersey, develops and commercializes cleaner burning fuels and technologies to produce bio-chemicals that are components of those fuels, and patents its fuel formulations.

Other direct government efforts to boost the commercialization of AFVs include the Job Creation and Worker Assistance Act of 2002, which provides for a 10 percent credit up to $4,000 for the purchase of hybrid (conventional internal combustion engine combined with an electric battery-powered motor), fuel cell, or electric vehicles before 31 December 2006, while the Internal Revenue Service allowed for a tax write-off of up to $2,000 for the purchase or conversion of engine components for the utilization of clean fuels.

But industry observers noted mixed signals from government policies in the early years of the first decade of the 2000s. While the Bush administration stepped up its commitment to fuel cell technologies, major industry players and financiers noted that government backing for most types of alternative vehicle fuels remained well behind what competitors in Japan and Europe could expect from their governments. Moreover, in 2001 the administration announced that the U.S. was backing out of the international Kyoto Protocol, the cornerstone of global efforts toward the reduction of greenhouse gas emissions. The GAO determined that the nation would fail to meet the goals of 30 percent alternative-for-gasoline substitution by 2010.

The Southwest was a leading center of AFV deployment in the late 1990s and early 2000s. Long a leader in the development and employment of environmentally friendly energy, California launched an ambitious zero emission vehicle (ZEV) program to aggressively boost fuel economy and mitigate periodic price fluctuations like the one that so angered consumers in the summer of 2004. A study by the California Air Resources Board (CARB) conservatively concluded that ZEVs consumed about 25 percent less energy than conventional vehicles. Arizona, meanwhile, offered attractive incentives to individuals and businesses to convert to AFVs utilizing various fuels, including dollar-for-dollar tax credits to consumers reaching up to $5,000 or 30 percent of the total vehicle cost.

Initial Corporate Efforts

U.S. auto manufacturers took the new technology seriously enough as a fixture in their operations that they began to bypass the traditional outsourcing methods for gas power conversions in favor of investment in plants specifically devoted to alternative fuel vehicles. Ford Motor Co. also broke new ground by initiating a new brand specifically devoted to ecologically friendly vehicles when it established its Th!nk Group. Ford, which manufactures about 90 percent of the AFVs sold in North America, committed over $1 billion in research by 2005 to develop its alternative fuel capacity.

Toyota aggressively pushed ahead with its plans to boost long term market share by pressing AFVs. The Japanese auto giant introduced successive models of its Prius hybrid sedan, and planned a hybrid Lexus sports utility vehicle. Similarly, rival Honda achieved impressive sales with hybrid versions of its popular Civic and Accord models. In 2002, Honda introduced its hydrogen-powered FCX, which became the first fuel cell vehicle to be certified for commercial use by the California Air Resources Board and the Environmental Protection Agency. The city of Los Angeles agreed to lease nine FCX vehicles from Honda by 2003 for roughly $500 per month. The deal marked the first U.S. retail agreement for a fuel cell vehicle.

General Motors and Ford even teamed up with the DOE and National Instruments of Austin, Texas in a project offering engineering students the chance to convert the automakers' sport utility vehicles-one of their best-selling vehicle types and the scourge of environmentalists pushing for less polluting automobiles-into clean running AFVs. Ford and GM supplied the SUVs to top engineering students to compete in their FutureTruck competition, which aimed to boost gas mileage and reduce emissions without sacrificing consumer appeal or vehicle performance. Both firms planned to use these efforts as stepping stones to the rollout of new alternative fuel SUVs in the late 2000s. By 2005, GM planned to begin manufacturing hybrid Saturn VUE sports utility vehicles with highway fuel efficiency improvements of 50 percent over conventional models, and other SUV makers were poised to follow suit, particularly in the face of the mounting public backlash against gas-guzzling SUVs.

Early Hurdles

For the average car buyer, AFVs remained an impractical choice during the first half of the first decade of the 2000s. They had little to offer customers in terms of standard market-based choices such as price or convenience. As a result, such vehicles were mainly the preserve of those with deep pockets and environmental concerns, or of city, state, or federal government fleets mandated to deploy a designated number of alternative fuel vehicles.

Cost remains a primary impediment to mass consumption of AFVs. Vehicles powered by natural gas, for instance, cost about $3,000 to $5,000 more than standard gasoline vehicles, according to the U.S. General Accounting Office (GAO). However, while alternative fuel technology was still more or less in the gestation process in the early 2000s in terms of achieving mass viability of AFVs, competition was already intense. Most auto manufacturers as well as the research firms they forged contracts with were becoming notoriously tight-lipped about their development programs for fear of tipping off competitors or breaching restrictive confidentiality agreements.

Hampering the proliferation of automobiles powered by liquefied petroleum gas (LPG) and compressed natural gas (CNG) was the finding by researchers from BP Amoco and Ford that the retrofitting of traditional fueling systems for use of LPG and CNG can in fact lead to more rather than less net emissions. Similarly, skeptics of alcohol-based fuels such as ethanol have called for studies of the entire production process. That is, while studies have found significant emission reduction in ethanol fuels, critics have claimed that the entire process from development to delivery to emission actually results in a net increase in greenhouse gases.

CURRENT CONDITIONS

While a host of alternative fuel types vied for long term viability heading into the late 2000s, the commercial market that did exist was filled primarily with what were seen as short term solutions, in the form of hybrid vehicles. In particular, politicians and automakers alike were looking to gasoline-ethanol blends and vegetable oil based bio-diesel as a way to reduce the nation's dependence on foreign oil.

Each AFV type has its own particular benefits and drawbacks. Dedicated alternative fuel vehicles, for instance, utilize only one alternative fuel, the most common being compressed natural gas (CNG). Bio-fuel vehicles house separate tanks for regular gasoline and one type of alternative fuel. Flexible fuel models utilize a gas-alcohol mixture such as the popular E85, which blends a maximum of 85 percent ethanol and 15 percent gasoline, in one tank.

Many automobiles utilizing these alternative fuels met the criteria for Low Emissions Vehicles designed specifically to target the emissions standards established by the U.S. Environmental Protection Agency, which call for undercutting U.S. governmental standards by 70 percent in the field of smog-forming hydrocarbons and by 50 percent in the realm of nitrogen oxides.

Natural gas remained the most viable alternative fuel in the first decade of the twenty-first century. As the market awaited more sophisticated and affordable fuel cell vehicles, natural gas and alcohol fueling systems represented the most effective mass solution to the demand for more efficient and clean-burning vehicles. For all hydrocarbon emissions, compressed natural gas (CNG) vehicles save up to 48 percent and liquefied petroleum gas (LPG) cars cut emissions up to 31 percent.

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The Emergence of Biofuel

One of the most intriguing possibilities for alternative fuels was the prospect of utilizing environmental waste, or "biomass," as an energy source. This subcategory of alternative fuels, known as "biofuels," converts agricultural and forestry residue, and even municipal solid and industrial waste, into bioethanol, biodiesel, biomethanol, and pyrolysis (chemical change by heat) oil fuels. Biofuels are, by composition, alcohols, ethers, esters, and other chemicals made from cellulosic (of cellulose, the main part of the cell wall) biomass.

Biodiesel, made from animal fats and soybean oil, emerged as the most promising alternative fuel in the early years of the first decade of the 2000s. The National Biodiesel Board reported that 35 U.S. biodiesel plants supplied more than 1,400 distributors nationwide in 2005. In turn, these distributors served 450 retail pumps. The most widely used biodiesel was a mixture of 20 percent biodiesel with 80 percent petrodiesel called B20, though lower grades such as B5 or B2 were used as well. Biodiesel was approved as an alternative fuel by the DOE in 1998 under amendments to the Energy Policy Act of 1992 (EPAct) that allow regulated fleets to use up to 450 gallons of biodiesel per vehicle per year to qualify for EPAct credit.

A U.S. Environmental Protection Agency (EPA) study found that biodiesel bests petrodiesel's emissions reductions of particulate matter by 47 percent, while further reducing unburned hydrocarbons 67 percent and carbon monoxide 48 percent. Increasingly, it is replacing traditional fuel in work environments that require exposures to diesel exhaust such as near airports or locomotive systems. The nation's first biodiesel fueling station opened in 2001 in pioneer Biodiesel Industries Inc.'s hometown of Las Vegas, which purchased one million gallons of the firm's fuel each year and used it exclusively in 325 fleet vehicles.

By 2005, the National Biodiesel Board reported that all major branches of the U.S. military were using biodiesel in their fleet operations. Other users included more than 100 U.S. school districts, NASA, Yellowstone National Park, the city of Seattle, Washington, and public utility fleets. In late 2006, U.S. production of biodiesel was expected to double following plans by Chevron Technology Ventures and Galveston Bay Biodiesel to build a plant and distribution center in Galveston, Texas capable of producing 100 million gallons of fuel per year.

Ethanol remained the most widely marketed biofuel. Made from brewed starch crops such as corn or, in the case of bioethanol, from cellulosic biomass, it was marketed in the late 1990s as an octane booster and a cleaner emissions fuel additive. In 2005, a record 4 billion gallons of ethanol were produced by 95 refineries in 19 states. This was a 17 percent increase from 2004, according to the Renewable Fuels Association.

Ethanol can be used in its pure form or blended as E10 (10 percent ethanol) on up to E85 (85 percent ethanol) blends. Ethanol derived from biomass generates emissions reductions of up to 90 percent and can be used in traditional vehicle infrastructures, thus making it a popular alternative for auto manufacturers who would prefer that the overhaul of their production processes be kept to a minimum.

Government Involvement

A national Renewable Fuels Standard (RFS) was implemented in August 2005, when President George W. Bush signed the Energy Policy Act (EPACT) of 2005. Beginning with a baseline of 4 billion gallons of renewable fuel in 2006, production must reach 7.5 billion gallons by 2012. According to data from global expert services firm LECG, LLC cited in the Renewable Fuels Association's (RFA) *Ethanol Industry Outlook 2006,* one goal of the legislation was to cut crude oil imports by 2 billion barrels by 2012, at the same time keeping $64 billion from foreign producers. The legislation was expected to be especially beneficial to ethanol producers, according to the RFA, causing domestic ethanol production to double by 2012.

While Congress and automakers like General Motors and Ford were supportive of the president's push for more flexible fuel vehicles (FFVs), oil companies like ConocoPhillips, Exxon Mobil, and Royal Dutch Shell were skeptical of E85's ability to compete with regular gas. According to Manimoli Dinesh in the February 22, 2006 issue of *The Oil Daily,* the naysayers cited the limited number of cars that were E85-ready, the need for a separate fuel storage infrastructure at filling stations, adding complexity to the supply chain, and poor fuel economy among their reasons.

Other critics charged that the president was not supporting the research and development needed to support his alternative fuel plan. For example, before hitting the road to promote his agenda, Dinesh noted that the Bush administration quickly reversed several cuts that had been made to the National Renewable Energy Laboratory's budget, which would have resulted in the elimination of scientist positions.

Corporate Efforts

The Big Three automakers were all engaged in the movement toward flexible fuel vehicles (FFVs) heading into the late years of the first decade of the 2000s. In 2006, DaimlerChrysler, General Motors, and Ford sent a letter to Congress pledging to double their annual FFV production by 2010, according to the National Ethanol Vehicle Coalition.

The commitment of manufacturers to FFVs was evident heading into 2007. In 2006 there were 22 FFV models on the market, for a total of approximately 6 million vehicles. For 2007, General Motors, Ford, DaimlerChrysler, Mercedes Benz, and Nissan added 12 additional models to their lineups. Toyota also had plans to introduce FFVs in the U.S. market in 2006 or 2007, according to *Automotive News.*

In 2006, Ford announced a research effort to develop a Ford Escape that would be the industry's first hybrid FFV. Ford already produced Mercury Mariner and Escape hybrids that used regular gas in 2006. In addition, the company had plans to roll out other hybrid models in the future, including a Ford Edge, Ford Five Hundred, Ford Fusion, Mazda Tribute Hybrid, Mercury Milan, Mercury MKX, and Mercury Montego.

Toyota also had plans to double the number of hybrid vehicles it offered by the early 2010s. *Automotive News.* revealed that the company would increase the number of models it offered from seven to fourteen in that timeframe. Toyota also was stepping up its research in the area of plug-in hybrid cars.

While hydrogen-powered vehicles were still far from ready for the mass market, a promising development took place in mid-2006 when Ford announced that a fleet of hydrogen-powered E-450 vans was being produced. Incorporating hand-built 10-cylinder engines, the vehicles were slated to begin service during the summer as airport shuttles in Florida, according to *Automotive News.* Production of the vans, leased at a price of $250,000 each, was being limited to 100, so that the vans could be monitored. BMW also had plans to introduce a combination hydrogen/gasoline engine in its 7-series sedan.

AMERICA AND THE WORLD

The tightly regulated European market offers expansive opportunities for alternative fuel vehicles. With high congestion and a long-standing commitment to greater fuel efficiency, Europe has attracted the world's major automakers as a prime target for introducing AFV automobiles to a mass audience. By the early years of the first decade of the 2000s, however, some proponents of alternative fuels were taking shots at major European countries such as Germany and the United Kingdom for failing to match rising consumer support for more efficient fuels with an infrastructure to support it.

Heading into the late years of the first decade of the 2000s, there was a call for more research into biofuels in Europe. Manufacturers, representatives from the European Commission, and academics called for scientific exploration of the risks and benefits of biofuel as the EU moved toward a goal of replacing nearly 6 percent of fossil fuels with biofuels by 2010, according to *Agra Europe.*

Interest in biofuels also was emerging in Asia. In mid-2006, South Korea announced it would make biofuels available to consumers. According to *ICIS Chemical Business,* the move was a first among Asian nations, and was part of the country's effort to reduce air pollution and oil imports.

RESEARCH AND TECHNOLOGY

In July 2006, researchers at the University of Minnesota found that biodiesel was a better alternative fuel choice than ethanol, according to *Chemistry and Industry.* The researchers found that biodiesel generated 41 percent less greenhouse gas than fossil fuels, while ethanol generated 12 percent less. In addition, they reported that soybean-derived biodiesel generated 93 percent more energy than was invested into its production, while ethanol generated 25 percent more. Based on these and other findings, the team endorsed the subsidizing of biodiesel production.

In another short term solution en route to the hydrogen economy proposed by President Bush, the Massachusetts Institute of Technology (MIT) Plasma Science and Fusion Center devised a plasmatron hydrogen-enhanced engine, which aimed to make traditional vehicle engines runs more cleanly by converting some gasoline to hydrogen-rich gas. Estimating the technology could boost fuel efficiency by some 20 percent, the MIT researchers discovered the plasmatron while studying fusion power. Fuel entering the device is sparked with electricity, transforming the fuel and the surrounding air into electrically charged gas, according to *The Engineer,* which then produces hydrogen-rich gas that can boost fuel efficiency while running on about 1 kilowatt of electricity.

Breakthroughs in the use of biomass for fuel have been at the forefront of industry development. Scientists at the University of California at Berkeley, sponsored by the Department of Energy (DOE), discovered a process by which green algae, known affectionately as "pond scum," ceases oxygen production in favor of hydrogen. Algae-generated hydrogen has been known to scientists for years, but dislodging the element under controlled circumstances proved troublesome. The Berkeley team found that the answer lay not in the molecular structure of hydrogen but in its diet. By effectively starving the algae of the sulfur it requires to produce protein, the scientists halted its oxygen production, thereby forcing the algae to switch its emissions to hydrogen to survive. As a bonus, they found that hydrogen was emitted in much greater quantities when sulfur was cut off than researchers had believed possible. The team added that the metabolic switch does not kill the algae, which can be reused over and over. After a few days of sulfur starvation, all the plant's production capacity is exhausted, at which point sulfur is reintroduced to its diet allowing it to regenerate its necessary carbohydrates for protein production.

Although the integration of this process into a large industrial framework remains to be configured, requiring alternative land use strategies, its potential benefits include vastly more efficient, cost-effective, and ecologically sound energy production than oil drilling and coal mining. A researcher on the project, Michael Seibert of the National Renewable Energy Laboratory, surmised that algae production lands covering the size of New Mexico would sufficiently supply all the energy needs in the United States.

The expanding market for alternative fuels has inevitably led to a market for alternative fuel components. Among the most potentially useful of these are hydrogen sensors. In the form of tiny chips, hydrogen sensors monitor the amount of hydrogen circulating through a fuel system, sending signals to the engine to adjust its operations accordingly. Most analysts expect that hydrogen sensors will be a standard component of any hydrogen-fueled vehicle, especially on fuel cell cars. Thus, as the alternative fuel market grows, so goes the sensor market.

Other technologies deal with pollutant emissions after the fact. A process called Gas-to-Liquids, patented by Colorado-based Rentech, Inc. was developed to capture solid, liquid, and gas carbon dioxide industrial emissions for conversion into hydrocarbons. The process was slated for use in the manufacturing facilities of Oroboros AB, a Swedish steel firm. Whereas industrial greenhouse gases are typically flared into the atmosphere at standard facilities, the Gas-to-Liquids process will capture hydrogen and carbon monoxide and convert the materials into safe, usable energy, reducing by an estimated 200 tons the plant's carbon dioxide emissions.

One of the original criticisms of alternative fuels was their ostensibly lower "energy density," technical jargon for the formularized relationship between weight or mass of the energy source and the energy it would produce. Historically, gallon for gallon, alternative fuels have offered smaller driving ranges, less acceleration capability, and more vulnerability at high speeds or in heavy traffic situations than their gasoline counterpart. But interestingly, most of the energy in gasoline and diesel fuel was burned off as combustible heat and friction, not as locomotive power. Notwithstanding, it was true that gasoline engines were distinguishable for rapid acceleration capability, a desirable quality in a nation with as many freeway systems as the United States.

Conversely, alternative fuels such as ethanol and methanol burned cleaner than gasoline, an important consideration in urban areas plagued with smog. Beginning in the late 1990s, federal Clean Air laws began to require automobile manufacturers to increase the number of vehicles offered that met the newly mandated Ultra Low Emissions Vehicles standards. Ultimately, vehicles will be required to meet Zero Emissions Vehicle standards, and clearly, alternative fuel vehicles held the competitive edge in this arena. In fact, combustible natural gas was so clean burning that the only byproducts were carbon dioxide and water vapor.

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