



## **ALTERNATIVE TRANSPORTATION FUELS AND ENERGY EFFICIENCY**



Western States Petroleum Association

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## PETROLEUM COMPANIES - ALTERNATIVE TRANSPORTATION FUELS AND ENERGY EFFICIENCY

Future energy demand will make it likely, if not certain, that petroleum-based energy supplies will continue to play an important role for many decades. Nevertheless, WSPA companies recognize that alternative sources of energy are a growing part of the world energy mix. They are investing dollars and manpower to help make that happen.

Much of their current activity is directed towards stationary power generation – such as the development of new, more efficient and/or cleaner ways to generate electricity (e.g., solar, wind, geothermal). This report focuses on the petroleum industry's work on the development and commercialization of alternative transportation fuels. Many WSPA companies have created and staffed new organizations to spearhead these efforts. There are a few areas of special emphasis: hydrogen, biofuels, research, and energy efficiency.

### HYDROGEN

Some consider hydrogen an ideal future transportation fuel. It can be used to power conventional, internal combustion engines, promising water as the only vehicle emission. But, its use in fuel-cell powered electric vehicles promises to be much more efficient. Two disadvantages are that hydrogen is difficult to distribute from a centralized production facility, and it is difficult to store, especially on-board a vehicle.

Many WSPA company efforts involve participating in programs to evaluate the viability of fuel-cell powered vehicles. Some companies provide refueling stations where hydrogen is produced from natural gas on-site, often using technology developed in-house. Some company projects involve technology to produce hydrogen from liquid fuels on board the vehicle itself.

Shell has built hydrogen refueling infrastructure for fuel-cell powered vehicle demonstration projects in Tokyo, Reykjavik, Shanghai, Washington, D.C., New York, and Los Angeles.

BP has partnered with Ford and Daimler Chrysler to provide hydrogen for fuel-cell powered demonstration vehicles in London, Barcelona, Oporto, Sydney, Beijing, Michigan, Florida, and California. All sites outside the USA have been closed.

BP is currently operating five hydrogen demonstration refueling stations in Florida, Michigan, and California evaluating different technologies. Two sites, one in Sacramento and one in Florida are being used to evaluate

the production of hydrogen through electrolysis. One site in Michigan is evaluating liquid hydrogen supply. The Burbank, CA site and Dearborn, MI sites are evaluating 700 bar technology. Burbank is also evaluating larger scale supply and on-site production by using a Steam Methane Reformer (SMR).

Chevron is currently operating five hydrogen demonstration refueling stations across the U.S.; three stations in California, one in Michigan, and one in Florida. Each is demonstrating and evaluating a different technology for on-site production of hydrogen.

- Two of the California stations are located in Southern California and were designed to support a fleet of Hyundai-Kia fuel cell vehicles.
- In Northern California, Chevron has built a prototype hydrogen refueling station as part of the Bay Area HyRoad project. The station will provide fuel for small fleets of fuel-cell powered buses and automobiles operated by the Alameda-Contra Costa Transit District (AC Transit).
- In Florida, Chevron is collaborating with Ford and the State of Florida on the evaluation of hydrogen-fueled internal combustion engine buses.
- In Michigan, Chevron is collaborating with the Air National Guard to demonstrate and evaluate Chevron's advanced steam methane reforming and pressure swing adsorption technologies to convert natural gas into purified hydrogen.

**A**s part of a collaboration with the U.S. Department of Energy, Chevron has partnered with the Gas Technology Institute on a pilot-scale partial oxidation gas turbine project to evaluate the simultaneous production of hydrogen and power.

ExxonMobil is active in the Department of Energy's Freedom Car and Fuel Partnership activities. The company has also announced it is carrying out R&D on a new process for generating hydrogen from hydrocarbon fuels. If successful, they believe it could impact future use of fuel-cell powered vehicles via improved ways to generate hydrogen, either at retail refueling stations or on-board the vehicle.

Several WSPA member companies, including Chevron, and Shell are also members of the California Fuel Cell Partnership, a private-public consortium targeted at addressing the technological challenges that are presented by hydrogen fuel cells when used as transportation power sources.

BP is a corporate sponsor of the University of California, Davis Sustainable Transportation Energy Pathways (STEPS) program researching technologies for sustainable transportation alternatives and greenhouse gas reductions.

## ETHANOL

**M**any petroleum companies are blending more and more ethanol into gasoline. Some are also investing to reduce the cost and increase the benefits of ethanol production, and to investigate its more widespread use in gasoline.

BP, for example is investing in feedstocks which minimize pressure on food supplies and in technologies designed to create advanced fuels with a higher energy content. BP has a 50% stake in Tropical BioEnergia SA, a joint venture with Santelisa Vale and Maeda Group, to produce bioethanol from sugarcane. Tropical's first facility in Edéia, Goiás State, Brazil, began production of bioethanol in September 2008 and will have a capacity of 115 million US gallons.

BP is also partnering with Verenium Corporation to develop low-cost, lignocellulosic bioethanol from energy grasses, including miscanthus and energy cane, which have a greater yield per acre of feedstock and potentially greater greenhouse gas emissions reductions compared with conventional fuels.

BP also partnered with ABF (British Sugar) and DuPont to construct a \$400 million world-scale bioethanol plant in Hull, UK. The plant will use some of the UK's surplus of feed-grade wheat as its feedstock.

Since 2002, Shell has been working with Iogen Corporation, a Canadian company, to develop the processing technology that enables ethanol to be made from straw using enzymes. This next generation biofuel can be used as a blend in today's cars and if used at 100% concentration can cut Well-to-Wheels CO<sub>2</sub> production by up to 90% compared with conventional petrol.

Iogen Corporation and Shell are exploring commercialization of a full-scale commercial cellulosic ethanol plant. Shell is contributing to Iogen's detailed feasibility and design assessment work.

Since 2007 Shell has partnered with US company Codexis to develop new super enzymes to convert biomass to fuel. Research will focus on adapting enzymes to improve the conversion of a range of raw materials into high-performance fuels. The agreement will see Codexis working closely with both Shell and Iogen Energy Corporation to enhance efficiency within the Iogen cellulosic ethanol production process. The aim of this research is

enhancement of the logen process and shortened timeframes to full-scale commercial deployment. However, the Codexis deal is not limited to cellulosic ethanol but will include other exciting biofuels routes. Scientists will accelerate existing research into new biocatalysts to convert biomass directly into hydrocarbon components.

ConocoPhillips is conducting R&D on the production of ethanol from coal via intermediate synthesis gas produced using gasification technology. That work is being done in collaboration with the Department of Energy, Oak Ridge National Laboratory, and the universities of Louisiana State and Clemson.

Chevron collaborated with the state of California, General Motors, and Pacific Ethanol to evaluate the use of E-85 as a vehicle fuel. Over a one-year period, Chevron provided E-85 (a mixture containing 85% ethanol and 15% gasoline) at two refueling sites to refuel a fleet of 50-100 vehicles owned by the state of California.

In March, 2009, Valero Energy announced the purchase of seven ethanol plants from VeraSun Energy capable of producing around 800 million gallons of ethanol a year.

## BIODIESEL

In 2006, ConocoPhillips began commercial production (1000 bpd) of renewable diesel produced from soybean oil at their Whitegate refinery in Cork, Ireland. They have also produced renewable diesel from beef tallow at their Borger Texas refinery as part of their strategic alliance with Tyson Foods.

Shell has partnered with CHOREN Industries in the development of a new process for producing diesel fuel from wood chips, straw, and other sources of biomass. The biomass is first used to produce synthesis gas, which is then converted to biodiesel using Shell's GTL process for converting gas to liquids. Following successful pilot production, CHOREN industries is building a demonstration plant.

In 2007, Shell formed a joint venture company, Cellana, which operates a pilot facility in Hawaii to grow marine algae and produce vegetable oil for conversion into biodiesel. Algae hold great promise because they grow very rapidly, are rich in vegetable oil, and can be cultivated in ponds of seawater, minimizing the use of fertile land and fresh water.

## OTHER BIOFUELS

**B**P, since 2003, has been working with DuPont to explore new approaches to the development of biofuels. The first product from this collaboration will be a new fuel molecule called biobutanol. Biobutanol can be blended at higher concentrations than bioethanol, potentially providing further reductions in GHG emissions. BP and DuPont are constructing a demonstration plant for butanol in Hull, UK that will test and further develop the new biobutanol technology and ensure it is ready for commercial deployment. The plant will be fully operational in 2010. BP and DuPont have also been carrying out vehicle and infrastructure product testing.

Chevron has entered into a partnership with the National Renewable Energy Laboratory (NREL) to explore the production of liquid fuels from algae.

In February 2008, Chevron and the Weyerhaeuser Company created a 50-50 joint venture company that will focus on developing the next generation of renewable transportation fuels from nonfood sources. The joint venture, Catchlight Energy LLC, will research and develop technology for converting cellulose-based biomass into economical, low-carbon biofuels. The formation of Catchlight Energy is the first milestone of a biofuels alliance announced by Chevron and Weyerhaeuser in April 2007, and reflects the companies' shared view that nonfood biofuels will play an important role in diversifying the nation's energy supply.

ConocoPhillips and Archer Daniels Midland Company have announced they will collaborate on developing renewable transportation fuels from biomass. The alliance will research and seek to commercialize the conversion of crops, wood or switchgrass into biocrude, which would then be converted into fuels.

Since March 2008 Shell has partnered with Virent Energy Systems in the US on a research project to convert plant sugars directly into gasoline and diesel, rather than ethanol. The collaboration could herald the availability of new biofuels that can be used at high blend rates in standard gasoline engines.

## UNIVERSITY RESEARCH

The biofuel production technologies in widest use today require feedstocks that are also food crops (e.g., corn, sugar cane and soybeans). These feedstocks may be comparatively expensive and their use sets up competition between the food and energy markets for the same agricultural resources.

Economic processes able to produce biofuels from cellulose (biomass) on a commercial scale would be a major step forward. Scientific breakthroughs are needed to make this a reality. For this reason, a substantial part of petroleum industry attention is focused on appropriate University R&D. Examples include the items below.

BP is committing \$500 million funding over 10 years to the Energy Biosciences Institute (EBI), which combines the efforts of UC Berkeley, the Lawrence Berkeley National Laboratory, and the University of Illinois. Biotechnologists at the EBI will investigate many applications of biotechnology to energy, including advanced fuels. BP is also supporting research at Arizona State University into a range of biofuel feedstocks.

ExxonMobil founded the Global Climate and Energy Project at Stanford University in 2002. Funding is also expected to be in the hundreds of millions of dollars.

ConocoPhillips began an 8-year program at Iowa State University to develop new biofuel technologies. They are focusing on converting biomass to oil through pyrolysis, a process that uses heat in the absence of oxygen to decompose biomass into a liquid product. This “bio-oil” can be converted to transportation fuels at petroleum refineries.

ConocoPhillips and Iowa State have also been awarded a \$2 million grant from DOE to advance biomass gasification and eventually biomass-to-liquids technology.

Chevron and the Georgia Institute of Technology formed a strategic research alliance to pursue advanced technology aimed at making cellulosic biofuels and hydrogen viable transportation fuels. The alliance is focusing its research on four areas: production of cellulosic biofuels; understanding the characteristics of biofuel feedstocks; developing regenerative sorbents; and, improving sorbents used to produce high-purity hydrogen.

Chevron and UC Davis executed a research agreement directed at the development of technology for production of liquid transportation fuels

from biomass feedstocks. The objective of the Chevron-UC Davis research is to develop commercially viable processes for the production of transportation fuels from renewable resources such as new energy crops, forest and agricultural residues, and municipal solid waste.

The collaboration is expected to focus its research on four areas: understanding the characteristics of current California biofuel feedstocks; developing additional feedstocks optimized for features such as drought tolerance, minimal land requirements, and harvesting technology; production of cellulosic biofuels; and, design and construction of a demonstration facility for biochemical, and thermo chemical production processes.

**C**hevron and Texas A&M University executed a strategic research agreement to accelerate the production and conversion of crops for manufacturing ethanol and other biofuels from cellulose.

Chevron will support research initiatives that will focus on several technology advancements to produce biofuels including: identifying, assessing, cultivating, and optimizing production of second-generation energy feedstocks for cellulose and bio-oils with a focus on non-food crops; characterizing and optimizing the design of dedicated bioenergy crops through advances in genomic sciences and plant breeding; developing integrated logistics systems associated with the harvest, transport, storage, and conversion of bioenergy crops; and, developing advanced biofuels processing technologies.

Chevron, ConocoPhillips, and Shell are founding members of the recently formed Colorado Center for Biorefining and Biofuels. Other participants include the University of Colorado, Colorado State University, the Colorado School of Mines and the National Renewable Energy Laboratory. The mission of C2B2 is to improve fundamental understanding and develop new technologies in areas relevant to the future commercialization of integrated, sustainable biorefining and biofuels processes.

In 2008 Shell entered into six research agreements with experts in academic institutions across the world. They are part of a growing program of agreements designed to complement Shell's own biofuels research and development, and to accelerate results. The research program investigates new raw materials and new biofuels production processes, with a focus on improving efficiencies and lowering costs. The research agreements will last between two and five years. They are with: The Massachusetts Institute of Technology (MIT), Massachusetts, US; the University of Campinas (Unicamp), Sao Paulo, Brazil; the Institute of Microbiology, Chinese Academy of Sciences (IMCAS), Beijing, China; the Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese

Academy of Sciences (QIBEBT), Qingdao, China; the Centre of Excellence for Biocatalysis, Biotransformations and Biocatalytic Manufacture (CoEBio3) based at Manchester University, UK; and the School of BioSciences Exeter University, UK.Shell.

## ELECTRIC AND ENERGY EFFICIENCY

**E**xxonMobil has developed a battery separator film technology to allow lithium-ion batteries to be used to power drivetrains of all electric or hybrid vehicles. This may result in increased safety, power, efficiency, and reliability of next generation battery technology for vehicles. ExxonMobil has signed an agreement with an all-electric auto manufacturer to apply the technology in actual commercial operations.

ConocoPhillips has developed graphite anode materials for high-power lithium-ion batteries that are integral to the commercialization of advanced electric-powered vehicles. These materials are now being sold to Li-ion battery manufacturers under the "CPreme" brand name for applications in automotive, power grid management, and power tools. CPreme® anodes have been qualified for multiple hybrid electric, plug-in hybrid electric, and pure electric vehicle platforms that are due to be rolled out to consumers over the next few years.

Valero is implementing advanced control technologies to improve combustion efficiency at refineries nationally. That new technology is expected to reduce CO<sub>2</sub> emissions by 1.8 million tons per year by approximately 2008. Project upgrades at its Benicia and Wilmington refineries are planned to decrease CO<sub>2</sub> emissions by more than 140,000 tons per year.

**T**esoro installed two state-of-the-art flare gas compressors at its Golden Eagle Refinery in Concord, CA. This equipment takes flare gases – hydrogen, nitrogen, methane and other hydrocarbons – compresses them and returns them to the refinery for use as fuel. The project reduced flaring by 90 percent, which in turn reduced flare emissions by 94 percent.

At its Salt Lake City Refinery, Tesoro's cogeneration operation (using natural gas to generate both electricity and steam), reduces emissions at that facility by more than 500 tons each year.

## **SOURCES**

The activities described in this report were found on the public web sites of the individual companies. Most were found in recent, publicly available press releases archived by each company.

### **Chevron:**

[www.chevron.com/news/press](http://www.chevron.com/news/press) contains a search function. Entering “biofuels”, “hydrogen”, and “alternative fuels” led to the information cited.

[www.chevron.com/globalissues/climatechange/actionplan](http://www.chevron.com/globalissues/climatechange/actionplan) was also useful.

### **ConocoPhillips:**

[www.conocophillips.com/newsroom/news\\_releases](http://www.conocophillips.com/newsroom/news_releases) provided most information.

The home page also has a major heading called “Technology & Innovation”, with a subsection “Emerging Technologies” which was helpful.

### **ExxonMobil:**

[www.exxonmobil.com/corporate/files/corporate/tomorrows\\_energy.pdf](http://www.exxonmobil.com/corporate/files/corporate/tomorrows_energy.pdf) leads to a report in which pp. 14-17 contain the information cited.

### **BP:**

[www.bp.com](http://www.bp.com) provides a search function. Entering “biofuels” and “hydrogen” led to all the information used.

### **Shell:**

[www.shell.com](http://www.shell.com)

Selecting the major heading “Technology and Innovation”, then the subsection “New Energy Sources” leads to sections on hydrogen and biofuels.