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ALTERNATIVE FUEL: PAST, PRESENT, AND FUTURE (PLUG-IN FLEX FUEL HYBRID ELECTRIC VEHICLES)

by

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PAST

Work on alternative fuel began at Middle Tennessee State University (MTSU) in 1979. The work was spurred by the fact that the Iranians had taken hostages, and OPEC was attempting to control the world's fuel (petroleum) supply. Out of frustration, the author and his students started the conquest for the American farmer to be energy independent in the time of global crisis.

Running an engine off corn (ethanol) was the first challenge. Although many other persons or groups were doing similar research making ethanol, it was the persistency of the MTSU team that eventually led to the building and running of an ethanol-powered truck that ran over 25,000 miles on pure ethanol. Presentations were made at the 1982 World's Fair and TVA's 50th Anniversary Barge Tours.

Having succeeded in building an ethanol-powered vehicle, the next challenge was to run an engine off cow manure (methane). Once hydrogen sulfide and carbon dioxide are removed, the gas which remains is CH_4 (natural gas.) Natural gas engines were fairly common, and several engines were reviewed that ran off methane. It was found that methane production was viable and methane digesters were available in selected large dairy farms.

The knowledge gained in the study of methane production lead to the ultimate challenge; to run an engine off hydrogen from water. On October 14, 1987, the MTSU team ran an engine for eight seconds off hydrogen from water. The next day they ran the eight horsepower engine for two minutes.

Since that time, the author and his students have run tractors, cars, trucks, and stationary engines off hydrogen. The MTSU team was invited to the world's first hydrogen race at the 1991 Bonneville Speed Trials at the Great Salt Flats in Wendover, Utah, where they set the world's land speed record (timed only) for a hydrogen vehicle. Researchers at MTSU proceeded to build another engine to run off pure hydrogen. The MTSU team entered the vehicle in the Southern California Timing Association (SCTA) World Finals on October 18, 1992, at the Bonneville Salt Flats in Wendover, Utah, and set a new world land speed record for pure hydrogen-fueled vehicles. The record stood for several years.

Comment [M1]: Need to correct word vehicle on photo :)

The next fuel to be tested was soybean oil. An Allis-Chambers diesel tractor engine was placed in a 1975 Corvette. The author and his students placed fourth of 40, behind two entries by NASA and one from American Honda, in an alternative fuel road rally sponsored by the Florida Solar Energy Commission and others. The rally started at Cape Canaveral and ended at Disney World. A clogged fuel line resulted from the decomposition of soybean oil. Soybean oil breaks down after six months.

PRESENT

The lifetime goal of the MTSU research is to run engines off sun and water (hydrogen from water). This is presently happening at Middle Tennessee State University. An electric/hydrogen hybrid truck is presently being developed. The electric component (plug-in) is complete, and the internal hydrogen combustion engine generator set is complete. The range and on-board charging system is in the process of being tested.

The following explains how to run engines off sun and water.

Sun

A 10-kilowatt unit was installed. The unit was installed by Big Frog Mountain Energy. Through the Green Power Switch program with the Tennessee Valley Authority (TVA), the electricity produced by the solar array goes into the Murfreesboro Electric Grid Lines within TVA. With the aid of automatic computer readings and calculations, all the electricity produced is monitored. Since the 10-kilowatt solar unit was started March 9, 2004, over 28,000 kilowatts have been produced.

The system works analogously to the banking system. The energy is stored in the "bank" for use at any time--day or night, sunny or cloudy. When the electric component (plug-in) of the electric hybrid truck is charged, the kilowatts used are counted through another meter. In other words, the electricity is taken from the bank and an immediate balance is also available by comparing the difference in the input meter and output meter. The kilowatt balance is presently over 24,000. This is enough stored kilowatts to drive from New York City to Los Angeles, approximately four road trips. The "plug-in" component of the hydrogen/electric hybrid truck uses approximately 1 kilowatt per mile.

Water (Hydrogen)

A similar procedure occurs when the hydrogen is produced. The kilowatts needed to power the 40 cubic foot per hour electrolysis unit is metered. The unit is a Proton 40 electrolysis unit from the Proton Energy Company. The banked electricity powers the electrolysis unit which separates the hydrogen and oxygen from the water. The hydrogen is then temporarily stored in two 500-gallon tanks at 200 psi. Another system, constructed by General Hydrogen, Gallatin, Tennessee (U.S. headquarters), compresses the hydrogen to fill the 4-K cylinders at 6,500 psi. Using a cascading system, a 5,000 psi (4.2 kilogram) hydrogen tank is filled on-board the hydrogen electric/hybrid truck. (NOTE: We also have three hydrogen internal combustion engine cars which can run off sun and hydrogen from water.)

By using the system just described, vehicles are being driven with the only power sources being sun and water. Please note that both the electric component of the truck and the hydrogen component of the truck could be powered directly from the solar unit. However, approximately 90 percent of the electricity produced would be lost. By banking the electricity through the grid, the solar unit is working and saving any time the sun is shining and somewhat when it is cloudy. Time has not permitted energy cost calculations as of today.

FUTURE

I believe the alleviation of the future U.S. energy crisis lies within Plug-in Flex Fuel Hybrid Vehicles. I will explain my rationale. At Middle Tennessee State University, as mentioned before, we are running engines off sun and/or water. We are working on a vehicle that runs off most any fuel. The vehicle is a plug-in hybrid but not in the sense that modern hybrids are once they have the proper adaptation kits. Here is my vision for the future, with the versatile use of PHEVs.

***Option 1 (Plug-in wall outlet)** – The plug-in hybrid can be driven on short trips of 20-40 miles simply by plugging into either a 110 or 220-watt outlet. You get a quicker and deeper charge with 220 current.

***Option 2 (Make it a solar car)** – We are doing this at Middle Tennessee State University. People think that you have to have a solar panel on a vehicle for it to run off the sun. This is not true. As explained earlier, the 10-kilowatt solar unit that we have installed at MTSU produces electricity and stores it ("banks it") into the electric grid. Once the vehicle is charged, the stored electricity is taken from the "bank." Let us say that we have to travel to an adjoining county that has a different electric cooperative. By using a bar code system, the electrical charge or kilowatts used could be transferred from the visited electric cooperative to your home-based electric cooperative. The amount would be charged against, or taken from, your "banked" amount. For example, the University is a member of the Murfreesboro Electric Cooperative, but my home residence is served by Middle Tennessee Electric. Nashville (32 miles away) is a part of Nashville Electric Service. Electric plug-ins could be installed in selected parking lots with the appropriate bar code system. This way, people could drive their cars off solar energy without having a solar unit on board the vehicle. Obviously, the same principle would work with wind generators.

***Option 3 (Gasoline)** – For trips with a range over 20-40 miles, the internal combustion engine starts charging the system and the vehicle works like a normal hybrid. Even though we are using gasoline, our electric utilities are saying the electricity to move a plug-in hybrid electric vehicle (PHEV) down the road costs about one-third the cost of the equivalent gasoline at today's prices.

***Option 4 (Ethanol – E85)** – A flex-fueled vehicle that uses spark plugs can run off practically anything except diesel fuel and any oil-based alternative fuels (soybean oil, cooking oil, etc.). Ford Motor Company has the Ford F-250 Super Chief that can run off hydrogen, gasoline, or E-85 ethanol fuel. Option 4, ethanol, would be used as an alternative to gasoline.

Using E-85 instead of gasoline is also good for the environment because it generates 30% less carbon monoxide and 27% less CO_2 than a comparable gallon of gasoline, and most of that CO_2 is carbon cycle neutral because it is derived from plants which need CO_2 to grow. (E-85 generates 17.06 pounds of CO_2 to create 15,500 BTUs compared to the 23.95 pounds for gasoline.) (www.evworld.com/electrichybrid.cfm)

***Option 5 (Hydrogen from water, separated by the sun)** – This process was explained earlier. I really believe that the fuel of the future is hydrogen and sun. (NOTE: From an agriculture point of view, I am for ethanol from corn and soybean oil as fuels. However, realistically, I believe they are only short-term solutions. I believe the price of corn and soybeans in five to ten years will become so expensive due to agriculture economics (supply and demand) that these products will be cost prohibitive as a fuel stock. I don’t have a “handle” on the potential of switch grass and other cellulose materials.)

With the flex-fuel hybrid, the automotive technology will already be in place while the hydrogen technology continues to gain momentum. Realistically, sun and water are the most viable fuel alternatives. Once they are gone, we will have no need for fuel anyway.

Answers to Specific Questions About PHEVs

1. What major research, development, and demonstration work remains on plug-in hybrid electric vehicle technologies? How should this work be prioritized?

The biggest obstacles are conversions of the existing hybrids to become plug-in hybrids. The cost of most conversions listed on the internet was approximately $10,000. It seems reasonable that if the automotive companies engineered the cars as PHEVs, the cost should not be much more than the price of conventional hybrids currently coming off the assembly line.

I believe the priority on PHEVs should be developing flex-fuel PHEVs. The rationale for this was given earlier. There are so many options on alternatives to the purchase of foreign oil with flex-fuel PHEVs. There are also environmental and other implications.

2. What are the largest obstacles facing the widespread commercial application of plug-in hybrid electric vehicles, and what steps need to be taken to address these hurdles (batteries, infrastructure, consumer preferences, automotive inertia, cost-competitiveness, etc.)?

Three issues need to be mentioned:

First, the development of the perfect battery is always an issue and a challenge. If the perfect battery had already been developed, it would have a range of 300-350 miles with a 15-minute charging time at an affordable cost. Obviously, we are not there. However, nickel cadmium, nickel-metal hydride batteries, and lithium-ion are very adaptable and would work quite well with PHEVs. One battery engineer told me to give him the range needed and he could build the battery. On the other hand, the cost would probably be prohibitive.

The second issue would be cost competitiveness. Presently, hybrids are around $4,000 more than an equal counterpart. A PHEV would be around $6,000 more than a regular car. It seems that a flex-fuel PHEV would be even higher, but I have no data for proof.

The third issue would be infrastructure. Charging at home would not be a problem; but charging at work, while shopping, or while on simple leisure trips could pose a problem. Coin-operated charging meters would need to become commonplace. While visiting the University of Alaska at Fairbanks last summer, I noticed the electrical outlets at nearly every parking spot. These were a necessity for block heaters on the vehicles with the -50^{o} temperatures in the winter. Yet, it was a part of the infrastructure in Fairbanks, Alaska.

3. How does the federal government support the development of plug-in hybrid electric vehicles technologies? What can the federal government do to accelerate the development and deployment of plug-in hybrid electric vehicles?

I am not aware of any direct federal funding of plug-in electric hybrids. Indirectly, converted PHEVs have been at U. S. Energy Department-sponsored "Future Truck" competitions. Also, General Dynamics built the U. S. Marine Corps' diesel-electric PHEV-20 HUMVEE.

The federal government can offer grants to develop a more economic conversion kit. Secondly, automotive companies need some incentive to build PHEVs. Thirdly, customers that buy PHEVs or flex-fuel PHEVs could be offered a tax credit between the difference in cost of a regular automobile and a PHEV or flex-fuel PHEV.

4. Does the discussion draft address the most significant technical barriers to the widespread adoption of plug-in hybrid electric vehicles?

Yes. However, I do not believe we should overlook the internal combustion engine for hydrogen. Hydrogen can work with a flex-fuel vehicle. Fuel cells are great, but the cost makes them a non-issue for several years. The minimum cost for any fuel cell strong enough to power a highway vehicle would be $55,000 plus the price of the vehicle. Presently, the cost of construction for a fuel cell is around $700 per kilowatt (1.2 horsepower) compared to $50 per kilowatt for an internal combustion engine.

5. Would commercial applications of PHEVs be delayed by incorporating flexible fuel capabilities?

I suspect that the commercial applications of PHEVs might be delayed a year or two. As stated earlier, Ford Motor Company already has a flex-fuel vehicle and a hybrid. I suspect other manufacturers are close behind. Since the present hybrids have to be redesigned and engineered to offer the plug-in options, it may take the same amount of time to develop their flex-fuel vehicle hybrids.

BIOGRAPHY

Dr. S. Cliff Ricketts is a professor of Agricultural Education and Acting Director in the School of Agribusiness and Agriscience at Middle Tennessee State University, Murfreesboro, Tennessee.

Dr. Ricketts has been involved with alternative fuel research since 1978. He and his students have designed and built engines powered from a variety of sources, including ethanol, methane, soybean oil, hydrogen, solar/electric, and hydrogen/electric hybrid.

Financial Disclosure: I have not received federal funding on these projects. The funding that I received in 2005-2006 includes:

Corporate Sponsor/Partnership-Tractor Supply Company	$9,500
MTSU Match	$9,500
Basic and Applied Sciences	$2,500
School of Agribusiness and Agriscience	$5,000
TOTAL	$26,500

Other funding:

One time TAF Funds (Technology Access Funds - 2001)	
Electrolysis Unit	$70,000
One time TAF Funds (Technology Access Funds - 2003)	
10 Kilowatt Solar Unit	$70,000
TOTAL	$140,000