MTSU ALTERNATIVE FU

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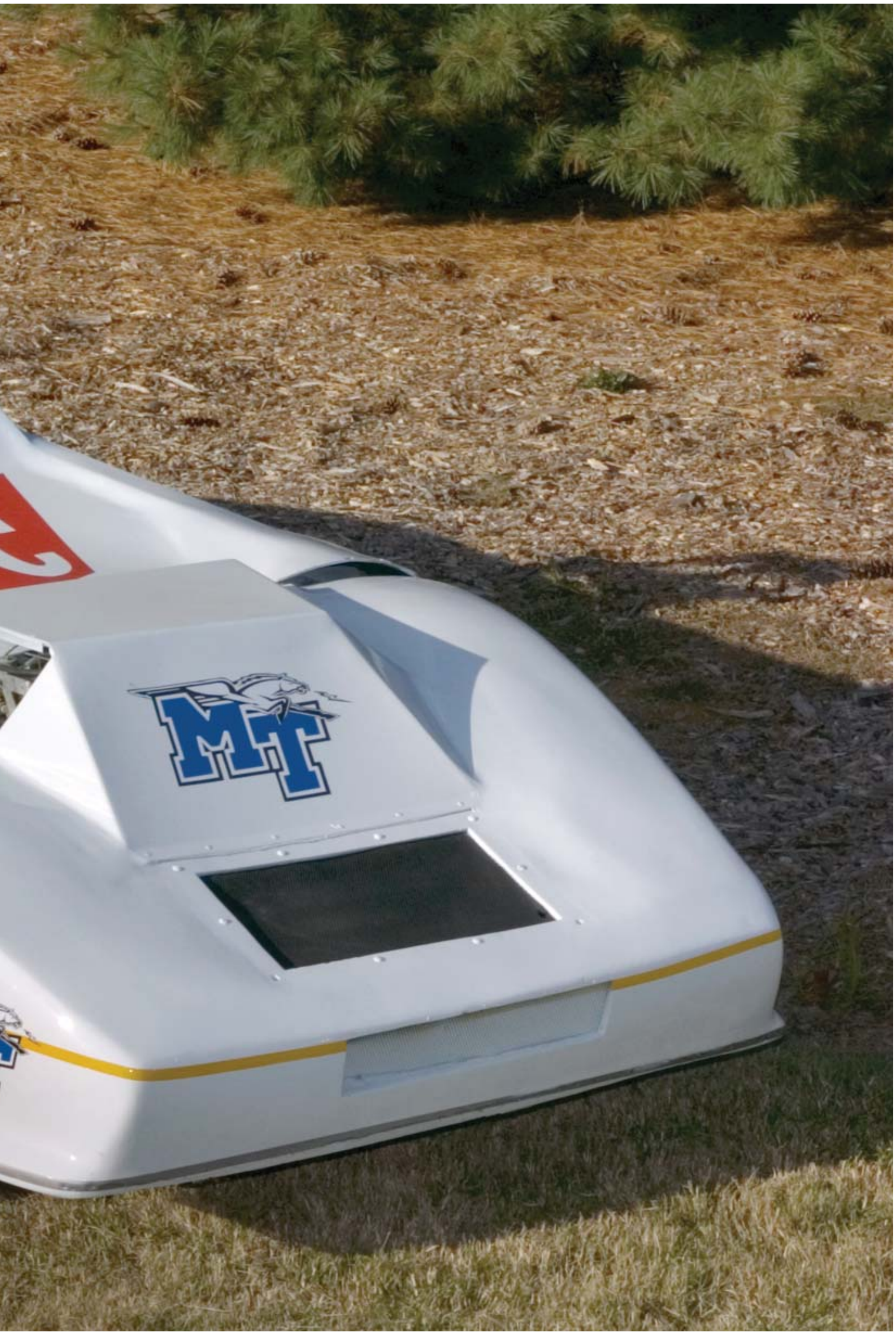
The MTSU team's World Land Speed Record for a hydrogen-powered vehicle set at Bonneville Salt Flats in Wendover, Utah, stood for more

UEL RESEARCH



e than 15 years.

Hydrogen- and solar-powered vehicles, biodiesel fuels, and plug-in hybrid technology are among the cutting-edge research projects on campus.

Several MTSU faculty members have received grants to conduct research into alternative fuels. Here is their brief overview of some of the research.

TVA Grid Sun/ Hydrogen Vehicles

by Cliff Ricketts

MTSU started working on alternative fuel projects in 1979, spurred on by the fact that the Iranians had taken hostages and OPEC was attempting to control the world's petroleum supply. My students and I started the quest to make the American farmer energy independent in a time of global crisis.

Running an engine off corn (ethanol) was the first challenge. Although many others were doing similar research, the persistency of our MTSU team eventually led to building and running a truck that ran more than 25,000 miles on pure ethanol. Presentations were made at the 1982 World's Fair and TVA's 50th Anniversary Barge Tours.

The next challenge was to run an engine off cow manure (methane). Once hydrogen sulfide and carbon dioxide are removed, the gas that remains is CH_4 (natural gas). Natural

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MTSU's School of Agribusiness and Agriscience received a $79,000 grant to convert a Toyota Prius to run off only sun and hydrogen from water.

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gas engines were fairly common, and observation of several engines running off methane proved methane production was viable; selected dairy farms were using methane digesters.

The knowledge gained in the study of methane production led to the ultimate challenge: to run an engine off hydrogen from water. On October 14, 1987, our 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 then my students and I have run tractors, cars, trucks, and stationary engines off hydrogen. We were invited to the World's First Hydrogen Race at the 1991 Bonneville Speed Trials at the salt flats in Wendover, Utah, where we set the World Land Speed Record for hydrogen. We proceeded to build another engine that ran off pure hydrogen, entered the vehicle in the Southern California Timing Association (SCTA) World Finals in 1992 at the Bonneville Salt Flats, and set a new World Land Speed Record for a pure hydrogen-fueled vehicle that stood for more than 15 years.

Sun. A School of Agribusiness and Agriscience system uses a 10-kw solar unit to generate electricity for the Murfreesboro Electric Grid Lines within TVA to bank energy to later charge a plug-in electric/hybrid truck or generate hydrogen from water through electrolysis to run an internal-combustion engine car. The only energy sources running the vehicles are sun and water. The 10-kw solar unit has produced more than 30,000 kilowatts since March 2004.

The system is analogous to banking. The energy is stored for use at any time—day or night, sunny or cloudy. When the plug-in electric component of the hybrid truck is charged, the kilowatts used are metered. The electricity is taken from the bank, and an immediate balance is available by comparing the difference in the input and output meters. The balance is currently over 44,000 kw. The plug-in component of the hydrogen/electric hybrid truck uses approximately one kilowatt per mile. With a Toyota Prius plug-in component, it gets .35 miles per kilowatt. There is enough stored solar energy in the MTSU system to run the Prius for more than 117,000 miles.

Hydrogen from Water. A similar procedure occurs when hydrogen is produced. The kilowatts needed to power the 40-cubic-foot-per-hour electrolysis unit are metered. The banked electricity powers the unit, which separates the hydrogen and oxygen from the water. The hydrogen is temporarily stored in two 500-gallon tanks at 200 psi and then compressed to fill the 16-K cylinders at 6,500 psi. Using a cascading system, a 5,000 psi (4.2 kg) hydrogen tank is filled onboard the hydrogen vehicle.

The school has three projects ongoing:

- *Hydrogen/Electric Truck*. This vehicle consist of 26 Trojan 145-amp, 6-volt deep cycle batteries. With electric/solar power, the vehicle has a range of 60 miles. This increases to 300 when hydrogen is used.
- *Hydrogen Car Two*. In a Toyota Tercel, two 5,000 psi (4.2 kg) tanks are adapted to run off hydrogen. The range is about 300 miles.
- *Plug-In, Flex-Fuel Vehicle*. This is a 22 hp/.9 liter Daihatsu generator set converted to run off hydrogen (also ethanol, natural gas, methane, or any other spark-ignited fuel). Its electric power train can run off only sun or hydrogen from water separated by the electrolysis unit powered by the sun.

All the vehicles are being driven with the sun and water as the only power sources. Both the electric and hydrogen components could be powered directly by the solar unit, but about 90 percent of the electricity produced would be lost. By banking the electricity through the grid, the solar unit stores energy any time the sun is shining and somewhat even when it is cloudy.

Future: Plug-In, Flex-Fuel Toyota Prius. MTSU's School of Agribusiness and Agriscience received a $79,000 grant to convert a Toyota Prius to run off only sun and hydrogen from water. I believe the alleviation of the future U.S. energy crisis lies in plug-in, flex-fuel hybrid vehicles. This project entails the following steps.

- *Step 1* includes a plug-in hybrid component that can be driven on short trips of 20–40 miles simply by plugging into either a 110- or 220-watt outlet. This includes using a solar unit that stores the sun's energy in the electric grid. Once the vehicle is charged, the stored electricity is taken from the bank. The future viability of this phase is as follows. Say you have to travel to an adjoining county served by a different electric cooperative. By using a bar-code system, the electrical charge or kilowatts used could be transferred from the visited cooperative to your home-based cooperative and the amount charged against your banked amount. For example, MTSU is a member of the Murfreesboro Electric Cooperative, your residence might be served by Middle Tennessee Electric Membership Corporation, and Nashville (32 miles away) is served by Nashville Electric

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Cliff Ricketts shows off MTSU's plug-in solar-electric hydrogen hybrid vehicle.

Service. Electric plug-ins could be installed in selected parking lots with the appropriate bar code so cars could run off solar energy without a solar unit onboard the vehicle. The same principle would work with wind generators in certain geographic areas throughout the state.

- *Step 2* involves obtaining hydrogen from water, separated by the sun. This portion of the plug-in, flex-fuel hybrid vehicle would run off hydrogen. I believe the fuel of the future consists of hydrogen and the sun. The gas engine on the Prius will be converted to run off hydrogen with an anticipated range of 240 miles. If we add the plug-in solar electric component from the first step, the range will be about 265 miles. If we add an extra tank, the range will be approximately 500 miles using only the sun and hydrogen from water.
- *Step 3* uses ethanol. A flex-fueled vehicle with spark plugs can run off practically any fuel but diesel. Better for the environment than gasoline, E-85 generates 30 percent less carbon monoxide and 27 percent less CO_2. Most of that CO_2 is carbon-cycle neutral because it is derived from plants that need CO_2 to grow. E-85 generates 17.06 pounds of CO_2 to create 15,500 BTUs compared to 23.95 pounds for gasoline (www.evworld.com/electrichybrid.cfm.)

Conclusion. The economic impact would be a reduction of foreign oil imports and improved balance of payments with foreign countries. The environmental and ecological impact would include immediate reduction in auto emissions in proportion to numbers of vehicles produced/sold/driven; reduction in atmospheric pollution from petroleum refineries and service-station escape; improvement in world greenhouse effects; reduction in pollution to ground water, river, sea, and ocean waters from petroleum transportation and storage; and reduction of wildlife and ecosystems loss from petrospill. The energy impact would include significant reduction of nonrenewable energy consumption, preservation of domestic nonrenewable petroleum reserves, and availability of petroleum for production of medicine and life-sustaining materials for which there are no substitutions.

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MTSU Department of Engineering Technology and Industrial Studies students build solar-powered cars f

Solar Vehicles

by Saeed Foroudastan

MTSU's Department of Engineering Technology and Industrial Studies is one of the frontrunners in advancing knowledge of the alternative fuel industry. MTSU offers not only a strong academic foundation but also the ability to build, enhance, and test experimental designs in an engineering team environment. Outfitted with skills such as team cooperation, dedication, and hard work along with the knowledge of cutting-edge technology, students leave MTSU with a greater understanding of an ever-evolving engineering technology society.

Each year students compete in developing a solar vehicle or boat. Even though 2007 was MTSU's second year competing in the Solar Splash World Championship of Intercollegiate Solar Boating, the team performed well and had the best-looking, most unique design. It attracted the attention of the audience, and

Courtesy Saeed Foroudastan

MTSU student Mika Dyer competed in the Solar Splash World Championship.

for the annual Solar Raycer competition. Shown is a 2004 entry.

The development of valuable co-products from biofuel facilities will allow renewable biofuels to compete more effectively with their petroleum counterparts.

many spectators left their bleacher seats to view it more closely. Moreover, MTSU's solar boat was able to participate in all events.

MTSU won first place in Outstanding Drive Train Design, third for Outstanding Technical Report, fourth for Visual Display, and sixth in Workmanship. In the Technical Design Report, MTSU scored 85 out of 90 possible points, less than one point from winning second place. In 2006, the solar boat received the Rookie of the Year award with the highest overall score.

A Chemist's Perspective on Air Quality Improvement via Biofuel Technology

by Ngee Chong

Several companies have started to produce biodiesel fuels in Tennessee. The viability of this nascent industry depends on the demand for and supply of biofuels. The demand will be shaped by the public perception of biofuels with regard to cost, performance, and environmental benefits. A proposal from the MTSU Chemistry Department recently funded by the Tennessee Department of Environment and Conservation will seek to improve biodiesel quality in order to ensure consumer acceptance of the fuel.

The supply of biofuels is dependent on the successful integration of the most cost-effective biofuel production technology. Existing methods of biodiesel production involve the use of corrosive chemicals such as sodium hydroxide or sulfuric acid and require large amounts of water to wash the biodiesel to remove residual salts and glycerol byproduct.

MTSU biodiesel research will focus on identifying and characterizing catalysts that may overcome these drawbacks, including development of a chemical process to permit the recovery of glycerol—a valuable byproduct that sells for about 50 cents per pound ($3.50 per gallon) if it is kosher or pharmaceutical grade—and methods for converting glycerol into valuable and high-volume chemicals. The development of valuable co-products from biofuel facilities

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Student Kellee Hill (in foreground) conducts quality control analysis of the chemical composition of MTSU biodiesel samples to ensure complete conversion of the vegetable or canola oil feedstocks.

will allow renewable biofuels to compete more effectively with their petroleum counterparts.

I have been collaborating with researchers at the Center for Nanoscale Materials Sciences at Oak Ridge National Laboratory (ORNL) to develop a new type of catalyst for biodiesel production that would fill an urgent need to lower the cost of production while ensuring American Society of Testing and Materials (ASTM) specifications for biodiesel are met. The cetane number, cloud point, and total glycerin of biodiesel can potentially be improved by the use of a solid-supported catalyst as opposed to the current practice of dissolving a sodium hydroxide catalyst in the reaction mixture. Other benefits expected are (1) the ability to tolerate free fatty acids and moisture in waste cooking oil that can be used as an inexpensive feedstock for biodiesel production, (2) the ease of separating the biodiesel product without large amounts of water, and (3) the production of almost neutral-pH biodiesel that is less likely to adversely affect engine parts.

Most biodiesel production facilities do not have in-house laboratory instrumentation for monitoring fuel quality and routinely send samples to commercial laboratories for analysis, potentially posing a quality assurance problem. Sporadic, delayed testing may lead to undesirable consumers' experience with biofuels or disruption in production. I have been working on analytical methods for biodiesel quality control to ensure a superior biofuel with widespread consumer acceptance.

Another aspect of this proposal is monitoring emissions for a biodiesel-powered bus and a lawnmower fueled with E-85 bioethanol. Many agencies, companies, and school districts now require the use of biofuels in fleet vehicles. Emissions testing will help convince the public of the merits of biofuels, especially in two-stroke engines that contribute to air pollutants disproportionately because catalytic converters are typically not used with these engines. Public outreach projects demonstrating the environmental benefits of biofuels, the cost-benefit analysis of alternative fuels, and agronomic evaluation of bioethanol and biodiesel will be undertaken via the creation of a Web site on biofuels.

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Plug-In Hybrid Modification for Automobiles and Small Trucks

by Charles Perry

Increasing energy costs globally have generated many approaches to reducing dependence on oil as the primary energy source for motor vehicles. Biofuels of many types are in various stages of development and implementation as are hydrogen, fuel cells, solar, mechanical and chemical energy storage, and various methods for using energy from the power grid. Plug-in hybrid operation is receiving increasing attention for two reasons: energy generated for the power grid is 40 percent less polluting than automobile emissions, and combining energy from the grid with energy from oil to power a vehicle reduces total energy costs by approximately 50 percent during hybrid operation.

The advantages of plug-in hybrid operation have motivated major automotive producers to invest in producing vehicles with this capability. However, development time will delay high-volume availability of new automotive platforms compatible with plug-in hybrid operation until 2010 or 2011. Even when available, the percentage of plug-in hybrids on the road will remain relatively small as the purchase of new vehicles with this capability slowly increases.

Another approach is to develop a method to convert an automobile or small truck to allow plug-in hybrid operation. Many individuals and small companies already sell kits or plans to convert a suitable automobile to plug-in hybrid operation. The problems associated with these conversions are cost and complexity, both mechanical and electrical.

An attractive solution would allow widespread adoption of a plug-in hybrid kit adaptable to any car or small truck: an inexpensive and mechanically simple method to add the electric drive motor(s) to an existing mechanical drive system, complicated somewhat by differences in automobile design (front versus rear or all-wheel drive, brake configurations, etc.). MTSU's Department of Engineering Technology and Industrial Studies is developing and testing an electric drive system adaptable to any car or small truck. Emphasis is on the method used to add electric drive to an existing vehicle. The general concept is to use available battery and control electronics and add electric drive to each rear wheel assembly, creating a wheel-hub motor without significantly modifying the design.

Feasibility of this approach was tested on a 1994 Honda Accord wagon. Figure 1 shows the batteries and drive electronics, and Figure 2 shows the external electric drive system added to each rear wheel. The goal of the initial evaluation was to validate the parallel operation of the electric drive and the drive from the internal combustion engine. In hybrid operation the Honda wagon averaged more than 100 miles per gallon for a total energy savings of about 50 percent per mile in hybrid operation (considering both gasoline and electricity costs).

While the motor drive system shown satisfies the requirement of adaptability to any vehicle because the electric motor torque is applied externally to the rear wheels by a bracket attached to the wheel lug bolts, it is not the best approach. The department is researching and developing a better approach that integrates the electric motor into the structure of the rear wheel spindle, brake, and wheel, converting the rear wheel structure into a wheel-hub motor, leaving unchanged the original design's bearings, brakes, and suspension. The patent-pending process will allow any vehicle or small truck to be converted to plug-in hybrid operation. ■

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Cliff Ricketts is a professor in the School of Agribusiness and Agriscience, Ngee Chong is an associate professor in the Chemistry Department, Saeed Foroudastan is associate dean of Basic and Applied Sciences, and Charles Perry holds the Robert E. and Georgianna West Russell Chair in Manufacturing Excellence.

Figure 1. 1994 Honda wagon batteries and drive electronics

Courtesy Charles Perry

Figure 2. External electric drive system added to rear wheels