Teaching Students about Clean Fuels and Transportation Technologies

By Joe Busby, DTE and Pam Page Carpenter

Technology teachers are part of the global solution for educating a greater public about energy inputs, processes, and outputs.

Junior Solar Sprint students ready to race.

Global warming, going green, ethanol, biodiesel, fuel cells, hydrogen combustion, and hybrids are some of the terms being tossed around in mainstream media these days. The grassroots efforts of many environmentalists and concerned citizen groups, Al Gore's (2006) documentary, *An Inconvenient Truth,* on global warming, rising petroleum fuel prices, concerns for dependency on oil, national security, and jobs are a few of the issues driving the need to become more informed and involved in going green.

Regardless of a person's convictions and belief system, science has provided a body of knowledge that points to human interaction with nature as being the leading cause of pollution and a variable to the cause of global warming. Some of this knowledge is being debated within the science community, and even more within the mainstream of society. For many, the question of what is fact or fiction is real.

Technology teachers are part of the global solution for educating a greater public about energy inputs, processes, and outputs as indicated in *Standards for Technological Literacy: Content for the Study of Technology (STL)* (ITEA, 2000/2002/2007): Standard 5 – the effects of technology on the environment, Standard 15 – agricultural and related biotechnologies, Standard 16 – energy and power technologies, and Standard 18 – transportation technologies. Therefore, technology teachers need reliable and basic information about renewable energy technologies to incorporate into their classroom instruction in order to better fulfill *STL*.

There are many alternative energy and transportation technologies being implemented that will make a positive difference on the environment. Many other technologies that hold great promise are currently in a research and development phase. The following topics are environmentally friendlier energy and transportation technologies that are currently being implemented in various places around the world.

Fuel-Efficient Vehicles

Fuel-efficient vehicles, referred to as FEVs, are determined by the maximum miles per gallon (MPG) and the lowest emissions. Emissions contribute to greenhouse gases, with transportation being the largest contributor to carbon dioxide (CO_2). According to the Energy Information Administration (2007), 98% of CO_2 is emitted as a product of the combustion of fossil fuels in the United States.

Some vehicles are partial zero-emissions vehicles (PZEVs). An example of a PZEV is the Toyota Prius, a hybrid car that runs on gasoline and batteries. When the Prius is using only battery power, it is said to be a zero-emissions vehicle (ZEV) because it is not emitting any pollutants into the atmosphere. The batteries have a limited range, so the gasoline internal-combustion engine (ICE) provides most of the power for the auto. When a hybrid's ICE is running, gasoline is burned and emissions are released into the atmosphere. A hydrogen vehicle is considered a ZEV because its only emission is a harmless water vapor (Air Resources Board, 2004a). This makes it an excellent vehicle to drive to help eliminate greenhouse gases.

In order to achieve clean-air standards, California has enacted strict regulations requiring automobile manufacturers to produce and sell zero-emission vehicles (Air Resource Board, 2004b). These standards can be met by producing and selling a greater number of PZEVs. These regulations will push the automobile industry to create a variety of vehicles with zero and partial emissions.

Alternative Fuels

Alternative fuels are non-petroleum-based fuels and are sources of renewable energy. Alternative fuels include battery power, biodiesel, biomass, ethanol, hydrogen, solar, and wind energy. Most of these renewable energy sources are currently being used to power alternative fuel vehicles and as oxygenates in low-level fuel blends (U.S. Department of Energy, 2008b). Hydrogen is presently being researched and developed, with the first leased vehicles powered by hydrogen fuel cells and hydrogen internal combustion engines now available for consumers in some states.

Alternative Fuel Vehicles

Alternative Fuel Vehicles (AFVs) are defined by the use of non-petroleum-based renewable fuels. Examples of AFVs are automobiles that use biodiesel, ethanol, hydrogen, and solar energy. Approximately 1.8 million AFVs were sold in 2007 in the U.S. During 2008, it was estimated that over 11 million AFVs were in service in the U.S., and automobile manufacturers offered over 70 models of AFVs to consumers, a marked increase from 11 models in 2001 (AutoblogGreen, 2008).

Flexible-Fuel Vehicles

Flexible-fuel vehicles (FFVs) are defined by the use of both fossil fuels and alternative fuels (e.g., gasoline and ethanol, diesel and biodiesel). Onboard sensors detect which fuel is being utilized in order to accommodate for and efficiently burn the fuel in an ICE. The U.S. Department of Energy (2008a) estimates more than 6 million FFVs were in service in 2008, and many of the owners were not aware their vehicles were FFVs. The lack of awareness causes an underutilization of alternative fuels by the owner/operator and reduces the environmental benefits of the vehicle.

Biomass

Biomass is plant and animal matter that is used to make energy. It is considered the most common renewable source of energy (Markert and Backer, 2003). Examples of biomass are wood, corn stalks and shucks, grain, wheat stubble, and animal dung. Ethanol and biodiesel are two alternative fuels acquired from biomass resources and utilized in FFVs.

Ethanol

Ethanol is a renewable grain alcohol fuel derived from the fermentation of plant materials that are high in carbohydrates. Some plants that are used to create ethanol include corn, sugar cane, grains, and woody fibers. The woody fibers (cellulosic) tend to be the most difficult from which to obtain ethanol because of the lignin in the plant, but hold the greatest potential for future production and meeting the U.S. Department of Energy's (30 x 30) goal for replacing 30% of automobile gasoline by 2030 (Neilson, 2007).

Currently, researchers at North Carolina State University are manipulating the genes in popular trees to create trees with less lignin and improve ethanol production (Burns, 2007). Ethanol is usually mixed with gasoline of a blend of E-85 (85% ethanol, 15% gasoline) for flexible-fuel vehicles (FFVs), and heavy-duty trucks use E-95, which is a blend of 95% ethanol and 5% gasoline.

Biodiesel

Biodiesel is derived from soy beans, canola, and other plants. It is also processed from recycled vegetable oil. All diesel engines can operate on biodiesel blends of 5% (B5) and 95% petro-diesel. Blends higher than 5% may require modifications to the vehicle. Biodiesel may be used in the pure form of B100 or mixed with diesel as a blend of 20% biodiesel and 80% petroleum diesel known as B20. Biodiesel results in lower emissions of particulate matter, carbon monoxide, hydrocarbons, and other pollutants. These lower emissions have less adverse impact on the environment.

Concerns about the harmful effects from diesel exposure have given cause for some school districts to use biodiesel in school buses. Biodiesel is a safer alternative for the students riding buses because carbon monoxide and particulate matter (breathing irritants) are reduced by almost one half. Further, two potential cancer-causing compounds, polycyclic aromatic hydrocarbons (PAH) and nitrated polycyclic aromatic hydrocarbons (nPAH), are reduced by large amounts. Most of the PAH compounds are reduced by 75 percent, and the nPAH are reduced by 90 percent or more (National Biodiesel Board, 2008).

Hydrogen

Hydrogen holds great promise as a fuel for advanced technology vehicles. Currently, hydrogen is being used in hydrogen fuel cells to make electricity and in ICEs where it is burned instead of gasoline. Hydrogen is considered the simplest of elements because its structure is one proton and one electron. Individual hydrogen elements are rarely found alone in nature because of their single electron. When hydrogen is concentrated, it is usual for two hydrogen elements to join by sharing their electrons and form H_2 gas (Ewing, 2007). Hydrogen is the cleanest of fuels since its emissions are clean water. Hydrogen is also being combined with natural gas and propane systems to improve emissions of the systems.

Hydrogen Fuel Cells

A fuel-cell vehicle (FCV) uses a hydrogen fuel cell. The fuel cell, like a battery, is an electrochemical energy conversion device. The difference between a battery and fuel cell is that a battery has to be recharged and eventually discarded, while a fuel cell, as long as it has a constant flow of chemicals to contact the catalyst, will continue to produce electricity.

There are several types of hydrogen fuel cells. The electrolyte used in the fuel cell provides the primary

Triumph Spitfire EV converted by high school students.

classification for the fuel cell. Alkaline Fuel Cells (AFCs) are the first type of fuel cells to be used in the space program. Although expensive to operate, these fuel cells produce electricity for the spacecraft and consumable water for the astronauts (U.S. Department of Energy, 2007).

The Proton Exchange Membrane fuel cell (PEM) is presently the most suitable for land transportation applications. This fuel cell is fueled by hydrogen that is carried onboard and oxygen obtained from the atmospheric ambient air. The only emissions from a PEM are heat and water. The need for stored hydrogen is a current challenge for this system. A great amount of storage is necessary for PEM-powered vehicles to have ranges comparable to gasoline-powered vehicles.

Other types of fuel cells exist but each exhibits challenges for application to vehicular transportation systems. Several systems produce extreme heat well past the boiling point of water. Others produce by-products that are not environmentally friendly.

Battery-Powered Electric Vehicles

Electric vehicles (EVs) are advanced technology vehicles that rely on rechargeable batteries as the source of energy. Refueling is only a plug-in to an electrical supply system. EVs have a range of 50 to 200 miles (Plug In America, 2007). There are zero emissions from EVs, and they require no oil changes, no tune-ups, and little in the way of purchasing parts for the vehicles.

Hybrid Electric Vehicles

There are numerous hybrid electric vehicles (HEVs) on the road today. HEVs have a combination of an ICE and an electric motor to provide power. The HEVs are able to travel greater ranges while consuming less fuel and producing fewer emissions than conventional vehicles. HEVs are generally classified as partial zero-emissions vehicles (PZEV). While being powered only by the electric motor, zero emissions are being emitted, but when the gasoline engine is in operation, emissions are expelled.

Plug-in hybrid electric vehicles (PHEVs) are just entering the market for private transportation. PHEVs utilize an ICE and an electric motor just like other HEVs. The difference is that the PHEV works like an EV and plugs into a wall socket to charge the batteries. It also works like an HEV and gets energy from the ICE, which gives the automobile a greater range than an EV.

Solar Vehicles

While EVs obtain energy from batteries, solar electric vehicles (SEVs) use the sun as their source of power. Photovoltaic cells, mounted on the exterior of the vehicle, are used to convert sunlight into electricity. SEVs are considered by many to be impractical because of the limitations of sunlight. Still, photovoltaic modules are being produced as add-on applications to HEVs. The gains recognized by the addition of the photovoltaics reduce the operation of the gasoline engine, thus further reducing emission.

An Example Educational Energy and Transportation Initiative

The North Carolina Solar Center is an educational initiative of the College of Engineering at North Carolina State University and has provided K-12 programs in alternative fuels and transportation for over ten years. Two Solar Center programs that can serve as models for technology education are the Junior Solar Sprint and the Students Making Advancements in Renewable Transportation Technologies (SMARTT) Challenge programs.

The Junior Solar Sprint program provides a hands-on opportunity for middle school students to learn about solar energy. The students study content materials developed by the National Renewable Energy Laboratory (2001) that enable them to design, build, and test a small vehicle powered by a photovoltaic cell. The culminating activity is the annual competition with other schools on the campus of North Carolina State University.

The SMARTT Challenge program is a year-long curriculum program that includes converting a gasoline-powered vehicle into an electric vehicle. The SMARTT Challenge program is a hands-on thematic program with many requirements that ends with a competition. The students are expected to study a specific curriculum that intentionally integrates science, technology, engineering, and mathematics (STEM) concepts. For the competition, the students have to create a web page that explains their environmental education and their activities while building the electric vehicle, create a display explaining building the electric vehicle and document its use in the community, and develop oral presentations per requirements.

Both the Junior Solar Sprint and the SMARTT Challenge programs provide opportunities for students to work cooperatively in a hands-on learning environment. These programs give students, who may not be academically engaged, opportunities to become interested in school again. Further, the programs provide extended learning opportunities for all students involved, including those who are more inclined towards academics.

The North Carolina Solar Center provides workshops to prepare teachers for teaching the Junior Solar Sprint and the SMARTT Challenge programs. They also offer a number of other workshops for teachers about wind energy and other renewable energy technologies. The Solar House, part of the North Carolina Solar Center, is the premiere facility where students and the public can see and experience firsthand solar energy apparatus incorporated in residential dwellings. These apparatus include active and passive solar energies, photovoltaics, wind turbine, and alternative fuels.

Facts into Action – An Activity

All technology education teachers can create opportunities for their students to experience alternative energy and transportation technologies. These experiences can happen in well-equipped laboratories or in programs with meager means for hands-on activities, as whole class, partial class, enrichment, or after-school activities. With appropriate and adequate planning, successful experiences can be realized by all.

A constructivist's model to follow that allows for engineering design and problem solving is for the teacher to present information about alternative energy sources as applied to transportation technologies and then have students help create a list of alternative transportation energy source topics for further investigation. The students can choose a topic from the list and work individually, in pairs, or in small groups to research the topic. Based on the research, the student or team should plan, build, and test a working model of the system. Data collection for the intent of making informed decisions and reporting the findings should be included as part of the testing. The students should utilize professionals from the community to help develop the plans for building the system, as well as the plans for testing the system and reporting the data from the tests. Ultimately a report and display can be developed to show the findings of the research project and to serve as an outlet to disseminate the information to a greater public.

Conclusion

Clean fuels and transportation technologies are part of the puzzle for cleaning up the earth's environment. While this article was being written, the United States passed the Energy Independence and Security Act of 2007 (Office of the Press Secretary, 2007). This bill enacts the first increase in fuel economy standards for automobiles since 1975, calling for a 40 percent increase by setting a national fuel economy threshold at 35 miles per gallon by 2020. The bill also sets a mandatory Renewable Fuel Standard (RFS) where fuel producers are required to use a minimum amount of biofuel in 2022.

Technology education teachers can be part of the solution to environmental challenges by educating about clean, alternative fuels and transportation technologies. Many changes are happening within these areas and students need

The NC State Wolfpack Energy-Efficient Locomotion at the Junior Solar Sprint and Students Making Advancements In Renewable Transportation Technologies (SMARTT) final event.

to have experiences and develop understanding so they can be wise consumers as well as conscious contributors to future developments.

References

Air Resources Board. (2004a). *Fact sheet: California vehicle emissions.* California Environmental Protection Agency. Retrieved November 14, 2007, from www.arb.ca.gov/msprog/zevprog/factsheets/calemissions.pdf.

Air Resources Board. (2004b). *Manufacturers advisory correspondence (MAC) 2004-01*. California Environmental Protection Agency. Retrieved November 14, 2007, from www.arb.ca.gov/msprog/macs/mac0401/mac0401.doc.

AutoblogGreen. (2008). *Auto Alliance: 1.8 million alternative fuel vehicles sold in 2007*. Retrieved May 27, 2008, from www.autobloggreen.com/2008/04/05/auto-alliance-1-8-million-alternative-fuel-vehicles-sold-in-200/.

Burns, M. (2007). Breeding better biofuels*. Results: Research and graduate studies at North Carolina State University.* Retrieved November 13, 2007, from www.ncsu.edu/research/results/vol7n2/09.html.

Energy Information Administration. (2007). Emissions of greenhouse gases in the United States 2005: Executive summary – carbon. *Official energy statistics from the U.S. Government.* Retrieved January 6, 2008, from www.eia.doe.gov/oiaf/1605/archive/gg06rpt/summary/carbon.html.

Ewing, R. A. (2007). *Hydrogen – hot stuff cool science*. Masonville, CO: PixyJack Press, LLC.

Gore, A., et. al. (2006). *An inconvenient truth*. Hollywood, CA: Paramount Classics and Participant Productions.

International Technology Education Association. (2000/2002/2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Markert, L. R. and Backer, P. R. (2003). *Contemporary technology: Innovations, issues, and perspectives*. Tinley Park, IL: The Goodheart-Willcox Company, Inc.

National Biodiesel Board. (2008). *Biodiesel: Biodiesel emissions*. Retrieved May 22, 2008, from www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf.

National Renewable Energy Laboratory. (2001). *Junior solar sprint: So…you want to build a model solar car*. Retrieved June 16, 2007, from www.nrel.gov/docs/gen/fy01/30826.pdf.

Neilson, R. M., Jr. (2007). *The role of cellulosic ethanol in transportation*. Idaho Falls, ID: Idaho National Laboratory. (INL/CON-07013406 Preprint). Retrieved May 27, 2008, from www.inl.gov/technicalpublications/Documents/3867727.pdf.

Office of the Press Secretary. (2007, December 19.) *Fact sheet: Energy independence and security act of 2007. The White House*. Retrieved January 5, 2008, from www.whitehouse.gov/news/releases/2007/12/20071219-1.html.

Plug In America. (2007). *Frequently asked questions*. Retrieved June 14, 2007, from www.pluginamerica.com/faq.shtml.

U.S. Department of Energy. (2007). Hydrogen, fuel cells & infrastructure technologies program. *Energy efficiency and renewable energy*. Retrieved November 6, 2007 from www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html.

U.S. Department of Energy. (2008a). Alternative fuels & advanced vehicles data center. *Alternative & advanced vehicles: Fuels*. Retrieved May 27, 2008, from www.eere.energy.gov/afdc/vehicles/flexible_fuel.html.

U.S. Department of Energy. (2008b). Alternative fuels & advanced vehicles data center. Data, analysis & trends: *Fuels*. Retrieved May 27, 2008, from www.eere.energy.gov/afdc/data/fuels.html.

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