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AFDC UPDATE

News of the Alternative Fuels Data Center

Latest Report Shows AFVs Closer to Driver Expectations

Drivers of Federal fleet vehicles report that their alternative fuel vehicles (AFVs) are approaching the performance and reliability they expect from gasoline vehicles. That finding is part of the latest report recently released by the National Renewable Energy Laboratory (NREL) as part of the U.S. Department of Energy's AFV light-duty vehicle data collection effort.

Although NREL is well known for its alternative fuel emissions data, its latest report, *Alternative Fuel Light-Duty Vehicles*, "is the first thing we've published specifically for fleet managers to see what we've learned about performance and reliability," said Peg Whalen, NREL staff project engineer. "We wanted to put something together that fleet managers and Clean Cities coordinators could use."

The AFVs studied used compressed natural gas (CNG), ethanol, methanol, and propane. Gasoline control vehicles were also included. Researchers hope the Federal fleet's experience with these fuels will help fleet managers decide which fuel best suits their needs.

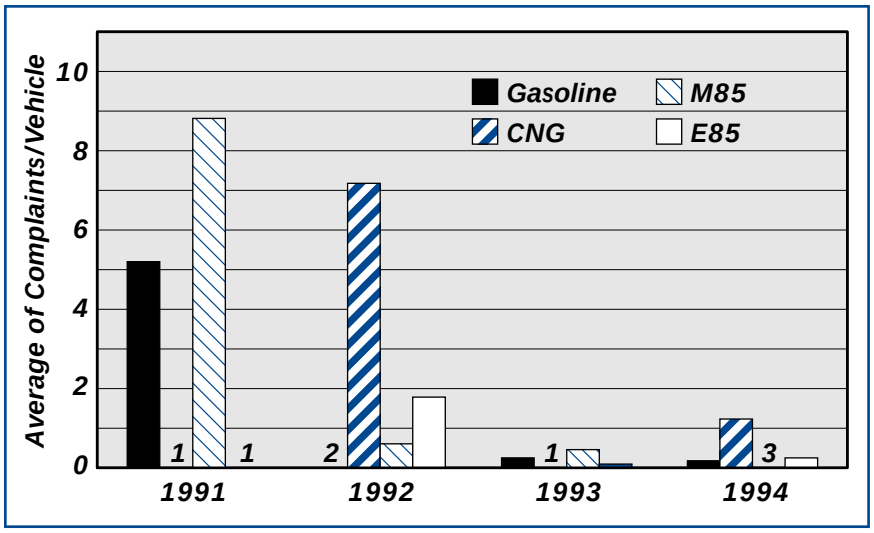

Figure 1. Driver-reported complaints by fuel type (in first 10,000 miles of vehicle operation)

1 No CNG vehicles in 1991 or 1993 and no E85 vehicles in 1991
2 No gasoline vehicle complaints reported in 1992
3 No M85 vehicle complaints reported in 1994

What NREL learned is based on comments collected during the past 4 years from drivers each time they refueled, as well as vehicle service and maintenance records obtained from auto dealers, repair shops, and the General Services Administration, the procurement agency for many of the Federal government's vehicles. Drivers noted performance problems such as stalling, hesitation, and lack of power.

Driver-reported complaints were significantly more common for the earlier model AFVs (see Figure 1). This conclusion was

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How to Reach Us

- The AFDC World Wide Web address is **http://www.afdc.doe.gov**
- This *AFDC Update* newsletter is available on-line 2 or more weeks before the newsletter is mailed at **http://www.afdc.doe.gov/news**
- For modem users, dial **(800) 588-2336** with a vt100 emulator and type www. This takes you to the nongraphical LYNX browser. You don't need a user ID or a password.
- To speak to a human being, call the Alternative Fuels Hotline at ***(800) 423-1DOE.***

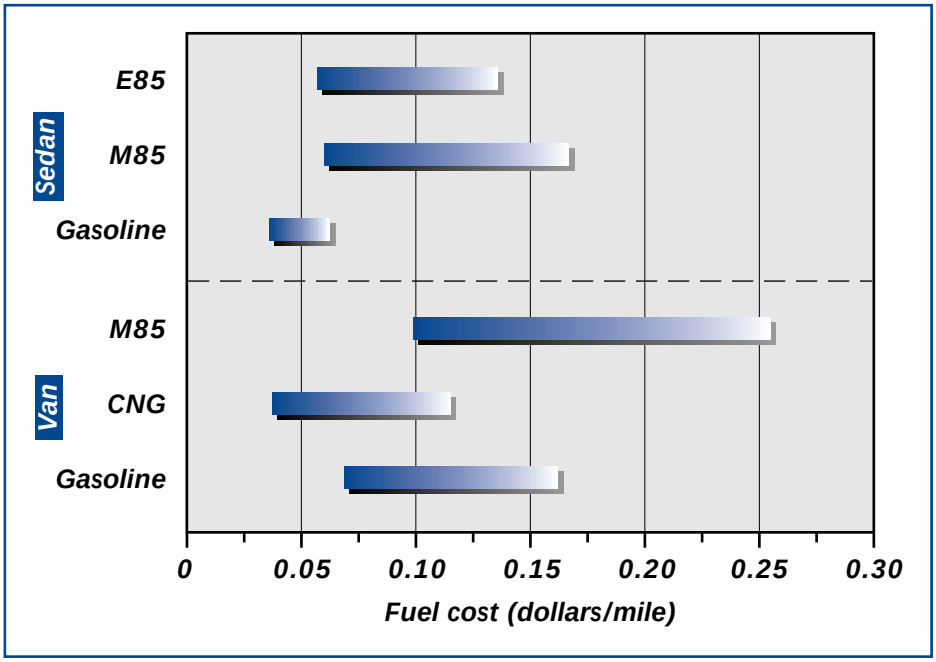


Figure 2. Range of fuel costs per mile (alternative fuel costs are based on gallons of gasoline equivalent)

reached after comparing comments received on all of the vehicles during their first 10,000 miles of service. In general, driver satisfaction with AFVs has increased significantly since the vehicles were introduced into the fleet. "I think the figures show the vehicles are getting better," Whalen said.

In the 1992–1994 model years, the CNG vehicles received the most complaints per vehicle. Drivers reported poor idling and hesitation most frequently. Limited range was a concern throughout the program.

Drivers of methanol vehicles also reported poor idling and hesitation, but those complaints also decreased with later model years. The number of ethanol vehicle complaints was closer to that of gasoline. When it came to the number of unscheduled repairs, CNG and methanol had fewer incidences than gasoline for new model year vehicles. Researchers noted that the limited number of E85 (85% ethanol, 15% gasoline) vehicles makes it difficult to reach general conclusions.

Using data from chassis dynamometer testing and in-service fuel use, the AFVs showed a wide range of fuel economy (see Figure 2). On average, each AFV was within 1 or 2 miles per gallon of the fuel economy on gasoline. Because a vehicle's fuel economy depends on factors such as driving style and road conditions, these results are comparable to those of their gasoline counterparts.

Fleet managers may be especially interested in the cost data NREL gathered. The Federal fleet experience indicated that AFVs initially can cost up to 25% more than gasoline vehicles; CNG vehicles are at the high end (as much as $5,000), while the alcohol fuel vehicles have been sold for the same price or close to the gasoline version ($0–$800 additional cost).

These incremental costs are expected to drop as more AFVs are produced, but fleet managers who choose CNG can also make up the difference in reduced fuel costs during the life of the vehicle, NREL researchers found, especially if they have high-mileage fleets. After averaging gasoline and CNG fuel costs nationwide, CNG vehicles driven 3,500 miles each month matched the gasoline vehicles' cost per mile.

Although the acquisition cost is low, maintenance costs for the alcohol vehicles can be slightly higher then those of gasoline vehicles because of more frequent oil changes, lower fuel economy, and higher fuel costs. Although gasoline fuel costs hovered around 5 cents per mile, the alcohol fuels ranged from 6 to 17 cents per mile. Overall, unscheduled maintenance costs associated with all AFVs have decreased with newer models.

The summary also includes results from emissions testing completed on 169 AFVs representing CNG, ethanol and methanol models, and 161 gasoline control vehicles. These results have been widely reported in the Alternative Fuels Data Center's (AFDC) database and past issues of *AFDC Update* (January 1996). Vehicles converted to run on CNG and propane were also tested; see the Spring 1996 *AFDC Update* for more information. The latest report does include valuable information, but a new method of surveying drivers and fleet managers implemented earlier this year is expected to improve NREL's data collection program. Instead of asking drivers to fill out cards when refueling, NREL has contracted with a company to perform random phone surveys. The summary of the first quarter's results is available on the AFDC's World Wide Web site, and future quarterly summaries will follow. A full report will be published after a year when AFV experience during all seasons has been represented in the demonstration.

For more information, visit the AFDC's World Wide Web site at ***http://www.afdc.doe.gov*** *and click on "What's New," or call the Alternative Fuels Hotline at* ***1-800-423-1DOE****.*

Natural Gas and Refuse Trucks a Good Combination

Trash haulers are not commonly associated with fresh air, but developments in heavy-duty compressed natural gas (CNG) engines are making them a lot cleaner. Since 1992, the Alternative Fuels Data Center (AFDC) at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has been accumulating refueling and maintenance data on six New York City Department of Sanitation (NYCDOS) refuse haulers using the Cummins L-10 engine.

The trucks have been driven more than 60,000 miles and have yielded hundreds of records. "Overall the performance was excellent," said Paul Norton, NREL program manager. "New York was happy with the trucks for two main reasons: they were quiet and they were clean." The different engine combustion dynamics of CNG and diesel help account for the reduced noise—CNG engines are spark-ignited; diesels use compression.

Refuse trucks are good candidates for using CNG because they typically drive a limited range and are centrally refueled. The average range of New York City's CNG trucks is about 61 miles, but their short routes have allowed NYCDOS to refuel them about once every 2 days.

Although the drivers noticed improved emissions from the CNG trucks, NREL researchers were not surprised that emissions levels were highly variable because the engines were not optimized.

"The engines we tested were early demonstration engines from Cummins Engine Corporation," said Ken Kelly, NREL emissions project engineer. "The carbon monoxide emissions didn't look so great. Since then Cummins has done quite a lot to optimize the engines."

Even without optimization, the CNG trucks consistently demonstrated a clear advantage over diesel for particulate matter (PM) emissions (see Figure 3), a serious health concern in urban areas. Diesel engines emit about 80% of the mobile-source PM emissions in urban areas. However, the PM emissions from the CNG engines were "quite often too low to measure," Kelly said.

Last year NYCDOS placed 10 more CNG refuse trucks into service. "We've really enjoyed running the trucks on natural gas," said NYCDOS Manager Tim Harte.

New York City has not been alone in recognizing the value of CNG refuse haulers. In California, 10 of Long Beach's 65 trucks run on CNG. "The guys love them," said Paul Smock, CNG coordinator for the City of Long Beach Gas Company. The trucks pick up trash at about 1,000 houses each day, and the stop-and-start driving pattern caused the diesel exhaust to hover around the cab instead of dissipating. With the CNG trucks, "they [the drivers] say they feel better at the end of the day."

Because Long Beach owns the gas utility, it made sense to become its own customer. "We save a lot on fuel costs," Smock said. "We also have a commitment to clean air, and any CNG plan usually breezes through the city council."

Range has not been a problem for Long Beach—it opened a CNG station at the resource recovery facility. "It's not inconvenient," Smock said, "so they refuel every time." Fueling takes 5–10 minutes. With a station on site, Smock said the city hopes private haulers will switch as well.

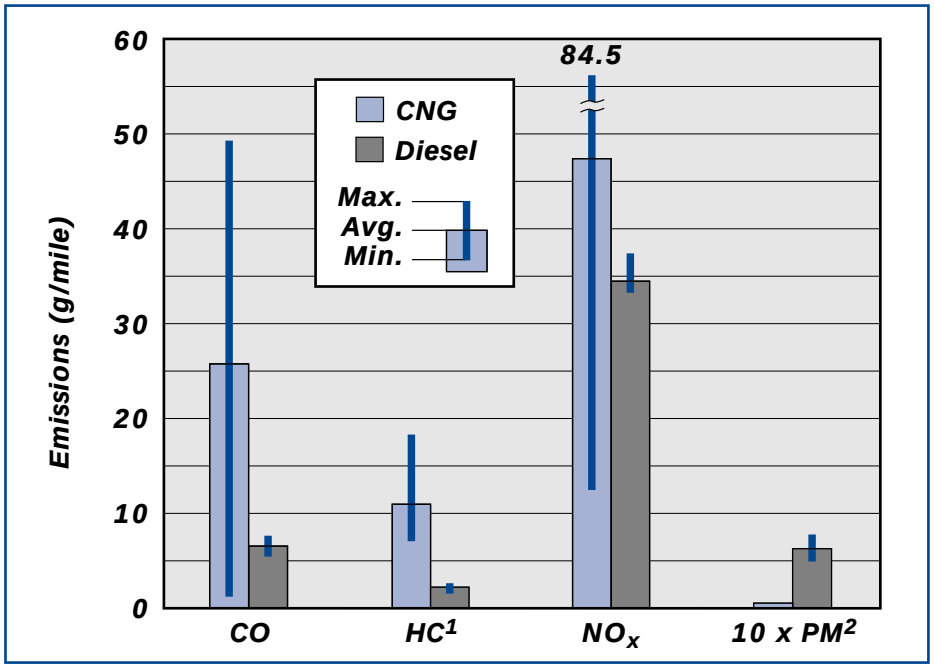


Figure 3. Chassis dynamometer emissions results for New York City garbage packers

1 Total hydrocarbons 2 Particulate matter values magnified 10 times

The report, Alternative Fuel Trucks Case Studies: Running Refuse Haulers on Compressed Natural Gas, *is available on the AFDC's World Wide Web site,* ***http://www.afdc.doe.gov*** *under "What's New," or by calling the Alternative Fuels Hotline at* ***800-423-1DOE****.*

Student Competitions Drive Enthusiasm for AFVs

Challenging students to design cars for the future may generate vehicles that look like spacecraft, but recent competitions have progressed to demonstrating viable commercial technologies.

"Student competitions meet two primary goals," said Shelley Launey, manager of Student Vehicle Competitions for the U.S. Department of Energy's (DOE) Office of Transportation Technologies. "They demonstrate technologies this office supports, such as propulsion and materials, in real-life, functioning vehicles. They are also the best way to get the next generation of engineers to bring with them to the auto industry an enthusiasm for advanced technology and alternative fuels."

Past such events sponsored by DOE have already delivered promising technologies. The Gas Research Institute is further developing a compressed natural gas (CNG) fuel-quality sensor demonstrated by Northwestern University in the 1991 Natural Gas Vehicle (NGV) Challenge. Chrysler Corporation plans to use a multi-alternative fuel injector (CNG, liquefied natural gas, and propane) that was developed by Old Dominion University with Siemens Automotive in its 1998 CNG vehicles for the 1992 NGV Challenge. Hybrid electric vehicles (HEVs) built by the University of Illinois, the University of Maryland, and the University of California at Davis for the HEV Challenge were used by the Society of Automotive Engineers' to develop draft HEV emissions test procedures.

This year DOE was a sponsor of three major events: the Tour de Sol, the Propane Vehicle Challenge, and FutureCar Challenge.

Tour de Sol Student Teams

Boston University, Boston, MA
Greenwich High School, Greenwich, CT
North Hunterdon High School, North Hunterdon, NJ
Parkland High School, Orefield, PA
Rocky Hill High School, Rocky Hill, CT
Villanova University, Villanova, PA
Riverside School, Lyndonville, VT
Newburgh Free Academy, Newburgh, NY
Virginia Polytechnic Institute, Blacksburg, VA
Pennsylvania State University, University Park, PA
University of Florida, Gainesville, FL
University of Tennessee, Knoxville, TN
Western Washington University, Bollingham, WA
Cato-Meridian High School, Cato, NY
Union College, Schenectady, NY
Polytechnic University, Farmingdale, NY
Wentworth Institute of Technology, Boston, MA

Tour de Sol, May 10–17, 1996

The Northeast Sustainable Energy Association's (NESEA) Tour de Sol, a road rally for electric and hybrid vehicles, has served as a benchmark of electric vehicle (EV) technology progress since 1989. Over the years, that progress has been measured in terms of increased vehicle efficiency and range.

"It has really grown from a small, modest event primarily focused on hobbyist solar electric vehicles to much more sophisticated, production-oriented vehicles," Launey said. DOE has been a sponsor for the last 5 years, and this is the first year the event included a hybrid vehicle category. Hybrid vehicles combine the emissions benefits of the electric battery with the range and convenience of liquid fuels.

The Tour de Sol attracts a variety of participants, from major and minor manufacturers to university students and hobbyists. This year 50 vehicles were registered and traveled from New York City to Washington, D.C., with stops along the way for exhibitions.

The level of technology will continue to increase, but students will always play a valuable role in the Tour de Sol. "Each year, the student entries provide us with a pleasant surprise or two," said Michael Bianchi, an EV devotee who has followed the event for the past 4 years and provided reports on the 1996 race for NESEA's Internet home page

Kurt Ettinger, Information Resources, Inc./PIX 02447

The Solectria Team poses with its winning vehicles.

Propane Vehicle Challenge Teams

Texas A&M University, College Station, TX
University of Texas, Austin, TX
University of Texas, El Paso, TX
University of Oklahoma, Norman, OK
Western Washington University, Bollingham, WA
Cedarville College, Cedarville, OH
GM Engineering and Management Institute, Flint, MI
Illinois Institute of Technology, Chicago, IL
University of Alberta, Edmonton, Alberta
Ecole de technologie Superieure, Montreal, Quebec
Texas Tech University, Lubbock, TX
Villanova University, Villanova, PA

FutureCar Challenge Team

California State University, Northridge, CA
Concordia University, Montreal, Quebec
Lawrence Technological University, Southfield, MI
Michigan Technological University, Houghton, MI
Ohio State University, Columbus, OH
University of California, Irvine, CA
University of Illinois, Chicago, IL
University of Maryland, College Park, MD
University of Michigan, Ann Arbor, MI
University of Wisconsin, Madison, WI
Virginia Polytechnic Institute, Blacksburg, VA
West Virginia University, Morgantown, WA

(http://www.crest.org/clients/nesea/index.html). Cato-Meridian High School's "Sunpacer" ran with efficiencies competitive with the well-heeled companies, Bianchi noted, and Western Washington University's "Viking 25" hybrid met California's strict ultra-low-emission-vehicle standards.

"We had a couple of breakdowns that anyone would reasonably expect would be the end of the line, but the Greenwich High School team and the University of Wisconsin team refused to give up. Each pulled the rabbit out of the hat and finished the race," Bianchi said.

The fifth through eighth grade students from Riverside School in Lyndonville, Vermont, who made up the "Helios the Heron III" team won "The Teaching the Next Generation of EV Enthusiasts" award "for enthusiastic explanations given to children who came to the displays."

"When I hear the enthusiasm with which students describe what they have done and how they have done it, the energy and imagination they contribute to their teams, and the pride they have in their accomplishments, I sense that I've met the people who someday will improve the world for all of us," Bianchi said.

At least one record was set this year when the all-composite sedan "Sunrise," produced by Massachusetts-based Solectria completed 373 miles on a single charge of its Ovonic nickel-metal-hydride batteries. The Sunrise broke its own record of 238 miles in last year's event.

But the Tour de Sol is about more than setting records. "They do a wonderful job of introducing the status of EV technology to the public," Launey said. "The media does a better job of covering this event than any other. It is also an opportunity to compare data from a range of vehicles which would not normally be competing in the same events."

Propane Vehicle Challenge, May 30–June 4, 1996

DOE recently expanded its relationship with Natural Resources Canada to demonstrate propane vehicle technology. Students at 13 schools (10 in the United States) prepared for the event by converting a conventional Chrysler minivan to propane—their challenge was to demonstrate improved performance and emissions, and also experiment with innovative fuel storage and injection technology.

Canada is interested in developing a propane vehicle market and customers are responding. Chrysler Canada, another sponsor of the event, already produces a propane vehicle for the Canadian market.

The challenge included an over-the-road event from Windsor to Toronto, Ontario, and ended with a recap and an awards banquet at the Windsor Workshop held in Toronto on June 2–5, 1996.

Students representing Texas A&M were the overall winners of the event. "The scores, however, don't tell everything," Launey said. Students at the University of Windsor attained ultra-low emission levels with their vehicle, Texas Tech's entry had better acceleration than a comparable gasoline minivan, and Illinois Institute of Technology's vehicle achieved 26–28 miles per gallon.

Four University of Alberta students further proved their success after the competition when they traveled 2,400 miles from Toronto to Edmonton. During the 75-hour journey, their vehicle ran flawlessly over smooth highways as well as winding mountain roads, according to Neall Booth, the school's project coordinator.

DOE is already working on next year's Propane Vehicle Challenge, which will expand to include Chrysler Dakota trucks. The Texas Railroad Commission will host the event and plans a major road rally around the state.

FutureCar Challenge, June 17–24, 1996

Tomorrow's automotive engineers will work closely with their potential employers to meet perhaps the industry's greatest challenge: to design a vehicle that achieves up to 80 miles per gallon while maintaining the cost, safety, and performance of a conventional vehicle. This is the goal set by the Partnership for a New Generation of Vehicles, an initiative of the Federal government and domestic auto industry established in 1993.

"The students will face the same challenges and obstacles our

(Continued on page 8)

Electric Vehicles Ready to Charge Forward

As more electric vehicles (EVs) enter the market, the Alternative Fuels Data Center (AFDC) is working to add public charging stations to its refueling site database.

Although most EVs are expected to charge in personal residences during off-peak hours, cities like Sacramento and Los Angeles are already installing public charging outlets. At press time, the AFDC database included detailed information on 34 EV charging station opportunities in California, from grocery store parking lots to public parking garages.

Much of that development was done in anticipation of a market influx projected for the 1998 model year, when California would require 2% of the vehicles sold by seven major auto manufacturers to be zero-emission vehicles. That requirement was dropped in favor of a voluntary program earlier this year, but EVs are coming to market anyway.

Five major automobile manufacturers—General Motors, Honda, Toyota, Ford, and Chrysler—have all announced plans for EV production models during the next 2 years (see Table 1). These plans are sequentially listed in the table in terms of announced dates of EV availability.

Several cities targeted for EV marketing are developing public charging sites, but many are already in place. The Electric Vehicle Association of the Americas lists 295 public charging outlets at 43 sites in its directory, most in California, but a few in Virginia, Vermont, Washington, and Arizona.

EVs introduced by Ford, Chrysler, Honda, and Toyota will all be charged conductively (via a yet-to-be-determined conductive contact-type connector assembly—a conductive plug inserted into a receptacle in the vehicle's inlet).

Although Nissan Motor Company has announced it will use inductive charging when it begins demonstrating its electric Prairie Joy EV in Japan, so far GM is the only domestic auto

Table 1. Upcoming EV Production Models

Maker	Model	Battery	Range	Where	When	Contact
Ford	TDM Ranger pickup truck	lead-acid	50 miles	to fleets in California and selected U.S. markets	Summer 1996	800-ALT- FUEL
General Motors	EV1	lead-acid	70 miles city, 90 highway	to Saturn dealers in Tucson, Phoenix, San Diego, and Los Angeles	1997 Model Year	800-25-ELECTRIC
General Motors	Chevrolet S-Series Pickup	lead-acid	40 miles city, 45 highway	to fleets nationwide	1997 Model Year	800-222-1010
American Honda Motor Co.	Honda EV	nickel-metal-hydride	125 miles city	300 leased to fleets in California	Spring 1997	310-783-3164
Toyota Motor Sales USA	RAV4-EV sport utility	nickel-metal-hydride	118 miles city / highway combined	320 leased to fleets in California	1998 Model Year	800-331-4331
Chrysler	EPIC minivan	lead-acid	60 miles	to be announced	1998 Model Year	800-255-2616
Ford	Ranger pickup	lead-acid	50 miles	to fleets nationwide	1998 Model Year	800-ALT-FUEL

manufacturer to produce inductively charged EVs. This type of charging uses a high-frequency transformer-coupled interface (a plastic paddle assembly that houses the transformer's primary side that is inserted into the vehicle's inlet, which incorporates the secondary side of the transformer and completes the magnetically coupled charging-power transfer system).

Each method has pros and cons, but many in the industry compare it to the VHS versus Beta videotape contest in which the VHS format eventually took over the marketplace based on consumer preference. Most of the existing sites are for conductive charging, but there are still many sites with inductive charging or both available.

Although the auto manufacturers have adopted different charging methods, they have all proposed and/or adopted standard systems for the home charging infrastructure elements and three power levels for charging EVs. Other industry standards are being developed or finalized through the Society of Automotive Engineers, Underwriters Laboratories, American National Standards Institute, National Electric Code, and four regional building codes and standards organizations. Closer cooperation with international standards and code-making bodies is evolving to make an internationally marketable EV available. However, many of the existing charging sites were installed before current and ongoing standards were established.

These standards will play a critical role in siting a public recharging station, but EV owners can be sure of getting a full charge by "filling up" at their home overnight. Most residences and buildings can be equipped with EV recharging facilities for $200–2,000, depending on the adequacy of existing wiring in addition to the cost of an off-board charger if required.

To check out EV charging sites in the AFDC, click on the "Refueling Site Database" on the home page, ***http://www.afdc.doe.gov****. "ELEC" is now a fuel option when setting up a search.*

What's New at the AFDC's World Wide Web Site

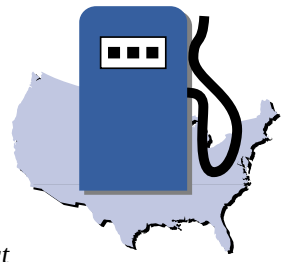
The Alternative Fuels Data Center's (AFDC) World Wide Web site has added several new features that provide more on-demand information for users. The new search system, AFDC Search, will help AFDC home page visitors find alternative fuel information faster and easier.

AFDC Search is a quick, easy-to-use system. You will find it by clicking on "Search" in the center of the blue button bar on the home page. This system allows you to search by topics and keywords. You can scroll through the topic categories to pick one or more that matches your needs, such as "School Buses," and "Safety." The result of this search was the report *Inspection of Compressed Natural Gas Cylinders on School Buses*, #2830.

To obtain more information about a report, click on the document number, which is linked to the report's abstract. The system either links you to the full document or the World Wide Web page, or explains how you can obtain it through sources such as the National Technical Information Service or your local library.

Many other new features are now available through the new button bar located below the AFDC logo. Recent additions include:

- Under "In the News," you can click to "Mideast Oil Forever," a comprehensive evaluation of global energy use and the United States' outlook written by the U.S. Department of Energy's Joseph Romm and Charles Curtis and published in The *Atlantic Monthly*'s April 1996 issue.



- The nine volumes that make up the *FedEx Clean Fleet Executive Project Summary and Final Report* are also available through "What's New." Fleet managers may find this study contains useful case study information.
- Refueling site information for liquefied natural gas is now available through the AFDC's refueling site database. Although there are only a few listed at present, refueling station owners can now enter or update their site information through the "Web-User Refueling Site Update Form" (click on the "What's New" button or enter through the refueling site database).

The AFDC's World Wide Web address is **http://www.afdc.doe.gov**. *For more information, e-mail the Alternative Fuels Hotline at* ***hotline@afdc.nrel.gov***.

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engineers and national lab scientists deal with," said John McTague, vice president of technical affairs for Ford Motor Company.

Since the beginning of the year, 12 student teams signed up for the 2-year FutureCar Challenge have worked with a Dodge Intrepid, Ford Taurus, or Chevrolet Lumina to meet this goal. Possible technologies include ultracapacitors, flywheels, fuel cells, advanced materials, advanced diesel technology, and gas turbine engines. This year the teams chose ethanol, propane, electricity, and compressed natural gas.

The first round of testing was performed in 7 days in Dearborn, Michigan. The vehicles were evaluated for quality and execution of new ideas, manufacturing potential, emissions, fuel economy, range, handling, and consumer acceptability. The event ended with a road rally and parade in Detroit.

With one exception (fourth-place winner Ohio State), all winning vehicles this year were hybrids. Virginia Tech won first place as well as special awards for most energy efficient, lowest emissions, and best use of alternative fuels (propane). Lawrence Tech won second place and was recognized with awards for best application of advanced technology, best application of advanced materials, and best engineering design. The University of Wisconsin came in third and had the best over-the-road range. All of the schools will now build on their designs for next year's competition.

To help the public stay in touch with upcoming student competitions, DOE's Argonne National Laboratory publishes the *FutureDrive* newsletter. For a subscription, write Cheryl Drugan, *FutureDrive*, Argonne National Laboratory, Energy Systems Division, Bldg. 362, 9700 South Cass Avenue, Argonne, IL 60439.

For more information on DOE's program, contact Shelley Launey at (202)586-1573 or e-mail shelley.launey@hq.doe.gov.

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