COMPETITION RESULTS ISSUE!

FutureDrive

Volume 5, Number 3 **DOE/Industry Competitions Advancing Automotive Technology** Winter 1999

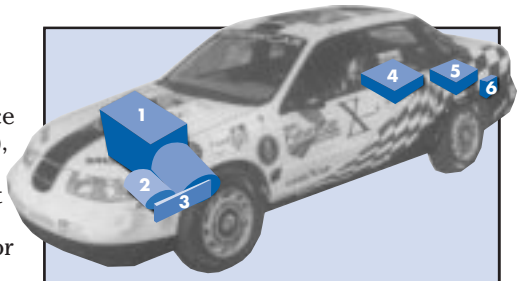
TECHNOLOGY FEATURE

UW-Madison Puts New Spin on Cordless Drill Batteries for First-Place "Aluminum Cow"

When the University of Wisconsin-Madison's entry in the 1999 FutureCar Challenge, the "Aluminum Cow," captured first-place honors (see related story on page 4), the team's aluminum-intensive approach to reducing vehicle weight and boosting fuel efficiency got a lot of attention. But another major factor in the car's performance—62.7 mpg using diesel fuel—is a highly original lightweight battery pack.

The Aluminum Cow is a charge-sustaining, parallel-assist hybrid-electric vehicle (HEV). Its electric motor and diesel engine (a Ford-Europe 1.8-L TDI that burns Fischer-Tropsch diesel fuel) are each capable of sending power to the wheels. The primary source of motive power is the diesel engine; the Solectria electric motor helps out when power demand is high. The vehicle recharges its battery pack as it goes, so range is not limited by battery capacity.

The 20 in. by 30 in. by 10 in. battery pack weighs just 110 pounds, about one-third what a standard lead acid battery weighs. It contains 840 individual sub-C nickel-cadmium cells, packaged in 56 18-V "strings" of 15 cells each. The cells come from Milwaukee Electric Tool cordless drill pack modules (donated by the company for use in the project), and according to Ethan Brodsky, the team's controls group leader, "they're designed to be tough."



Hybrid Drive Components of the Aluminum Cow

1. 90-hp diesel engine
2. 43-hp electric motor
3. Student-designed gearbox to couple engine and motor
4. 13-gallon fuel tank
5. Ni-Cd battery pack
6. Motor controller/inverter

The pack operates at a nominal voltage of 270 V, with an 8 A·hr capacity and energy storage of 2.16 kWh. Milwaukee Electric Tool recommended its cordless drill batteries to the UW-Madison team because they are designed for high-current applications. Their low impedance results in less internal heating, hence low losses and long run time per charge. Steady current drains of 30-40 A can be handled quite easily.

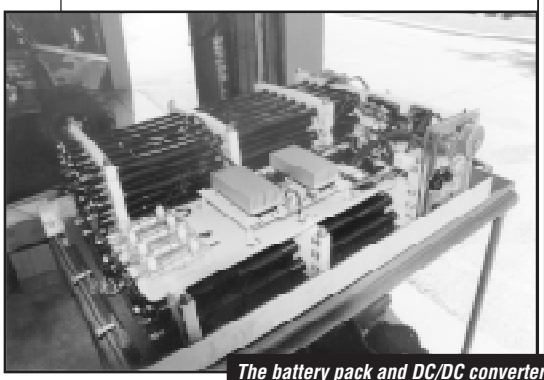
The energy used to keep the battery pack charged comes from the vehicle's diesel engine and, in city driving, from regenerative braking—energy that would otherwise be wasted.

An on-board computer system controls the use of the electric motor, engaged only when the car requires it. However, the driver can choose to run the car in diesel mode only, with the electric motor off. This option is available via a button on a dashboard touch-screen.

What are the prospects for using battery packs like the Aluminum Cow's in commercial HEVs? Troy Nergaard, leader of the team's electrical group, notes that the high power-to-weight ratio of NiCd cells makes them well-suited to HEVs, which have to be able to accept or deliver considerable power but don't need to store much energy. NiCd cells are readily available. The main difference in a mass-produced pack for HEVs would be the packaging; the basic design could remain the same.

The 1999 FutureCar Challenge was the last in a four-year series, but the UW-Madison team is not letting its experience and hard-won knowledge go to waste. "This year," says team leader Jenny Topinka, "we are refocusing our efforts on FutureTruck 2000, using an SUV vehicle platform. We are applying what we've learned in the past—not only in technical areas, but more generally in how to produce a reliable, successful vehicle—to this new competition."

Floyd Bennett



The battery pack and DC/DC converters

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FUTUREDRIVE (ISSN 1523-2727)
Volume 5, Number 3, Winter 1999

Purpose
To inform sponsors, participants, organizers, volunteers, and others interested in DOE-sponsored student vehicle competitions of the plans for and results of the competitions.

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FutureDrive is published by the Energy Systems Division, Argonne National Laboratory. Publishing support services are provided by Argonne's Information and Publishing Division (for more information, see IPD's home page: http://www.ipd.anl.gov/).

Current and back issues of FutureDrive are available on the World Wide Web at www.transportation.anl.gov/ttrdc/publications/futuredrive/futuredrive.html.

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Teams Selected for FutureTruck

Earlier this year, student teams from many engineering schools proposed detailed reengineering strategies meant to lessen the greenhouse gas impacts of sport utility vehicles. Fifteen of them will have the opportunity to carry out their plans on model-year 2000 Chevy Suburbans in time for the new FutureTruck 2000 competition next spring.

Selected to participate are Concordia University; Cornell University; The George Washington University; Georgia Institute of Technology; Michigan Technological University; The Ohio State University; The Pennsylvania State University; Texas Tech University; University of California, Davis; University of Idaho; University of Maryland; University of Tennessee; University of Wisconsin-Madison; Virginia Polytechnic Institute and State University; and West Virginia University.

The student teams are setting to work with game plans that span a range of advanced automotive technologies from hydrogen fuel cells, hybrid electric/internal-combustion powertrains, and alternative fuels to lightweight materials and advanced electronics.

FutureTruck evolved from the four-year FutureCar Challenge program. The move to a light-duty truck platform—to reflect a large proportion of vehicles sold today—is not the only difference between the two competitions. Instead of looking at traditional miles-per-gallon fuel economy, the goal for FutureTruck is a two-thirds reduction in the total fuel-cycle greenhouse gas emissions of the stock Suburban. As in the FutureCar series, comfort, safety, and performance cannot be compromised in the modified vehicle. For example, the reengineered truck must tow the same weight as the stock vehicle (7,000 pounds).

Like FutureCar, FutureTruck will last four years. GM joins DOE as a principal sponsor for the opening biennium, with Ford Motor Company picking up the torch in 2002 and 2003. Natural Resources Canada, the National Science Foundation, the Aluminum Association, and the National Highway Traffic Safety Administration are also contributing resources and expertise.

Shelley Launey

Manager, Advanced Vehicle Technology Competitions
Manager, National Clean Cities Program
U.S. Department of Energy

Find additional details on the official FutureTruck website at www.futuretruck.org

Tom Stephens, Vice President of Engineering, General Motors Truck Group, presents Ohio State University FutureTruck team representatives with $10,000 in "seed money" to use toward reengineering a model-year 2000 Chevy Suburban.

Canadian Companies and Government Unite to Host 2000 Ethanol Vehicle Challenge

Several Canadian companies and organizations have joined forces with the Canadian government to help sponsor the 2000 Ethanol Vehicle Challenge. Their goal is to spark interest in biomass-based, clean-burning ethanol and ethanol-blend fuels.

Tom Smyth of **Natural Resources Canada (NRCan),** working with representatives of other Canadian groups, helped convince event organizers to hold the 2000 Challenge in Ontario. The reasons are many, Smyth says: to further cooperation between the United States and Canada in developing clean fuels; increase awareness of and opportunities for using ethanol, clean fuels, and clean fuel vehicles; increase political support for ethanol; and provide the transportation sector with evidence that commercial opportunities exist for reducing greenhouse gas emissions.

Closest to Smyth's heart is the goal of giving engineering students hands-on experience and opening up job opportunities for them. NRCan, the Canadian counterpart to the U.S. Department of Energy, is a veteran sponsor of DOE's advanced vehicle technology competitions.

General Motors Canada is welcoming the chance to join with the government and academia to promote the use of ethanol, according to Phil Kling, manager of product communications. GM will be hosting the vehicles' appearance and engineering design judging and the students' oral presentations. The company will offer tours of its Oshawa, Ontario, assembly plant, where the 14 Silverado pickup trucks that are participating in the 2000 Challenge were built.

The driving force behind the first-time sponsorship by **Environment Canada,** the Canadian version of the U.S. Environmental Protection Agency, is two words: clean air. Although Environment Canada has no targets to meet with regard to ethanol use, it does have a mandate to support events that will help reduce atmospheric pollutants. All emissions testing for the 2000 Challenge will take place at the agency's Environmental Technology Center in Gloucester, Ontario.

The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) is sponsoring the 2000 Challenge for the event's potential to boost rural economic development in southern Ontario, where the majority of Canadian corn is produced. Increased demand for ethanol should open more opportunities for agribusinesses to expand into this nontraditional market, says OMAFRA's Ken Linington. OMAFRA will host a press conference in Toronto during the competition.

Currently, most commercial ethanol is made from corn, which has a competing food/feedstock market. **Iogen Corporation** has developed a technology for producing ethanol from other biomass. The company uses a unique enzymatic hydrolysis process to convert cellulose from wood waste and crop residue to glucose, which can then be refined into ethanol. The potential of the process for the ethanol fuel industry is huge, says Jeff Passmore, executive vice-president of Iogen. Iogen will host an opening banquet on Parliament Hill in Ottawa for Ethanol Vehicle Challenge participants.

Petro-Canada will provide the E85 fuel blend (15% gasoline/85% ethanol) for the 2000 Challenge. Canada's largest integrated oil and gas company is partnering with Iogen Corporation to construct a $25 million fermentation and distillation facility next to Iogen's enzyme plant in Ottawa. Petro-Canada and Iogen believe the success of this plant could be the impetus for the construction of as many as 20 other cellulose-ethanol plants across Canada.

Service stations are not required to offer ethanol-blend fuels in Canada like they are in the United States, so only about 1,000 Canadian stations offer them. Terry Boland of the 21,000 member **Ontario Corn Producers' Association** believes that when Canadian businesses and agencies work with oil companies to make the E10 fuel blend (90% gasoline/10% ethanol) as available and economical as it is in the U.S., it will become an effective and relatively painless tool for helping to reduce air pollution in Canada. "The Ethanol Vehicle Challenge is an excellent opportunity to get the word out on ethanol and renewable fuels," Boland says.

The Canadian Renewable Fuels Association (CRFA) has been involved with the Ethanol Vehicle Challenge since CRFA was formed three years ago. Its mission is to promote renewable biofuels (ethanol, biodiesel) for automotive transportation.

Commercial Alcohols Inc. (CAI) is the largest manufacturer of industrial-grade alcohol in Canada. Its main product is fuel ethanol made from corn. CAI's Chatham, Ontario, distillery, the largest in Canada, will be a stop on the Challenge road tour. There CAI will host a press conference, dinner, and tours of its facility. Matt Janes, vice-president of technology for CAI, hopes the event will make auto dealers, and mechanics in particular, more aware of ethanol's potential.

Marita Moniger

FutureCar Challenge • June 2-10, 1999

The fourth and final FutureCar Challenge again tested students' ingenuity at redesigning family sedans to reach the same goals that the U.S. government is asking of the auto industry: double to triple fuel efficiency, reduced emissions, and no loss of consumer acceptability. The event culminated in a two-day road rally from Detroit to Washington, D.C., where Secretary of Energy Bill Richardson and many members of Congress met with the future automotive engineers of the United States and Canada.

Over 62 mpg reached

Each of 13 university teams converted a conventional gasoline-powered car into a hybrid-electric vehicle with a unique combination of powertrain control system, fuel, exhaust system, and vehicle weight reduction innovations. The University of Wisconsin-Madison was the clear winner, scoring 973 of 1,000 possible points with a hybrid diesel whose engine cradle and many other components were replaced with aluminum parts. The "Aluminum Cow" weighed nearly 500 pounds less than its gasoline counterpart Mercury Sable and achieved an impressive 62.7 mpg-equivalent in over-the-road fuel efficiency. (See related story on page 1.)

Fuel cell first

Virginia Tech finished second overall with a practical and comfortable fuel cell car, becoming one of the first groups to demonstrate a fuel-cell-powered automobile in the United States. The feat is even more remarkable considering the students took less than two years to convert their stock Chevy Lumina into a hybrid electric/fuel cell FutureCar. "The DOE fuel cell experts were awed by Virginia Tech's efforts," said Shelley Launey, manager of DOE's Advanced Vehicle Technology Competitions and director of the DOE National Clean Cities Program.

Not surprisingly, the hydrogen-powered Virginia Tech entry prevailed in the emissions categories. Hydrocarbon emissions were 1/60 and carbon monoxide emissions were less than 1/100 of the Federal Tier 1 standards.

Next up: FutureTruck

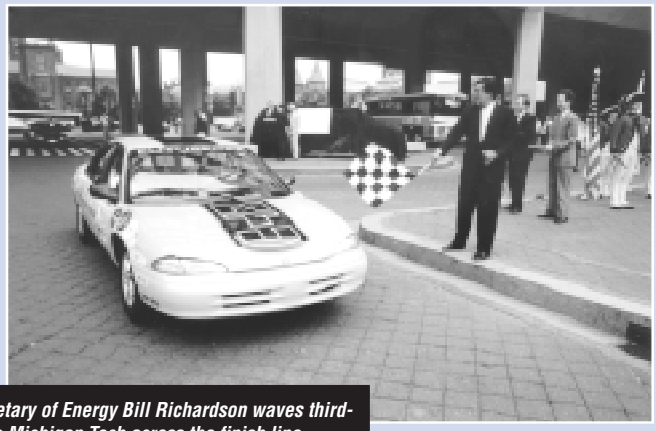
DOE and the auto industry are continuing their aggressive partnership for creating cleaner, more efficient consumer vehicles. Changing with the times, FutureCar has become FutureTruck, and more emphasis is being placed on greenhouse gas emissions. In lieu of traditional fuel economy measurements on a miles-per-gallon-equivalent basis, FutureTruck will measure the vehicles' efficiency based on the amount of greenhouse gas emissions for the total fuel cycle using the GREET computer model developed by Argonne National Laboratory.

Thanks!

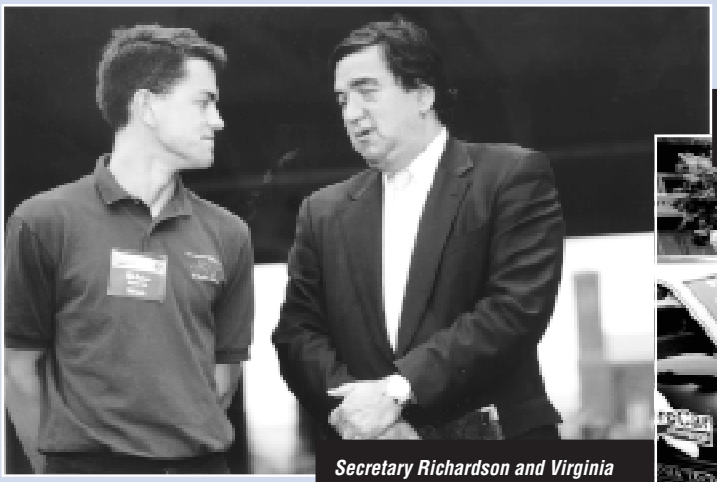
Like many of the students who participated in FutureCar 1999, Alan Holmes of the Ohio State team expressed gratitude. "Thanks to all of those organizers, sponsors, and fellow teams who made our competition a success! My teammates and I learned many lessons about cars and teamwork, and we all helped pull the world just a little bit closer to some better transportation."

The University of Wisconsin's Michael Koplin discusses his team's hybrid diesel engine with Michael Grimaldi, Vice President and Vehicle Line Executive of Full-Size Truck Products, General Motors.

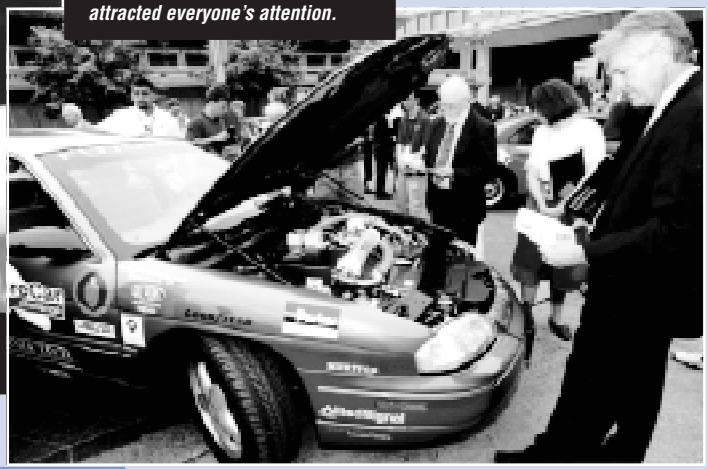
1999 FutureCar Team	Powertrain	Fuel
Concordia University of Montreal	parallel HEV	dimethyl ether
Lawrence Technological University	parallel HEV	Fischer-Tropsch diesel
Michigan Technological University	series HEV	California Phase 2 gasoline
The Ohio State University	parallel HEV	Fischer-Tropsch diesel
Texas Tech University	series HEV	hydrogen
University of California, Davis	parallel HEV	reformulated gasoline
University of Illinois at Urbana-Champaign	series HEV	Fischer-Tropsch diesel
University of Maryland-College Park	series HEV	ethanol (E85)
University of Michigan, Ann Arbor	parallel HEV	Fischer-Tropsch diesel
University of Tennessee-Knoxville	series & parallel HEV	compressed natural gas
University of Wisconsin-Madison	parallel HEV	Fischer-Tropsch diesel
Virginia Polytechnic Institute and State University	series HEV	hydrogen
West Virginia University	parallel HEV	compressed natural gas



Secretary of Energy Bill Richardson waves third-place Michigan Tech across the finish line.



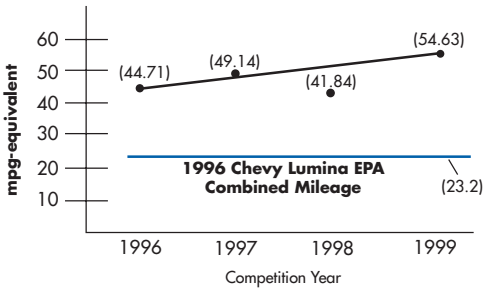
Secretary Richardson and Virginia Tech Team Leader Mike Ogburn



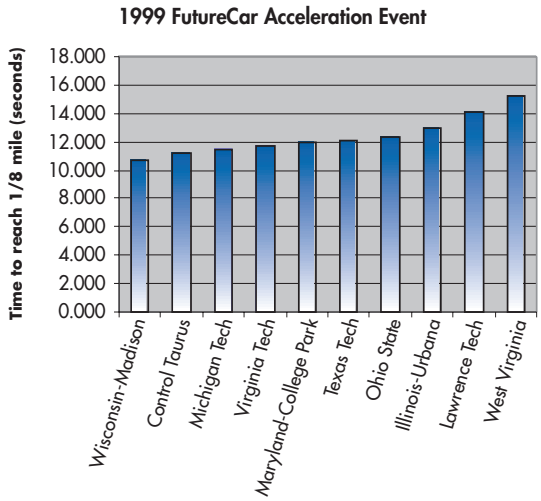
Virginia Tech's fuel cell powertrain attracted everyone's attention.

1999 FutureCar Competition Results

1st Overall	University of Wisconsin-Madison
2nd Overall	Virginia Polytechnic Institute and State University
3rd Overall	Michigan Technological University
4th Overall	University of Maryland-College Park
5th Overall	The Ohio State University
6th Overall	Lawrence Technological University
Most Energy Efficient Vehicle	University of Wisconsin-Madison
Best Acceleration	University of Wisconsin-Madison
Best Dynamic Handling	University of Wisconsin-Madison
Best Endurance	University of Wisconsin-Madison
Lowest Emissions	Virginia Polytechnic Institute and State University
Best Technical Report	University of California, Davis
Best Vehicle Design Inspection	University of California, Davis
Best Oral Design Presentation	Virginia Polytechnic Institute and State University
Best Consumer Acceptability	Michigan Technological University
Best Appearance	University of Wisconsin-Madison
Best Use of Alternative Fuels	University of Maryland-College Park
Best Use of Advanced Technologies	University of California, Davis
Innovations in Aluminum	University of Wisconsin-Madison



HOW FAR THEY'VE COME: FUTURECAR FUEL EFFICIENCY
EPA Combined City/Highway

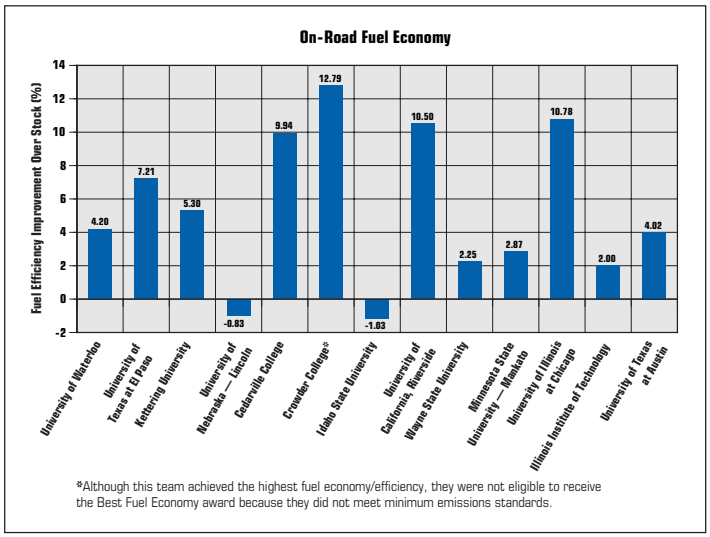


Ethanol Vehicle Challenge May 19-26, 1999

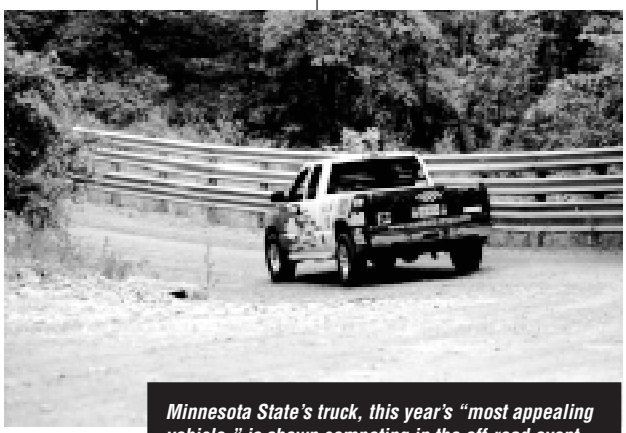
The second Ethanol Vehicle Challenge, held at General Motors' Milford Proving Ground in Michigan, challenged students from the 14 competing universities to convert full-sized pickup trucks to run on E85 (85% corn-based ethanol + 15% gasoline). When the points from a dozen judging categories were totaled, the University of Illinois at Chicago emerged the victor. The University of Texas at El Paso came in a very close second, and Kettering University rounded out the top three.

"The results showed that E85 can perform as well as or better than gasoline in every way," said Shelley Launey, manager of DOE's Advanced Vehicle Technology Competitions and director of the DOE National Clean Cities Program.

The students were allowed to recalibrate the stock powertrain control module to accommodate the differences between gasoline and ethanol-blend fuels. "The level of refinement of the vehicles was extremely high this year," said Mark Maher of GM's Truck Group, which provided 1999-model Chevy Silverados to the schools. "The students demonstrated a nice mix of approaches for air induction, emissions control, and catalytic conversion. We got more than we expected."



*Although this team achieved the highest fuel economy/efficiency, they were not eligible to receive the Best Fuel Economy award because they did not meet minimum emissions standards.



Minnesota State's truck, this year's "most appealing vehicle," is shown competing in the off-road event.

Better fuel efficiency

Three-quarters of the E85-converted trucks exceeded the fuel efficiency of the stock gasoline-powered truck on a mpg-equivalent basis. The University of Illinois at Chicago improved fuel efficiency by more than 10%. This is especially impressive because ethanol has lower potential energy than gasoline.

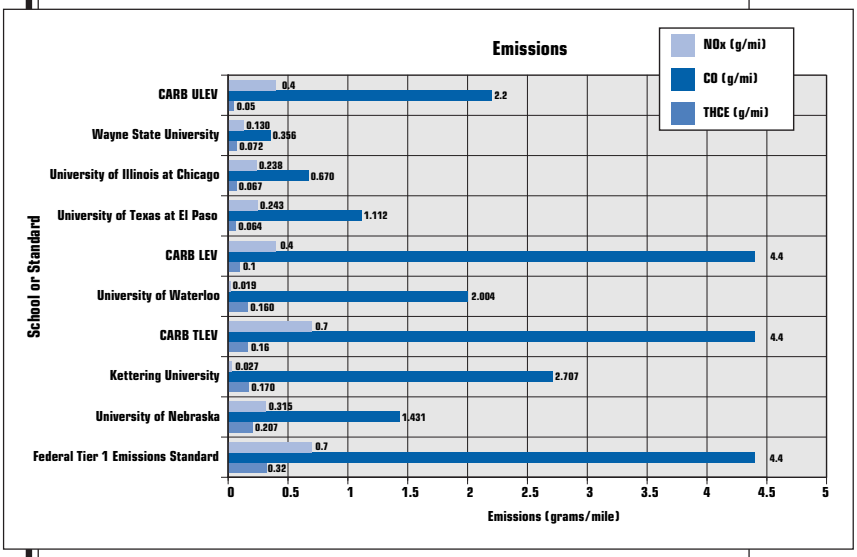
Lower emissions

Three of the student entries exceeded the California Air Resources Board's Low Emissions Vehicle (LEV) standards and were within .025 grams for hydrocarbons of meeting CARB's Ultralow Emissions Vehicle (ULEV) standard.

More power

Thirteen of the 14 E85-converted vehicles outperformed the stock truck in the acceleration and hill-climb events.

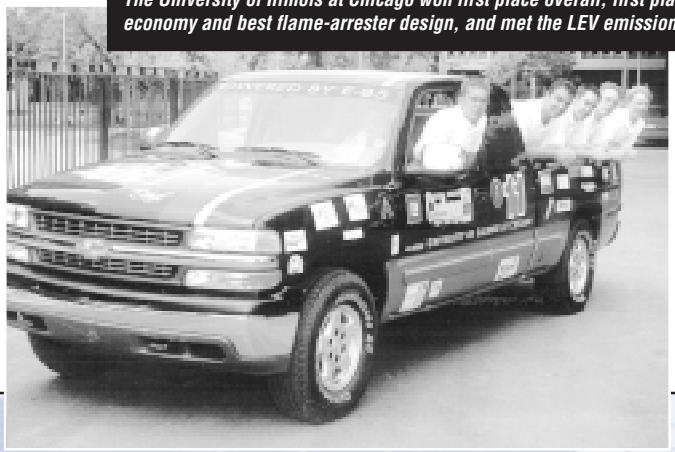
The 2000 Ethanol Vehicle Challenge will be held next spring in Ontario, Canada. Argonne National Laboratory manages the Ethanol Vehicle Challenge for the U.S. Department of Energy as part of the ongoing Advanced Vehicle Technology Competition series. Joining DOE as event sponsors are Natural Resources Canada, GM Canada, and 12 other corporate and government organizations from the United States and Canada. (See related story on page 3.)



1999 Ethanol Vehicle Challenge Results

1st Overall	University of Illinois at Chicago
2nd Overall	University of Texas at El Paso
3rd Overall	Kettering University
4th Overall	University of Waterloo
5th Overall	Wayne State University
Best Fuel Economy	University of Illinois at Chicago
Lowest Emissions	Wayne State University
Best Cold Start Performance	University of Texas at El Paso
Best Ethanol Conversion	University of Nebraska-Lincoln
Most Innovative Component	University of Nebraska-Lincoln
Best Engine Out Emissions	University of Waterloo
Best Flame Arrester Design	University of Illinois at Chicago
Best Oral Presentation	University of Waterloo
Most Appealing Vehicle	Minnesota State University-Mankato
Best Off-Road Handling	Kettering University
Best Acceleration	Cedarville College
Best Hill Climb	Minnesota State University-Mankato

Kettering University did well in design judging and performance events to take third place overall.



The University of Illinois at Chicago won first place overall, first place in fuel economy and best flame-arrester design, and met the LEV emissions standards.

COMPETITION RESULTS

(continued from page 8)

SAE Supermileage

June 11-12, 1999

One-person vehicles powered by a small four-cycle engine strive to break world fuel-economy record. *www.sae.org*

1st Place
St. Thomas Academy, Mendota Heights, MN
Fuel economy: 882.07 mpg
2nd Place
Ryerson Polytechnic University, Toronto
Fuel economy: 526.84 mpg

Sunrayce 99

June 20-29, 1999

1,425-mile road rally (Washington, DC, to Orlando, FL) for purpose-built, one-person solar-powered cars. Power must be solely solar. 1999's event had a record lack of sunshine. *www.sunrayce.com*

1st Place
University of Missouri-Rolla
Average speed: 25.3 mph
2nd Place
Queen's University, Kingston, Ontario
Average speed: 24.95 mph

EVTC Events

Competition categories include High School Stock, Street Stock, Super Stock, ABB University Spec Series, and Formula E. Points are awarded for design, acceleration, braking and handling, and range. *www.evrace.com*

Arizona Electrics

March 18-21, 1999

1st Place
Mirimar High School, Mirimar, FL
2nd Place
Port Townsend High School, Port Townsend, WA

East Valley Electric 99 Classic

February 20, 1999

1st Place
Palo Verde High School, Phoenix
2nd Place
North High School, Phoenix

Indy Electric Classic 99

May 1999

1st Place
The Ohio State University
2nd Place
Bowling Green State Univ.

Motor Trend Thunder

June 12-13, 1999

1st Place
Brigham Young Univ.
2nd Place
Bowling Green State Univ.

Northern Arizona Electric 99 Classic

May 1, 1999

1st Place
Palo Verde High School, Phoenix
2nd Place
St. Johns High School, St. Johns, AZ

Ethanol Vehicle Challenge 1999
see page 6

FutureCar Challenge 1999
see page 4

Formula SAE Collegiate Design Competition
May 19-23, 1999

Formula-style racing cars are judged on engineering design, solar performance, and high-performance track endurance. DOE-sponsored awards are also given for entries fueled with methanol-85.

www.sae.org

1st Place
University of Akron, OH (M85-fueled)
2nd Place
Rochester Institute of Technology, NY
3rd Place
Cornell Univ., Ithaca, NY (M85-fueled)
USCAR Recycling Award
Michigan Technological Univ., Houghton

NESEA American Tour de Sol
May 22-28, 1999

Road rally for electric, hybrid-electric, and solar-assisted electric vehicles practical for everyday use.

Prizes are based on reliability, acceleration, handling, range, fuel efficiency, and low greenhouse gas emissions. *www.nesea.org*

Production Vehicles

Light duty: EVermont/Solectria, Waterbury, VT, and Wilmington, MA Solectria Force, nickel metal hydride battery

Heavy duty: New York Power Authority Solectria CitiVan, lead-acid battery

One-person: Team PET, Kailua, HI Caballito electric scooter, lead-acid battery

Commuter

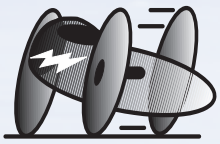
SEV of NHTI, Concord, NH
Two-person purpose-built sedan, nickel metal hydride battery

Hybrid (DOE-sponsored award)
Hurricane Motorworks, Tulsa, OK
1992 GeoMetro, lead-acid battery/ reformulated gasoline

Solar Commuter
University of Maine, Orono
Chevy S-10, lead-acid battery

One-Person
Team Newburgh, NY
Purpose-built solar-electric vehicle, lead-acid battery

Pentad U.S. National Electrathon Championship
April 16-18, 1999



Participants build lightweight vehicles powered by lead-acid batteries. The winner travels the farthest in 1 hour.

elecrathonamerica.org

1st Place
Team Cloud, Seattle
Range: 40.07 miles (new record)
2nd Place
Lake Orion High School, MI
Range: 39.86 miles (new high school record)

(continued on page 7)

To learn more about DOE-sponsored student vehicle competitions, visit the Argonne National Laboratory transportation website at www.transportation.anl.gov/ttrdc/

FutureDrive
DOE/Industry Competitions Advancing Automotive Technology

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