Advanced Vehicle Testing Activity

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Overview of Advanced Technology Transportation, 2005 Update

TECHNICAL REPORT

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U.S. Department of Energy
Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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Introduction

Since 2000, the U.S. Department of Energy's (DOE) Advanced Vehicle Testing Activity (AVTA) has produced an annual overview of the transportation market. The document—which covers vehicle sales, emissions, potential partners, advanced technology vehicle availability, and other factors—offers a "snapshot" of current vehicle technologies and trends. DOE program managers use this document to plan testing and evaluation activities that focus resources where they have the greatest impact. This document is the update for 2005. To download overviews from previous years, visit www.avt.nrel.gov/overview.html.

The scope of this document has changed slightly this year. The content is simplified and streamlined, eliminating discussion of energy use, which has not changed dramatically year to year, and focusing on advanced technology vehicles and associated industry trends. Up-to-date information on energy use is available from several DOE sources including:

- The Energy Information Administration's (EIA) *Annual Energy Review*, *Monthly Energy Review*, and *Alternatives to Traditional Transportation Fuels*
- Oak Ridge National Laboratory's *Transportation Energy Data Book* (Edition 24)
- NREL's Alternative Fuels Data Center (AFDC) (www.eere.energy.gov/afdc)

Information on alternative fueled vehicles (AFV) is updated yearly in the *Transportation Energy Data Book.* Chapter 6 includes a wealth of statistics on AFVs including estimated fuel use, numbers of vehicles in use, and current models available from manufacturers. For convenience, the Appendix of this document contains several figures on AFVs and their use in the United States from EIA. Also included is a table listing the numbers of alternative fuel stations by state and fuel from the AFDC.

The information on advanced technology vehicles in development came from various sources, including vehicle manufacturers and news services. Because this information changes daily, we set February 1, 2005 as the cut-off date for inclusion in this document. However, the vehicle tables are updated quarterly and posted as separate documents on the AVTA Web site at www.avt.nrel.gov/overview.html.

Advanced Technology Vehicles

The following sections provide a snapshot of the current market for advanced technology vehicles. The tables concentrate on the vehicles most likely to be available in the U.S. market. For a more complete listing of advanced technology vehicles around the world, refer to the companion tables at www.avt.nrel.gov/overview.html.

Hybrid Electric Technology

Light-Duty Vehicles

Automotive manufacturers continue to work on light-duty hybrid electric technology. There are now seven different vehicle models available for sale in the United States, and plans to introduce many more are in the works. Table 1 lists light-duty hybrid vehicles in production, those planned for introduction in the next few years, and some of the more recent concept vehicles. (For more information on these and other light-duty hybrid vehicles introduced around the world, refer to the companion tables at www.avt.nrel.gov/overview.html.)

Table 1. Light-Duty Hybrid Electric Vehicles

OEM	Model	Body Style	Power Type	Fuel	Date Introduced/ Announced	Production Date
Currently in Production						
DaimlerChrysler	Ram Pickup Contractor Special	Truck	Mild Hybrid	Diesel	Nov-00	2004 (Limited)
Ford	Escape	SUV	Hybrid	Gasoline	Jan-01	2004
General Motors	Silverado/Sierra	Truck	Mild Hybrid	Gasoline	Jan-01	2004 (Limited)
Honda	Accord	Sedan	IMA[1] Hybrid	Gasoline	Jan-04	2005
Honda	Insight	Coupe	IMA[1] Hybrid	Gasoline	Dec-99	2000
Honda	Civic	Sedan	IMA[1] Hybrid	Gasoline	Jan-00	2002
Lexus	RX400h	SUV	Hybrid	Gasoline	Jan-03	2005
Toyota	Prius	Sedan	Parallel Hybrid	Gasoline	Jun-00	2000
Toyota	Highlander	SUV	Hybrid	Gasoline	Jan-04	2005
Suzuki	Twin	Mini	Hybrid	Gasoline	Nov-02	2003 (Japan)
Toyota	Estima	Minivan	Parallel Hybrid	Gasoline	Jun-01	In Japan Only
Toyota	Crown	Sedan	Mild Hybrid	Gasoline	Aug-01	In Japan Only
Toyota	Alphard	Minivan	Hybrid	Gasoline	Jul-03	In Japan Only
Planned for Production						
Ford	Fusion	Sedan	Full Hybrid	Gasoline	Apr-03	2006
General Motors	Silverado/Sierra & Tahoe/Yukon	Truck & SUV	Strong Hybrid	Gasoline	Nov-03	2007
General Motors	Equinox	SUV	Hybrid	Gasoline	Jan-03	2006
General Motors	Malibu	Sedan	BAS[2] Hybrid	Gasoline	Jan-03	2007
General Motors	Graphyte	SUV	Full Hybrid	Gasoline	Jan-05	2006
Hyundai	Click	Sedan	Hybrid	Gasoline	Nov-03	2005/06 (Korea)
Mercury	Mariner	SUV	Full Hybrid	Gasoline	Apr-04	2005 (limited) 2006 (full)
Nissan	Altima	Sedan	Hybrid	Gasoline	Jun-04	2006
Saturn	Vue	SUV	BAS[2] Hybrid	Gasoline	Jan-03	2006
Toyota	Camry	Sedan	Unknown	Gasoline	Unknown	Unknown
Toyota	Sienna	Minivan	Hybrid	Gasoline	2003	2007
Recent Concepts - Production Plans Unknown						
Honda	ASM	Minivan	IMA[1] hybrid	Gasoline	Oct-03	Unknown
Ford Focus	C-MAX	Sedan	Hydrogen ICE	Hydrogen	Jul-04	Unknown
Daewoo	S3X	SUV	Unknown	Unknown	Oct-04	Unknown
Opal	Astra	Sedan	Unknown	Diesel	Jan-04	Unknown
Mercury	Meta One	Unknown	Hybrid	Diesel	Jan-04	Unknown
Mercury	Milan	Unknown	Unknown	Unknown	Jan-04	Unknown

[1] Integrated motor assist.
[2] Belt alternator starter.
(Source: Collected by Robb Barnitt and Leslie Eudy, National Renewable Energy Laboratory, from various sources)

In 2004, U.S. sales of hybrid vehicles totaled more than 86,200, a 60% increase from 2003. Sales included established models such as the Honda Civic, Honda Insight, and Toyota Prius, as well as the newcomers Ford Escape, Honda Accord, and GM Silverado and Sierra. U.S. sales of hybrid vehicles since 1999 have totaled nearly 200,000. Strong sales growth trends continue. For example, Toyota Prius 2004 sales increased nearly 120% over 2003 figures. Figure 1 illustrates sales trends for hybrids in 2004.

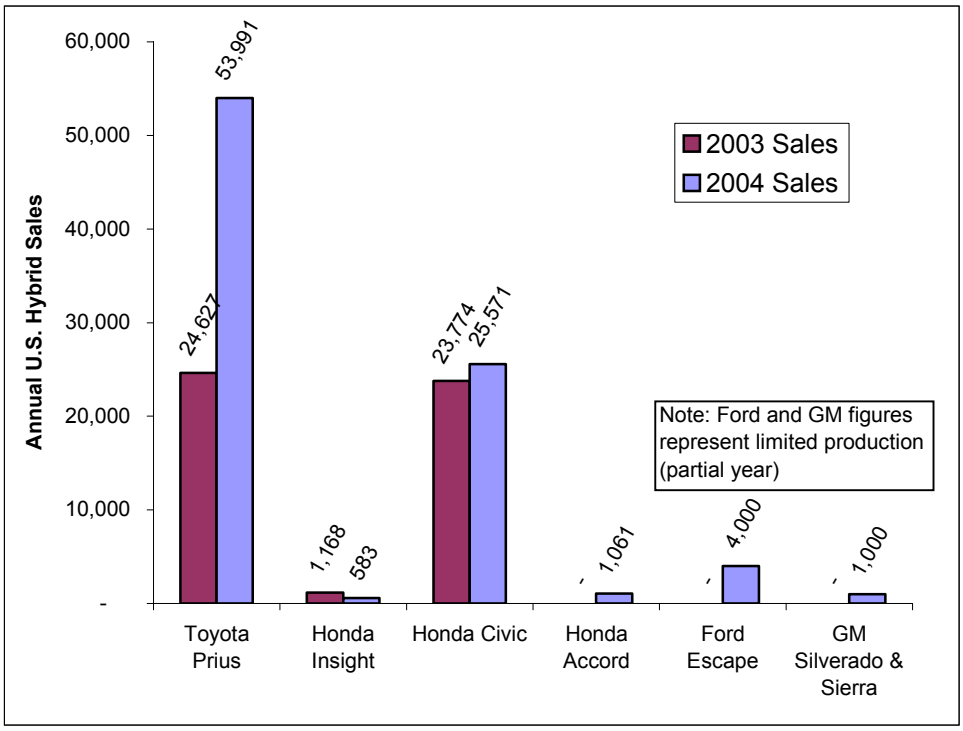


Figure 1: 2004 U.S. Hybrid Sales

U.S. vehicle manufacturers entered the hybrid market in 2004 with several models. Ford garnered considerable attention in late September by introducing the Escape Hybrid, which is the first HEV to offer seating for up to five adults with ample cargo space. Ford sold 4,000 between the product launch and the end of the year and estimates sales of 20,000 in 2005.

The Ford Escape Hybrid was recognized as one of the top twelve greenest cars, as determined by the American Council for an Energy-Efficient Economy (ACEEE). Additionally, the Ford Escape Hybrid was named the North American Truck of the Year for 2005 at the North American International Auto Show (NAIAS) held in Detroit, Michigan.

As planned, GM's mild hybrid version of its full-size Silverado and Sierra pickups was released to fleet customers in 2004. It will be available in 2005 to retail customers in six states (California, Oregon, Washington, Alaska, Nevada, and Florida) and nationwide in 2006. The company plans to introduce a "strong" hybrid system in its full-size pick-ups and SUVs. The system is a scaled-down version of the GM Allison hybrid drive used for transit buses. Instead of a full hybrid system, the Saturn Vue will use a belt alternator starter hybrid system, which is expected to improve fuel economy 12%–15%. Dodge plans to enter the hybrid market with a mild hybrid pick-up designed with commercial fleets in mind. This hybrid uses a diesel engine and can double as a mobile generator.

In addition to the explosion in sales of the Prius, Toyota enjoyed a warm reception for its Lexus RX400h hybrid luxury SUV. Presold orders have exceeded 12,000 for the April 2005 release. The RX400h's technological features include electric, rather than belt-driven, accessories.

In a reversal of a trend noted last year, the number of hybrid concept vehicles decreased in the past year as the number of production models increased. The introduction of hybrid models by several of the smaller OEMs may indicate an increasing acceptance of the technology, and the focus seems to be on refining existing production models and gaining market share.

Heavy-Duty Vehicles

The past several years have seen a sharp increase in orders for heavy-duty hybrid electric vehicles. Most of these orders were for transit applications, but several hybrid electric trucks are being developed for delivery and utility applications. Most of these hybrid bus and truck projects involve partnerships between vehicle OEMs, companies specializing in integration of systems, and fleets. These partnerships help push advanced vehicles from the prototype stage into commercial products.

Many transit agencies are investigating hybrids because of increasing pressure to reduce pollution. Several successful demonstration projects over the past few years have led to larger orders. According to the American Public Transportation Association (APTA) 2004 *Vehicle Databook*, there were 184 hybrid buses in active service as of January 1, 2004, with 614 on order and a potential for 228 more. These figures represent a substantial change since last year, including increases of 36% in hybrid buses in active service and 65% in hybrid bus orders. Table 2 lists active heavy-duty vehicle projects in the United States, and Table 3 lists those that are planned.

Two of the largest orders of heavy-duty hybrid transit buses have been made by Seattle, Washington's King County Metro (213) and New York City Transit (325). Both transit agencies are pleased with the performance of the hybrid buses they currently operate in revenue service. King County Metro is using New Flyer buses with Allison parallel hybrid powertrains. New York City Transit is using Orion buses with BAE SYSTEMS HybriDrive™ series hybrid powertrains.

A 40-foot hybrid bus designed by ISE Research uses a ULEV-certified, gasoline-fueled Ford V10 engine. Early emission tests show very low levels of criteria pollutants. Two transit agencies are currently using the ISE bus, including Elk Grove, California, which recently began using buses retrofitted with ISE's system. Seven transit agencies have plans to add these hybrids to their operations. ISE also offers this hybrid system powered by a diesel engine or a hydrogen internal combustion engine.

Plug-in hybrid electric vehicles (PHEVs) have received more attention in the past year because of advantages such as electric-only range, improved net fuel economy with recharging, potentially lower lifetime service costs, and stored energy to offset the need for generators for construction or utility applications. One recent prospect involves parallel-drive Sprinter utility trucks and public transit vans being promoted by DaimlerChrysler and the Electric Power Research Institute (EPRI). The Sprinter PHEV has an all-electric, zero emission range of about 30 kilometers (19 miles). Key vendors participating in the development of the Sprinter PHEV include Varta (NiMH batteries), Saft (optional lithium ion batteries), and ZF Sachs (permanent magnet electric traction system). Should these PHEVs prove successful, interest exists from an Austin, Texas-based consortium, in purchasing these vehicles in volume, which should dramatically reduce the per vehicle cost.

Table 2. Heavy-Duty Hybrid Electric Vehicles – Active Projects

Project	Agency	City	State	Vehicle Type	Fuel	Project Start Date	No. In Project
Allison/Gillig	Hillsborough Area Transit	Tampa	FL	40-ft Bus	Diesel	Jan-05	3
Allison/Gillig	IndyGo	Indianapolis	IN	40-ft Bus	Diesel	Feb-05	2
Allison/Gillig	Metro Transit	Minneapolis	MN	40-ft Bus	Diesel	Nov-02	3
Allison/Gillig	Port Authority of Allegheny County	Pittsburgh	PA	40-ft Bus	Diesel	Apr-05	6
Allison/Gillig	San Joaquin RTD	Stockton	CA	40-ft Bus	Diesel	Oct-04	2
Allison/Gillig	Transit Authority of River City	Louisville	KY	40-ft Bus	Diesel	Jun-04	5
Allison/Gillig	Yosemite National Park	Yosemite	CA	40-ft Bus	Diesel	May-05	18
Allison/MCI/ISE Research	NJ Transit	Newark	NJ	Coach Bus	Diesel	Apr-04	4
Allison/New Flyer	Albuquerque	Albuquerque	NM	60-ft Artic	Diesel	Dec-04	60
Allison/New Flyer	BC Transit	Vancouver area	BC	40-ft Bus	Diesel	Spring 2005	6
Allison/New Flyer	Capital Metro	Austin	TX	40-ft Bus	Diesel	Oct-03	2
Allison/New Flyer	Connecticut Transit	Hartford, Stamford	CT	40-ft Bus	Diesel	Jun-03	2
Allison/New Flyer	King County Metro	Seattle	WA	60-ft Artic	Diesel	Aug-04	213
Allison/New Flyer	SEPTA	Philadelphia	PA	40-ft Bus	Diesel	Oct-02	12
Allison/New Flyer	SEPTA	Philadelphia	PA	40-ft Bus	Diesel	2004	20
Allison/New Flyer	Sound Transit	Seattle	WA	60-ft Artic	Diesel	Aug-04	22
Allison/New Flyer	The Bus	Honolulu	HI	60-ft Artic	Diesel	2004	10
Allison/New Flyer	Tri-Met	Portland	OR	40-ft Bus	Diesel	Apr-02	2
Allison/New Flyer	UTA	Salt Lake City	UT	40-ft Bus	Diesel	2003	3
Allison/Stewart & Stevenson Services	Metro	Houston	TX	40-ft Bus	Diesel	Aug-03	4
Azure Dynamics/ Canada Post	Canada Post	Various		Delivery Step Van	Diesel	Aug-03	5
Azure Dynamics/ Purolator	Purolator Courier	Toronto	ON	Delivery Step Van	Diesel	May-05	30
BAE/Orion VII	NYCT MTA	NY	NY	40-ft Bus	Diesel	Nov-03	125
BAE/Orion VII	NYCT MTA	NY	NY	40-ft Bus	Diesel	2005	200
BAE/ Orion	Fresno Area Express	Torrance	CA	40-ft Bus	Diesel	May-01	2
BAE/ Orion	MUNI	San Francisco	CA	40-ft Bus	Diesel	May-01	2
Eaton	FedEx fleet	Tampa	FL	Delivery Truck	Diesel	Nov-04	4
Eaton	FedEx fleet	New York City	NY	Delivery Truck	Diesel	Oct-04	10
Eaton	FedEx fleet	Washington	DC	Delivery Truck	Diesel	Feb-05	2
Eaton	FedEx fleet	Sacramento	CA	Delivery Truck	Diesel	Feb-01	2
Ebus	City of Coral Gables Trolley	Coral Gables	FL	22-ft Trolley	Diesel	Feb-04	5
Ebus	IndyGo	Indianapolis	IN	22-ft Bus	Diesel	Jul-03	5
Ebus	Knoxville Area Transit	Knoxville	TN	22-ft Trolley	Diesel	Oct-03	4
Ebus	Monrovia Transit, Monrovia	Monrovia	CA	22-ft Trolley	Diesel	Nov-02	2
Ebus	Pasadena Area Rapid Transit System (ARTS)	Pasadena	CA	Trolley	Diesel	Oct-03	5
Ebus	Visalia City Coach	Visalia	CA	22-ft Trolley	Diesel	Mar-02	3
Hybrid Bus Technologies	LAX	Los Angeles	CA	45-ft Bus	CNG	2005	2
ISE Research (Novabus chassis)	NJ Transit	Newark	NJ	40-ft Bus	Diesel	Apr-04	3
ISE Research/New Flyer	Commerce Municipal Bus Lines	Commerce	CA	40-ft Bus	Gasoline	2005	2
ISE Research/New Flyer	Fresno Area Express	Fresno	CA	40-ft Bus	Gasoline	2005	2
ISE Research/New Flyer	Long Beach Transit	Long Beach	CA	40-ft Bus	Gasoline	2005	27
ISE Research/New Flyer	Montebello Bus	Montebello	CA	40-ft Bus	Gasoline	2005	5
ISE Research/New Flyer	Norwalk Transit System	Norwalk	CA	40-ft Bus	Gasoline	2005	4
ISE Research/New Flyer	Omnitrans	San Bernardino	CA	40-ft Bus	Gasoline	2005	15
ISE Research/Gillig/Complete Coachworks	City of Elk Grove	Elk Grove	CA	40-ft Bus	Gasoline	Jan-05	17
ISE Research/New Flyer	OCTA	Orange	CA	40-ft Bus	Gasoline	2005	10
ISE Research/New Flyer	Omnitrans	San Bernardino	CA	40-ft Bus	Gasoline	Apr-02	3
Solectria	DHL fleet, LAX	Los Angeles	CA	Class 7 Truck	Diesel	Unknown	1
Transportation Techniques (Transteq)	Denver RTD	Denver	CO	45-foot Bus	CNG	Oct-98	36

(Source: Collected by Robb Barnitt and Leslie Eudy, National Renewable Energy Laboratory, from various sources)

Table 3. Heavy-Duty Hybrid Electric Vehicles – Planned Projects

Project	Agency	City	State	Vehicle Type	Fuel	Project Start Date	No. In Project
Allison/New Flyer	Greater Cleveland RTA	Cleveland	OH	60-ft Artic	Diesel	2007	21
Allison/New Flyer (modified Invero)	Lane Transit District	Eugene	OR	60-ft Artic	Diesel	Aug-06	5
BAE/ Orion	MUNI	San Francisco	CA	Bus	Diesel	2006/07	Up to 96
BAE/ Orion VII	Rochester-Genesee Regional Transportation Auth.	Rochester	NY	Bus	Diesel	Unknown	5
BAE/ Orion	Toronto Transit Commission	Toronto	ON	Bus	Diesel	Late 2005	100-150
DaimlerChrysler/EPRI	KC Regional Transit Authority	Kansas City	KS	Sprinter van	Diesel	2005/06	1
DaimlerChrysler/EPRI	SCAQMD	Los Angeles	CA	Sprinter van	Diesel	2005/06	1
DaimlerChrysler/EPRI	SoCal Edison	Unknown	CA	Sprinter van	Diesel	2005/06	1
Gillig	Vail Transit	Vail	CO	40-ft Bus	Diesel	Unknown	1
Optima Bus Corp	Unknown	Wichita	KS	Bus	Unknown	Unknown	1
Urban Transport Showcase Program - Transport Canada	Société de Transport de l'Outaouais (STO)	Gatineau	QC	Bus	Biodiesel	Unknown	12
Urban Transport Showcase Program - Transport Canada	Société de Transport Montréal (STM)	Montréal	QC	Artic	Biodiesel	Unknown	11
Undetermined	Durham Chapel Hill Carrboro Metro Planning Organization	Durham, Chapel Hill	NC	Bus	Unknown	Unknown	9
Undetermined	Livermore Amador Valley Transit Auth.	Livermore	CA	Bus	Unknown	Sep-05	Unknown
Undetermined	Westchester County	Westchester	NY	Bus	Diesel	Unknown	4
Undetermined	WMATA	Washington	DC	Bus	Diesel	FY2005	100

Fuel Cell Technology

Light-Duty Vehicles

Most manufacturers continue to develop prototype vehicles powered by fuel cells. Table 4 provides a list of models introduced in the past few years, many of which are currently being tested in California as well as various other parts of the United States. For more details, see the companion tables at www.avt.nrel.gov/overview.html.

In a trend that began last year, manufacturers continue to place fuel cell vehicles into selected fleets, generally in the form of commercial lease to customer agreements. The California Fuel Cell Partnership (CaFCP) reports to have 65 fuel cell vehicles in California, with current or planned demonstration activities. Manufacturers are also testing their fuel cell vehicles in other parts of the world.

In early 2003, DOE initiated the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project. This project involves an integrated DOE-industry effort to monitor real-world applications of fuel cell vehicles and hydrogen infrastructure and to test, demonstrate, and validate system solutions. Results will be fed back into DOE's R&D program to guide future research funding and direction. Four cooperative agreements have been signed by DOE and industry teams; vehicles are being deployed, and hydrogen fueling infrastructure is being constructed. These projects will be executed over 5 years, and iterations of technology will be compared and measured against DOE technical targets.

Table 4. Light-Duty Fuel Cell Vehicles

OEM	Model	Body Style	Fuel Type	Date of Introduction
Vehicles in Demonstration Programs				
DaimlerChrysler	F-Cell	Sedan	Hydrogen	Oct-02
Ford	Focus FCV	Sedan	Hydrogen	Mar-02
GM	HydroGen 3	Minivan	Liquid Hydrogen	Sep-01
Honda	FCX	Sedan	Hydrogen	Sep-01
Hyundai	Tucson	SUV	Hydrogen	Mar-04
Hyundai	Santa Fe FCEV	SUV	Hydrogen	Nov-01
Mercedes-Benz	Sprinter	Van	Hydrogen	2001
Nissan	Xterra	SUV	Hydrogen	Nov-00
Nissan	X-Trail FCV	SUV	Hydrogen	Dec-02
Toyota	FCHV	SUV	Hydrogen	Jun-01
Volkswagen	Bora HyMotion	Sedan	Hydrogen	Nov-00
Recently Introduced Concept Vehicles				
Audi	A2H2	Sedan	Hydrogen	Apr-04
GM	Sequel	Sedan	Hydrogen	Jan-05
Michelin	HY-LIGHT	Sedan	Hydrogen	Oct-04
Kia	Sportage	SUV	Hydrogen	Oct-04

(Source: Collected by Robb Barnitt and Leslie Eudy, National Renewable Energy Laboratory, from various sources)

Heavy-Duty Vehicles

Heavy-duty fuel cell vehicles, mainly transit buses, continue to be developed. Table 5 lists heavy-duty fuel cell vehicle projects worldwide. For more details, see the companion tables at www.avt.nrel.gov/overview.html.

Demonstration of fuel cell buses in the United States is underway. Santa Clara Valley Transportation Authority of San Jose, California has received three buses and plans to begin revenue service in late February 2005. The 40-foot Gillig buses are powered by Ballard fuel cell systems. AC Transit of Oakland, California and SunLine Transit Agency of Thousand Palms, California expect to begin demonstrating fuel cell buses in September 2005. Their demonstration includes four buses with a fuel cell system designed and integrated by ISE Research. These buses, three of which will be operated by AC Transit and one by SunLine, are 40-foot Van Hool buses using UTC fuel cells.

The most significant demonstration of fuel cell buses to date involves 33 full-size DaimlerChrysler (Citaro) buses with Ballard fuel cell systems. The buses are being demonstrated as part of three parallel projects: Clean Urban Transport for Europe (CUTE), Ecological City Transport System (ECTOS), and Sustainable Transport Energy Project (STEP). A total of 30 full-size fuel cell buses will be deployed in nine European cities, in Iceland, and in Perth, Australia. Each city will operate three buses for 2 years. The various locations will allow for bus performance to be compared in multiple climates and topographical conditions. The CUTE and ECTOS programs are reporting impressive results to date, including the following:

- 420,000 km driven as of November 2004
- 33,000 hours of fuel cell operation
- 40,000 kg hydrogen used.

Infrastructure permitting and station redesigns have proven more onerous than has implementing the vehicles. The cities are developing infrastructure for providing hydrogen in a variety of ways, 50% of which will employ renewable sources. The CUTE and ECTOS programs are employing a similar philosophy to

that of the DOE technology validation effort, i.e., the introduction of vehicles must occur in concert with fueling infrastructure. For more information on these projects visit www.fuel-cell-bus-club.com.

Table 5. Heavy-Duty Fuel Cell Vehicles

Project	Vehicles Deployed	Vehicle Type	Fuel	Type	Status of Project	Project Start Date	No. in Project
Projects in the United States							
DaimlerChrysler	UPS fleet in LA & Sacramento, CA, Ann Arbor, MI	Sprinter Van	Hydrogen	PEM	Demonstration	Aug-04	3
Georgetown (Gen III)	In development	30-ft Bus	Methanol	Unknown	Development	Unknown	3
Georgetown/Novabus/Ballard (Gen II)	SunLine, Thousand Palms, CA	40-ft Bus	Methanol	PEM	Active	Dec-01	1
Georgetown/Novabus/UTC (Gen II)	Washington, DC - WMATA	40-ft Bus	Methanol	PAFC	Active	1998	1
Gillig/Ballard	VTA, San Jose, CA	40-ft Bus	Hydrogen	PEM	Active	Apr-04	3
ISE/UTC (Van Hool)	AC Transit, Oakland, CA	40-ft Bus	Hydrogen	PEM	Ordered	Fall 2005	3
ISE/UTC (Van Hool)	SunLine, Thousand Palms, CA	40-ft Bus	Hydrogen	PEM	Ordered	Fall 2005	1
US Air Force/Enova/High Technology Development Corp.	Hickam Air Force Base, Honolulu, HI	30-ft Bus	Hydrogen	PEM	Active	Dec-03	1
US Air Force/Enova/Hydrogenics/HTDC	Hickam Air Force Base, Honolulu, HI	Van	Hydrogen	PEM	Active	Jun/Jul-05	1
UTC/Thor/ISE Research (30-foot)	AC Transit, Oakland, CA	30-ft Bus	Hydrogen	PEM	Complete	Aug-02	1
Projects Outside the United States							
DaimlerChrysler (EvoBus) Citaro/CUTE project	Europe, various cities	40-ft Bus	Hydrogen	PEM	Active	Mid-2003	27
DaimlerChrysler (EvoBus) Citaro/ECTOS project	Reykjavik, Iceland	40-ft Bus	Hydrogen	PEM	Active	Mid-2003	3
DaimlerChrysler/Hermes Versand	Stuttgart and Hamburg, Germany	Van	Hydrogen	PEM	Active	Sep-01	1
Hino/Toyota FCHV-BUS2 (JHFC Project)	Tokyo-Yokohama	10.5-m Bus	Hydrogen	PEM	Active	Demo 2003	5
Irisbus - City Class	Turin, Italy	12-m Bus	Hydrogen	PEM	Demonstration	Jan-01	1
MAN	Berlin, Copenhagen, Lisbon	12-m Bus	Liquid Hydrogen	PEM	Planning	2004	Unknown
MAN/Ballard	Munich Airport	12-m Bus	Hydrogen	PEM	Planning	2004	1
Natural Resources Canada/Hydrogenics/New Flyer	Winnipeg Transit (first)	40-ft Bus	Hydrogen	PEM	Planning	mid - late 2004	1
Purolator Courier/Azure Dynamics/Hydrogenics	Toronto, Canada	Delivery van	Hydrogen	PEM	Development	early-2005	1
Sustainable Transport Energy for Perth (STEP)	Perth Central Area Transit, Austrailia	40-ft Bus	Hydrogen	PEM	Planning	Jul/Aug 2004	3
Tsinghua Univ., Beijing/Beijin Green Power Co.	China	12-m Bus	Hydrogen	PEM	Active	Unknown	Unknown
Tsinghua Univ/Shanghai Shen-Li High-Tech Co.	Beijing (2008 Olympics)	Bus	Unknown	Unknown	Planning	Unknown	Unknown
UNDP-GEF China (Citaro)	Shanghai, Beijing, China	10.5-m Bus	Hydrogen	PEM	Ordered	Sep-05	3
UNDP-GEF Egypt	Cairo, Egypt	Bus	Hydrogen	Undetermined	Planning	Unknown	8
UNDP-GEF India	Delhi, India	Bus	Hydrogen	Undetermined	Planning	Unknown	8
UNDP-GEF Mexico	Mexico City, Mexico	Bus	Hydrogen	Unknown	Planning	Unknown	10
UNDP-GEF Brazil	Sao Paulo, Brazil	Bus	Hydrogen	Unknown	Planning	Sep-05	10
Volvo/Proton Motor	Berlin, Germany	Double-decker bus	Hydrogen	PEM	Planning	Unknown	2

(Source: Collected by Robb Barnitt and Leslie Eudy, National Renewable Energy Laboratory, from various sources)

The United Nations Development Programme and the Global Environmental Facility are supporting another fuel cell bus initiative. The 5-year program plans to introduce up to 46 fuel cell buses in six cities in developing countries: Beijing and Shanghai in China; Cairo, Egypt; Mexico City, Mexico; New Delhi, India; and Sao Paulo, Brazil. The demonstrations for each city are in various stages of development.

Progress in Mexico is reportedly slightly behind that in Brazil and China. The Egypt and India programs are in early development. Specific updates are provided below (for more information on the initiative visit www.undp.org/gef).

Mexico

- International expression of interest being prepared to gauge the interest of fuel cell bus OEMs, to be distributed in early 2005

Brazil

- Plan for eight buses in this phase and up to 200 buses in the next phase
- Currently negotiating with bus manufacturers; expect announcement early 2005
- Will use Ballard fuel cell as part of a hybridized system
- Buses projected to begin operation in January 2006

China

- Ordered buses for the 2008 Olympic Games
- Pollution and congestion major reasons for project
- Contract finalized with DaimlerChrysler to procure three fuel cell buses with the Ballard fuel cell system (identical to CUTE buses)
- BP building hydrogen fueling infrastructure
- Proposal for second phase of project includes three additional buses for Beijing and three for Shanghai (plan to use a hybrid system)

An international effort began last year to bring representatives from these various demonstrations together to collaborate and share results and experiences. These projects provide a unique opportunity to collaborate in validating this advanced technology in real-world applications. The U.S. Federal Transit Administration and DOE are working together to facilitate this collaboration. Two workshops have been held to facilitate the sharing of information and experiences, with a third scheduled for late 2005. A major goal of the effort is to standardize a set of data items and methods to allow comparison of projects worldwide. Progress at the most recent meeting in Porto, Portugal, included the following:

- The participants agreed to share a set of fixed data in a common template for easy comparison. Fixed data include project summaries, descriptions of the fleet and infrastructure, status of the demonstration, and vehicle specifications. No proprietary data are included.
- The participants agreed to share summary data and lessons learned during the fuel cell bus demonstrations. The list of specific data was discussed but not finalized. The organizing team will draft a proposal to the group that includes a list of performance data.
- The participants agreed to form an International Fuel Cell Bus Working Group that will meet once each calendar year.

Hydrogen and Hydrogen/Natural Gas Blend ICE Technology

Several automotive and bus engine manufacturers are developing vehicles that use internal combustion engines (ICEs), which operate on hydrogen or a blend of hydrogen and CNG. Using hydrogen in mature technologies, such as ICEs, could help support the expansion of infrastructure for the fuel while manufacturers continue to perfect fuel cell vehicle systems.

Light-Duty Vehicles

Several light-duty vehicles using hydrogen have been introduced in the last few years, the most recent being a Ford Focus concept vehicle which uses hydrogen as a fuel for an ICE instead of gasoline (see Table 6). A project sponsored by the South Coast Air Quality Management District will involve demonstration of 30 hydrogen ICE hybrids which are modified Toyota Prius sedans. Quantum Technologies will modify the vehicles to enable operation on hydrogen, and the fleet will be operated in various locations within southern California.

Table 6. Light-Duty Hydrogen Vehicles

OEM	Model	Body Style	Power Type	Fuel	Date Introduced/ Announced	Status
Ford Focus	C-MAX	Sedan	ICE hybrid	Hydrogen	Jul-04	Concept
Alternate Energy Corp./ Feel Good Cars	Zenn	Urban low-speed	ICE hybrid	Hydrogen	Jun-04	Demonstration in 2005
Quantum	Toyota Prius	Sedan	ICE hybrid	Hydrogen	Mar-01	Demonstration

(Source: Collected by Robb Barnitt and Leslie Eudy, National Renewable Energy Laboratory, from various sources)

Heavy-Duty Vehicles

More extensive work has been done in the heavy-duty sector, building upon experience with natural gas. Table 7 lists projects involving heavy-duty hydrogen ICE vehicles in production, those planned for introduction in the next few years, and some of the more recent concept vehicles. (For more information on these and other hydrogen and blend-fueled vehicles introduced around the world, refer to the companion tables at www.avt.nrel.gov/overview.html.)

Table 7. Heavy-Duty Hydrogen Vehicles

Project	Vehicles Deployed	Vehicle Type	Fuel	Type	Status of Project	Project Start Date	No. in Project
Penn State/Collier Technologies	Centre Area Transportation Authority, State College, PA	Bus	HCNG	ICE	Unknown	Fall 2004	1
Cummins Westport	SunLine, Thousand Palms, CA	40-ft Bus	HCNG	ICE	Demonstration	2003	2
Sustainable Development Technology Canada	Vancouver, BC	Bus	HCNG	ICE	Planning	Unknown	Up to 5
Tasman Resources	Beijing (2008 Olympics)	Bus	HCNG	ICE	Planning	Jan-05	2000
Ford/ Dallas-Fort Worth Airport	Dallas, TX	Shuttle	Hydrogen	ICE	Planning	2006	100
ISE Research	SunLine, Thousand Palms, CA	40-ft Bus	Hydrogen	ICE hybrid	Active	Dec-05	1
Ford/ State of Florida	Unknown	Shuttle	Hydrogen	ICE	Unknown	2006	8
Cheung Kong Infrastructure Holdings, Ltd./ Stuart Energy	Hong Kong	Bus	Hydrogen	ICE hybrid	Planning	Late 2003	1
Cheung Kong Infrastructure Holdings, Ltd./ Stuart Energy	Hong Kong	Shuttle Bus	Hydrogen	ICE	Planning	Nov-03	1

Ford has initiated an effort to introduce shuttle buses powered by hydrogen-fueled internal combustion engines. Two projects, still in the planning phase, could place eight of these vehicles in service with the State of Florida and up to 100 at Dallas-Fort Worth Airport in Dallas, Texas. The shuttle bus would use the Ford E-450 chassis and the Ford 6.8L Triton V10 engine.

Additional Developments

Several developments in the past year could have an effect on advanced technology and alternative fuel vehicles in the United States. The following are some of the most recent:

Ford Discontinues AFV Production: Ford discontinued production of its CNG and LPG vehicles after model year 2004. This has reduced the selection of AFVs and could result in fewer AFVs being added to fleets in the future. Ford reportedly dropped its AFV efforts to focus on production of hybrid electric vehicles and development of hydrogen ICE vehicles (see Tables 1, 4, and 6).

Fuel Cell Vehicle Demonstration Programs Start Around the World: Automotive OEMs are placing fuel cell vehicles in fleets around the globe. Demonstrations are being conducted in various countries, including the United States, Japan, Germany, and Canada. The demonstrations include vehicles in all classes, from heavy-duty transit buses to light-duty cars. These demonstrations will show manufacturers how the new technology works in real-world applications and will help to optimize systems to meet the needs and expectations of consumers.

Hybrid Electric Vehicle Named North American Truck of the Year: Hybrid electric vehicles are becoming more mainstream in the United States. Following in the footsteps of the Toyota Prius, which was named *Motor Trend* Car of the Year in 2004, the Ford Escape Hybrid SUV was named North American Truck of the Year for 2005. The continued national recognition for hybrid vehicles could result in increased interest in advanced technology vehicles among consumers. Also following the lead of the Prius, the Ford Escape Hybrid is being used as a taxicab in San Francisco; 10 are already in service, and 15 more may be on the road soon.

Parts Supply for Hybrids Could Cause Production Delays: Several sources indicate that increases in production of hybrids could be limited by the availability of specialized components, including batteries. Many manufacturers are building hybrid vehicles on the same production lines as the traditional versions of the same model, therefore streamlining the production process, boosting capacity, and minimizing cost. However, specialized parts are still required, which may limit production. For example, Ford's estimated 2005 production of 20,000 Escape Hybrids may fall short, given that Sanyo, which supplies the NiMH batteries, does not currently have the production capacity to supply more than 20,000 units.

Mergers Prevalent in Hybrid and Fuel Cell Industries: Mergers in the hybrid and fuel cell arenas are becoming common as companies that have been slow out of the gate attempt to make up ground and companies seek competitive advantage by combining technological niches or customer bases. Examples include GM teaming with DCX to develop vehicles using GM's two-mode full hybrid, Azure purchasing Solectria, and Hydrogenics purchasing Stuart Energy.

Hybrid Fuel Economy Claims Scrutinized: The difference between manufacturers' fuel economy claims and real-world results has received negative press. Estimates based on modeling do not necessarily apply to real-world driving conditions, which involve unique driving cycles, hills, traffic, and variable passenger load. Fleets are beginning to recognize the importance of apples-to-apples comparisons between new and conventional powertrains and that in-use comparisons are more accurate than marketing claims.

Hybrid FedEx Trucks Begin Demonstration: Hybrid powertrains have debuted in a high-profile demonstration by FedEx, which is employing Eaton's parallel architecture in delivery trucks. A total of 16 trucks are currently in service in Sacramento, California, New York City and Staten Island, New York, and Tampa, Florida. An additional two trucks are expected to begin service in Washington, DC in February

2005. The hybrid trucks use Hitachi lithium ion batteries, Hitachi motors, Mercedes 4.3L engines, and Engelhard DPFs. The on-road testing period is scheduled for 2 years.

Summary

The direction and funding of transportation programs and the marketplace for advanced technologies continues to develop. Understanding the trends within the context of today's marketplace is critical to focusing public and private resources where they can have the most impact. Key points from this document include the following:

- Total U.S. sales of light-duty hybrid vehicles topped 86,200 in 2004; increasing sales, rapid proliferation of hybrid models planned for release, and increasing mainstream acceptability suggest a bright future for this technology.
- Heavy-duty hybrid vehicles continue to gain market acceptance, particularly in the transit bus sector.
- A range of hybrid powertrain architectures and energy storage options are being evaluated in many different applications nationwide.
- There are gaps between real-world driving behavior and region- and route-specific drive cycles and manufacturer-estimated fuel economy. Additional research is needed to understand and predict the relationship between drive cycle and actual, not advertised, fuel economy.
- Although industry experts do not expect full commercialization until after 2010, development of pre-production fuel cell vehicles is progressing rapidly, with numerous demonstrations of light- and heavy-duty vehicles being conducted worldwide.

Appendix

Summary of Alternative Fuel Vehicle Information

(Source for Figures A, B, and C: EIA, *Alternatives to Traditional Transportation*)

Figure A. Estimated Consumption of Fuels in the U.S. (2004)

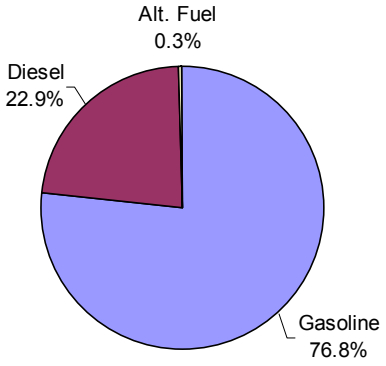


Figure B. Estimated Consumption of Alternative Fuels in the U.S. (2004)

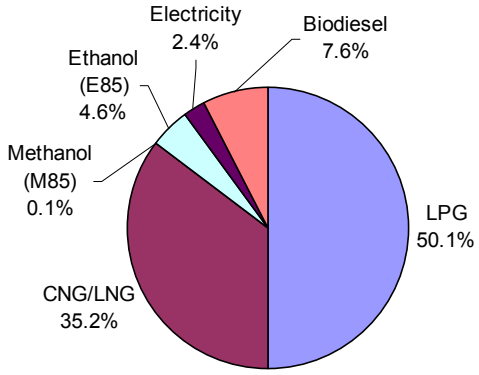
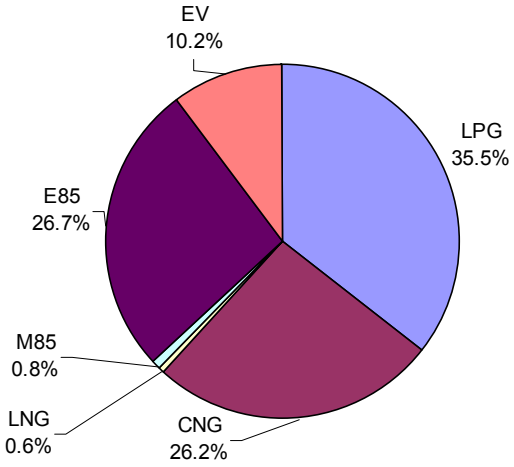


Figure C. Estimated Percent of AFVs in the U.S. (2004)



Note: EIA estimates that there were about 4.1 million flexible fuel vehicles (FFVs, which can run on E85 or gasoline) in the United States in 2002. The number counted as E85 vehicles reflects those FFVs believed to be fueled with E85 instead of gasoline; these are primarily fleet vehicles. EIA assumes that most FFVs owned by individuals are not fueled with E85 because of a lack of available E85 fueling stations.

Table A. U.S. Fueling Locations by State and Fuel

State	CNG	E85	LPG	ELEC	BD	HY	LNG	Totals by State
Alabama	1	0	79	0	0	0	0	80
Alaska	0	0	12	0	0	0	0	12
Arizona	31	2	67	18	3	1	6	128
Arkansas	4	0	62	0	0	0	0	66
California	180	3	259	498	17	9	30	997
Colorado	21	11	72	4	16	0	0	124
Connecticut	12	0	24	4	1	0	0	41
Delaware	2	0	5	0	3	0	0	10
Dist. of Columbia	1	0	0	0	0	1	0	2
Florida	27	3	111	6	4	0	0	151
Georgia	20	1	55	0	4	0	0	80
Hawaii	0	0	6	11	3	0	0	20
Idaho	8	1	30	0	1	0	1	41
Illinois	14	59	83	0	6	0	0	162
Indiana	11	3	42	0	10	0	0	66
Iowa	0	25	35	0	1	0	0	61
Kansas	3	4	52	0	5	0	0	64
Kentucky	0	4	36	0	4	0	0	44
Louisiana	12	0	25	0	0	0	0	37
Maine	0	0	12	0	3	0	0	15
Maryland	16	3	23	0	4	0	0	46
Massachusetts	9	0	28	29	1	0	0	67
Michigan	14	2	94	0	12	2	0	124
Minnesota	3	130	40	0	1	0	0	174
Mississippi	0	0	42	0	1	0	0	43
Missouri	6	18	106	0	2	0	0	132
Montana	2	3	32	0	5	0	0	42
Nebraska	1	24	24	0	1	0	0	50
Nevada	16	0	25	0	9	1	0	51
New Hampshire	1	0	17	9	6	0	0	33
New Jersey	18	0	13	0	1	0	0	32
New Mexico	7	3	60	0	2	0	0	72
New York	33	6	47	1	0	0	0	87
North Carolina	9	3	69	0	31	0	0	112
North Dakota	4	10	18	0	0	0	0	32
Ohio	13	4	77	0	10	0	0	104
Oklahoma	54	3	78	1	1	0	0	137
Oregon	16	0	41	0	6	0	0	63
Pennsylvania	40	0	75	0	3	0	1	119
Rhode Island	6	0	4	1	0	0	0	11
South Carolina	4	14	40	2	22	0	0	82
South Dakota	0	25	25	0	0	0	0	50
Tennessee	6	5	59	0	8	0	0	78
Texas	29	3	708	2	5	0	2	749
Utah	63	3	27	0	1	0	0	94
Vermont	1	0	12	10	0	0	0	23
Virginia	16	2	39	0	9	0	2	68
Washington	19	2	70	2	15	0	0	108
West Virginia	2	2	8	0	0	0	0	12
Wisconsin	20	10	59	0	1	0	0	90
Wyoming	12	2	33	0	12	0	0	59
Totals by Fuel:	787	393	3060	598	250	14	42	5145

Source: AFDC Refueling Stations www.afdc.doe.gov/refuel/state_tot.shtml as of August 2, 2005

List of Sources

Fuel Cell/Hydrogen

Ballard Power Systems	http://www.ballard.com
California Hydrogen Business Council	http://www.californiahydrogen.org
Fuel Cells 2000	http://www.fuelcells.org
Fuel Cell Bus Club: Information on European Fuel Cell Bus Demo	http://www.fuel-cell-bus-club.com/index.html
Fuel Cell Today	http://www.fuelcelltoday.com/index
Georgetown University Fuel Cell Bus Program	http://fuelcellbus.georgetown.edu
German Hydrogen Association	http://www.dwv-info.de
Hydrogen and Fuel Cell Information	http://www.hyweb.de/index-e.html
Hydrogen and Fuel Cell Letter	http://www.hfcletter.com
UTC Fuel Cells	http://www.utcfuelcells.com/fuelcells/index.shtm
Hydrogenics	http://www.hydrogenics.com
National Fuel Cell Research Center	http://www.nfcrc.uci.edu
National Hydrogen Association	http://www.hydrogenus.com
Nuvera	http://www.nuvera.com

Government/Other Organizations

Advanced Vehicle Technologies Program	http://scitech.dot.gov/partners/nextsur/avp/avp.html
Alternative Fuels Data Center	http://www.eere.energy.gov/afdc
American Public Transportation Association	http://www.apta.com
California Fuel Cell Partnership	http://www.cafcp.org
California Air Resources Board	http://www.arb.ca.gov/homepage.htm
CALSTART	http://www.calstart.org
U.S. Department of Transportation	http://www.dot.gov
DOE's Energy Information Administration	http://www.eia.doe.gov
DOE's AVTA	http://www.eere.energy.gov/vehiclesandfuels/avta
Electric Drive Transportation Association	http://www.electricdrive.org
EPA's Emissions Trends Site	http://www.epa.gov/ttn/chief/trends/index.html
EPA's Fuel Economy Trends Site	http://www.epa.gov/orcdizux/fetrends.htm
EPA's Global Warming Site	http://www.epa.gov/oppeoee1/globalwarming/index.html
EPA's Office of Transportation and Air Quality	http://www.epa.gov/otaq
Northeast Advanced Vehicle Consortium	http://www.navc.org
Northeast Sustainable Energy Association	http://www.nesea.org
Transportation Energy Data Book	http://www-cta.ornl.gov/data/Index.html

Manufacturers – Heavy Duty

Allison Transmission	http://www.allisontransmission.com
Caterpillar	http://www.cat.com
Cummins Engine	http://www.cummins.com
Designline Coach Builders	http://www.designline.co.nz
Detroit Diesel Corporation	http://www.detroitdiesel.com
Electric Vehicles International	http://www.evi-usa.com
Fuji Heavy Industries	http://www.fhi.co.jp/english/index.html
ISE Corporation	http://www.isecorp.com
John Deere	http://www.deere.com
Mack Trucks	http://www.macktrucks.com
Navistar/International	http://www.navistar.com
New Flyer Bus	http://www.newflyer.com
North American Bus Industries	http://www.nabiusa.com
NovaBUS	http://www.novabus.com
Orion Bus Industries	http://www.orionbus.com/orion
Volvo Trucks	http://www.volvotrucks.volvo.com
Trolley Enterprises	http://www.trolleyent.com/

Manufacturers – Light Duty

Audi News	http://www.audi.com/com/en/home.jsp
BMW	http://www.bmw.com
Daihatsu	http://www.daihatsu.com
DaimlerChrysler Corporate	http://www.daimlerchrysler.com
DaimlerChrysler Fleet Vehicle Site	http://www.fleet.chrysler.com
Ford Motors Environmental Vehicles Site	http://www.ford.com/en/vehicles/specialtyVehicles/environmental/default.htm
Ford Media Site	http://media.ford.com/news/index.cfm?make_id=92
GM Alternative Fuel Vehicle Site	http://www.gm.com/automotive/innovations/altfuel
GM News	http://www.gm.com/cgi-bin/pr_index.pl
Honda Newsroom	http://www.hondacars.com/info/news/landing.asp
Hyundai	http://www.hyundai-motor.com/eng/innovation/index.html
Mercedes-Benz	http://www.mercedes-benz.com
Mitsubishi Advanced Technology	http://www.mitsubishi-motors.co.jp/inter/technology/technology.html
Mitsubishi News	http://www.mitsubishi-motors.co.jp/inter/NEWS/Index/news_index.html
Nissan	http://www.nissanusa.com/
Peugeot Alternative Energy Developments	http://www.psa-peugeot-citroen.com/en/afternoon.php
Renault	http://www.renault.com/gb/accueil.htm
Subaru Global	http://www.subaru-global.com/index.html
Suzuki	http://www.suzukiauto.com
Toyota News	http://www.toyota.com/about/news

Manufacturers – Other

Arotech	http://www.arotech.com
Azure Dynamics	http://www.azuredynamics.com
BAE Systems	http://www.baesystems.com/
Capstone Turbine	http://www.capstoneturbine.com
DRS Technologies	http://www.drs.com
Eaton	http://www.eaton.com
Enova Systems	http://www.enovasystems.com
Saft Batteries	http://www.saftbatteries.com/010-Home/10-10_home.asp
UQM Technologies	http://www.uqm.com

Miscellaneous

Asian Technical Information Program	http://www.atip.or.jp
AC Transit	http://www.actransit.org
SunLine Transit Agency	http://www.sunline.org
Santa Clara VTA Zero Emission Bus Program	http://www.vta.org/projects/ZEBs.html

News Articles/Magazines

ATA's Green Truck	http://www.greentruck.com
Automotive Engineering International: SAE Publication	http://www.sae.org/automag/current.htm
Automotive Intelligence News	http://www.autointell.com/news
Automotive News	http://www.autonews.com
Butane-Propane News	http://www.bpnews.com
Car and Driver	http://www.caranddriver.com
Detroit Free Press	http://www.freep.com
Electrifying Times	http://www.electrifyingtimes.com
Energy Futures	http://www.energy-futures.com
Environmental News Network	http://www.enn.com
EV World	http://www.evworld.com
Fleets & Fuels Newsletter	http://fleetsandfuels.com
Fuel Cell Industry Report	http://www.sanewsletters.com
New Fuels and Vehicles	http://www.fuelsandvehicles.com
Mass Transit Magazine	http://www.masstransitmag.com
Metro Magazine	http://www.metro-magazine.com/t_home.cfm
Road and Track	http://www.roadandtrack.com
School Bus Fleet Statistics	http://www.schoolbusfleet.com
The Auto Channel News	http://www.theautochannel.com/