Alternative FUELS IN TRUCKING

Volume 6, Number 2

Future Fuels for Heavy-Duty Trucks

by James J. Eberhardt, Director, Office of Heavy Vehicle Technologies, Energy Efficiency and Renewable Energy, U. S. Department of Energy (DOE)

Recent articles in the press have raised the specter of another possible energy crisis (see sidebar on pg. 2). In addition, concern is growing about the air quality issues resulting from vehicle exhaust emissions and about global climate change from greenhouse gases such as carbon dioxide. Despite these concerns, we still have an economic imperative of continuing to produce and transport goods, and of providing services important for economic growth.

Figure 1 shows the correlation between gross domestic product (and hence, economic activity and growth) and freight transport (in ton-miles of travel). Meeting energy demands for moving goods is, therefore, critical to the economy. Freight transport is expected to continue growing, and with it, the amount of energy used by heavy-duty trucks. Projections by the Energy Information Administration (EIA) show that by the year 2010, if current trends continue, heavy vehicles (trucks of all classes including the heavy-duty Class 7 and 8) will be consuming as much fuel as automobiles (Figure 2). Truck energy use is less discretionary, even essential for maintaining economic growth. The question, then, is how can we sustain this continuing expansion of economic activity in an environmentally sound manner?

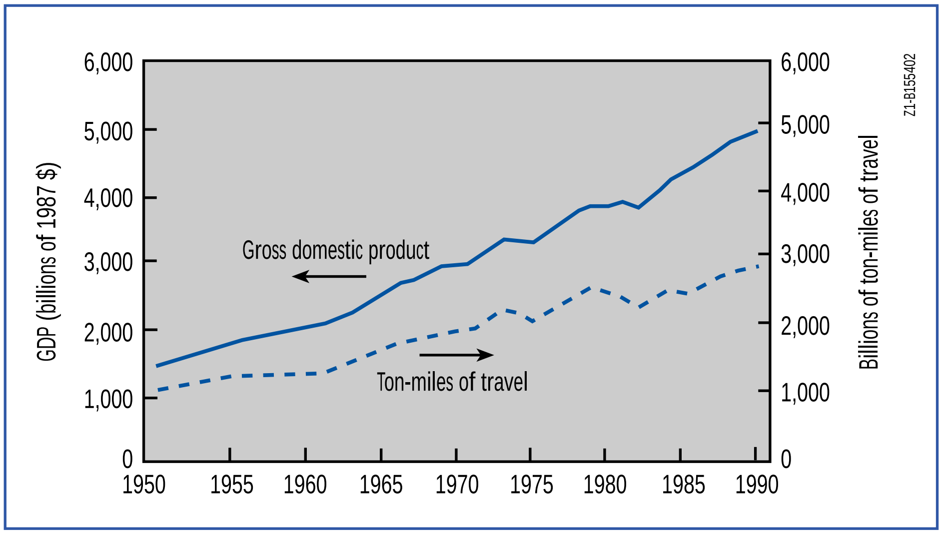


Figure 1. Gross domestic product correlated with freight transport

The Importance of Efficiency

The diesel cycle (compression-ignition) engine is the engine of choice for heavy-duty freight transport, where efficiency and low-speed power requirements are important. In conjunction with industry partners, the DOE Office of Heavy Vehicle Technologies is funding research and development of advanced low-emissions, 55% efficient (known as LE-55) diesel engine technologies to enable heavy-duty trucks to continue operating efficiently, plus meet EPA emissions standards proposed for 2004. Research to date indicates that the heavy-duty diesel is well on its way to being an environmentally sound engine. Indeed, three Cummins Diesel engines running on natural gas have been certified as meeting the California Air Resources Board

(Continued on pg. 2)

INSIDE THIS ISSUE

LNG Tax Relief......................4

The Status of the Federal Clean Fuel Fleet Program....4

Cummins Engine Successfully Meets EPA and CARB Standards..............................7

(CARB) and EPA 1998 on-highway heavy-duty truck and bus emissions standards without using exhaust aftertreatment catalysts.

Relevant Publications

- Hodel, D., *Crisis in the Oil Patch: How America's Energy Industry is Being Destroyed and What Must be Done to Save It*, Washington, D.C., Lanham, MD: Regnery, 1993.
- Romm, J.J. and C.B. Curtis, "Mid-east Oil Forever?" *The Atlantic Monthly*, April 1996.
- Romm, J.J. and C.A. Ervin, "How Energy Policies Affect Public Health," *Public Health Reports*, September/October 1996.
- "Development of a Production-Feasible Common Rail Fuel Injection System for Liquid Dimethyl Ether (DME) for Use in Heavy-Duty Vehicles," Golden, CO: National Renewable Energy Laboratory, 1996, http://www.afdc.nrel.gov/fuelutil/engoptim96.html
- Fritsch, P., "Exxon Project to Expand Use of Natural Gas," *The Wall Street Journal*, October 30, 1996.

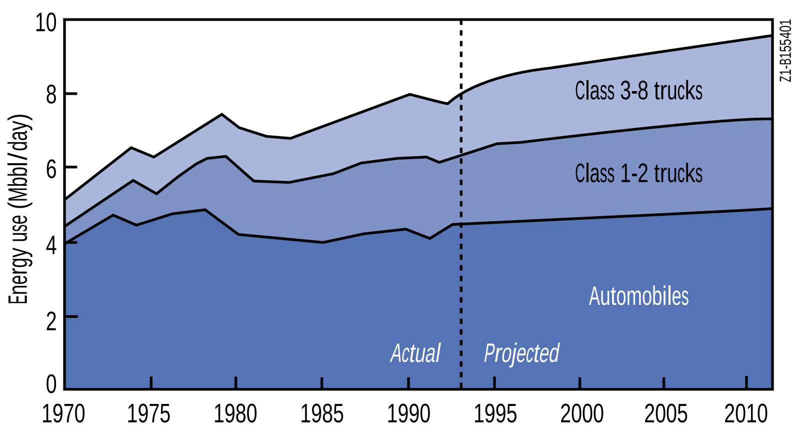


Figure 2. Actual and projected fuel use by cars and by trucks

Comparable efficiency and emissions levels have been achieved in diesel engines running on dimethyl ether (DME) with exhaust gas recirculation (EGR). DME is a fuel with physical properties close to those of propane but with excellent compression ignitability.

As important as efficiency is to profitability and to emissions reductions, efficiency improvements alone are not enough to greatly reduce petroleum consumption for heavy-duty transport.

Perhaps the most significant barrier to the use of alternative fuels for heavy-duty trucks is the lack of a fuel production and distribution infrastructure. Commercial transport operators depend on the ready availability of cost-competitive fuel for seamless operation and for profitability. In addition, the cost and expected service life of engines in commercial applications (for example, one million miles or more are expected of diesel engines in tractor-trailer combinations) preclude these operators from investing in alternative fuel engines for which the fuel production and distribution infrastructure is limited or nonexistent.

Research has demonstrated that diesel engines can run on natural gas, DME, diethyl ether, methanol, ethanol, and biodiesel. These dedicated alternative fuel engines, however, have not made significant inroads into the heavy-duty transport market, for the reasons outlined above. In addition, the alternative fuel engines have needed extensive tuning. Moreover, running such engines on fuels requiring ignition assist (e.g., spark, glow plug, or pilot injection) results in efficiencies lower than those achieved with petroleum-based (compression-ignitable) diesel fuel.

Future Fuels Strategy

To design a stategy for future fuels, it makes sense to focus on fuel properties that are suitable for the heavy-duty diesel cycle engine and use plentiful feedstocks to produce the fuel with these properties. The current feedstock is almost exclusively petroleum. However, if other feedstocks such as natural gas, coal, and biomass can be converted cost effectively into fuels appropriate for the diesel engine, they can be dispensed using the existing fuel infrastructure, and then used by a single energy conversion system, the diesel cycle engine. These future fuels from alternative, non-petroleum resources could then find significant penetration into the heavy-duty transport market. The DOE Office of Heavy Vehicle Technologies envisions the diversity-of-feedstocks strategy shown in Figure 3.

What fuel properties are required by the diesel engine? Cetane number has traditionally been an empirical measure of fuel ignitability. Fuels

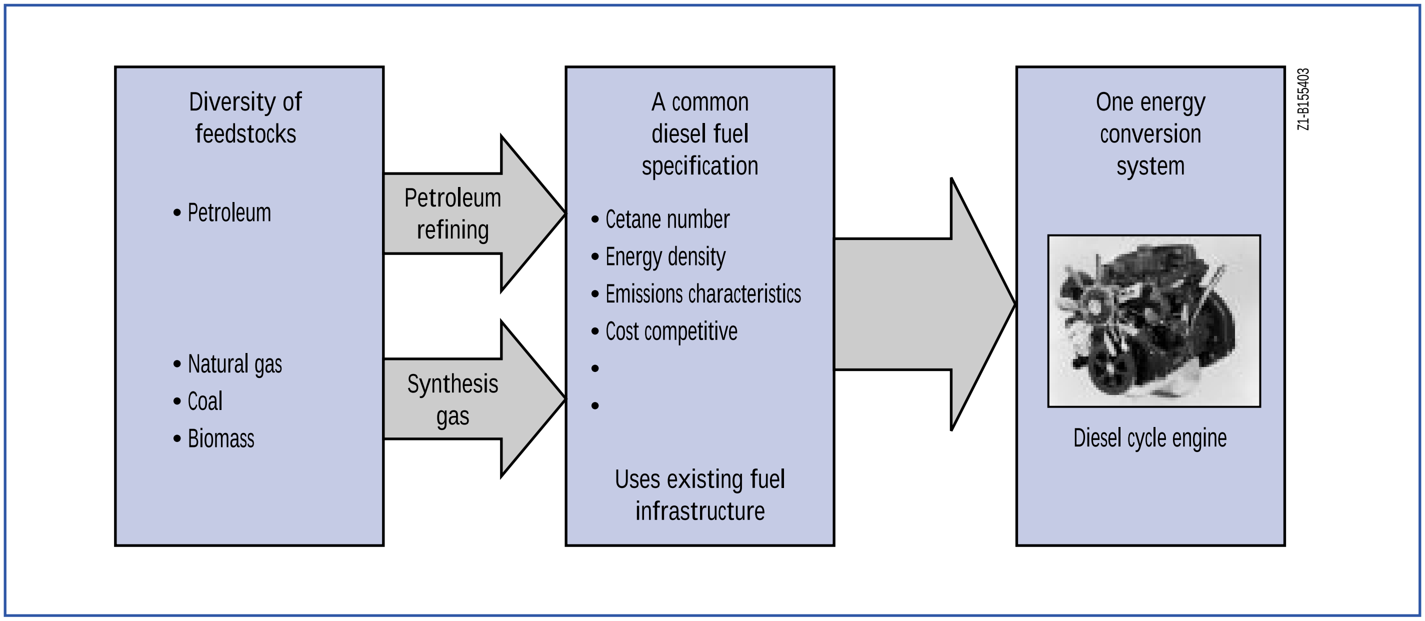


Figure 3. A diversity-of-feedstocks strategy

with a cetane number of 50 or higher are suitable for compression ignition in diesel engines. Table 1 shows the properties of some of the alternative fuels that have been tested as well as those of petroleum-based diesel fuel. Comparing cetane numbers, we can see why certain fuels do not perform very well in diesel cycle engines.

It is possible for the nation to take advantage of its indigenous feed-stock resources (coal, natural gas, and biomass) to produce high-quality fuels for heavy-duty diesel engines. Since World War II, we have known that coal can be converted to diesel fuels through the synthesis gas route, commonly called Fischer-Tropsch (FT) synthesis. Not so widely recognized is that the same process can be used to convert methane (natural gas) to FT diesel fuel as well. Last but not least, biomass can be "gasified" (turned into a mixture of carbon monoxide and hydrogen called synthesis gas or syngas). From syngas, a number of high-quality fuels appropriate for compression ignition engines can be made, including DME and FT diesel.

DME has physical properties akin to propane (see Table 1) for which a distribution infrastructure already exists. In Canada, for example, significant numbers of propane-pumping stations are available at gasoline retail outlets. FT diesel is compatible with the current diesel fuel infrastructure. Indeed the first usage of FT diesel is likely to be as

Table 1. Selected Properties of Potential Diesel Engine Fuel(s)

Property	DF-2 Diesel	Fischer-Tropsch	Biodiesel	CNG	Propane HD-5	Methanol	Ethanol	DME	Diethyl ether
Formula	Hydrocarbons C10-C21		Various oils and esters	Principally CH_4	Principally C_3H_8	CH_3OH	CH_2H_5OH	CH_3OCH_3	$C_2H_6OC_2H_6$
Boiling point (%F)	370–650	350–670	360–640	-258.5	-43.9	149	172	-13	94
Vapor pressure (psi @ 100°F)	<0.2	n/a	n/a	n/a	170	4.6	2.3	116	16.0
Cetane number	40–55	>74	>48	low	low	low	<5	>55	>125
Auto-ignition temp. (°F)	~600	~600	–	990	870	867	793	662	320
Stoichiometric air-fuel ratio (wt)	15.0	15.2	13.8	16.4	15.7	6.45	9.0	8.9	11.1
Lower heating value (Btu/lb)	18,500	18,600	16,500	20,750	19,940	8570	11,500	12,120	14,571
Specific gravity (60°F)	0.860	0.783	0.880	–	0.506	0.796	0.794	0.66	0.714

a blend for petroleum-derived diesel fuels to upgrade their cetane number and lower their sulfur and aromatics content.

In addition to being gasifiable, the renewable biomass feedstock has two additional routes to provide additional fuels for heavy-duty diesels. Biodiesel can be made from vegetable oils by a simple esterification process. Reaction of soybean or canola oils high in carboxylic acids with methanol (or ethanol) produces the dimethyl or diethyl ester of these carboxylic acids. Both have good properties for diesel fuel. Indications are that biodiesel formulations may be useful in blends to upgrade petroleum-based diesel fuels.

Conclusion

The diesel cycle engine has already been established as the engine of choice for the heavy-duty transport industry because of its fuel efficiency, durability, and reliability. In addition, it has proven to be capable of using alternative fuels, albeit at efficiencies lower than those achieved with petroleum-derived diesel fuel. Alternative fuel dedicated engines have not made significant inroads into the heavy-duty truck market because truck fleet operators need a cost-competitive fuel and a reliable supply and fueling infrastructure. In lieu of forcing diverse fuels from as many diverse domestic feedstocks onto the end users, the Office of Heavy Vehicle Technologies envisions a future fuels strategy for the heavy-duty transport sector where the diverse feedstocks are utilized to provide a single fuel specification (dispensed from the existing fueling infrastructure). Under this scenario, this fuel would run efficiently in a single high-efficiency energy conversion device, the diesel cycle engine. This strategy may also allow the U.S. commercial transport industry to gain a measure of security from rapid fuel price increases by relying less on a single feedstock source to meet its increasing fuel requirements.

Liquefied Natural Gas (LNG) Tax Relief

As a result of the Revenue Reconciliation Act of 1997, the federal excise tax on LNG will be reduced from 18.3 cents per gallon to 11.9 cents per gallon as of October 1, 1997. Because of the difference in energy content of LNG compared with diesel fuel, the LNG federal excise tax, which supports the Highway Trust Fund, now stands at approximately 20.5 cents per diesel equivalent gallon, down from 31.5 cents. Given that the federal excise tax on diesel itself is 24.3 cents per gallon, this tax rate actually gives LNG a tax advantage over diesel, the fuel with which it competes most directly.

The Status of the Federal Clean Fuel Fleet Program

On May 22, 1997, the EPA announced a 1-year delay for nonattainment areas subjected to the Clean Fuel Fleet Program (CFFP), but it is not yet clear if this delay is voluntary. With this delay, covered fleets must begin purchasing clean fuel fleet vehicles (CFFVs) in model year 1998 (MY 98). The CFFP provisions are part of the Clean Air Act Amendments of 1990, in which Congress chose to create a market for low-emission vehicles (LEVs) by requiring fleet operators to purchase these vehicles. They mandated that metropolitan areas with 1980 populations greater than 250,000, which either (1) the EPA has designated "serious," "severe," or "extreme" for ozone, or (2) have a design value of 16.00 parts per million for carbon monoxide, implement a Clean Fuel Fleet Program starting in MY 98. However, the provisions of the CFFP prohibit the EPA from ordering vehicle manufacturers to produce clean fuel fleet vehicles.

In a press release dated July 15, the EPA announced the delay and that it will issue its final ruling later this year. It will allow areas to start the program this fall, although most areas subjected to the program will probably wait until model year 1999. Initially, the EPA didn't expect any problems with implementing its plan as designed, but the agency was unprepared for the concerns raised at a recent CFFP stakeholders meeting. Various air quality officials raised issues about the lack of clean-fuel vehicle offerings, and participants at the meeting criticized the EPA for waiting so long to take action. EPA representatives assured these participants that it intends to work with the automakers, fuel providers, and state providers to make the program work. The EPA intends to change its certification program to make it easier for automakers to certify products to the CFFV standards. The impact of using federal reformulated gasoline in vehicles certified on California's reformulated gasoline (CARFG) will also be reviewed. The EPA wants to determine whether vehicles currently certified on CARFG can be operated on federal gasoline within CFFV standards.

Under original CFFP regulations, 30% of light-duty (<8500 gross vehicle weight) vehicles purchased by covered fleet operators with 10 or more centrally fueled vehicles in MY 98 must use clean fuels—fuels that burn more completely and meet EPA emissions standards. For heavy-duty vehicles, the requirements are 50% in MY 98. The EPA estimates that in MY 98, the demand for clean-fuel fleet vehicles would be approximately 47,000 for light-duty vehicles, and 12,000 for heavy-duty vehicles.

CFFP rules further require that in 1999, 50% of fleet vehicles purchased must use clean fuels, and this increases to 70% in the year 2000. The CFFP rules do not apply to small fleets—fleets with less than 10 vehicles—nor does it apply to emergency, law enforcement, or construction vehicles.

The Clean Air Act (CAA) allows states to opt out of the CFFP requirements if they can devise other methods of controlling the air pollution problem in their nonattaining metropolitan areas. The CAA also allows these areas to request a 1-year delay in adopting the policies. Originally, the Clean Air Act Amendments (CAAA) Clean Fuel Fleet Program affected 22 metropolitan areas. At present, Atlanta, Metropolitan Washington D.C., Chicago-Gary-Lake County, Milwaukee-Racine, Denver-Boulder, and Baton Rouge are the only six areas that remain in the EPA program.

Several nonattainment areas have decided to opt out of the federal CFFP program and have started their own programs for attaining the EPA's standards for air quality. California, for example, has implemented its own Clean Fuel Fleet Program by setting up the California LEV program. This program, however, does not cover vehicles between 14,000 and 26,000 gvwr. It only applies to lighter vehicles; that is, Classes 1-3 trucks and cars. The sidebar lists the industry classification of trucks by weight.

Connecticut has also opted out of the federal CFFP by adopting its own CFFP. In addition, Connecticut chose to achieve compliance by obtaining further emission reductions through enhancing its inspection and maintenance (I/M) program in the areas not affected by the state CFFP. Connecticut also gives tax benefits to fleets that purchase electric vehicles, or those that run on alternative fuels that burn cleaner and meet the EPA's emissions requirements. Incentives also apply to equipment purchased for the purpose of converting trucks to alternative fuels, and equipment for compressed natural gas fueling stations.

Definitions of Trucks and Cars by Weight

Class I:	6000 lb or less
Class II:	between 6001 and 10,000 lb
Class III:	between 10,001 and 14,000 lb
Class IV:	between 14,001 and 16,000 lb
Class V:	between 16,001 and 19,500 lb
Class VI:	between 19,501 and 26,000 lb
Class VII:	between 26,001 and 33,000 lb
Class VIII:	33,001 lb and higher

As shown in Table 2, Massachusetts and Rhode Island have also opted out of the EPA's CFFP program. Both states have devised their own programs for improving the air quality of their metropolitan areas. Massachusetts has adopted the California LEV program, and Rhode Island has agreed to use reformulated gasoline, and will probably implement a voluntary alternative fuel program as well.

The areas that have petitioned for a 1-year delay are: Chicago-Gary-Lake Counties, Baton Rouge, Metropolitan Washington D.C., and Milwaukee-Racine. These areas must have revisions to their State Implementation

Plans (SIPs) approved by the EPA, which means they have to conform to the provisions established in Section 246(c) of the Clean Air Act. The areas asking for the delay have to start phasing in their CFFPs by MY 99. In all cases, if fleet operators purchase CFVs under the current regulations earlier than the 1999 model year, they can earn credits. Table 2 shows the status of the State Clean Fuel Fleet Program as of May 1997.

The fleet operators who work under the CFFP will have to deal with the increased costs of adapting their fleets to use alternative fuels. Much work has been done to develop infrastructure for the alternative fuels so that fleets around the country can use them, and the EPA allows some added flexibility with its 1-year delay option. This delay should make it easier for fleet operators to make necessary arrangements to adjust to the mandates of the CFFP. This will also allow for expanded certified vehicle availability to meet these requirements and the additional time will allow fleets to learn their capabilities and integrate them, as well as provide greater opportunity for truck original equipment manufacturers to market their alternative fuel vehicles.

Table 2. Current Status of Federal CFFP in Nonattainment Areas

State	CFFP Covered Area	Current Status
California	Bakersfield Fresno Los Angeles-Anaheim-Riverside Sacramento San Diego	Opted out of CFFP
Colorado	Denver-Boulder	Developed federal CFFP
Connecticut	Greater Connecticut	Opted out of CFFP
Delaware	Wilmington-Trenton	Plans to opt out of CFFP
District of Columbia	Metro Washington D.C.	Requested 1-year delay for CFFP
Georgia	Atlanta	Developed federal CFFP
Illinois	Chicago/Gary Lake	1-year delay for CFFP granted via May 22 means
Indiana	Gary	1-year delay for CFFP granted via May 22 means
Louisiana	Baton Rouge	1-year delay for CFFP granted via May 22 means
Maryland	Baltimore	Plans to opt out of CFFP
New Hampshire		Developed state CFFP
Pennsylvania	Philadelphia	Plans to opt out of CFFP
Rhode Island	Providence	Opted out of CFFP
Texas	Houston-Galveston-Brazoria El Paso Beaumont-Port Arthur	Developed state CFFP
Virginia	Northern VA/Washington D.C.	1-year delay granted, developing state CFFP for Richmond/Hampton Roads area
Wisconsin	Milwaukee-Racine	1-year delay for CFFP granted

Cummins Engine Successfully Meets EPA and CARB Standards

In 1996, the Cummins Engine Company, Inc., introduced on the market a natural gas engine that has been recognized as one of the most technologically advanced and versatile engines available today. The Cummins B5.9G engine has successfully met both the EPA's 1998 emissions requirements and the low oxides of nitrogen (NO_x) standards set by CARB. As a result, both of these agencies certified the B5.9G engine as of February 1997.

The Cummins B5.9G engine is a spark-ignited, six-cylinder, 5.9-liter engine with closed-loop air/fuel ratio control, lean-burn technology, advanced engine controls management, and integrated subsystems. It also has altitude and fuel variability compensation mechanisms that make it very useful at high altitudes. The lean-burn technology increases the thermal efficiency of the B5.9G to up to 37% while decreasing its NO_x emissions, and it does not even need an exhaust catalyst to meet these emissions standards.

Truck operators can use it in any number of vehicles, including school buses, shuttle buses, recycling trucks, pickup and delivery trucks, and sweepers. The engine is available in 195 hp and 150 hp with 420 and 375 ft-lb torque peak ratings, respectively. A 230 hp, 500 ft-lb rating should be available in January of 1998. Table 3 shows the B5.9G's original equipment manufacturer (OEM) availability for use in trucks, buses, and utility vehicles.

The Cummins B5.9G has already attracted a significant customer, the U.S. Postal Service (USPS). As part of a joint venture between DOE and USPS, the Freightliner Custom Chassis Corporation's plant in Gaffney, S.C. has been building two-ton mail trucks with the B5.9G engine. The mail trucks will be used and tested in Atlanta, GA; Denver, CO; El Paso, TX; Huntington Beach, CA; and New York City.

The Gas Research Institute (GRI) has also taken an active interest in the Cummins B5.9G natural gas engine, and will closely monitor the performance and efficiency of the mail trucks that use it. GRI conducts performance evaluations on these engines in heat and cold, humid and dry weather, and sea-level to high altitude environments at several EPA-certified testing facilities. The natural gas engines are being compared to diesel engines under similar environ-mental conditions. GRI plans to make a final report on these tests available to fleet operators in 1998.

With interest in natural gas engines increasing because of the more stringent requirements of the Clean Fuel Fleet Program, the Cummins B5.9G engine has a very promising future. This engine's strengths—cool burning combustion technology, utility in a wide variety of trucks, and double certification from the EPA and CARB—are making it a popular choice for the trucking industry's many medium-sized vocations.

Table 3. The B5.9G's Availability

School / Shuttle / Transit	Medium-Duty Truck	Refuse
Blue Bird	Elgin-sweeper	Crane Carrier
Cespel/EAG (Europe)	ERF (UK)	ERF (UK)
Champion Coach	Freightliner Custom Chassis	
Chance Coach	Leyland-DAF (UK)	
Dennis Specialty (UK)	Ottawa Truck-yard spotter	
El Dorado National	SISU (NA)-yard spotter	
Goshen Coach		
Matthews Bus		
North American Transit		
Neoplan (Europe and NA)		
Optare (UK)		
Orion Bus		
Metrotrans		
Spartan		
Specialty Vehicles		
Thomas Built		

Alternative **FUELS** IN TRUCKING

Volume 6, Number 2
René Howard, Editor
Jim Miller, Graphic Designer

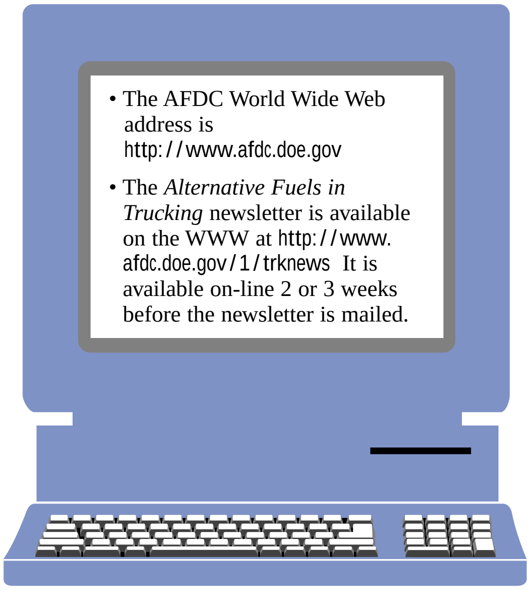
Alternative Fuels in Trucking is published quarterly by the National Renewable Energy Laboratory (NREL), a U.S. Department of Energy (DOE) national laboratory. The newsletter is written by the American Trucking Association Foundation's (ATAF's) Trucking Research Institute.

The aim of **Alternative Fuels in Trucking** is to inform fleet owners and operators, equipment suppliers, government officials, and other interested parties about important developments in the use of alternative fuels in heavy-duty trucks. Suggestions and comments are welcome and may be directed to the National Alternative Fuels Hotline at 800-423-1DOE. Views expressed by guest authors are their own, and not those of ATAF, DOE, or NREL.

NREL/BR-540-23440
October 1997

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste

How to Reach Us



U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Office of Transportation Technologies