Diesel Electric Hybrid Vehicles

Diesel hybrid technology has blossomed over the last several years to become one of the most advanced heavy-duty vehicle technologies available today. These vehicles combine the latest advances in hybrid vehicle technology with the inherent efficiency and reduced emissions of modern clean diesel technology to produce dramatic reductions in both emissions and fuel consumption while offering superior vehicle performance and the benefit of using existing fueling infrastructures.

Understanding Hybrid-Electric Vehicles

The term "hybrid vehicle" refers to a vehicle with at least two sources of power. A "hybrid-electric vehicle" indicates that one source of power is provided by an electric motor. The other source of motive power can come from a number of different technologies, but is typically provided by an internal combustion engine designed to run on either gasoline or diesel fuel. The term "diesel-electric hybrid" describes an HEV that combines the power of a diesel engine with an electric motor.

The diesel engine in a diesel electric hybrid vehicle generates electricity for the electric motor, and in some cases can also power the vehicle directly (See "Series vs. Parallel Hybrids" below). HEVs are fueled just like their more traditional counterparts with conventional diesel fuel. HEVs generate all the electricity they need on-board and never need to be recharged before use. The diesel fuel powers an internal combustion engine that is usually smaller (and thus more efficient) than a conventional engine, which works along with an electric motor to provide the same power as a larger engine. The electric motor derives its power from an alternator or generator that is coupled with an energy storage device (such as a set of batteries or a supercapacitor).

Sources of Hybrid Efficiency and Emissions Reductions

Whenever a power system transfers energy from one form to another – such as a hybrid's conversion of mechanical energy into electricity and then back again – the system will experience a decrease in energy efficiency. Hybrid electric vehicles offset those losses in a number of ways which, when combined, produce a significant net gain in efficiency and related emissions reductions. These aspects of the HEV system are able to save so much energy that the vehicle as a whole overcomes these initial conversion losses. There are four primary sources of efficiency and emissions reduction found in hybrids:

- **Smaller Engine Size:** Most traditionally "direct drive" vehicle engines are sized to provide enough power for relatively infrequent, fast accelerations. In the more frequent cruising mode, these engines are much larger than they need to be. By adding an electric motor to deliver partial or complete power during accelerations, an HEV can be equipped with a smaller, more efficient combustion engine while providing acceleration performance equal to its conventional counterpart.
- **Regenerative Braking:** Regenerative braking recovers energy normally lost as heat during braking, and stores it in the batteries for later use by the electric motor. Therefore, the engine-powered generator is used to produce electric energy only when regenerative braking does not provide a full charge.
- **Power-On-Demand:** HEVs can temporarily shut off the combustion engine during idle or coasting modes, when the electric motor alone can provide sufficient power to keep the vehicle's systems running without burning petroleum fuel.
- **Constant Engine Speeds and Power Output:** In a hybrid application, the diesel engine can be designed to operate more consistently at its optimum engine speed, power output and operating temperature to increase fuel efficiency and reduce emissions. In a series hybrid

this is done by providing power only to the electric generator rather than to the wheels directly. In a parallel hybrid, the diesel engine only powers the wheels directly when it is operating and optimum speeds. This at relatively constant, optimum performance level also improves the performance of emissions control technologies.

Series vs. Parallel Hybrids

There are two principal types of HEV, "Series" and "Parallel"

In a **series hybrid**, the engine is not directly linked to the transmission for mechanical driving power. Rather, all of the energy produced from the engine is converted to electric, power by the generator which re-charges the energy storage device in order to provide power to one or more electric motors. The electric motor system – by itself – provides torque to turn the wheels of the vehicle. Because the combustion engine is not directly connected to the wheels, it can operate at a more optimum rate and can be automatically (or sometimes manually) switched off for temporary all-electric, zero-emission operation. Series hybrids are well-suited for lightweight commuting vehicles and stop-and-go transit buses.

In a **parallel hybrid**, both the combustion engine and the electric motor have direct, independent connections to the transmission. Either power source –or both of them together-can be used to turn the vehicle's wheels. These vehicles are often designed so that the combustion engine provides power at high, constant speeds; the electric motor provides power during stops and at low speeds; and both power sources work together during accelerations. Parallel hybrids are well-suited to improve the fuel economy of higher performing vehicles.

Evolution of Diesel Hybrid Vehicles

In 1993, seven federal agencies and the nation's Big Three automakers entered a cooperative research and development program called the Partnership for a New Generation of Vehicles (PNGV) to develop family-size sedans that would triple fuel efficiency while maintaining all levels of performance. In 2000, General Motors, Ford and DaimlerChrysler all unveiled PNGV concept cars achieving between 70 and 80 mpg due to the combination of diesel power's thermal efficiency with the latest advances in hybrid technology. Several automobile manufacturers have produced diesel hybrid concept cars or issued press releases about future offerings, however the incremental costs of both diesel and hybrid powertrain technologies have delayed the emergence of light-duty HEVs. In the heavy-duty vehicle sector, this dual power system can add more power at low engine speeds and improve diesel's existing efficiencies, making them particularly beneficial when used in stop-and-go operations such as transit buses and urban delivery trucks. As a result, these are the first areas where such vehicles have become commercially available.

Diesel Electric Hybrid Buses

To date, the largest application of diesel-electric hybrid technology has occurred in urban transit buses. Public transportation managers are often under political and regulatory pressure to reduce emissions and cut fuel consumption. New York City currently has the largest diesel hybrid transit bus fleet in the world, reaching 1,700 when the current order of 850 is filled by 2010. Sizeable diesel-electric hybrid bus fleets are also operating in several other cities across the country, including Seattle, Washington, DC and San Francisco.

Over the last several years, the Department of Energy's National Renewable Energy Lab has studied the performance of these buses in New York and Seattle. In its most recent review of New York City transit buses, NREL found the diesel hybrids to be 22 percent more fuel efficient than conventional diesel buses and 43 percent more fuel efficient than CNG buses. They also found the total maintenance costs of the diesel hybrid buses to be 42 lower than the CNG buses. These benefits are driving many transit agencies to invest in diesel hybrid buses despite their somewhat higher cost. According to the American Public Transportation Association's Public Transportation Vehicle Database, 30 percent of all U.S. transit bus order for 2008 were for diesel hybrids. When looking at the nation's 10 largest transit agencies, this percentage rose to 77 percent, and 67 percent for the top 20 agencies.

Diesel-Electric Hybrid Trucks and Buses

Diesel hybrid technology's success in the transit bus world is now being followed in the heavy duty truck and bus market. The most promising truck applications for this technology has been in the refuse, utility and delivery sectors. Fed-Ex did much to propel the commercialization of this technology when it announced in 2000 that it would convert its entire fleet of medium-weight pickup/delivery trucks into diesel hybrids. It has since chosen to work with Eaton Corporation in pursuit of this goal, beginning with an initial pilot fleet of 20 hybrid delivery trucks and growing into the largest fleet of commercial hybrid trucks in North America. Truck performance to date has been exceptional, meeting expectations of a 96 percent reduction in PM, a 65 percent reduction in NOx, and increased fuel efficiency of 57 percent.

As a result of the Energy Policy Act of 2005, purchasers of heavy-duty diesel hybrid electric vehicles are eligible for a one-time federal tax credit. The tax credits were effective in late 2005 and are set to expire on December 31, 2010. They range in amount from $4,500 to $12,000 per vehicle.

Qualified Heavy Hybrid Vehicles			
Year	**Vehicle Description**	**Vehicle Weight**	**Credit Amount**
2007	**Freightlinter MT45** with Utilitmaster body, and Eaton 44KW Hybrid Electric System	14,001 - 26,000 lbs.	$4,500
2007	**International Model 4300SBA 4X2** with Eaton Hybrid Electric System	14,001 - 26,000 lbs.	$6,000
2007	**International Model 4300SBA 4X2** with Eaton Hybrid Electric System	26,000 lbs. or more	$12,000
2008	**Kenworth Model T270** utility boom vehicle with Eaton Hybrid System	19,501 - 26,000 lbs.	$6,000
2008	**Kenworth Model T230** utility boom vehicle with Eaton Hybrid System	>26,000 lbs.	$12,000
2008	**Kenworth Model T270** package delivery vehicle with Eaton Hybrid System	19,501 - 26,000 lbs.	$6,000
2008	**Kenworth Model T370** package delivery vehicle with Eaton Hybrid System	>26,000 lbs.	$12,000
2008	**Peterbilt Model 330** utility boom vehicle with Eaton Hybrid system	19,501 - 26,000 lbs.	$6,000
2008	**Peterbilt Model 335** utility boom vehicle with Eaton Hybrid system	>26,000 lbs.	$12,000
2008	**Peterbilt Model 330** package delivery vehicle with Eaton Hybrid system	19,501 - 26,000 lbs.	$6,000
2008	**Peterbilt Model 335** package delivery vehicle with Eaton Hybrid system	>26,000 lbs.	$12,000

Thanks to the Hybrid Truck Users Forum, several fast track projects were developed to speed the commercialization of this technology. One national pilot project for diesel hybrid utility trucks has shown 50% fuel economy benefits together with exceptional reliability. Progress is also being made on the commercialization of diesel hybrid school buses, refuse and long-haul trucks. More detailed information about the development of products for these and other markets is available at www.htuf.org.

Conclusion

As businesses seek ways to conserve fuel and reduce emissions, diesel hybrid technology provides a trusted, cost-effective solution. The combination of diesel and electric power sources maximizes diesel's inherent efficiencies, thereby transforming this trusted, reliable technology into an emerging advanced transportation solution. The technology's expansion into other vehicle types and sizes, along with greater volumes of renewable diesel fuel will contribute to the achievement of national, state and local economic and environmental goals.