Department of Commerce
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# Commercial Vehicle and Fuel Technologies

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Commercial vehicles consume nearly 40% of the US transportation energy budget and encompass an incredibly wide range of vehicle types and configurations. These vehicles are primarily involved in moving freight or passengers. The principal commercial vehicle subcategories discussed include on-road freight, commercial aircraft, commercial watercraft, and rail. Aircraft, watercraft and rail include passenger and freight subcategories, but generally these are similar types of vehicles and propulsion systems. Technology and cost forecasts for future commercial vehicles were primarily drawn from a National Research Council and US Department of Energy publications, which concluded that significant reductions in commercial vehicle fuel consumption can be realized with current and emerging technologies. Commercial vehicles can also use alternative fuels to displace petroleum fuels, but technology, infrastructure cost and feedstock availability challenges remain for these. Intermodal shifting from plane and car transport to rail can also provide significant reductions in fuel use, but requires substantial long-term infrastructure investment.

## Medium and Heavy Duty Vehicles

On-road freight transport by medium and heavy duty vehicles (MHDVs) is the largest subcategory, comprising about 22 %of total transportation energy nationwide in 2007 (Figure 1). This subcategory has slowly but steadily been increasing its share of the total transportation energy budget as the level of imports has grown and more consumer goods are moved around the nation. In 2007 the Energy Independence and Security Act for the first time gave the EPA and NHTSA authority to set standards for medium and heavy duty freight vehicles *EPA Heavy Duty Vehicle Regulations*.

On-road freight is the most complex category of commercial vehicles, encompassing a wide range of vehicles designs. Some, like tractor trailer units, frequently run long distances at highway speeds, while others, such as garbage trucks, experience stop and go situations. Because of the large differences in load and duty cycles, the technologies employed to reduce fuel consumption vary depending on vehicle design.

The National Research Council (NRC) published a detailed report in 2010, *Technologies and Approaches for Reducing Fuel Consumption in Medium and Heavy Duty Vehicles*, which evaluated mid-term technologies available to reduce the fuel consumption of MHDVs. The technology categories include engine and transmission improvements, tire and wheel improvements, electric hybridization, weight reduction and aerodynamic improvements. Figure 2 illustrates the potential reduction in fuel consumption associated with several technologies, for seven different vehicle configurations. As expected tractor trailers benefit from engine and aerodynamic improvements but less so from electric hybridization, whereas for vehicles that have stop and go duty cycles the converse holds. In addition, long haul tractor trailers can use a significant amount of fuel heating or cooling the truck cab when the driver is resting or sleeping. To avoid running the primary diesel engine, thus reducing fuel consumption and emissions, small Auxiliary Power Units (APUs) are becoming available and some truck stops and rest areas provide electric connections to run the truck heating and cooling equipment and other auxiliary electric loads.

**FIGURE 1: 2007 US Transportation Sector Energy Consumption by Type and Mode (EIA).**

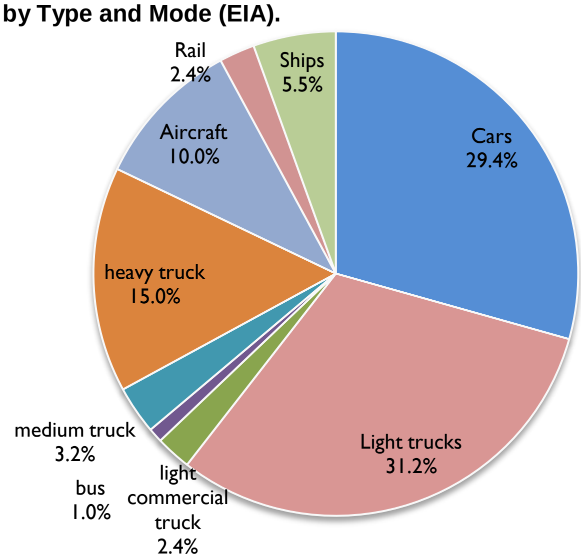
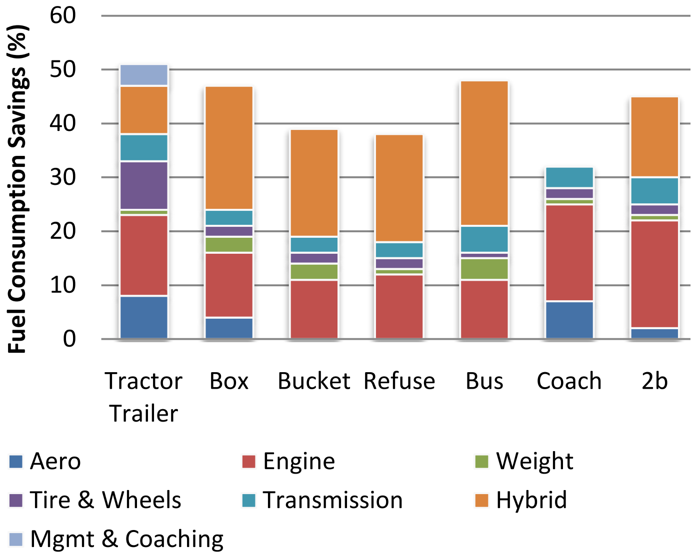


**FIGURE 2: Comparison of 2015-2020 new-vehicle potential fuel-saving technologies for seven vehicle types: tractor trailer, Class 3-6 box, Class 3-6 bucket, Class 8 refuse, transit bus, motor coach, and Class 2b pickups and vans. (National Research Council, 2010)**




Implementing all technologies in the NRC package may not be economical from a vehicle owner's perspective as the breakeven fuel prices, far column, in Table 1 indicate. Electric hybridization in particular, reduces fuel consumption by 25 to 30% but can add up to 40% to the cost of a vehicle. It therefore requires a consistently higher fuel price in order for the vehicle owner to recoup the higher initial cost of the hybrid vehicle. Companies such as UPS, FedEx and Coca Cola have purchased or converted more than a thousand delivery vehicles in total to diesel or gas electric hybrids. In 2009 municipal and county transit authorities added 1300 hybrid buses (1/3 of fleet additions) and operated over 4500 hybrid buses (7% of the transit bus fleet).

Compressed natural gas (CNG) powered MHDVs also hold significant promise, especially with steadily rising diesel prices. Currently CNG is about half the price of diesel on an energy equivalent basis, providing a strong incentive for CNG powered MDHVs. This is countered by the approximately 30% higher cost for CNG vehicles. Because refueling infrastructure is limited and costly to install, CNG is usually seen as a better fit for large fleets of short-range vehicles or local delivery vehicles such as buses and refuse trucks. United Parcel Service has experimented with CNG powered delivery trucks and tractor trailers with good results, and has plans to expand its CNG fleet. A number of transit agencies, including Pierce Transit, have also made the switch to CNG powered buses. Approximately 18% of transit buses are CNG powered. Numerous refuse hauling fleets have switched to CNG power and some have begun to use biogas derived from landfills. An added benefit of CNG powered buses and refuse trucks is that exposure to diesel fine particulate matter, a recognized health hazard, is eliminated. Federal legislation (H.R. 1380) recently proposed a subsidy for the production and purchase of natural gas powered vehicles.

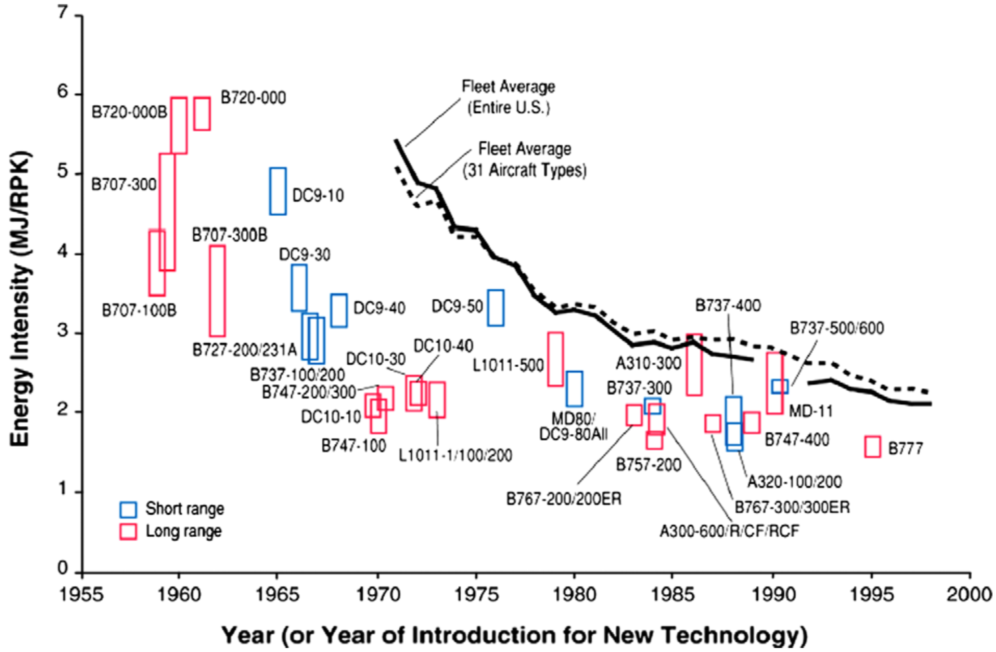
Biodiesel is also a realistic option to replace petroleum-based diesel used by MHDVs and other types of commercial vehicles. Many private fleets are already using blends of biodiesel in the 2 – 20% range. Another option is coal-to-liquids (CTL), which has been deployed for decades in South Africa. Both these alternative fuels can reduce dependence on foreign oil. Biodiesel offers, additionally, substantial reductions in greenhouse gas emissions and conventional pollutants, while CTL results in increased emissions. Challenges confronting biodiesel and CTL include cost, feedstock limitations, manufacturing capacity, and lack of distribution systems. The NRC's *Liquid Transportation Fuels from Coal to Biomass* (2009) provides estimates for the U.S. technical potentials for coal-to-liquids and biofuels through the year 2035 in the U.S. Reliable estimates of potential biodiesel penetration by 2035 are not available, but CTL could replace up to 25% of petroleum used for transportation by 2035, but this requires a 50% increase in coal mining. The costs to produce biodiesel or CTL fuel currently exceed the cost to produce petroleum based diesel, but several new cost-reducing technologies may make it possible to reach at least portions of these technical potentials.

**TABLE 1 Fuel Consumption Reduction Potential for Typical New Vehicles, 2015-2020, and Cost-Effectiveness Comparisons for Seven Vehicle Configurations. NRC 2010**

| | | | cost-effectiveness metric | |
|---|---|---|---|---|
| vehicle class | fuel reduction | capital cost ($)per vehicle | $ spent per % fuel saved | breakeven fuel price ($/gal) |
| Tractor-trailer | 51% | 84,600 | 1,670 | 1.10 |
| Class 6 box truck | 47% | 43,120 | 920 | 4.20 |
| Class 6 bucket truck | 50% | 49,870 | 1,010 | 5.40 |
| Class 2b pickup | 45% | 14,710 | 330 | 4.80 |
| Refuse truck | 38% | 50,800 | 1,320 | 2.70 |
| Transit bus | 48% | 250,400 | 5,230 | 6.80 |

# Aircraft

FIGURE 3: Comparison of fuel economy for aircraft (Lee, 2010)




Commercial aircraft account for 10% of the national transportation energy budget, but are not subject to fuel economy regulations like LDVs or MDHVs. However, airlines have a strong incentive to manage expenditures on fuel. Despite growing demand for air travel, the total amount of energy consumed by commercial aircraft has remained constant for about a decade as more efficient new aircraft replace older aircraft and better corporate management has reduced fuel use per passenger mile. Fuel consumption per passenger or ton mile has been decreasing for decades as more efficient aircraft models have been introduced. For discussion see: *Can We Accelerate the Improvements of Energy Efficiency in Aircraft Systems?*

Technologies have reduced total aircraft fuel consumption since the 1970s through measures which include: engine efficiency 57%, increased aerodynamic efficiency 22%, more efficient use of aircraft capacity 17%, and 4% from increased aircraft size (Lee, 2010). Figure 3 illustrates the decline in aircraft fuel consumption.

The figure suggests that the rate of fuel consumption improvement is slowing due to technological maturing, but that some modest reductions can be expected over the next couple of decades. New composite aircraft such as the Boeing 787 and the Airbus 350, though more costly, are expected to further reduce fuel consumption by 15 to 20%. Operational measures such as single engine taxiing, slight reductions in cruising speeds and lower weight limits for luggage can also reduce per passenger fuel consumption.

In addition there is the opportunity to blend biofuels into conventional jet fuel. Sustainable Aviation Fuels Northwest (SAFN) was recently formed to promote the use of biofuels in aircraft. The report indicates that because commercial aircrafts are normally fueled only at major airports for a limited number of commercial users, there will be opportunities to quickly develop a supply chain and encourage widespread usage. Biojet is in early development and various feedstock such as oilseeds, forest residues, solid wastes, and algae are all being considered. The Pacific Northwest has abundant stocks of such biomass as well as the nation's largest commercial aircraft manufacturer, and this may enable the region to be a biojet development leader.

# Watercraft

Over the next two to three decades ocean-going commercial ships will continue to reduce fuel consumption via incremental gains in power system efficiency and power management. Reductions in fuel consumption can also be achieved by trip management measures (factoring in weather, ocean currents, ship speed) and ship maintenance (hull and engine upkeep). Ships also have the opportunity to reduce fuel use and emissions when in port by plugging into the local grid instead of running diesel or fuel oil generators. Several west coast ports are pursuing this option. Short haul watercraft, such as our state ferry fleet, will also benefit from incremental power system and maintenance measures. Short haul vessels may also be able to switch to alternative fuels such as biodiesel or natural gas. For several years the Washington State Ferry (WSF) system has been blending biodiesel with conventional diesel. The WSF system is also exploring the possibility of acquiring vessels powered by liquefied natural gas (LNG). There is the potential for significant reductions in fuel expenditures and emissions by switching to LNG. R. M. Stockholm (2002) reported that several LNG ferries are being used in Norway, and are generally well regarded. The challenges for LNG ferries are higher initial cost, the need to develop new refueling infrastructure, and public acceptance.

Like urban freight vehicles with their stop and go duty cycle, ferry boats and some cruise ships lend themselves to hybrid diesel electric propulsion. Diesel electric hybrid systems are more expensive, but offer operational advantages and fuel savings.

## Rail

Hurst (2009) reported that the fuel efficiency of freight trains has increased by 80% (40% decrease in fuel consumption) over the past 25 years. Like MHDV and watercraft, railroad locomotives power systems will continue to benefit from incremental efficiency improvements. The US Department of Energy, in its *21st Century Locomotive Technology program*, has provided funding for improving rail fuel efficiency and set a goal to improve efficiency for locomotives by 50% between 2000 and 2025: from 393 to 590 ton-miles/gal. The technologies to achieve this goal include improved diesel engine design and power control operation, and development of hybrid electric propulsion systems. Alternatively, fuel consumption can be dramatically reduced by converting rail lines to electric propulsion systems, as has been done in Europe and Japan. This switch has large initial capital costs and can take many years to implement. For local passenger rail, especially when new lines are being installed, electrification typically makes economic sense.

Freight trains often have the potential to replace long-distance freight trucks. Fascanha and Horvath (2007) estimate that freight trains use only about one sixth the fuel of MHDVs per ton-mile, implying large potential reductions in VMT and GHGs. Similarly, passenger rail has a potential to reduce fuel use by replacing mid-to-long-distance personal vehicle trips and short-distance air travel (Center for Clean Air Policy, 2006). The principal obstacle to expanding the use of freight and passenger trains is however not technology, but the limited capacity of current rail tracks. For instance, Washington still has a long stretch of single-track segment in the heavily used corridor near Edmonds, and an outdated track configuration near the Port of Vancouver which causes periodic formation of train queues. The Washington Department of Transportation (WSDOT, 2009) projects that the growing demand for both freight and passenger rail will exceed the capacity on the rail corridor along I-5 by the year 2018. The different operating speeds and practices between freight and passenger rail also pose scheduling difficulties. WSDOT's *Washington State 2010-2030 Freight Rail Plan* details its efforts to increase corridor capacity through a series of incremental improvements such as an advanced train control system and new bypass tracks, but implementation requires close cooperation with the track owners.

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