1.1.2 HEAVY VEHICLES

Technology Description

Freight vehicles (Class 7 and 8 trucks and rail) and commercial delivery vehicles (Class 2b through Class 6) are essential to the economic vitality of the nation. Diesel engines are the dominant motive source for these vehicles. Vehicle efficiency could be increased by as much as 50%, if all current research areas such as a new generation of ultra-high-efficiency diesel engines (using advanced emissions-control technology) and reduced aerodynamic drag, rolling resistance, and parasitic power losses are successful. Development and commercialization of trucks with higher efficiency will significantly reduce transportation oil use, emissions (including CO_2), and related costs to the economy. Increased use of lightweight materials will contribute to these goals. Hybrid propulsion systems have the potential to double the fuel economy of heavy-duty vehicles, such as buses or delivery vehicles, over urban driving cycles.

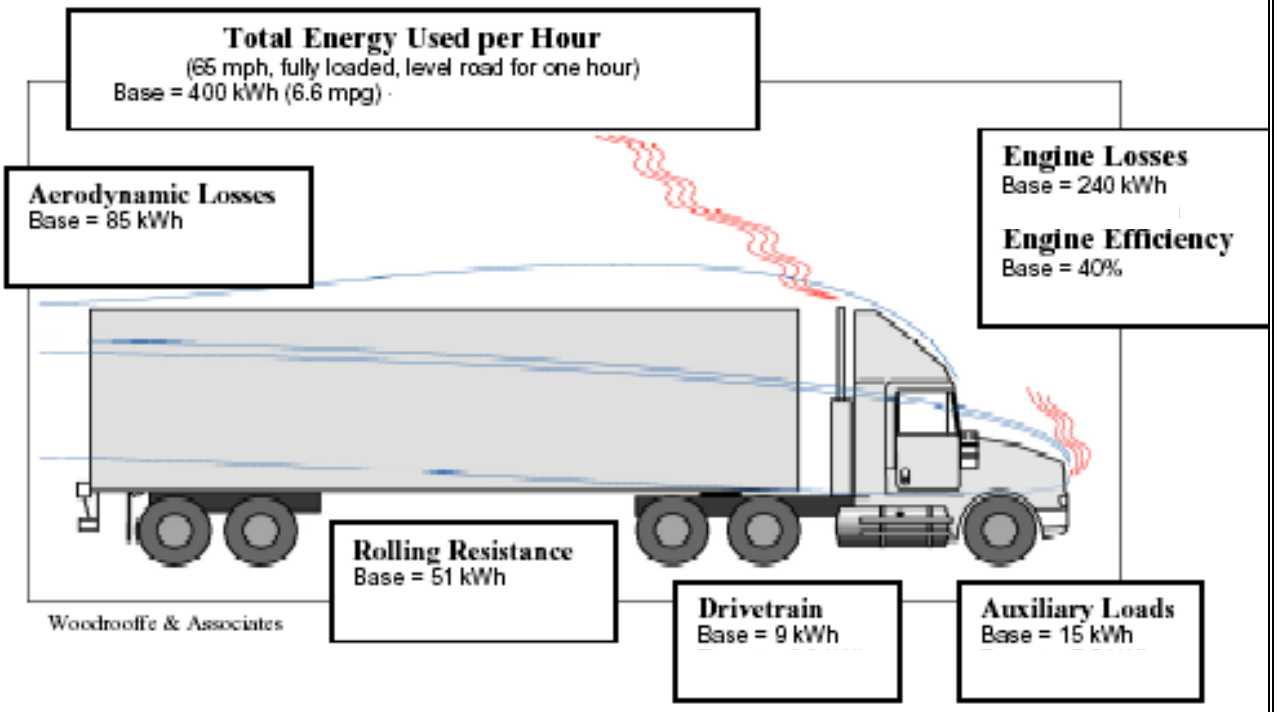

Fig. 4.1. Class 8 truck energy audit.

System Concepts

- Four-stroke, direct-injection diesel engines (with high peak-cylinder pressures, thermal barrier coatings, high-pressure fuel injection systems, and turbocharging) are being developed.
- Lightweight materials, truck aerodynamics, and advanced tires are being developed to improve overall fuel economy.
- Hybrid vehicles with regenerative braking may have application in local delivery vehicles and buses.
- Vehicle electrification can reduce parasitic losses from auxiliary loads and help reduce idling losses.

Representative Technologies

- High-pressure, common-rail fuel injection, bottoming cycles, and friction and wear reduction.
- Software technology to improve vehicle aerodynamics.
- Advanced power electronics, energy storage, hybrid powertrains, and lightweight materials technologies.

Technology Status/Applications

- Virtually all heavy-duty trucks and the entire fleet of locomotives are diesel powered, and there is an increasing trend to convert medium-duty trucks to diesel fuel as well. Advanced combustion concepts –

resulting in higher efficiency and lower emissions while maintaining power density – are needed. New advanced technologies for emission controls are required.
- Fuel cells are only considered a long-term option for heavy-duty trucks (except for truck auxiliary power units) due to hydrogen storage limitations. Fuel cell bus applications are seen as near term. A locomotive fuel cells program is being pursued by industry.
- Software tools are being developed to provide design guidance to reduce aerodynamic drag.

Current Research, Development, and Demonstration

RD&D Goals

- Engine systems including the integration of fuel, engine, and aftertreatment. Specific technology goals are:
  - Development and demonstration of a commercially viable, emissions-compliant engine system for Class 7-8 highway trucks that improves the engine system efficiency from the current 40% to 50%) by 2010 and demonstrate 55% efficiency in the laboratory by 2013.
- Parasitic losses account for 40% of the total fuel energy used to move a heavy vehicle down the road. These losses arise from aerodynamic resistance, rolling resistances, drivetrain, and auxiliary load losses. Specific 2012 technology goals are:
  - Develop and demonstrate advanced technology concepts that reduce the aerodynamic drag of a Class 8 tractor-trailer combination by 20% (from current 85 kWh to 68 kWh) in a practical, efficient, and commercially viable manner.
  - Develop and demonstrate commercially viable technologies that reduce auxiliary loads by 50% (from current 15 kWh to 7.5 kWh) for Class 8 tractor-trailers.
  - Develop and demonstrate commercially viable lightweight material and manufacturing processes that lead to a 5,000-pound reduction in Class 8 tractor-trailer combinations (a 15%-20% weight reduction)
  - Develop and demonstrate commercially viable technologies that increase heat-load rejected by thermal management systems by 20% without increasing radiator size.
- Class 7 and 8 trucks, alone, consume more than 825 million gallons of diesel fuel per year when idling. Technology goals are to reduce fuel use and emissions from idling heavy vehicles by greater than 65%. Specific technology goals are:
  - Develop and demonstrate a commercially viable fuel cell auxiliary power unit system in the 5-30kW range, capable of operating on diesel fuel at a delivered cost of $400/kW by 2012.

RD&D Challenges

- Technical challenges exist to improving engine efficiency, thus reducing CO_2 emissions, while meeting emission regulations
- Safety, durability, and reliability of new technology are being demanded by industry and required by other government agencies, all of which can add cost and weight.
- Meeting tighter emissions regulations can result in an additional load on the engine – such as additional backpressure – which can increase fuel consumption.

RD&D Activities

- DOE is working closely with industry in the 21st Century Truck Partnership.
- DOE programs and the Advanced Heavy-Duty Hybrid Propulsion System (AHHPS) industry teams are analyzing, developing, and validating a range of heavy hybrid vehicles, including Class 3-8 trucks and buses, to define system architecture, optimize control strategy, and quantify component requirements.
- Much heavy-vehicle testing is done at DOE's Renewable Fuels and Lubricants Laboratory, and EPA's National Vehicle Fuel Emissions Laboratory.
- Department of Defense Advanced Research Projects Agency, California Energy Commission, and the California Air Resources Board cosponsor R&D projects with DOE.
- DOE sponsors analytical and modeling work.

Recent Progress

- Under the AHHPS project, a validation truck and bus were developed, and tested (laboratory and field) successfully.

- An interim goal of 45% efficiency was achieved in heavy-duty multicylinder engines.
- Prototype engines operating in new combustion regimes have demonstrated, in the laboratory, 90% lower NOx and particulate matter – and with equal power density to that of conventional combustion engines.
- Demonstrated 51% reduction in aerodynamic drag for Class 8 trucks in wind tunnel tests.
- Electrification of underhood components – such as air compressors, water pumps, and oil pumps – was shown to reduce fuel consumption by up to 18%.

Commercialization and Deployment Activities

- The diesel engine is the workhorse of all the heavy-duty transport modes that are responsible for most of the nation's intercity freight movement, the lifeblood of the economy. Because of low fuel consumption, high reliability, and long service life, it is widely acknowledged that the diesel engine will continue to dominate heavy-duty transport propulsion for many years.
- Prominent participants in the heavy vehicle industry, DOE and others, through cost-shared R&D activities, are employing strategies to introduce advanced heavy-vehicle technologies into the marketplace.
- With DOE assistance, Cummins Engine, John Deere Company, and Mack Trucks have introduced heavy-duty natural gas engines with high efficiency, power ratings, and torque that maintain very low emissions.
- All new technologies must meet high durability requirements.

Market Context

- Stiff domestic and international competition from European and Japanese diesel-engine manufacturers has reduced domestic market share. U.S. manufacturers have limited resources to identify, research, develop, and commercialize many of the promising advanced emission technologies. Effective partnership with national labs is essential for successful completion of advanced automotive research activities. The market encompasses all commercial highway vehicles with some benefit to off-highway vehicles from advanced combustion-engine improvements.