

HD Perspective on Greenhouse Gas Reductions

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For HD Engine Manufacturers

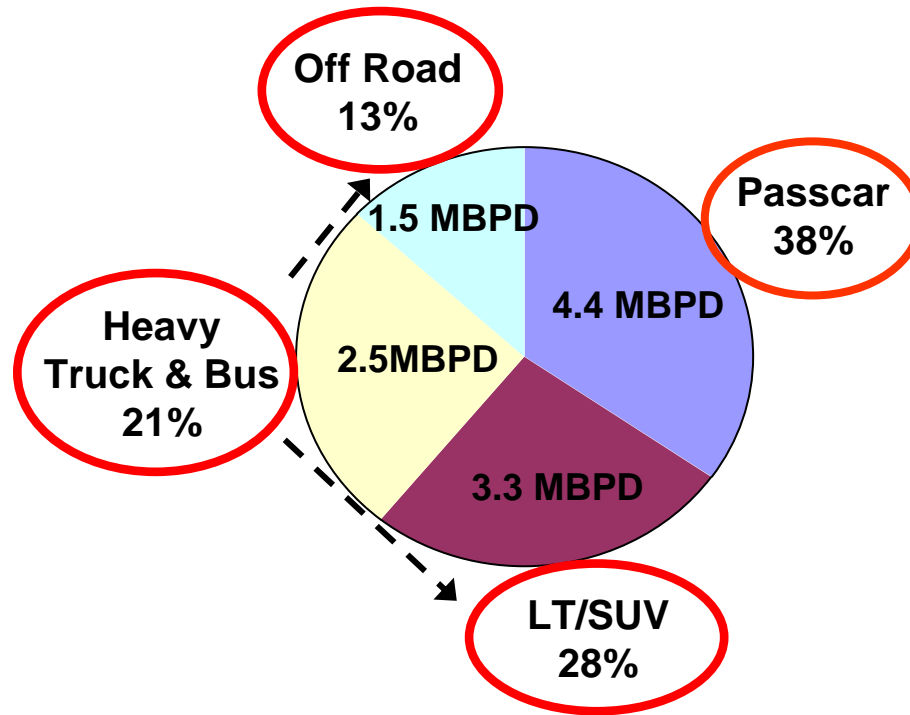


Commercial Vehicles Vital to the Economy

- Over 90% freight moved by diesel power
- 75-80% of the \$\$ move by truck
- Estimated 25-35% of production inventory is rolling as we speak
- JIT and e-commerce, upward impact on demand and modal mix
- Unlike passenger vehicles can't simply downsize the vehicle and still move the freight



Surface Transportation Fuel Use



**Total U.S. Surface Transportation
Diesel + Gasoline Fuel Use: 11.7
MBPD (Million Barrels Per Day)**

Trans. Energy Data Book, Edition 25, 2006

Class 8 Trucks Share of Heavy Duty Truck Fuel Use

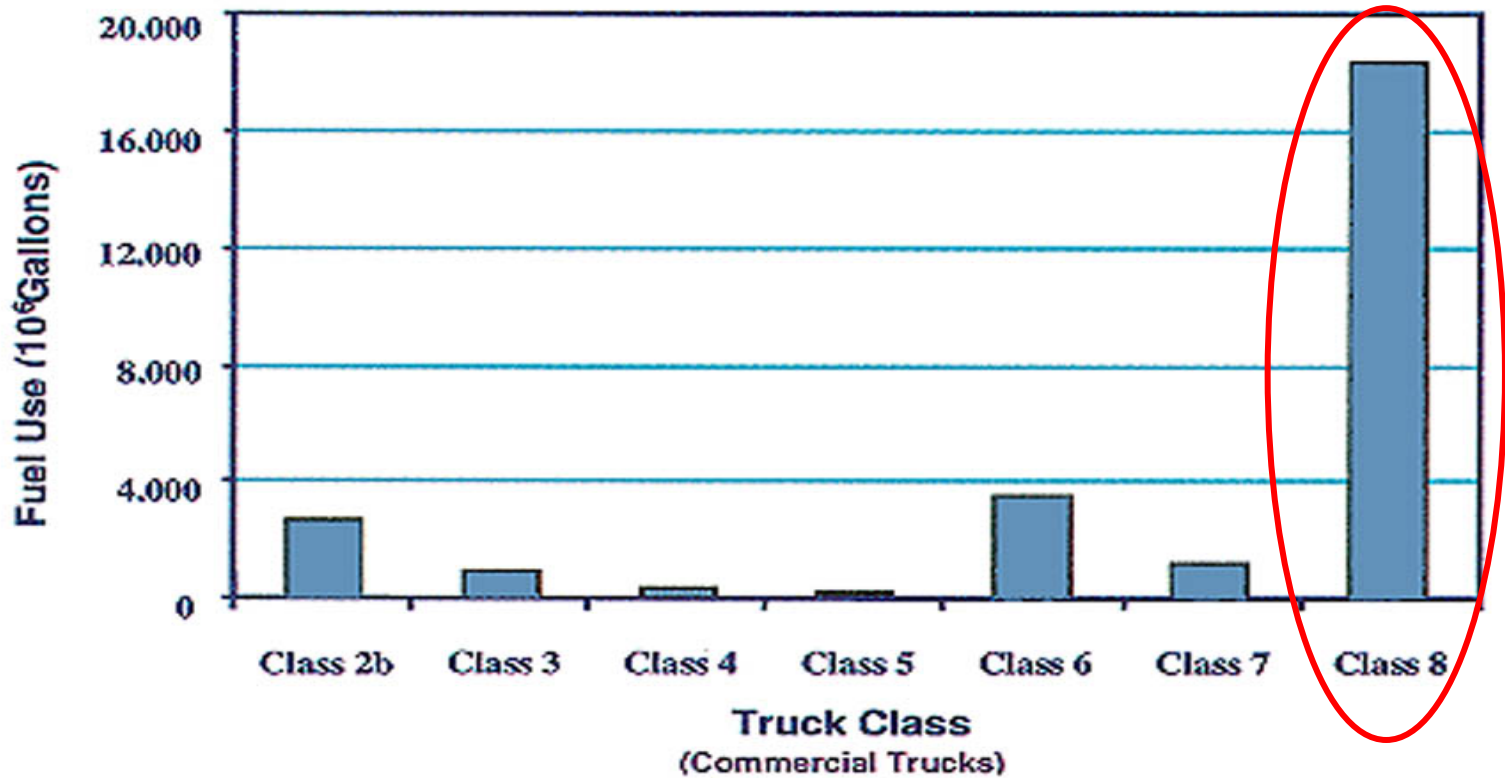


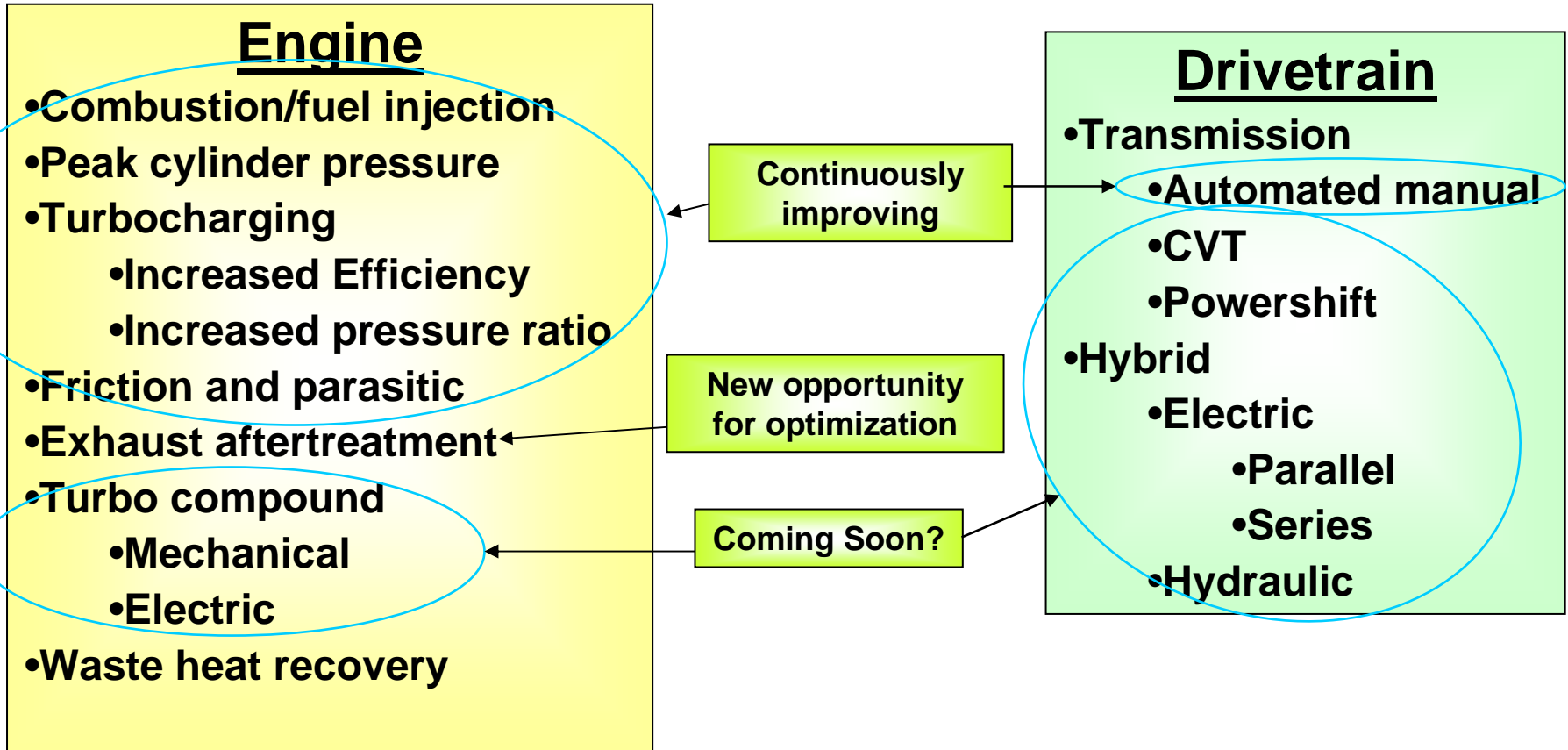
Fig. 3.2. Annual fuel use by commercial trucks (based on VIUS data).

Source: 21st Century Truck Technical Roadmap – 2001

Commercial Customers Provide Incentive

- Commercial customers demand fuel economy from their powertrain and vehicle suppliers
 - 120,000 annual VMT not uncommon
 - 6mpg fuel economy is optimal
 - Assume \$3.00/gallon fuel price
 - At 2% fuel economy improvement, \$1200/year per unit savings
 - For a fleet of 100 units, this represent \$120,000/year
- Fleet decisions can often be made over a 1.5% to 2.0% difference in fuel economy

Key Factors in HD Truck Efficiency -- Powertrain



Key Factors in HD Truck Efficiency -- Vehicle

Tractor

- Aerodynamics
 - Frontal area
 - Side skirts
 - Roof fairings
 - Mirrors
 - Air blowing
- Rolling Resistance
 - Super single tires
 - Proper inflation
- Reduced Mass

Trailers

- Rolling resistance
 - Super Single tires
 - Rolling resistance
- Aerodynamics
 - Side skirts
 - Boat tail
- Weight

Integration

- Matching Powertrain to intended load/speed
- Trailer gap
- Accessories
 - Air compressor
 - Air conditioning
 - Cooling system
 - Power steering
- Idle management
 - APU
 - Truck stop electrification
 - Energy storage systems

Key Factors in HD Truck Efficiency -- Regulation and Logistic

Regulations and Public policy

- Road Speed limiting
- **Weight limits**
- Trailer combinations
- Length limits
- Driver Hours of Service
- Congestion mitigation
- Incentives (hybrid)
- Education and support
 - EPA SmartWay program

State-to-state inconsistency is a major barrier to efficient freight movement.

Significant gains have been realized in logistics. Still room for improvement

Logistics

- Load management/backloads
- Route Optimization
 - Congestion Avoidance
 - Distance Minimization
- Vehicle management
 - Road speed limiting
 - Driver management
 - Smart gearing
 - Acceleration control
 - Idle management
 - Cruise management via GPS (anticipating grade and speed limit changes)

Biggest Opportunities for Long Haul Trucks



Opportunity	Est. FE Gain	Technology Readiness	Issues/Obstacles
Low rolling resistance tires (super singles) on tractors and trailers	3%	Available for high volume use. Increasingly deployed.	Cost & life factors. Skepticism by operators. Trailer ownership split
Turbo Compound	3-5%	Concept proven with some production, but outside USA.	Cost and reliability Package space
Trailer side skirts	4%	Commercially available	Trailer/truck ratio >3 Trailer ownership split Skirt damage Knowledge/incentives
Mandatory Road Speed limit to 65 MPH (controlled via truck software)	5% average	Available in all class 8 trucks since mid 90's	Drivers paid by mile Car traffic meshing/safety Congressional Action
Eliminate Idling in sleeper mode	5-7%	Available: APU, battery, storage systems, shore power in some stops, engine stop-start systems, Idle aire system	Storage system performance Shore power availability IdleAire system availability & cost Cost & weight for on board systems California APU DPF requirement Stop/start cycle disturbs sleep
Increase weight, length, and trailer combination limits	Fewer trucks needed on road	None required	Safety concerns Road damage concerns State variations
Optimization of powertrain and engine to duty cycle	2-5%	Available	Customer awareness Adequate sales engineering support Variation in duty cycle
Trailer gap reduction	3%	Commercially Available. Deployed in some fleets.	Mix of trailers hauled. Turning radius reduction DPF size

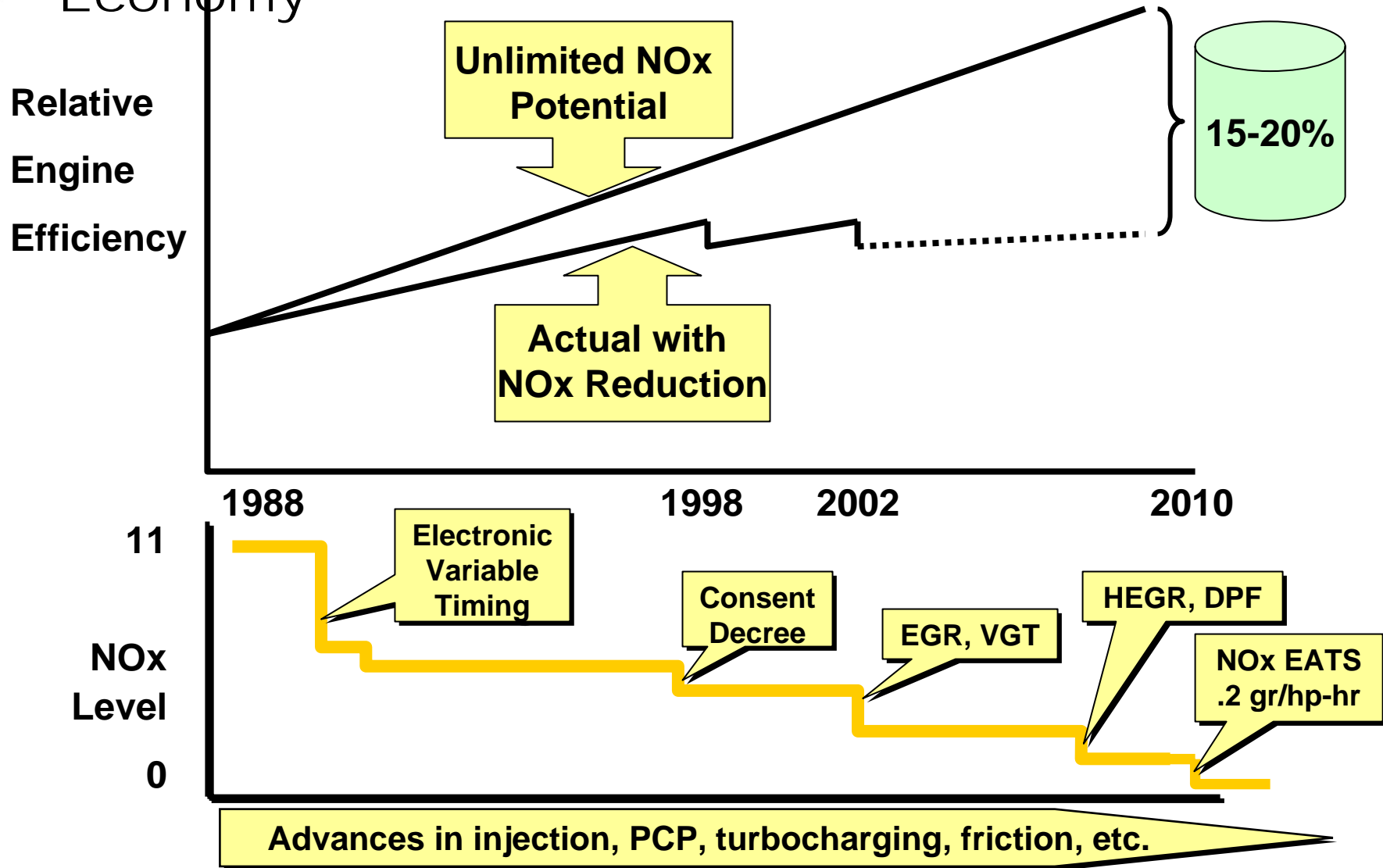


Most Long Haul Tractors are Incorporating Aero Features





Impact of Emissions Regulation on Fuel Economy



Vehicle Electrification/Hybrid

Hybrid for Stop/Go Duty Cycle:

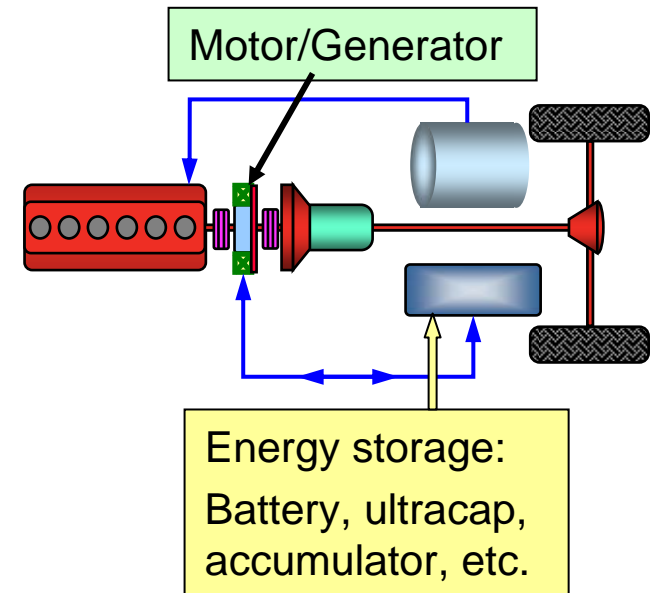
- Improved Fuel Economy (up to 50%)
- Improved Performance
- Reduced Emissions (per Ton-mile)
- Reduced transients and Idle operations
- Recovery/recycling of braking energy
- Quieter Operation
- Eliminates need for APU (uses battery power)

Electric Auxiliaries for Long Haul

- Modulate pumping, fans, air compressor, air conditioning, power steering
- Improved fuel economy
- Improved cooling
- Facilitate reduced idling
- 3-5% Fuel Economy improvement potential

Long Haul Hybrid with Electric Auxiliaries

- Hybrid electrical generator for quick charging of batteries
- Electric turbo-compound with power to auxiliaries and electric motor
- Hybrid battery system to eliminate idle
- 10-15% FE improvement potential (including idle elimination)



Incentives are needed to promote technology introduction until volume is sufficient to lower costs

Appropriateness of Public – Private Partnership

- Large return on national investment
- Industry can only afford very limited amount of higher risk R&D
- By far the greatest payback is to the nation, not the companies
- Heavy duty engine improvements cascade to off-highway and light truck applications
- 50% cost share by engine industry



Significant Outcomes From DOE Collaborative Projects

- Light duty diesel engine technology
 - Tier 2 Bin 3 demonstrated (exceeded Bin 5 goal)
 - Recent product announcement
- 2007 emissions compliant engines with no/minimal fuel penalty
- 45-50 % system efficiency demonstration @ 2010 emissions
- HCCI combustion at commercial engine power density
- DECSE program was a critical consensus enabler for ultra low sulfur fuel

Summary

- Commercial sector important for the economy
- Customers already demand fuel economy
- Improving fuel economy of commercial vehicles is complicated
 - Engines
 - Vehicles
 - Transmissions
 - Tires
 - Aerodynamic features
 - Trailer configurations
 - Etc
- Manufacturers are not integrated as in light duty business
- Integration among suppliers is important in securing the most efficient configuration
- Developing advanced technology is becoming very costly
- Future regulatory burden is confounding ability to make progress in fuel economy
- Public/Private investment is wise