Chapter 7

CLASSES 3 THROUGH 7 MEDIUM TRUCKS

1. Summary
The instantaneous potential for fuel savings from a *State of the Art (SOA*) technology portfolio, netted against a fuel economy penalty of approximately 5–6% for emission-control measures, is 66% when averaged across Classes 3 through 7 (fuel economy improvement of between 72% and 92%). This saving appears achievable at a blended average cost of $0.85 per gallon saved diesel-equivalent fuel (corrected for energy density, VMT (Vehicle Miles Traveled), and value-chain). Our analysis therefore shows that the majority of the 100% improvement target maintained by the Advanced Heavy Hybrid Propulsion System Program [1] could be achieved cost effectively and without internalization of costs other than that of the fuel.

These gains would amount to a total reduction of 0.59 Quads of diesel and gasoline use, or 66%, of the 0.90 Quads EIA *Annual Energy Outlook 2004* (*AEO*) 2025 forecast for these classes. In terms of oil reduction, this would decrease 2025 Class 3–7 use by 101M bbl, or approximately 0.25M bbl/day, at an average cost of $26.04/bbl of crude oil (after $0.18/gal refinery and $0.05/gal distribution value adjustments). These costs are based on the most recently available three- to five-year cost trajectory for Toyota's *Prius* hybrid powertrain, relayed to us via personal communication immediately prior to this writing.

The instantaneous potential for fuel savings from a *Conventional Wisdom* (*CW*) technology portfolio, netted against the same fuel economy penalty due to emission control measures, is 45% when averaged across Classes 3 through 7 (fuel economy improvement of between 72% and 92%). The lower savings arises from the simple assumption of a lower final ratio of diffusion of technologies. This saving appears achievable at a blended average cost of $1.23 per gallon saved diesel and gasoline fuel (corrected for energy density, VMT, and value-chain). It is at a higher cost than the *SOA* technology portfolio due to an assumption of a less aggressive cost trajectory relative to that of Toyota's.

2. Methodology

Classes 3 through 7 consume about 7% of highway vehicle fuel. While we have intentionally chosen to focus the majority of our efforts on Classes 1, 2, and 8 since these segments consume the remaining 93% of fuel, the following represents a rough estimate for the fuel saving potential and related cost of conserved energy for the intervening classes.

Due to their operating cycle, Classes 3 through 7 trucks are prime candidates for diesel engines and hybrid electric powertrains. Already in 1998 a 2x fuel economy improvement appeared quite feasible [2], and that target is maintained in 2004 [1]. More recent comprehensive estimates largely confirm this feasibility [3, p 28 for hybrid-specific data], even on a cost of conserved energy (CCE) basis [6]. We therefore assume that suitable combinations of technologies, particularly hybrid drivetrains deployed on gasoline and diesel engines, identified in this and previous sections will apply. Notably, FedEx® is *presently* deploying its OptiFleet E700 hybridized medium-light trucks, expecting a 50% improvement in fuel economy (i.e. a one-third-less fuel burn), along with a 90% reduction in emissions [4]. However, while planning to replace 30,000 trucks over the next ten years, it is difficult to determine at what cost FedEx is doing this. We have therefore chosen for our aggregate analysis of all classes to use recent MIT [5] and ANL [6] estimates for these five classes.

From [6] we apply the cumulated incremental costs of a combination of achievable parasitic resistance reductions, turbocharging, direct injection, integrated starter-alternator technology, lower engine friction, better injectors and more efficient combustion, and a diesel- and gasoline hybrid electric powertrain. However, for the cost of the hybridization, we update and appropriately scale these figures to functionally match the incremental costs of hybridization of the intervening classes 3–7 with the 2003 costs for mid-size trucks and large cars in [7] with the 2000 hybridization costs for Class 8 trucks in [5].

For the functional relationship we do a least-squares quadratic functional fit to the data of hybridization costs net of all other improvements vs. engine capacity for the otherwise improved vehicles. The power requirements for improved vehicles of Classes 3 to 7 were determined by first deducting the power reduction drop of 17% in [5] from the data on power required by non-improved vehicles in classes 1, 2, and 8. From this engine-adjusted data we then derived power requirements for the intervening Classes 3 through 7

	Average	Trucks, Class 3		Trucks, Classes 4–6		Trucks, Class 7		
	Classes 3–7	*Diesel*	*Gasoline*	*Diesel*	*Gasoline*	*Diesel*	*Gasoline*	Units
BUSINESS AS USUAL								
BAU fuel use, 2025	0.900	0.003	0.154	0.505	0.238	0.246	0.005	Quads
CONVENTIONAL WISDOM								
Fleet techn share by 2025		25%	35%	25%	35%	25%	35%	%
Fuel saved	0.40	0.00	0.03	0.06	0.04	0.03	0.00	Quads
Percentage saved	45%							
CSE	$ 1.23	$ 1.72	$ 1.37	$ 1.82	$ 1.40	$ 0.60	$ 0.46	$/gal
STATE OF THE ART								
Fleet techn share by 2025		100%	100%	100%	100%	100%	100%	%
Fuel saved	0.59	0.00	0.07	0.23	0.12	0.11	0.00	Quads
Percentage saved	66%							
CSE	$ 0.85	$ 1.11	$ 0.88	$ 1.21	$ 0.93	$ 0.40	$ 0.31	$/gal
FLEET								
Total vehicles		10,210	500,266	1,535,649	722,659	203,238	4,148	#
Fuel use by engine		15.42	755.58	2474.52	1164.48	1096	1096	M gal
Total fuel use, 2000		0.00	0.11	0.35	0.16	0.16	0.00	Quads
TRUCK								
Annual mileage		15,650	15,650	13,275	13,275	35,588	35,588	mi/yr-trk
Baseline fuel ec (diesel equiv)		10.4	10.4	7.6	6.8	6.4	5.8	MPG
Baseline fuel use		1,500	1,500	1,750	1,942	5,561	6,170	gal/yr-trk
Net fuel economy gain		77%	86%	85%	98%	77%	89%	%
New fuel economy		18.5	19.4	14.0	13.5	11.4	10.9	MPG
New fuel use		846	805	947	982	3,134	3,267	gal/yr-trk
Annual saved fuel		654	695	804	960	2,426	2,903	gal/yr-trk

from the quadratic regression of curb weight on reduced power using data from classes 1, 2, and 8. While rough, this method captures the need for more power in the heavier vehicle classes, as well as the fact that hybridization ‘per pound of total vehicle mass’ decreases non-linearly with vehicle mass.

However, in a conventional policy setting with conventional fleet diffusion, the average CCE of these improvements amount to $1.44 per gallon of fuel (here a blend of diesel and gasoline). This raises the question: by what percentage the cost of technologies would have to fall in order to break below the $1.00 per gallon of saved fuel. In line with Toyota’s apparent cost trajectory for hybrid powertrains, we assume a 36% and 33% cost-reduction across all technologies for Class 3 and Classes 4 through 7, respectively, giving an average cost of approximately $0.85 per gallon. This reduction appears highly plausible given that Toyota and Honda are very sure of being able to halve their current incremental hybrid cost within 35 years. Additionally, our curves from Classes 1 and 2 illustrate the changes over time from analyses done in 1990, 1995, and 2001.

Assuming the cost and savings-situation in out *SOA* scenario, we find that within the cutoff at $1.00/gal cost of saved fuel, a gross fuel economy improvement of around 77% results for diesels, and about 86% results for gasoline vehicles in Class 3. For vehicles in Classes 4 though 6, an 85% fuel economy improvement results for diesels, and 98% for gasoline. In Class 7, about 77% results for diesels, and about 89% results for gasoline vehicles. These fuel economy gains account for additive and multiplicative effects of non-engine and engine technologies, respectively.

Applying the appropriate annual mileages and harmonic mean fuel economies from [8, Tables 8.4, 5.4, 5.5, and 5.6], we find that netted against a parallel fuel economy penalty of approximately 5–6% for emission-control measures, between 72% and 92% fuel economy gain appears achievable across Classes 3 through 7. This amounts to a total reduction of 0.59 Quads, or 66%, vs. the 0.90 Quads in *AEO* 2025. This would bring 2025 Class 37 diesel and gasoline use to 0.31 Quads from 0.90 Quads.

REFERENCES

1 For details on program and program goals see Advanced Heavy Hybrid Propulsion System Program, EERE, DOE http://www.ctts.nrel.gov/heavyhybrids/index.html, 2004

2 "Multi-Year Program Plan for 1998-2002," Office of Heavy Vehicle Technologies, and Heavy Vehicle Industry Partners, U. S. Department of Energy, Energy Efficiency and Renewable Energy Office of Transportation Technologies, August 1998, p. 40, at http://www.eere.energy.gov/vehiclesandfuels/pdfs/program/program_plan_98-02.pdf

3 O'Keefe, M.P., Hendricks, T.J., and Rehn, R., "A New Composite Drive Cycle for the Evaluation and Test of Heavy Duty Hybrid Electric Class 46 Urban Delivery Vehicles", NREL, presented at the 2003 International Truck and Bus Meeting and Exhibition in Fort Worth, TX, 12 November, 2003 Available online at http://www.ctts.nrel.gov/heavyhybrids/internal/pdfs/its2003.pdf. Paper available from SAE March 2004

4 See http://www.fedex.com/us/about/responsibility/environment/hybridelectricvehicle.html?link=4 for details.

5 Müster, T., "Fuel Savings Potential and Costs Considerations for US Class 8 Heavy Duty Trucks through Resistance Reductions and improved Propulsion Technologies until 2020,", MIT Energy Laboratory, May 2000. Available at http://lfee.mit.edu/publications/reports

6 Vyas, A., Saricks, C., and Stodolsky, F., "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks," Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, IL, 2002

7 Lipman, T.E., and Dilucci, M.A., "Hybrid-Electric Vehicle Design Retail and Lifecycle Cost Analysis", Final Report, UCD-ITS-RR-03-01, Institute of Transportation Studies, UCD, CA, April 2003. Downloadable from www.its.ucdavis.edu/publications/2003/UCD-ITS-RR-03-1.pdf

8 Davis, S., and Diegel, S., "Transportation Energy Data Handbook: Edition 23," Center for Transportation Analysis, Oak Ridge National Laboratory, U.S. Department of Energy, 2003 http://www-cta.ornl.gov/data/Index.html