Taking on the Leadership Challenge in Class 8 Trucking

How To Double Class 8 Truck Efficiency — Profitably

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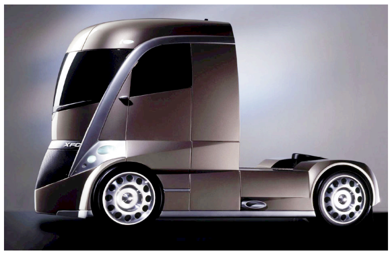
Leadership would give advanced trucks AND profit: Save ~65% of baseline fuel @ average cost of 25¢/gallon

Better aero & tires, better engines, less weight



PACCAR high-eff. concept truck

Colani/Spitzer tanker (Europe), reportedly 11.25 mpg w/o engine changes

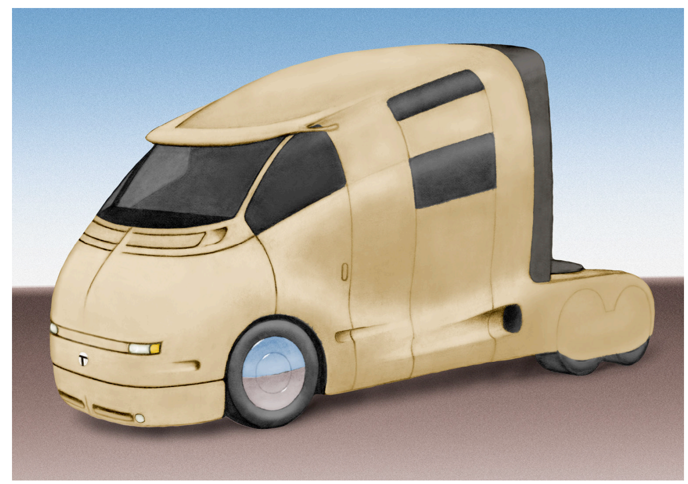
Two recent concept trucks

From 5.5-6.0 mpg to 11.8 mpg @ 60% IRR

- Aero drag, tires, mass, driveline, acc. loads, APU, engine

To ~16 mpg

- Operational & regulatory changes

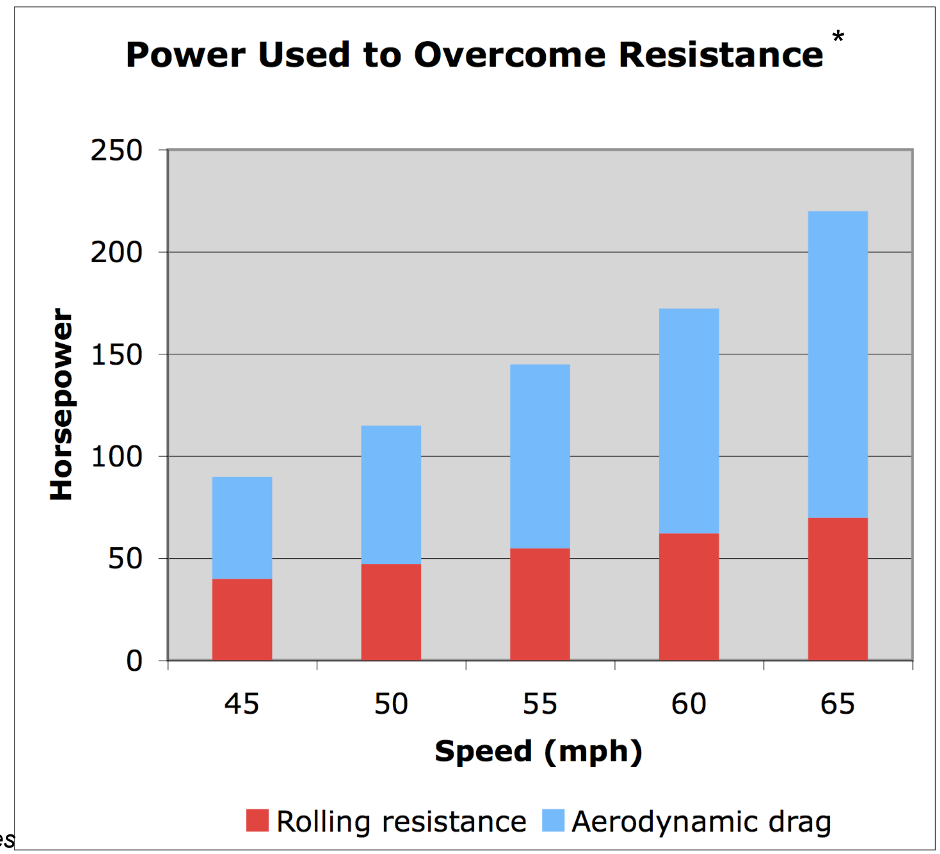


Artist’s rendition, aerodynamic tractor

Big haulers’ margins would double to 6–7% *v.* 2003 baseline

Basic physics: Overcoming aerodynamic resistance consumes the majority of truck fuel on a typical highway

$$E_{TR} = \{ \underbrace{[M + n(I_w/r^2)] \text{ x } dV/dt}_{\text{Inertia}} + \underbrace{C_r Mg}_{\text{Rolling resistance}} + \underbrace{0.5 C_d A \rho_a V^2}_{\text{Air resistance}} \} \text{ x } V \text{ x } \partial t$$

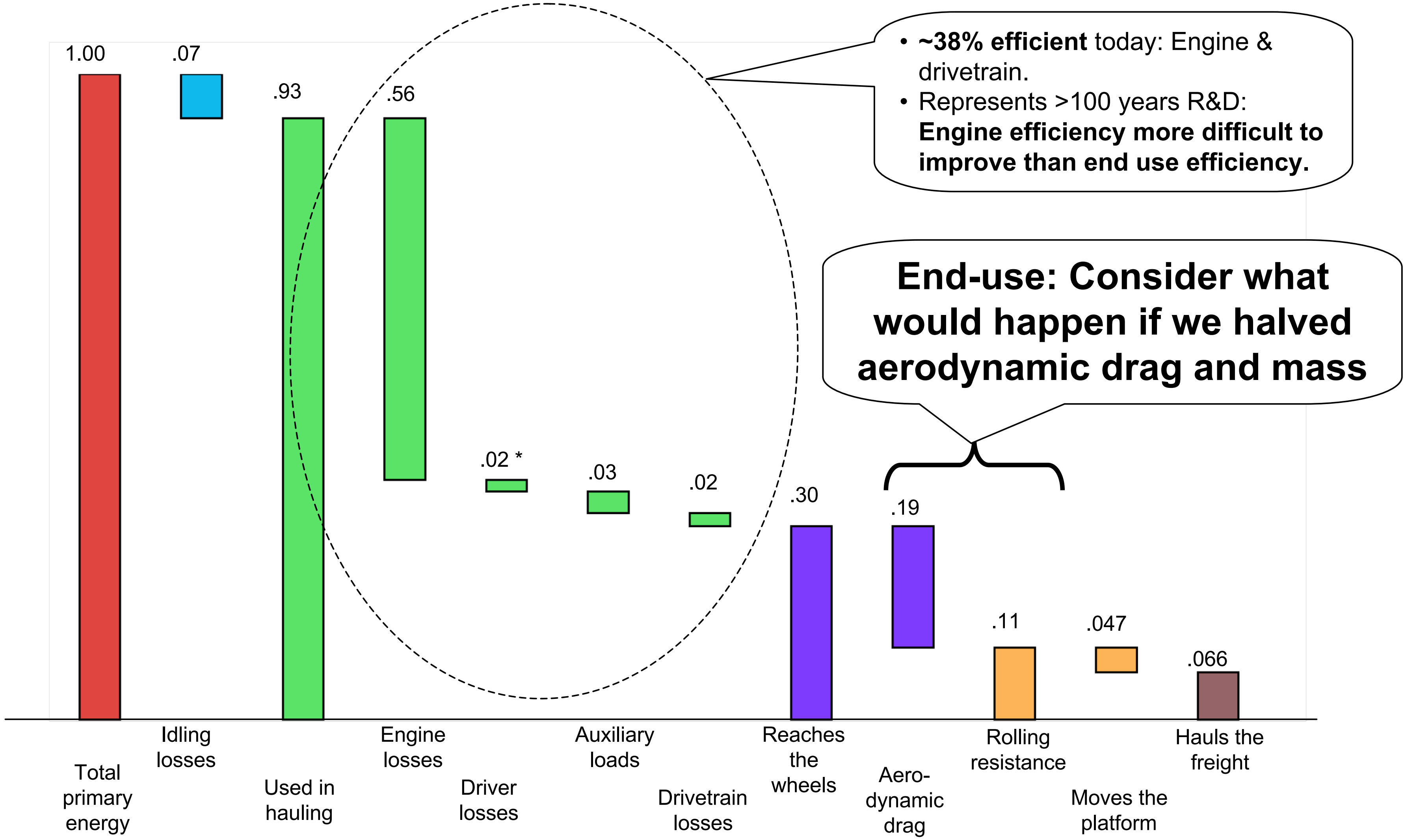


- **Aerodynamics** = ~2/3 of tractive load on highway
- **To lead:** Need to pay attention to COMBINATION of (tractor + trailer)

** Approximate values*
Source: Technology Roadmap for the 21st Century Truck Program (DOE 2000)

Breakdown of where a long-haul truck's total diesel goes: An excellent END-USE opportunity

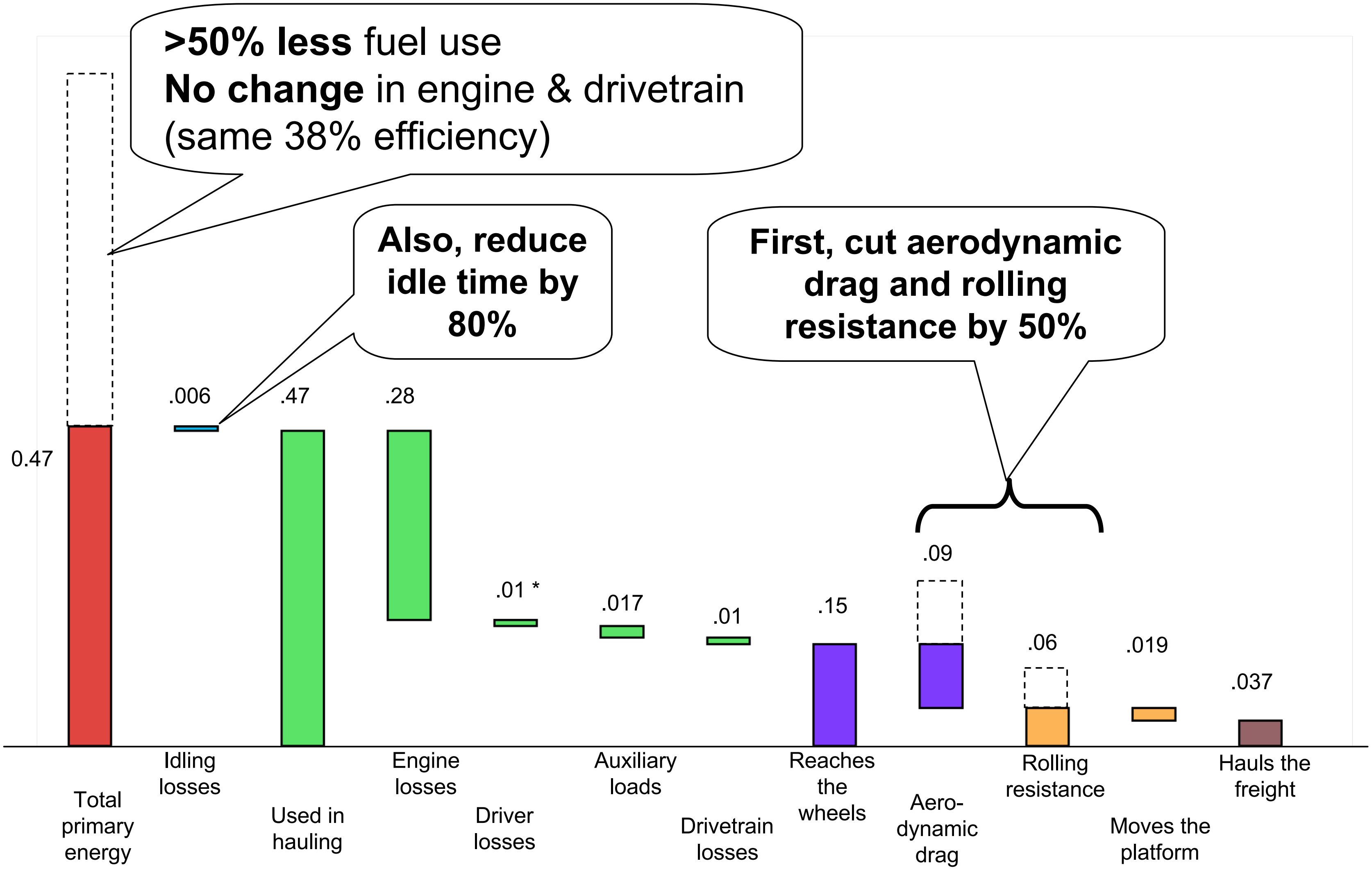
Focus: End of chain [fuel] → [engine] → [drivetrain] → **[tactive loads]**



** Assuming driver utilizes engine at 95% of max efficiency due to driving habits (probably much less than 95% in reality)*

Source: Technology Roadmap for the 21st Century Truck Program (DOE 2000), RMI analysis

Focus on END-USE: Reduce air drag + rolling resistance by 50%, idling by 80% saves ~50% of fuel — WITHOUT engine improvements



** Assume no change in driver behavior from previous slide*
Source: Technology Roadmap for the 21st Century Truck Program (DOE 2000), RMI analysis

Platform (1 of 3): Aerodynamics

Estimated Cost, Whole-System Cost, MPG-Effect, and Per-Gallon Cost; select measures

Aerodynamic Improvements	Gross up-front cost (2000 $)	Net up-front cost* (2000 $)	MPG Gain	Marginal cost of saved fuel** ($/gal diesel)
Trailer wake vortex flare	$500	- $512	4.9%	- $0.15
Cross-flow vortex trap device (CVTD)	$500	- $533	5.0%	- $0.16
Cab deflector / sloping hood / cab side flares	$1000	$422	2.8%	$0.27
Leading / Trailing edge and vortex strake device (VSD)	$750	$337	2.0%	$0.32
Tractor-trailer gap / wheel wells / baffles / bumper	$300	$197	0.5%	$0.96
Underbelly diffusers + enclosure and undercarriage flow	$2500	$1818	3.3%	$1.38
Electronic vision system	$1000	$793	1.0%	$2.04
Total	**$6550**	**$2522**		**$0.35**

* *Net up-front cost derived from avoided engine power (kW)*

** *Average cost weighted by MPG gain*

Source: RMI analysis, Winning the Oil Endgame (2004, www.oilendgame.org/ReadTheBook.html), *Heavy Trucking Annex (www.oilendgame.org/TechAnnex.html)*

Platform (2 of 3): Rolling Resistance

Estimated Cost, Whole-System Cost, MPG-Effect, and Per-Gallon Cost; select measures

Tire Improvements (rolling resistance)	Gross up-front cost (2000 $)	Net up-front cost* (2000 $)	MPG Gain	Marginal cost of saved fuel* ($/gal diesel)
Super singles	$466	- $76	4.0%	- $0.03
Low rolling resistance***	$181	$59	3.0%	$0.03
Automatic pneumatic pressure control	$500	$378	1.2%	$0.76
Total	**$966**	**$302**		**$0.15**

* *Net up-front cost derived from avoided engine power (kW)*
** *Average cost weighted by MPG gain*
*** *Generally, super singles and low rolling resistance tires are mutually exclusive options. The total here assumes a choice of super singles combined with automatic pneumatic pressure control.*

Source: RMI analysis, Winning the Oil Endgame (2004, www.oilendgame.org/ReadTheBook.html), *Heavy Trucking Annex (www.oilendgame.org/TechAnnex.html)*

Platform (3 of 3): Mass

Estimated Cost, Whole-System Cost, MPG-Effect, and Per-Gallon Cost; select measures

Weight reduction	Gross up-front cost (2000 $)	Net up-front cost* (2000 $)	MPG Gain	Marginal cost of saved fuel** ($/gal diesel)
Total	**$2000**	**$1449**	**10%**	**$0.18**
Tractor Eliminate two differentials Aluminum for differential housing Eliminate 6-inch spacer blocks Super singles Etc.	Eliminate about 5~7,000 lbs			
Trailer Alternative trailer floor materials Eliminate excess steel in trailer frame Etc.	Eliminate about 2,000 lbs			

* *Net up-front cost derived from avoided engine power (kW)*

** *Average cost weighted by MPG gain*

Source: RMI analysis, Winning the Oil Endgame (2004, www.oilendgame.org/ReadTheBook.html), *Heavy Trucking Annex (www.oilendgame.org/TechAnnex.html)*

Beyond the first ~100 years: Sketch of further engine improvements (1 of 2)

Engine Improvements	Immediate for September?	2006 ?	2007 ~ 2008 ?	2009 ~ 2010 and beyond?
Off the shelf, low cost:	• Lower parasitic losses - water pump, engine fan, A/C compressor, compressor hood • Advanced injection (high pressure, multi-event) • Variable geometry turbochargers	• Gen-2 advanced injection	• Bottoming cycles? • Improved lubricants	• Full-range HCCI? • Advanced fuels • Advanced fuel mixes
Near-shelf, “accelerate the market” opportunity		• Bottoming cycles • Dual mode-HCCI	• Camless engines • Advanced engine (injection, actuation, feedback) • Syn-fuels, etc. • Waste heat recovery	• Water injection??

Source: RMI analysis

Beyond the first ~100 years: Sketch of further engine improvements (2 of 2)

Engine Improvements	Efficiency Increase (% points)	NO_x Reduction (%)	PM Reduction (%)	HC Reduction (%)	CO Reduction (%)
Advanced Injection	2 ~ 4 % points	--	--	--	--
HCCI	0.8 ~ 1.2 % points	90 ~ 98%	--	Unclear: increase or decrease	Increase?
FT Diesel	--	5 ~ 8%	20 ~ 26%	23%	35 ~ 39%
Water Injection	0.8 ~ 1.7 % points	80 ~ 95%	7.5%	7 ~ 24%	75 ~ 86%
Total *	**3.6 ~ 6.9 % points**	**98.1 ~ 99.9%**	**26 ~ 31.5%**	**28.4 ~ 41.5%**	**83.8 ~ 91.5%**

** Efficiency total is additive, emissions totals are cumulative. Totals treat the unclear HC and CO effects of HCCI as "no change."*
Source: RMI analysis