U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

NHTSA
www.nhtsa.gov

DOT HS 812 177

June 2015

Commercial Medium- And Heavy-Duty Truck Fuel Efficiency Technology Cost Study

Suggested APA Format Citation:

Schubert, R., Chan, M., and Law, K. (2015, June). *Commercial medium- and heavy-duty truck fuel efficiency technology cost study.* (Report No. DOT HS 812 177). Washington, DC: National Highway Traffic Safety Administration.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 812 177		

4. Title and Subtitle	5. Report Date
Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Cost Study	June 2015
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Ray Schubert, Michael Chan, and Karen Law	100-TAG-T30999

9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)
Prepared for: Thomas E. Reinhart Southwest Research Institute 6220 Culebra Road San Antonio, TX 78228-0510	Prepared by: Michael Chan Tetra Tech, Inc. 3475 E. Foothill Blvd. Pasadena, CA 91107	11. Contract or Grant No. GS-23F-0006M/DTNH22-12-F-00428

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Highway Traffic Safety Administration 1200 New Jersey Avenue SE. Washington, DC 20590	Technical Report
	14. Sponsoring Agency Code NHTSA/NVS-132

15. Supplementary Notes

Contracting Officer's Technical Representatives (CORs):
Dr. John Whitefoot and James MacIsaac

National Highway Traffic Safety Administration
Fuel Economy Division, NVS-132
1200 New Jersey Avenue SE.
Washington, DC 20590

Technical Advisor:
Coralie Cooper
Volpe National Transportation Systems Center
Energy Analysis and Sustainability Division
55 Broadway
Cambridge, MA 02142

16. Abstract

This report accompanies the work performed by Southwest Research Institute (SwRI) in collaboration with the National Highway Traffic Safety Administration on fuel efficiency and emissions reduction technologies. Technologies are evaluated for medium- and heavy-duty vehicles for model years 2019 and beyond. Based on the list of technologies and configurations identified by SwRI, this report examines the costs of implementation in constant 2011 U.S. dollars in the areas of incremental retail prices and life cycle cost elements.

Incremental retail prices are evaluated relative to the prices of the specific baseline technologies that would otherwise be used in the vehicles if the fuel efficiency and emissions reduction technologies were not implemented. These prices include the technology components as well as their installation and incorporation in the vehicle. These prices account for all costs associated with the manufacturers and suppliers' production and sale of the technologies to the retail purchaser. The life cycle cost element examines the costs of using the technologies during the vehicles' lifetimes and are intended to inform separate, full-scale, life-cycle analysis. This report provides the overall details of the costing methodology and findings of the study.

Note: This report was subjected to external peer review per OMB guidelines for a Highly Influential Scientific Assessment (HISA). Material from the peer review process are publicly available in accompanying documents.

17. Key Words	18. Distribution Statement
Fuel Consumption, GHG Emissions, Medium Duty Truck, Heavy Duty Truck, Engine Technology Cost, Vehicle Technology Cost	Document is available to the public from the National Technical Information Service www.ntis.gov

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	279	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Acknowledgments

The authors gratefully acknowledge the guidance and assistance of Thomas Reinhart of Southwest Research Institute; Brian Dahlin, James MacIsaac, and John Whitefoot of the National Highway Traffic Safety Administration; and Coralie Cooper and Ryan Keefe of Volpe National Transportation Systems Center.

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Executive Summary

This report accompanies the work performed by Southwest Research Institute (SwRI) in collaboration with the U.S. Department of Transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA) on fuel efficiency and emissions reduction technologies. Technologies are evaluated for medium-duty (MD) and heavy-duty (HD) fuel vehicles model years 2019 and beyond. Based on the list of technologies and configurations identified by SwRI, this report examines the costs of implementation in constant 2011 U.S. dollars, in the areas of: 1) incremental retail prices and 2) life cycle cost elements.

Incremental retail prices are evaluated relative to the prices of the specific baseline technologies that would otherwise be used in the vehicles if the fuel efficiency and emissions reduction technologies were not implemented. These prices include the technology components as well as their installation and incorporation in the vehicle. Incremental retail prices account for all costs associated with the manufacturers and suppliers' production and sale of the technologies to the retail purchaser.

The life cycle cost element portion of the assessment examines the costs of using the technologies during the vehicles' lifetimes. In addition to the initial purchase costs of the technologies, the technologies' effects on fuel consumption, brake maintenance, major overhaul intervals, vehicle life, and other operations and maintenance (O&M) costs are quantified if the data were available (life cycle cost element data such as O&M were difficult to determine given new technologies had little in the field deployment for extended periods of time). Life cycle cost elements reported here are intended to inform a broader separate full life cycle analysis that takes into account additional factors such as fuel expenses outside the scope of this report.

Due to the limited timeframe and funding available for the study, this analysis relied on exiting MD/HD literature for price inputs, and it relied on peer reviewed documents if available. Direct surveys of manufacturers and teardown analysis were not possible.

Specific fuel efficiency and emissions reductions technologies for engines and vehicles were selected and modeled by SwRI (with input from NHTSA, Environmental Protection Agency, California Air Resources Board, and others). The costs corresponding to each of these technologies are estimated in this report. The technologies are divided into three applications: Class 2b&3, Vocational, and Line Haul. The Class 2b&3 application encompasses the light heavy-duty vehicles, operating with either gasoline or diesel engines, while at the other end of the spectrum, the Line Haul application encompasses the heaviest Class 8 diesel vehicles used in long distance duty cycles. The Vocational application spans a range of weight classes and is represented by Class 4 to Class 7 medium heavy-duty vehicles in this study. Vocational also includes straight trucks up

through Class 8, such as dump trucks, cement trucks, and refuse trucks (these vehicles were not specifically addressed in this study).

The methodology for determining incremental retail prices relies on a thorough literature review (peer reviewed or other highly credible sources available at the time of the literature search) for all target technologies to identify ranges of price points. The data reported here draw heavily upon the most recent peer reviewed National Research Council studies of medium- and heavy-duty vehicle technologies, in which OEMs agreed to provide detailed cost information during site visits and interviews.[1,2] From published studies and data, prices of fuel efficiency and emissions reduction technologies are reported as incremental retail prices.

The ranges of values found in the literature are scaled to project incremental prices using manufacturing volume-dependent cost curves. The cost curves are calculated from two components:

- Direct costs, which encompass materials, labor, and other relatively fixed costs of technology manufacture
- Indirect costs, which are divided into production overhead (warranty, R&D/engineering, and depreciation and amortization), corporate overhead, selling and dealer support (distribution, marketing, dealer support, and dealer discount), and net income to the manufacturer

Indirect costs are derived from direct costs using an adjusted multiplier. This multiplier contains two main factors (indirect cost factors and manufacturing process improvements) that determine the final incremental price of the technology to the purchaser over increasing production volume. The first main factor is derived from research conducted for the U.S. Environmental Protection Agency (EPA) and reflects manufacturer costs that are difficult to allocate to specific production activities, such as R&D, corporate operations, dealer support, and marketing.[3,4,5] Taking into account the

[1] National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.

[2] National Research Council, "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report," The National Academies Press Pre-Publication copy, 2014

[3] Rogozhin, A., M. Gallaher, W. McManus. “Automotive Industry Retail Price Equivalent and Indirect Cost Multipliers.” Prepared by RTI International and Transportation Research Institute, University of Michigan for the U.S. Environmental Protection Agency. February 2009.

[4] Rogozhin, A., M. Gallaher, A. Lentz, W. McManus. “Heavy Duty Truck Retail Price Equivalent and Indirect Cost Multipliers.” Prepared by RTI International and Transportation Research Institute, University of Michigan for the U.S. Environmental Protection Agency. July 2010.

[5] U.S. Environmental Protection Agency, "Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," EPA report # EPA-420-R-12-901, August 2012

complexity of the technology, this type of cost reduction results from short- and long-term indirect cost factors, as shown in Table E1. The time based short- and long- term indirect cost factors are used to estimate the decrease in costs as the cumulative manufacturing volume increases over time. The indirect cost factors account for differences in the technical complexity of the required vehicle modifications and adjust for increasing production volumes as new technologies become assimilated into the manufacturing process. The indirect costs portion of the incremental price is further broken out into four elements: production overhead, corporate overhead, selling and dealer support, and net income. The relative contributions of each of these elements to the total indirect cost are based on research by Argonne National Laboratory for the U.S. Department of Energy that examined and modified Argonne National Laboratory's incremental cost components of implementing new vehicle technologies.[6,7]

Table E1. Indirect Cost Factors

Low Technology Complexity		Medium Technology Complexity		High 1 Technology Complexity		High 2 Technology Complexity	
Short-Term	Long-Term	Short-Term	Long-Term	Short-Term	Long-Term	Short-Term	Long-Term
1.24	1.19	1.39	1.29	1.56	1.35	1.77	1.50

The second main factor of the adjusted multiplier reflects improvements in the manufacturing process that take place as the technology matures (newness of the technology as it applies to the manufacturing process). As described by the Center for Automotive Research, manufacturing process efficiencies that are learned over time are captured in this type of cost reduction and are expressed as an annual percent improvement from the previous year (Table E2).[8] Advanced Electronics and electronic control systems are the newest technology to be incorporated into the manufacturing process. Electrical Machines (such as motor, generator, gears, and electrical accessories) are more mature than Advanced Electronics in the manufacturing process. Mature Technologies are mature technologies in the manufacturing process but are still evolving (such as mass reduction materials).

[6] Cuenca, R.M., L.L. Gaines, A.D. Vyas. "Evaluation of Electric Vehicle Production and Operating Costs." Prepared by Argonne National Laboratory for the U.S. Department of Energy. ANL/ESD-41. November 1999.

[7] Vyas, A., D. Santini, R. Cuenca. "Comparison of Indirect Cost Multipliers for Vehicle Manufacturing." Prepared by Argonne National Laboratory for the U.S. Department of Energy. April 2000.

[8] Center for Automotive Research. "The U.S. Automotive Market and Industry in 2025." June 2011.

Table E2. Manufacturing Process Improvements

Advanced Electronics	Electrical Machines	Mature Technologies
3%	1%	0.5%

The indirect cost factors and the manufacturing process improvements (newness) then are multiplied together to derive the adjusted multipliers that make up the volume-dependent technology cost curves for each of the identified technologies. From the cost curves, incremental prices at different manufacturing volumes can be calculated.

All prices are presented on a *cumulative* volume basis across the entire market (time based units/year was a proxy to apply adjustment factors for production volume); no distinctions are made among specific suppliers, factories, or manufacturing lines. It is important to note that because prices are for cumulative volumes, volumes across vehicle classes may be additive. For example, if the same gasoline engine is used in both Class 2b&3 and Vocational vehicles, the industry total volume for a technology on that engine will include volumes from both vehicle categories. As a result, the incremental price of the technology may be lower than the price according to the volume in a single vehicle category. Technologies that apply only to a single vehicle category will accumulate volumes more slowly than those technologies that apply to multiple categories.

Projections of future price contain risk. As the technology matures, it may become more or less expensive, or it may prove unable to achieve the expected benefits. Only limited conclusions can be drawn from the evaluation of the technology price results in this report. These price results will be combined by the agencies with technology performance results in subsequent analyses to allow calculation of cost/benefit ratios for each technology.

The following tables (Table E3, Table E4, and Table E5) summarize the reduction in total incremental prices with increasing cumulative production volumes at four points along the cost curves for the three vehicle applications.

Table E3. Class 2b&3 Summary of Volumes and Total Incremental Price

Technology	Vol. 1	Vol. 2	Vol. 3	Vol. 4	Price 1	Price 2	Price 3	Price 4
Engine Technologies								
Coolant/Oil Pump (G)	50,000	300,000	600,000	1,000,000	180.00	165.38	157.03	154.52
Coolant/Oil Pump (D)	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Variable Valve Actuation (High 1)	50,000	300,000	600,000	1,000,000	620.00	520.44	453.38	423.87
Variable Valve Actuation (High 2)	50,000	300,000	600,000	1,000,000	620.00	509.66	443.98	415.08

Cylinder Deactivation	50,000	300,000	600,000	1,000,000	287.50	264.15	250.81	246.81
Stoichiometric GDI	50,000	300,000	600,000	1,000,000	625.00	574.24	545.23	536.53
Lean Burn GDI w/ SCR	50,000	300,000	600,000	1,000,000	1,930.00	1,773.24	1,683.68	1,656.81
Turbocharging and Downsizing	50,000	300,000	600,000	1,000,000	1,390.00	1,277.10	1,212.60	1,193.25
Engine Downspeeding	50,000	300,000	600,000	1,000,000	2,600.00	2,388.82	2,268.17	2,231.98
Low-Friction Engine Oil (G) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	7.50	7.16	6.95	6.84
Low-Friction Engine Oil (D) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	14.00	13.37	12.97	12.76
Engine Friction Reduction (G)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Engine Friction Reduction (D)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Stop / start (G)	50,000	300,000	600,000	1,000,000	700.00	643.14	610.66	600.92
Stop / start (D)	50,000	300,000	600,000	1,000,000	1,500.00	1,378.17	1,308.56	1,287.68
Vehicle and Trailer Technologies								
HEV (High 1)	50,000	300,000	600,000	1,000,000	19,500.00	16,368.75	14,259.38	13,331.25
HEV (High 2)	50,000	300,000	600,000	1,000,000	19,500.00	16,029.66	13,963.98	13,055.08
Air Conditioner System Improvements	50,000	300,000	600,000	1,000,000	317.50	291.71	276.98	272.56
Cab Insulation to Reduce A/C	50,000	300,000	600,000	1,000,000	375.00	358.08	347.28	341.89
Improved 2b and 3 Aerodynamics	50,000	300,000	600,000	1,000,000	280.00	267.37	259.30	255.27
Improved Transmissions (G)	50,000	300,000	600,000	1,000,000	480.00	441.01	418.74	412.06
Improved Transmissions (D)	50,000	300,000	600,000	1,000,000	875.00	803.93	763.33	751.15
Low Rolling Resistance Tires (per tire)	5,000,000	30,000,000	60,000,000	100,000,000	16.00	15.28	14.82	14.59
Weight Reduction (500 pounds)	300,000	1,800,000	3,600,000	6,000,000	2,000.00	1,909.76	1,852.18	1,823.39
Chassis friction reduction and improved lube	50,000	300,000	600,000	1,000,000	250.00	238.72	231.52	227.92

Table E4. Vocational Summary of Volumes and Total Incremental Price

Technology	Vol. 1	Vol. 2	Vol. 3	Vol. 4	Price 1	Price 2	Price 3	Price 4
Engine Technologies								
Coolant/Oil Pump (G)	50,000	300,000	600,000	1,000,000	180.00	165.38	157.03	154.52
Coolant/Oil Pump (D)	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Variable Valve Actuation (High 1)	50,000	300,000	600,000	1,000,000	635.00	533.03	464.34	434.12
Variable Valve Actuation (High 2)	50,000	300,000	600,000	1,000,000	635.00	521.99	454.72	425.13
Cylinder Deactivation	50,000	300,000	600,000	1,000,000	287.50	264.15	250.81	246.81
Stoichiometric GDI	50,000	300,000	600,000	1,000,000	625.00	574.24	545.23	536.53
Lean Burn GDI w/ SCR	50,000	300,000	600,000	1,000,000	1,930.00	1,773.24	1,683.68	1,656.81
Stoichiometric GDI + EGR	50,000	300,000	600,000	1,000,000	1,430.00	1,313.85	1,247.49	1,227.59
Turbocharging and Downsizing	50,000	300,000	600,000	1,000,000	1,390.00	1,277.10	1,212.60	1,193.25
Engine Downspeeding	50,000	300,000	600,000	1,000,000	2,600.00	2,388.82	2,268.17	2,231.98
Low-Friction Engine Oil (G) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	7.50	7.16	6.95	6.84
Low-Friction Engine Oil (D) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	14.00	13.37	12.97	12.76
Engine Friction Reduction (G)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Engine Friction Reduction (D)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Stop / start (G)	50,000	300,000	600,000	1,000,000	700.00	643.14	610.66	600.92
Stop / start (D)	50,000	300,000	600,000	1,000,000	1,500.00	1,378.17	1,308.56	1,287.68
Vehicle and Trailer Technologies								
HEV (High 1)	50,000	300,000	600,000	1,000,000	32,000.00	26,861.54	23,400.00	21,876.92
HEV (High 2)	50,000	300,000	600,000	1,000,000	32,000.00	26,305.08	22,915.25	21,423.73
Air Conditioner System Improvements	50,000	300,000	600,000	1,000,000	317.50	291.71	276.98	272.56
Cab Insulation to Reduce A/C	50,000	300,000	600,000	1,000,000	375.00	358.08	347.28	341.89
Improved Transmissions (G)	50,000	300,000	600,000	1,000,000	750.00	689.08	654.28	643.84

Improved Transmissions (D)	50,000	300,000	600,000	1,000,000	1,325.00	1,217.38	1,155.90	1,137.45
AMT vs. Manual	50,000	300,000	600,000	1,000,000	1,050.00	964.72	915.99	901.38
Dual Clutch Automatic (High 1)	50,000	300,000	600,000	1,000,000	2,700.00	2,266.44	1,974.38	1,845.87
Dual Clutch Automatic (High 2)	50,000	300,000	600,000	1,000,000	2,700.00	2,219.49	1,933.47	1,807.63
Low Rolling Resistance Tires (per tire)	700,000	4,200,000	8,400,000	14,000,000	30.50	29.12	28.25	27.81
Automatic Tire Pressure Control	50,000	300,000	600,000	1,000,000	800.00	763.90	740.87	729.35
Weight Reduction (1,000 pounds)	300,000	1,800,000	3,600,000	6,000,000	6,000.00	5,729.27	5,556.53	5,470.16
Chassis friction reduction and improved lube	50,000	300,000	600,000	1,000,000	250.00	238.72	231.52	227.92

Table E5. Line Haul Summary of Volumes and Total Incremental Price

Technology	Vol. 1	Vol. 2	Vol. 3	Vol. 4	Price 1	Price 2	Price 3	Price 4
Engine Technologies								
Advanced Bottoming Cycle (High 1)	50,000	300,000	600,000	1,000,000	14,900.00	12,507.40	10,895.63	10,186.44
Advanced Bottoming Cycle (High 2)	50,000	300,000	600,000	1,000,000	14,900.00	12,248.31	10,669.92	9,975.42
Coolant/Oil Pump	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Variable Valve Actuation (High 1)	50,000	300,000	600,000	1,000,000	525.00	440.70	383.91	358.92
Variable Valve Actuation (High 2)	50,000	300,000	600,000	1,000,000	525.00	431.57	375.95	351.48
Low-Friction Engine Oil (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	102.50	97.88	94.92	93.45
Engine Friction Reduction	50,000	300,000	600,000	1,000,000	282.00	269.28	261.16	257.10
Reduced Aftertreatment Backpressure	50,000	300,000	600,000	1,000,000	727.50	694.67	673.73	663.26
Air Handling Improvement	50,000	300,000	600,000	1,000,000	1,125.00	1,033.62	981.42	965.76
Mechanical Turbocompound	50,000	300,000	600,000	1,000,000	2,500.00	2,296.94	2,180.94	2,146.13
Electric Turbocompound (High 1)	50,000	300,000	600,000	1,000,000	4,200.00	3,525.58	3,071.25	2,871.35
Electric Turbocompound (High 2)	50,000	300,000	600,000	1,000,000	4,200.00	3,452.54	3,007.63	2,811.86
Vehicle and Trailer Technologies								
HEV (High 1)	50,000	300,000	600,000	1,000,000	35,000.00	29,379.81	25,593.75	23,927.88
HEV (High 2)	50,000	300,000	600,000	1,000,000	35,000.00	28,771.19	25,063.56	23,432.20
Diesel APU	50,000	300,000	600,000	1,000,000	10,000.00	9,187.77	8,723.74	8,584.53
Battery APU	50,000	300,000	600,000	1,000,000	6,400.00	5,880.17	5,583.19	5,494.10
Fuel-Fired Heater	50,000	300,000	600,000	1,000,000	1,200.00	1,102.53	1,046.85	1,030.14
Air Conditioner System Improvements	50,000	300,000	600,000	1,000,000	317.50	291.71	276.98	272.56
Cab Insulation to Reduce A/C	50,000	300,000	600,000	1,000,000	375.00	358.08	347.28	341.89

Air Compressor Improvements	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Shore Power	50,000	300,000	600,000	1,000,000	1,050.00	1,002.62	972.39	957.28
Aero: Trailer (Side) skirt (4 to 6 m)	25,000	150,000	300,000	700,000	550.00	525.18	509.35	498.79
Aero: Boat tail	25,000	150,000	300,000	500,000	1,200.00	1,145.85	1,111.31	1,094.03
Aero: Complete trailer skirt (7 to 9 m)	50,000	300,000	600,000	1,000,000	925.00	883.26	856.63	843.32
Aero: Full tractor skirt (over axles)	25,000	150,000	300,000	500,000	1,750.00	1,671.04	1,620.66	1,595.46
Aero: Gap filler	25,000	150,000	300,000	500,000	825.00	787.78	764.02	752.15
Aero on regional haul	25,000	150,000	300,000	500,000	1,150.00	1,098.11	1,065.00	1,048.45
Improved Transmissions	50,000	300,000	600,000	1,000,000	1,800.00	1,653.80	1,570.27	1,545.22
AMT vs. Manual	50,000	300,000	600,000	1,000,000	4,000.00	3,675.11	3,489.50	3,433.81
Dual Clutch Automatic (High 1)	50,000	300,000	600,000	1,000,000	10,350.00	8,688.03	7,568.44	7,075.82
Dual Clutch Automatic (High 2)	50,000	300,000	600,000	1,000,000	10,350.00	8,508.05	7,411.65	6,929.24
Low Rolling Resistance Tires (per tire)	3,000,000	18,000,000	36,000,000	60,000,000	40.50	38.67	37.51	36.92
Single Wide Tires (per tire and wheel)	300,000	1,800,000	3,600,000	6,000,000	141.00	134.64	130.58	128.55
Automatic Tire Pressure Control	50,000	300,000	600,000	1,000,000	1,142.50	1,090.95	1,058.06	1,041.61
Weight Reduction (2,000 pounds)	300,000	1,800,000	3,600,000	6,000,000	12,000.00	11,458.55	11,113.06	10,940.32
6X2 Tractors or Clutched 6X4	300,000	1,800,000	3,600,000	6,000,000	1,100.00	1,050.37	1,018.70	1,002.86
Chassis friction reduction and improved lube	50,000	300,000	600,000	1,000,000	250.00	238.72	231.52	227.92

Abbreviations

A/C	Air conditioner
AMT	Automated manual transmission
APU	Auxiliary power unit
ATI	Automated tire inflation
BMEP	Brake mean effective pressure
C_d	Drag coefficient
C_{rr}	Rolling resistance coefficient
CARB	California Air Resources Board
D	Diesel
DOT	Department of Transportation
ECM	Engine control module
EGR	Exhaust gas recirculation
EPA	Environmental Protection Agency
EV	Electric vehicle
G	Gasoline
GDI	Gasoline direct injection
GHG	Greenhouse gas
HD	Heavy-duty
HEV	Hybrid Electric Vehicle
ICF	Indirect Cost Factor
LRR	Low rolling resistance
MD	Medium-duty
mpg	Miles per gallon
MY	Model year
n/a	Not applicable
NA	Naturally aspirated
NAS	National Academy of Sciences
NHTSA	National Highway Traffic Safety Administration
NNI	No net increase
O&M	Operation and maintenance

OEM	Original equipment manufacturer
OHC	Overhead camshaft
OHV	Overhead valve
PFI	Port fuel injection
RPM	Revolutions per minute
SCR	Selective catalytic reduction
SwRI	Southwest Research Institute
TBD	To be determined
VMT	Vehicle miles traveled
VVA	Variable valve actuation
VVL	Variable valve lift
VVT	Variable valve timing

1 Introduction

This report accompanies the work performed by Southwest Research Institute (SwRI) in collaboration with the U.S. Department of Transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA) on fuel efficiency and emissions reduction technologies. Technologies are evaluated for medium-duty (MD) and heavy-duty (HD) fuel vehicles model years (MY) 2019 and beyond. Based on the list of technologies and configurations identified by SwRI, this report examines the costs of implementation in constant 2011 U.S. dollars, in the areas of: 1) incremental retail prices and 2) life cycle cost elements.

Incremental retail prices are evaluated relative to the prices of the specific baseline technologies that would otherwise be used in the vehicles if the fuel efficiency and emissions reduction technologies were not implemented (prices are assumed to remain unchanged in the absence of new regulations). These prices include the technology components as well as their installation and incorporation in the vehicle. Incremental retail prices account for all costs associated with the manufacturers and suppliers' production and sale of the technologies to the retail purchaser.

The life cycle cost element portion of the assessment examines the costs of using the technologies during the vehicles' lifetimes. In addition to the initial purchase costs of the technologies, the technologies' effects on fuel consumption, brake maintenance, major overhaul intervals, vehicle life, and other operations and maintenance (O&M) costs are quantified. Life cycle cost elements reported here are intended to inform a broader life cycle analysis that takes into account additional factors such as fuel expenses.

This report provides details of the costing methodology and findings and is organized as follows. First, Section 2 describes the fuel efficiency and emissions reduction technologies, including their vehicle applications and technology content. Next, Section 3 presents the incremental retail prices for the individual technologies with their corresponding cost curves by manufacturing volume. Finally, building off of these incremental prices, Section 4 presents the life cycle cost elements of using the technologies in the various vehicle applications.

2 Fuel Efficiency and Emissions Reduction Technologies

Specific fuel efficiency and emissions reductions technologies for engines and vehicles were selected and modeled by SwRI. The technologies were selected by NHTSA and SwRI with input from EPA, California Air Resources Board (CARB), and others. The costs corresponding to each of these technologies are estimated in this report. The technologies are divided into three applications: Class 2b&3, Vocational, and Line Haul. The Class 2b&3 application encompasses the light heavy-duty vehicles, operating with either gasoline or diesel engines, while at the other end of the spectrum, the Line Haul application encompasses the heaviest Class 8 diesel vehicles used in long distance duty cycles. The Vocational application spans a range of weight classes and is represented by Class 4 to Class 7 medium heavy-duty vehicles in this study. Vocational vehicles also include straight trucks up through Class 8, such as dump trucks, cement trucks, and refuse trucks (these vehicles were not specifically addressed in this study). At present, vehicles in classes 4 to 7 (such as delivery and bucket trucks) operate primarily with diesel engines, though improving gasoline engine technologies may encourage the increased use of gasoline engines in the Vocational category. Note that in many cases, engines (and therefore incremental prices) are common (or at least very similar) for the classes 2b to 7. Table 1 lists the fuel efficiency and emissions reduction technologies evaluated for each of these applications as specified by SwRI. Note that not all technologies are suitable for all vehicles, and technologies are applied where appropriate.

Table 1. Fuel Efficiency and Emissions Reduction Technologies

Technology	Application					Technology Content
	Class 2b&3 (gasoline)	Class 2b&3 (diesel)	Vocational (gasoline)	Vocational (diesel)	Line Haul	
Engine Technologies:						
Advanced bottoming cycle	N/A	N/A	N/A	N/A	X	For DD15 engine; Steam cycle for 30 kW system
Coolant/Oil Pump	X 2 stage pumps	X variable pumps	X 2 stage pumps	X variable pumps	X variable pumps	For 6.2L V8, ISB, DD15 engines; viscous drive clutch, actuator pin-out on ECM, wiring. 2-stage oil pump for gasoline engines, variable displacement for diesels.
Variable valve actuation (VVA)	X	N/A	X	N/A	X	For 6.2L V8 (OHC), DD15; variable valve lift and timing mechanism similar to BMW Valvetronic, Sturman is an option for diesel

Cylinder deactivation	X	N/A	X	N/A	N/A	For 6.2L V8 (OHC); systems similar to GM "Displacement on Demand" (pushrod) and Honda 3.5 V6 cylinder deactivation system (OHC)
Stoichiometric gasoline direct injection (GDI)	X	N/A	X	N/A	N/A	For 6.2L V8 (OHC); 150 to 200 bar GDI fuel system to replace PFI (assume PM filter)
Lean burn GDI with selective catalytic reduction (SCR)	X	N/A	X	N/A	N/A	For 6.2L V8 (OHC); add SCR system similar to that used on diesel pickup trucks
Stoichiometric GDI + exhaust gas recirculation (EGR)	New control strategy concept, no costs shown	N/A	X	N/A	N/A	For 3.5L V6; EGR valve, EGR cooler, plumbing, high energy ignition system
Turbocharging and downsizing	X	N/A	X	N/A	X cost limit*	Ford EcoBoost 3.5L V6 vs. 6.2L PFI V8, upgrade is higher cylinder pressure capability. *For 5-cylinder vs. 6-cylinder DD15 in Line Haul, Tetra Tech expects engine downsizing to be zero incremental cost if OEM has portfolio of alternative engine sizes.*
Engine downspeeding	X	N/A	X	N/A	X cost limit*	High BMEP 3.5 V6 with EGR vs. current version, with 8-speed auto vs. 6 speed (gasoline); high BMEP version of DD15 compared to current, with 10 speed AMT vs. 16-18 speed (diesel); reduced cruise RPM, requires transmission technology

Low friction engine oil	X	X	X	X	X	For 6.2L V8, ISB 6.7L, DD15; low friction oil vs. non-synthetic current product; priced per volume for full engine capacity
Engine friction reduction	X	X	X	X	X	For 6.2L V8, ISB 6.7L, DD15; improve low-tension piston rings, roller cam followers, crankshaft design and bearings, and piston/cylinder surface treatments.
Stop/start	X	X	X	X	N/A	For 6.2L V8, ISB 6.7L; more capable vehicle battery and starter, control system development
Improved SCR conversion	*N/A*	*X*	*N/A*	*X*	*X*	*Tetra Tech expects future SCR improvements to occur continuously at zero incremental cost.*
Reduced aftertreatment backpressure	N/A	N/A	N/A	N/A	X	For DD15; Increase catalyst volume by 50% to reduce backpressure
Turbo efficiency improvement	*X*	*X*	*X*	*X*	*X*	*Tetra Tech expects turbo efficiency improvement to be zero incremental cost.*
Air handling improvements	N/A	N/A	N/A	N/A	X	For DD15; larger, reduced restriction charge air cooler – 50% reduction
Mechanical turbo-compound	N/A	N/A	N/A	N/A	X	For DD15; turbocompound system hardware, including gear train
Electric turbo-compound	N/A	N/A	N/A	N/A	X	For DD15; system with drive for electric motor/generator (include 20 kW generator)

Vehicle and Trailer Technologies:						
Hybrid Electric Vehicle	X		X		X	Parallel hybrid-electric powertrain, integrated starter-alternator technology with idle off, and regenerative braking capability
Automatic engine shutdown	*N/A*	*N/A*	*X*	*X*	*X*	*Tetra Tech expects automatic engine shutdown to be zero incremental cost.*
Diesel auxiliary power unit (APU)	N/A	N/A	N/A	N/A	X	For DD15; existing market system
Battery APU	N/A	N/A	N/A	N/A	X	For DD15; existing market system
Fuel-fired heater	N/A	N/A	N/A	N/A	X	For DD15; existing market system
Air conditioner (A/C) system improvements	X		X		X	Vehicle dependent, not engine dependent; Higher efficiency compressor, separate electric condenser fan to avoid use of engine-driven fan.
A/C reduced reheat	*New control strategy concept, no costs shown*		*New control strategy concept, no costs shown*		*New control strategy, no costs shown*	*Cabin and intake air humidity sensors, controls. Control Strategy and no Hardware Cost.*
Cab insulation to reduce A/C	X		X		X	Vehicle dependent, not engine dependent; Infrared suppression glass treatment, 50% increase in cab thermal insulation
Air compressor improvements	N/A	N/A	N/A	N/A	X clutched/ variable pumps	Not engine dependent; Clutch similar to A/C compressor clutch, pinout on ECM, wiring
Shore power	N/A	N/A	N/A	N/A	X	For DD15; existing market system

Aero Bin III (not priced as a group)	N/A	N/A	N/A	N/A	X	For DD15; tractor features are baseline 2019, trailer (side) skirt (4 to 6 m) (priced separately)
	N/A	N/A	N/A	N/A	X	For DD15; tractor features are baseline 2019, boat tail (priced separately)
Aero Bin IV and V (not priced as a group)	N/A	N/A	N/A	N/A	X	For DD15; complete trailer skirt (7 to 9 m) (priced separately)
	N/A	N/A	N/A	N/A	X	For DD15; complete tractor skirt (over axles) (priced separately)
	N/A	N/A	N/A	N/A	X	For DD15; gap filler (priced separately)
Include trailer C_d and C_{rr} in rule	N/A	N/A	N/A	N/A	X	For DD15; compare SmartWay spec trailer to standard spec
Aero on regional haul	N/A	N/A	N/A	N/A	X	For DD15/ DD12; aero day cab tractor vs. standard (air dam, tank skirts, cab top shield, gap reducer), trailer skirts
Class 2b&3 improved aerodynamics	X		N/A		N/A	Not engine dependent; active grill shutters, belly pan under engine, belly pan under complete chassis, wheel well skirts
Improved transmissions	X	X	X	X	X	For 6.2L V8, ISB, DD15; ZF 8-speed vs. current Aisin 6-speed (Class 2b&3); 8 speed automatic vs. current Allison 2000 5/6 speed (Vocational); 16 - 18 speed AMT vs. current 10 speed (Line Haul); more gears, higher ratio spread, shift points

Automated manual transmission (AMT)	N/A		X		X	Not engine dependent; compare Eaton Ultrashift HV model FO-6406 B vs. manual equivalent (Vocational); Eaton Ultrashift AMT FO-16E301C-LAS vs. manual equivalent (Line Haul)
Dual clutch automatic	N/A		X		X	Not engine dependent; 10 speed DCT vs. current 6 speed automatic (Vocational); 16-18 speed DCT vs. current 10 speed manual (Line Haul)
Low rolling resistance (LRR) tires	X		X		X	Not engine dependent; lower C_{rr} tires; priced per tire
Single wide tires	N/A	N/A	N/A	N/A	X	For DD15; compare low C_{rr} wide base single wheels and tires to current SmartWay approved duals; priced per tire and wheel
Automated tire inflation (ATI)	N/A		X		X	Automated Tire Inflation systems continually monitor and adjust the level of pressurized air in tires.
Weight reduction	X		X		X	500 pounds for Class2b/3, 1,000 pounds for Vocational, 2,000 pounds for long haul tractor/trailer
6x2 tractors	N/A	N/A	N/A	N/A	X	For DD15; compare standard 6x4 setup with a 6x2 with air suspension that allows weight to be shifted to the one drive axle in low mu conditions.
Chassis friction reduction and improved lube	X		X		X	Not engine dependent; synthetic lube vs. standard, most efficient axles vs. standard

Speed limiters	*N/A*	*N/A*	*X*	*X*	*X*	For DD15. *Tetra Tech expects speed limiters to be zero incremental cost.*

* Customization Cost Limit - $600 million to develop a new engine (estimated cost of a new engine product line including engineering costs was not analyzed for this report)

3 Incremental Retail Prices

The methodology used here for determining incremental retail prices relies on a thorough literature review (peer reviewed or other highly credible sources available at the time of the literature search) for all target technologies to identify ranges of price points. The data reported here draw heavily upon the most recent peer reviewed National Research Council studies of medium- and heavy-duty vehicle technologies, in which OEMs agreed to provide detailed cost information during site visits and interviews.[9,10] From published studies and data, prices of fuel efficiency and emissions reduction technologies are reported as incremental retail prices. In cases in which single technologies are combined into a technology package, the price of the package is defined as the sum of the prices of the components (this is a conservative estimate since there may be price reductions from combining technologies).

The ranges of values found in the literature are scaled to project incremental prices using manufacturing volume-dependent cost curves. The cost curves are calculated from two components:

- Direct costs, which encompass materials, labor, and other relatively fixed costs of technology manufacture
- Indirect costs, which are divided into production overhead (warranty, R&D/engineering, and depreciation and amortization), corporate overhead, selling and dealer support (distribution, marketing, dealer support, and dealer discount), and net income to the manufacturer

Indirect costs are derived from direct costs using an adjusted multiplier. This multiplier contains two main factors (indirect cost factors and manufacturing process improvements) that determine the final incremental price of the technology to the purchaser over increasing production volume. The first main factor is derived from research conducted for the U.S. Environmental Protection Agency (EPA) and reflects manufacturer costs that are difficult to allocate to specific production activities, such as R&D, corporate operations, dealer support, and marketing.[11,12,13] Taking into account the complexity of the technology, this type of cost

[9] National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.

[10] National Research Council, "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report," The National Academies Press Pre-Publication copy, 2014

[11] Rogozhin, A., M. Gallaher, W. McManus. “Automotive Industry Retail Price Equivalent and Indirect Cost Multipliers.” Prepared by RTI International and Transportation Research Institute, University of Michigan for the U.S. Environmental Protection Agency. February 2009.

[12] Rogozhin, A., M. Gallaher, A. Lentz, W. McManus. “Heavy Duty Truck Retail Price Equivalent and Indirect Cost Multipliers.” Prepared by RTI International and Transportation Research Institute, University of Michigan for the U.S. Environmental Protection Agency. July 2010.

[13] U.S. Environmental Protection Agency, "Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," EPA report # EPA-420-R-12-901, August 2012

reduction results from short- and long-term indirect cost factors, as shown in Table 2. The time based short- and long- term indirect cost factors are used to estimate the decrease in costs as the cumulative manufacturing volume increases over time. The indirect cost factors account for differences in the technical complexity of the required vehicle modifications and adjust for increasing production volumes as new technologies become assimilated into the manufacturing process. The indirect costs portion of the incremental price is further broken out into four elements: production overhead, corporate overhead, selling and dealer support, and net income. The relative contributions of each of these elements to the total indirect cost are based on research by Argonne National Laboratory for the U.S. Department of Energy that examined and modified Argonne National Laboratory's incremental cost components of implementing new vehicle technologies.[14,15] Table 3 shows the complexity levels for the technology considered in this report.

Table 2. Indirect Cost Factors

Low Technology Complexity		Medium Technology Complexity		High 1 Technology Complexity		High 2 Technology Complexity	
Short-Term	Long-Term	Short-Term	Long-Term	Short-Term	Long-Term	Short-Term	Long-Term
1.24	1.19	1.39	1.29	1.56	1.35	1.77	1.50

Table 3. Technology Complexity Levels

Technology	Technology Complexity
Engine Technologies	
Advanced Bottoming Cycle	High 1/**High 2**
Coolant/Oil Pump	Medium
Variable Valve Actuation	**High 1**/High 2
Cylinder Deactivation	Medium
Stoichiometric GDI	Medium
Lean Burn GDI w/ SCR	Medium
Stoichiometric GDI + EGR	Medium
Turbocharging and Downsizing	Medium

[14] Cuenca, R.M., L.L. Gaines, A.D. Vyas. "Evaluation of Electric Vehicle Production and Operating Costs." Prepared by Argonne National Laboratory for the U.S. Department of Energy. ANL/ESD-41. November 1999.
[15] Vyas, A., D. Santini, R. Cuenca. "Comparison of Indirect Cost Multipliers for Vehicle Manufacturing." Prepared by Argonne National Laboratory for the U.S. Department of Energy. April 2000.

Engine Downspeeding	Medium
Low-Friction Engine Oil	Low
Engine Friction Reduction	Low
Stop / start	Medium
Reduced Aftertreatment Backpressure	Low
Air handling Improvement	Medium
Mechanical Turbocompound	Medium
Electric Turbocompound	**High 1**/High 2
Vehicle and Trailer Technologies	
Hybrid Electric Vehicle	**High 1**/High 2
Diesel APU	Medium
Battery APU	Medium
Fuel-Fired Heater	Medium
Air Conditioner System Improvements	Medium
Cab Insulation to Reduce A/C	Low
Air Compressor Improvements	Medium
Fan Power Demand Reduction	Medium
Thermal Storage for A/C	Medium
Shore Power	Low
Aero: Trailer (Side) skirt (4 to 6 m)	Low
Aero: Boat tail	Low
Aero: Complete trailer skirt (7 to 9 m)	Low
Aero: Full tractor skirt	Low
Aero: Gap filler	Low
Aero on regional haul	Low
Improved 2b and 3 Aerodynamics	Low
Improved Transmissions	Medium
AMT vs. Manual	Medium
Dual Clutch Automatic	**High 1**/High 2

Low Rolling Resistance Tires	Low
Single Wide Tires	Low
Automatic Tire Pressure Control	Low
Weight Reduction	Low
6X2 Tractors or Clutched 6X4	Low
Chassis friction reduction and improved lube	Low

The second main factor of the adjusted multiplier reflects improvements in the manufacturing process that take place as the technology matures (newness of the technology as it applies to the manufacturing process). As described by the Center for Automotive Research, manufacturing process efficiencies that are learned over time are captured in this type of cost reduction and are expressed as an annual percent improvement from the previous year (Table 4).[16] Advanced Electronics and electronic control systems are the newest technology to be incorporated into the manufacturing process. Electrical Machines (such as motor, generator, gears, and electrical accessories) are more mature than Advanced Electronics in the manufacturing process. Mature Technologies are mature technologies in the manufacturing process but are still evolving (such as mass reduction materials). Advanced Electronics are assumed to be associated with the highest technology complexity with Mature Technologies associated with the lowest technology complexity (leaving Electrical Machines with medium technology complexity).

Table 4. Manufacturing Process Improvements

Advanced Electronics	Electrical Machines	Mature Technologies
3%	1%	0.5%

The indirect cost factors and the manufacturing process improvements (newness) then are multiplied together to derive the adjusted multipliers that make up the volume-dependent technology cost curves for each of the identified technologies. From the cost curves, incremental prices at different manufacturing volumes can be calculated. NHTSA requested the analysis to be presented in terms of volume for their modeling analysis work. The agencies' modeling analyses assume "learning" for the purposes of reducing technology costs which resulted from efficiency improvements that occurred as production volumes increased, or with incremental process and design revisions that occurred over a period of time (years). Thus the

[16] Center for Automotive Research. "The U.S. Automotive Market and Industry in 2025." June 2011.

models assume two types of learning: volume-based learning, which reduces costs for newly available, low-volume technologies expected to undergo significant production volume increases during the rulemaking period; and time-based learning, which reduced the costs for established, readily available technologies currently in high-volume production, over the course of a multi-year contract. Since the Phase 2 GHG and fuel efficiency standards will potentially drive adoption of advanced technologies that are newly available and low-volume, the incremental technology prices are presented in terms of volume to facilitate a volume-based learning approach.

As production runs are successful, in terms of cost reductions from continuous improvements and paying off capital expenditures, profits for the manufacturer are expected to increase. In other words, production overhead is expected to decrease and net income is expected to increase over time and with increasing manufacturing volume (in the idealized case of successful production runs). In addition, because cost curves are different for different technology complexity levels, the relative contributions of the cost elements are expected to differ as well. This report primarily draws upon reported incremental retail prices (which may have been based upon varying indirect cost factor estimates) of published studies and data. A teardown analysis was not performed in this report to determine the breakout between the direct and indirect cost elements. To estimate the cost element breakouts in the incremental price, the relative cost contributions for truck manufacturers in RTI's 2010 heavy duty truck report were used.[17] Table 5, Table 6, Table 7, and Table 8 show the estimated cost breakouts applied to the total incremental price used in this analysis. As shown, the relative net income increases with increasing technology complexity, reflecting the manufacturers' business case for investing in the production of more complex technologies. The current analysis doesn't attempt to identify pre-production prices of experimental or very low volume production runs. The estimated volume for individual technologies is an attempt to identify the North American volume of a production assembly line (no assumptions of global volumes were made). This will vary by type of technology and vehicle class. 50,000 units was a baseline initial amount agreed upon as reasonable after discussions between Tetra Tech and SwRI. Adjustments were made for items that are produced in lower volume, like side skirts, and those at higher volume, like quarts of oil and tires.

Table 5. Relative Cost Contributions for Low Technology Complexity

Cost Element	Share of Incremental Price		
	50,000 Units	300,000 Units	600,000 Units

[17] Rogozhin, A., M. Gallaher, A. Lentz, W. McManus. "Heavy Duty Truck Retail Price Equivalent and Indirect Cost Multipliers." Prepared by RTI International and Transportation Research Institute, University of Michigan for the U.S. Environmental Protection Agency. July 2010.

Vehicle manufacturing (direct)	87%	89%	91%
Production overhead	6%	4%	3%
Corporate overhead	2%	1%	1%
Selling and dealer support	1%	1%	1%
Net income	4%	4%	5%

Table 6. Relative Cost Contributions for Medium Technology Complexity

Cost Element	Share of Incremental Price		
	50,000 Units	300,000 Units	600,000 Units
Vehicle manufacturing (direct)	79%	82%	86%
Production overhead	10%	8%	6%
Corporate overhead	2%	2%	2%
Selling and dealer support	5%	3%	2%
Net income	4%	4%	4%

Table 7. Relative Cost Contributions for High 1 Technology Complexity

Cost Element	Share of Incremental Price		
	50,000 Units	300,000 Units	600,000 Units
Vehicle manufacturing (direct)	70%	75%	79%
Production overhead	15%	12%	9%
Corporate overhead	4%	4%	4%
Selling and dealer support	7%	6%	5%
Net income	4%	4%	4%

Table 8. Relative Cost Contributions for High 2 Technology Complexity

Cost Element	Share of Incremental Price		
	50,000 Units	300,000 Units	600,000 Units
Vehicle manufacturing (direct)	64%	69%	73%

Production overhead	21%	18%	15%
Corporate overhead	6%	5%	4%
Selling and dealer support	6%	5%	4%
Net income	3%	3%	4%

Based on the methodology described above, the incremental price curve and price breakouts for each technology in each applicable vehicle category are presented below. Note that the vertical bars in the charts represent the low and high values used to calculate the median, not average, incremental price (values selected were based upon the range of values found and the detail is presented in Appendix A). The regression formulas for all the total incremental price curves (the solid green line) is a best fit polynomial (second order) regression analysis/trend line through the four total incremental price points. All prices are presented on a *cumulative* volume basis across the entire market (time based units/year was a proxy to apply adjustment factors for production volume); no distinctions are made among specific suppliers, factories, or manufacturing lines. It is important to note that because prices are for cumulative volumes, volumes across vehicle classes may be additive. For example, if the same gasoline engine is used in both Class 2b&3 and Vocational vehicles, the industry total volume for a technology on that engine will include volumes from both vehicle categories. As a result, the incremental price of the technology may be lower than the price according to the volume in a single vehicle category. Technologies that apply only to a single vehicle category will accumulate volumes more slowly than those technologies that apply to multiple categories (refer to Table 1).

Example using the methodology and application of Indirect Cost Factors (ICF):

a. Range of full retail price is estimated

b. High and low range limits are estimated for calculation (for example, $500 for High range).

c. Initial volume is estimated (for example, 50,000/year)

d. Complexity and Newness of Technology is estimated from Table 2, Table 3, and Table 4 above (for example, Medium complexity and newness of Electrical Machines) [Options are Low/Medium/High Technology Complexity with Mature Technologies/Electrical Machines/Advanced Electronics Newness]

e. With Medium Tech Complexity, the 2012 ICF for short (1 year) and long term (5 year) are 1.39 and 1.29 respectively. A power function formula is used to estimate the ICF in the initial years (years 1 – 5). For our example, Y=1.39X^(-0.046) where X=year and Y=ICF

f. Using the ICF power function, ICF for years 1 to 5 are calculated. Years after 5, the ICF remain constant. For this example, the ICF at this point in the calculation for the years 1

through 10 are:

Years	1	2	3	4	5	6	7	8	9	10
Cumulative Volume	50,000	100,000	150,000	200,000	250,000	300,000	350,000	400,000	450,000	500,000
ICF, Med Tech Complexity	1.39	1.35	1.32	1.30	1.29	1.29	1.29	1.29	1.29	1.29

g. For Newness of technology, a factor of 1 is assumed for years 1 to 5, but for years >5, the Electrical machines newness of 1% reduction for each year after year 5 is used to account for the learning curve/economies-of-scale volumes.

h. For example, year 1 has the ICF of 1.39 times the Newness of 1 equals the adjusted ICF multiplier which is 100% of the initial ICF value of 1.39.

i. For example year 5 has the ICF of 1.29 times the Newness of 1 equals the adjusted ICF multiplier which is 92.8% of the initial ICF (1.39).

j. For example year 6 has the ICF of 1.29 times the Newness of 0.99 (100%-1%) equals the adjusted ICF of 1.28 which is 91.9% of the initial ICF (1.39). For this example, the adjusted ICF and % of initial adjusted ICF (Medium Technology Complexity with Electrical Machines Newness) at this point in the calculation for the years 1 through 10 are:

Years	1	2	3	4	5	6	7	8	9	10
Cumulative Volume	50,000	100,000	150,000	200,000	250,000	300,000	350,000	400,000	450,000	500,000
ICF, Med Tech Complexity	1.39	1.35	1.32	1.30	1.29	1.29	1.29	1.29	1.29	1.29
Electrical Machines Newness	100%	100%	100%	100%	100%	99.0%	98.0%	97.0%	96.0%	95.0%
Adjusted ICF	1.39	1.35	1.32	1.30	1.29	1.28	1.26	1.25	1.24	1.23
% of Initial Adjusted ICF	100.0%	96.9%	95.1%	93.8%	92.8%	91.9%	90.9%	90.0%	89.1%	88.2%

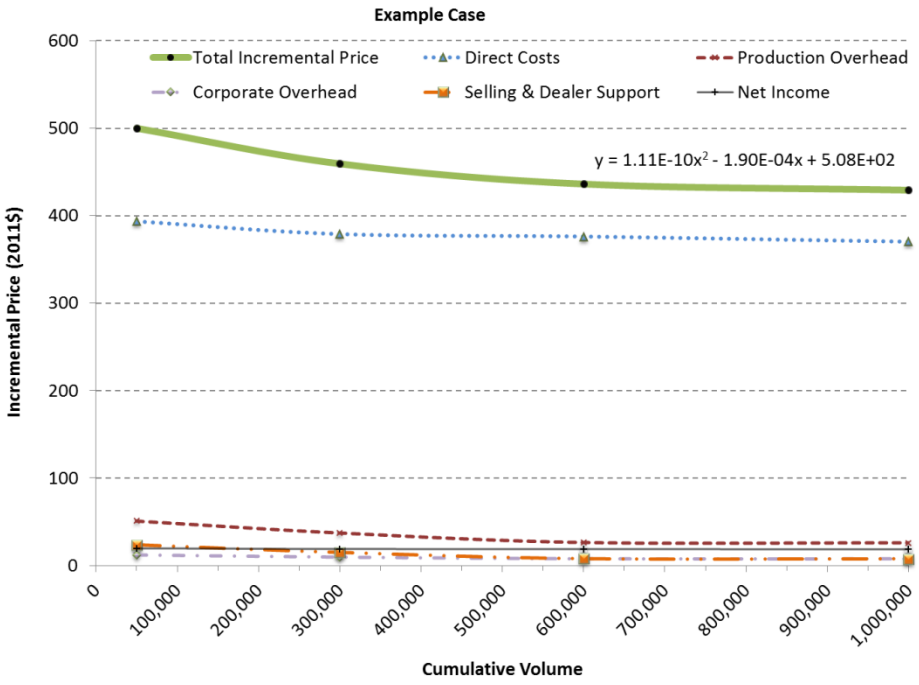
k. The High estimate of $500 (initial price at year 1 and 50,000 units) becomes in year 6 = $459 ($500 x 91.9%) at a cumulative volume of 300,000 (50,000 x 6).

l. This process is done for each year for the high and low ranges out to year 20 (which for our example of 50,000 start volume, has a cumulative volume of 1,000,000 in year 20).

m. The direct/indirect breakouts (direct cost, production overhead, corporate overhead, selling/dealer support, and net income) are applied to the median price based upon the Low/Medium/High Technology and the start/mid/long/end range estimate (Year 1/50,000, Year 6/300,000, Year 12/600,000, Year 20/1,000,000).

n. The 2010 RTI HD Report (for Truck Manufacturers) has the relative cost breakout shown in Table 5, Table 6, Table 7, and Table 8. For our example, we applied the Medium Tech % breakout for 50,000 units to year 1, 300,000 units to Year 6, and 600,000 units to Year 12 to get the data/curve breakouts. This produces the following example breakout table and chart:

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$500.00	$459.39	$436.19	$429.23
Direct Costs	$393.70	$378.91	$376.09	$370.09
Production Overhead	$51.18	$37.34	$26.25	$25.83
Corporate Overhead	$11.81	$9.39	$7.52	$7.40
Selling & Dealer Support	$23.62	$14.81	$7.52	$7.40
Net Income	$19.69	$18.95	$18.80	$18.50



To use the price curves, it is suggested that that the "beginning" production volume and an "ending" production volume for each modeling scenario would need to be identified by the modeler. It's unknown at this time if the modeling scenarios will be by year or by production run on a vehicle (multiple years). Since a supplier typically signs a contract to sell units at $/unit over that time, it is suggested that the average amount between the beginning and ending volumes be used for modeling. It's unlikely that manufacturers are going to buy (or sell) technologies at continually declining $/unit amounts. Additional details of the baseline technologies, prior technologies assumed, supporting data, and references can be found in Appendix A. Descriptions of the gasoline engine technologies, diesel engine technologies, vehicle technologies, and bottoming cycle technology can be found in Appendix A, Appendix B, Appendix C, and Appendix D respectively of an accompanying SwRI report.[18]

Projections of future price contain risk. As the technology matures, it may become more or less expensive, or it may prove unable to achieve the expected benefits. Conversely, a technology may provide greater benefits than projected in this analysis. Therefore, only limited conclusions can be drawn from the evaluation of the technology price results in this report. These price results will be combined by the agencies with technology performance results in subsequent analyses to allow calculation of cost/benefit ratios for each technology.

[18] Reinhart, T.E. (2015, June). *Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #1*. (Report No. DOT HS 812 146). Washington, DC: National Highway Traffic Safety Administration.

Table 9. Class 2b&3 Summary of Volumes and Total Incremental Price

Technology	Vol. 1	Vol. 2	Vol. 3	Vol. 4	Price 1	Price 2	Price 3	Price 4
Engine Technologies								
Coolant/Oil Pump (G)	50,000	300,000	600,000	1,000,000	180.00	165.38	157.03	154.52
Coolant/Oil Pump (D)	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Variable Valve Actuation (High 1)	50,000	300,000	600,000	1,000,000	620.00	520.44	453.38	423.87
Variable Valve Actuation (High 2)	50,000	300,000	600,000	1,000,000	620.00	509.66	443.98	415.08
Cylinder Deactivation	50,000	300,000	600,000	1,000,000	287.50	264.15	250.81	246.81
Stoichiometric GDI	50,000	300,000	600,000	1,000,000	625.00	574.24	545.23	536.53
Lean Burn GDI w/ SCR	50,000	300,000	600,000	1,000,000	1,930.00	1,773.24	1,683.68	1,656.81
Turbocharging and Downsizing	50,000	300,000	600,000	1,000,000	1,390.00	1,277.10	1,212.60	1,193.25
Engine Downspeeding	50,000	300,000	600,000	1,000,000	2,600.00	2,388.82	2,268.17	2,231.98
Low-Friction Engine Oil (G) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	7.50	7.16	6.95	6.84
Low-Friction Engine Oil (D) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	14.00	13.37	12.97	12.76
Engine Friction Reduction (G)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Engine Friction Reduction (D)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Stop / start (G)	50,000	300,000	600,000	1,000,000	700.00	643.14	610.66	600.92
Stop / start (D)	50,000	300,000	600,000	1,000,000	1,500.00	1,378.17	1,308.56	1,287.68
Vehicle and Trailer Technologies								
HEV (High 1)	50,000	300,000	600,000	1,000,000	19,500.00	16,368.75	14,259.38	13,331.25
HEV (High 2)	50,000	300,000	600,000	1,000,000	19,500.00	16,029.66	13,963.98	13,055.08
Air Conditioner System Improvements	50,000	300,000	600,000	1,000,000	317.50	291.71	276.98	272.56
Cab Insulation to Reduce A/C	50,000	300,000	600,000	1,000,000	375.00	358.08	347.28	341.89
Improved 2b and 3 Aerodynamics	50,000	300,000	600,000	1,000,000	280.00	267.37	259.30	255.27
Improved Transmissions (G)	50,000	300,000	600,000	1,000,000	480.00	441.01	418.74	412.06
Improved Transmissions (D)	50,000	300,000	600,000	1,000,000	875.00	803.93	763.33	751.15

Low Rolling Resistance Tires (per tire)	5,000,000	30,000,000	60,000,000	100,000,000	16.00	15.28	14.82	14.59
Weight Reduction (500 pounds)	300,000	1,800,000	3,600,000	6,000,000	2,000.00	1,909.76	1,852.18	1,823.39
Chassis friction reduction and improved lube	50,000	300,000	600,000	1,000,000	250.00	238.72	231.52	227.92

Table 10. Vocational Summary of Volumes and Total Incremental Price

Technology	Vol. 1	Vol. 2	Vol. 3	Vol. 4	Price 1	Price 2	Price 3	Price 4
Engine Technologies								
Coolant/Oil Pump (G)	50,000	300,000	600,000	1,000,000	180.00	165.38	157.03	154.52
Coolant/Oil Pump (D)	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Variable Valve Actuation (High 1)	50,000	300,000	600,000	1,000,000	635.00	533.03	464.34	434.12
Variable Valve Actuation (High 2)	50,000	300,000	600,000	1,000,000	635.00	521.99	454.72	425.13
Cylinder Deactivation	50,000	300,000	600,000	1,000,000	287.50	264.15	250.81	246.81
Stoichiometric GDI	50,000	300,000	600,000	1,000,000	625.00	574.24	545.23	536.53
Lean Burn GDI w/ SCR	50,000	300,000	600,000	1,000,000	1,930.00	1,773.24	1,683.68	1,656.81
Stoichiometric GDI + EGR	50,000	300,000	600,000	1,000,000	1,430.00	1,313.85	1,247.49	1,227.59
Turbocharging and Downsizing	50,000	300,000	600,000	1,000,000	1,390.00	1,277.10	1,212.60	1,193.25
Engine Downspeeding	50,000	300,000	600,000	1,000,000	2,600.00	2,388.82	2,268.17	2,231.98
Low-Friction Engine Oil (G) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	7.50	7.16	6.95	6.84
Low-Friction Engine Oil (D) (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	14.00	13.37	12.97	12.76
Engine Friction Reduction (G)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Engine Friction Reduction (D)	50,000	300,000	600,000	1,000,000	228.00	217.71	211.15	207.87
Stop / start (G)	50,000	300,000	600,000	1,000,000	700.00	643.14	610.66	600.92
Stop / start (D)	50,000	300,000	600,000	1,000,000	1,500.00	1,378.17	1,308.56	1,287.68
Vehicle and Trailer Technologies								
HEV (High 1)	50,000	300,000	600,000	1,000,000	32,000.00	26,861.54	23,400.00	21,876.92
HEV (High 2)	50,000	300,000	600,000	1,000,000	32,000.00	26,305.08	22,915.25	21,423.73

Air Conditioner System Improvements	50,000	300,000	600,000	1,000,000	317.50	291.71	276.98	272.56
Cab Insulation to Reduce A/C	50,000	300,000	600,000	1,000,000	375.00	358.08	347.28	341.89
Improved Transmissions (G)	50,000	300,000	600,000	1,000,000	750.00	689.08	654.28	643.84
Improved Transmissions (D)	50,000	300,000	600,000	1,000,000	1,325.00	1,217.38	1,155.90	1,137.45
AMT vs. Manual	50,000	300,000	600,000	1,000,000	1,050.00	964.72	915.99	901.38
Dual Clutch Automatic (High 1)	50,000	300,000	600,000	1,000,000	2,700.00	2,266.44	1,974.38	1,845.87
Dual Clutch Automatic (High 2)	50,000	300,000	600,000	1,000,000	2,700.00	2,219.49	1,933.47	1,807.63
Low Rolling Resistance Tires (per tire)	700,000	4,200,000	8,400,000	14,000,000	30.50	29.12	28.25	27.81
Automatic Tire Pressure Control	50,000	300,000	600,000	1,000,000	800.00	763.90	740.87	729.35
Weight Reduction (1,000 pounds)	300,000	1,800,000	3,600,000	6,000,000	6,000.00	5,729.27	5,556.53	5,470.16
Chassis friction reduction and improved lube	50,000	300,000	600,000	1,000,000	250.00	238.72	231.52	227.92

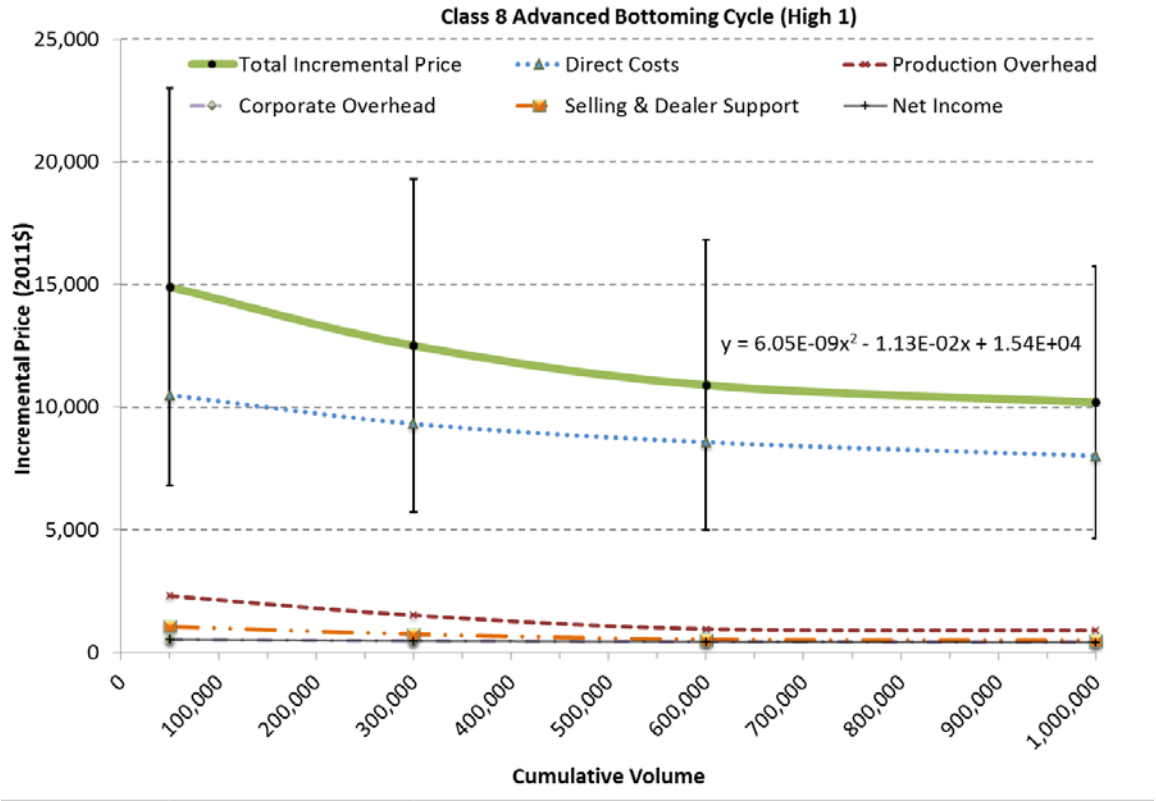
Table 11. Line Haul Summary of Volumes and Total Incremental Price

Technology	Vol. 1	Vol. 2	Vol. 3	Vol. 4	Price 1	Price 2	Price 3	Price 4
Engine Technologies								
Advanced Bottoming Cycle (High 1)	50,000	300,000	600,000	1,000,000	14,900.00	12,507.40	10,895.63	10,186.44
Advanced Bottoming Cycle (High 2)	50,000	300,000	600,000	1,000,000	14,900.00	12,248.31	10,669.92	9,975.42
Coolant/Oil Pump	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Variable Valve Actuation (High 1)	50,000	300,000	600,000	1,000,000	525.00	440.70	383.91	358.92
Variable Valve Actuation (High 2)	50,000	300,000	600,000	1,000,000	525.00	431.57	375.95	351.48
Low-Friction Engine Oil (per vehicle)	300,000	1,800,000	3,600,000	6,000,000	102.50	97.88	94.92	93.45
Engine Friction Reduction	50,000	300,000	600,000	1,000,000	282.00	269.28	261.16	257.10

Reduced Aftertreatment Backpressure	50,000	300,000	600,000	1,000,000	727.50	694.67	673.73	663.26
Air handling Improvement	50,000	300,000	600,000	1,000,000	1,125.00	1,033.62	981.42	965.76
Mechanical Turbocompound	50,000	300,000	600,000	1,000,000	2,500.00	2,296.94	2,180.94	2,146.13
Electric Turbocompound (High 1)	50,000	300,000	600,000	1,000,000	4,200.00	3,525.58	3,071.25	2,871.35
Electric Turbocompound (High 2)	50,000	300,000	600,000	1,000,000	4,200.00	3,452.54	3,007.63	2,811.86
Vehicle and Trailer Technologies								
HEV (High 1)	50,000	300,000	600,000	1,000,000	35,000.00	29,379.81	25,593.75	23,927.88
HEV (High 2)	50,000	300,000	600,000	1,000,000	35,000.00	28,771.19	25,063.56	23,432.20
Diesel APU	50,000	300,000	600,000	1,000,000	10,000.00	9,187.77	8,723.74	8,584.53
Battery APU	50,000	300,000	600,000	1,000,000	6,400.00	5,880.17	5,583.19	5,494.10
Fuel-Fired Heater	50,000	300,000	600,000	1,000,000	1,200.00	1,102.53	1,046.85	1,030.14
Air Conditioner System Improvements	50,000	300,000	600,000	1,000,000	317.50	291.71	276.98	272.56
Cab Insulation to Reduce A/C	50,000	300,000	600,000	1,000,000	375.00	358.08	347.28	341.89
Air Compressor Improvements	50,000	300,000	600,000	1,000,000	350.00	321.57	305.33	300.46
Shore Power	50,000	300,000	600,000	1,000,000	1,050.00	1,002.62	972.39	957.28
Aero: Trailer (Side) skirt (4 to 6 m)	25,000	150,000	300,000	700,000	550.00	525.18	509.35	498.79
Aero: Boat tail	25,000	150,000	300,000	500,000	1,200.00	1,145.85	1,111.31	1,094.03
Aero: Complete trailer skirt (7 to 9 m)	50,000	300,000	600,000	1,000,000	925.00	883.26	856.63	843.32
Aero: Full tractor skirt (over axles)	25,000	150,000	300,000	500,000	1,750.00	1,671.04	1,620.66	1,595.46
Aero: Gap filler	25,000	150,000	300,000	500,000	825.00	787.78	764.02	752.15
Aero on regional haul	25,000	150,000	300,000	500,000	1,150.00	1,098.11	1,065.00	1,048.45
Improved Transmissions	50,000	300,000	600,000	1,000,000	1,800.00	1,653.80	1,570.27	1,545.22
AMT vs. Manual	50,000	300,000	600,000	1,000,000	4,000.00	3,675.11	3,489.50	3,433.81
Dual Clutch Automatic (High 1)	50,000	300,000	600,000	1,000,000	10,350.00	8,688.03	7,568.44	7,075.82

Dual Clutch Automatic (High 2)	50,000	300,000	600,000	1,000,000	10,350.00	8,508.05	7,411.65	6,929.24
Low Rolling Resistance Tires (per tire)	3,000,000	18,000,000	36,000,000	60,000,000	40.50	38.67	37.51	36.92
Single Wide Tires (per tire and wheel)	300,000	1,800,000	3,600,000	6,000,000	141.00	134.64	130.58	128.55
Automatic Tire Pressure Control	50,000	300,000	600,000	1,000,000	1,142.50	1,090.95	1,058.06	1,041.61
Weight Reduction (2,000 pounds)	300,000	1,800,000	3,600,000	6,000,000	12,000.00	11,458.55	11,113.06	10,940.32
6X2 Tractors or Clutched 6X4	300,000	1,800,000	3,600,000	6,000,000	1,100.00	1,050.37	1,018.70	1,002.86
Chassis friction reduction and improved lube	50,000	300,000	600,000	1,000,000	250.00	238.72	231.52	227.92

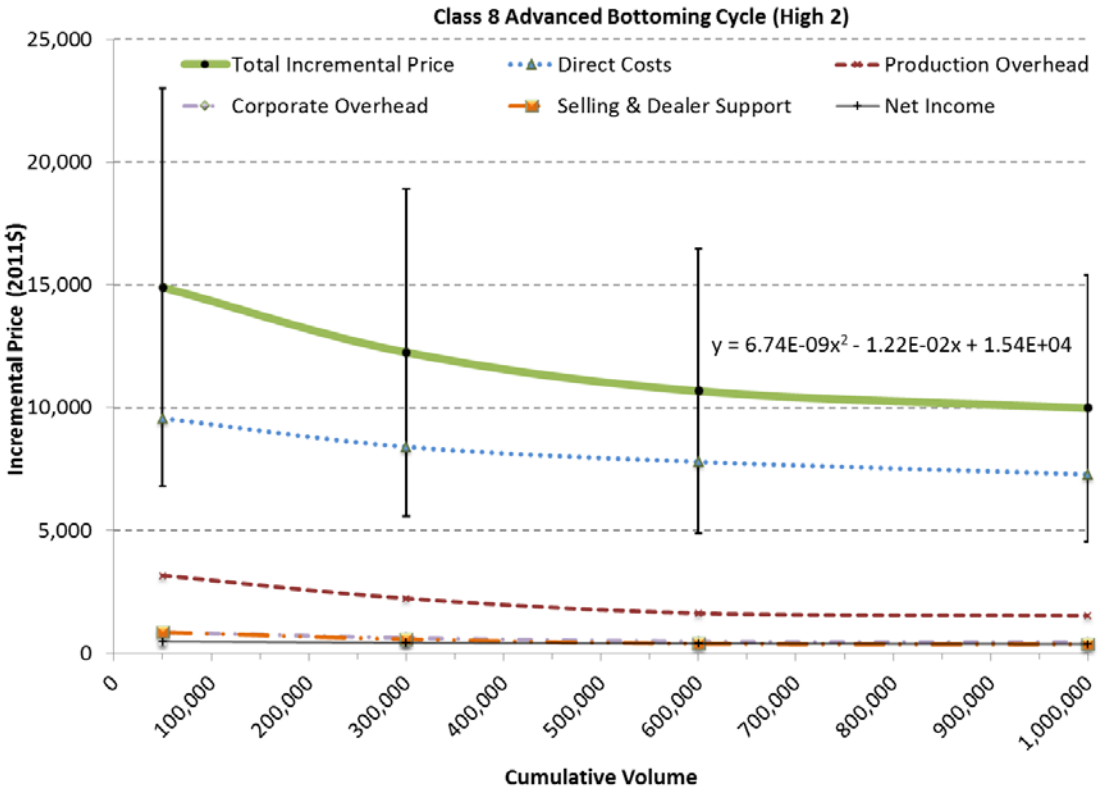
3.1 Advanced Bottoming Cycle



Class 8 Advanced Bottoming Cycle (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$14,900.00	$12,507.40	$10,895.63	$10,186.44
Direct Costs	$10,492.96	$9,328.19	$8,579.23	$8,020.82
Production Overhead	$2,308.45	$1,510.54	$943.72	$882.29
Corporate Overhead	$524.65	$466.41	$428.96	$401.04
Selling & Dealer Support	$1,049.30	$735.85	$514.75	$481.25
Net Income	$524.65	$466.41	$428.96	$401.04

Figure 1. Incremental Price and Breakouts for Line Haul Advanced Bottoming Cycle (High 1)

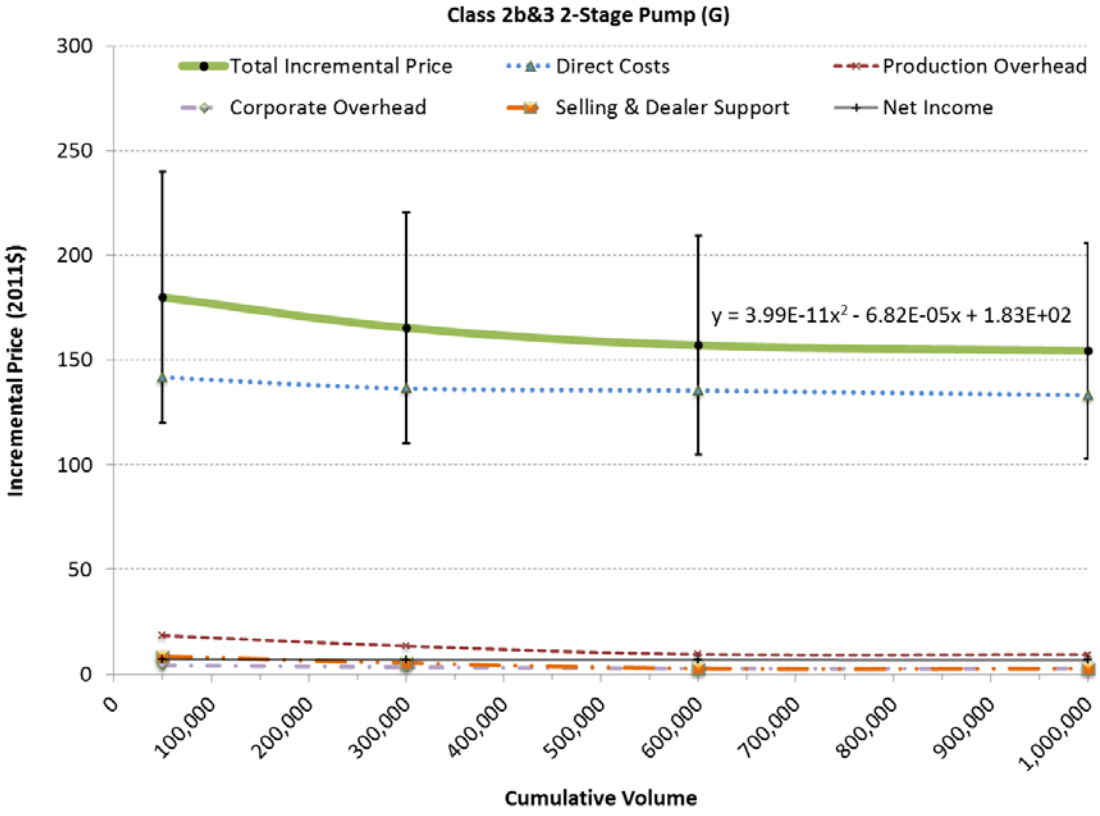


Class 8 Advanced Bottoming Cycle (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$14,900.00	$12,248.31	$10,669.92	$9,975.42
Direct Costs	$9,551.28	$8,402.46	$7,799.65	$7,291.98
Production Overhead	$3,151.92	$2,226.65	$1,622.33	$1,516.73
Corporate Overhead	$859.62	$621.92	$467.98	$437.52
Selling & Dealer Support	$859.62	$577.15	$389.98	$364.60
Net Income	$477.56	$420.12	$389.98	$364.60

Figure 2. Incremental Price and Breakouts for Line Haul Advanced Bottoming Cycle (High 2)

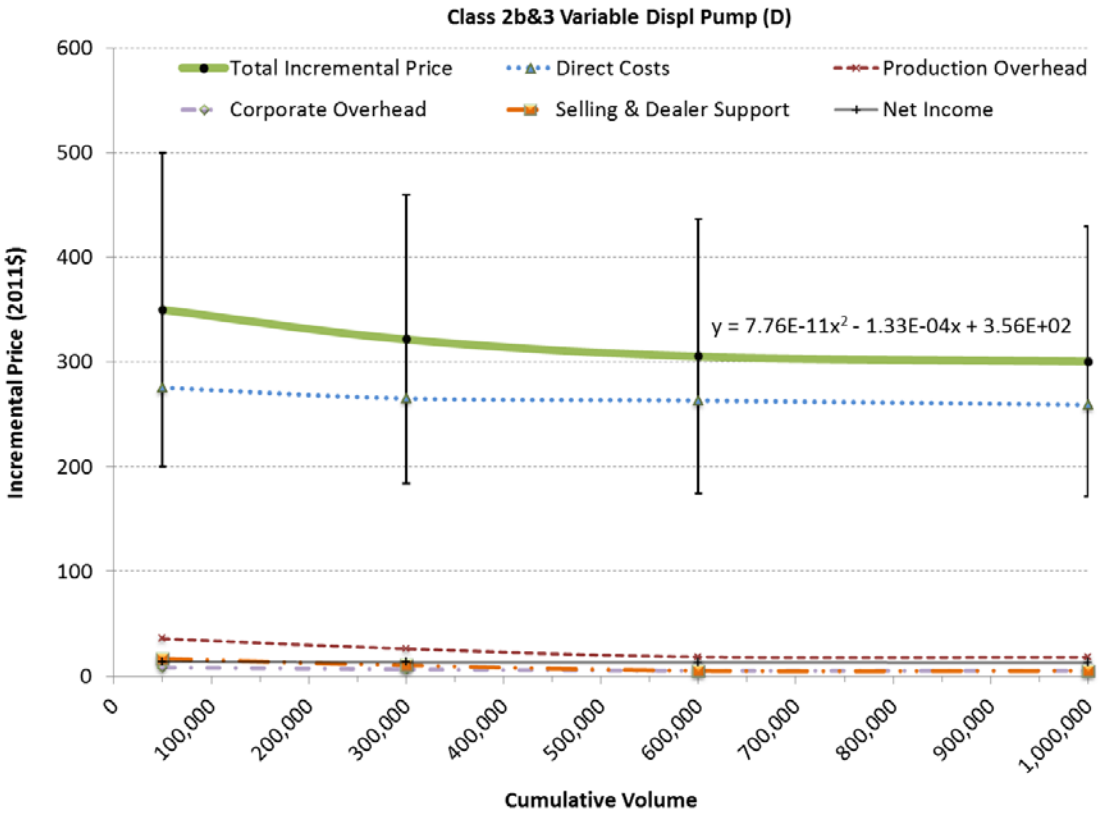
3.2 Coolant/Oil Pump



Class 2b&3 2-Stage Pump (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$180.00	$165.38	$157.03	$154.52
Direct Costs	$141.73	$136.41	$135.39	$133.23
Production Overhead	$18.43	$13.44	$9.45	$9.30
Corporate Overhead	$4.25	$3.38	$2.71	$2.66
Selling & Dealer Support	$8.50	$5.33	$2.71	$2.66
Net Income	$7.09	$6.82	$6.77	$6.66

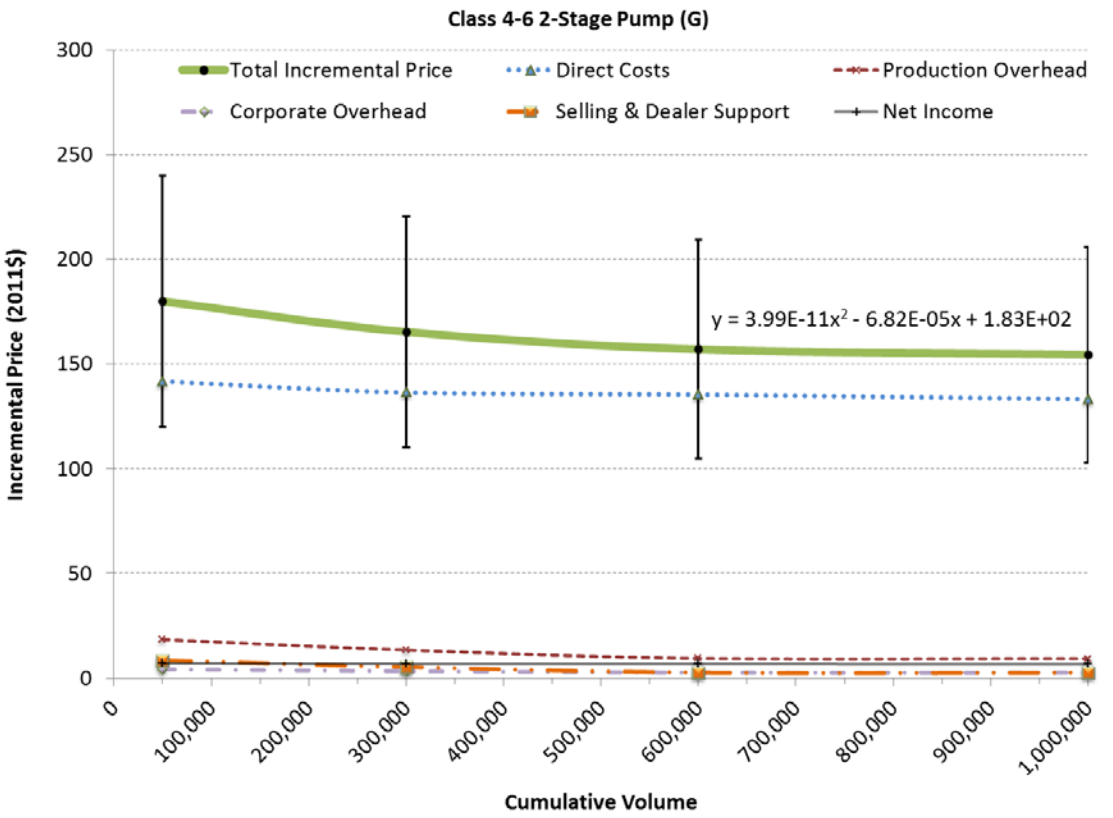
Figure 3. Incremental Price and Breakouts for Class 2b&3 (Gasoline) 2-Stage Pump (Coolant/Oil)



Class 2b&3 Variable Displ Pump (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$350.00	$321.57	$305.33	$300.46
Direct Costs	$275.59	$265.24	$263.26	$259.06
Production Overhead	$35.83	$26.13	$18.38	$18.08
Corporate Overhead	$8.27	$6.57	$5.27	$5.18
Selling & Dealer Support	$16.54	$10.37	$5.27	$5.18
Net Income	$13.78	$13.26	$13.16	$12.95

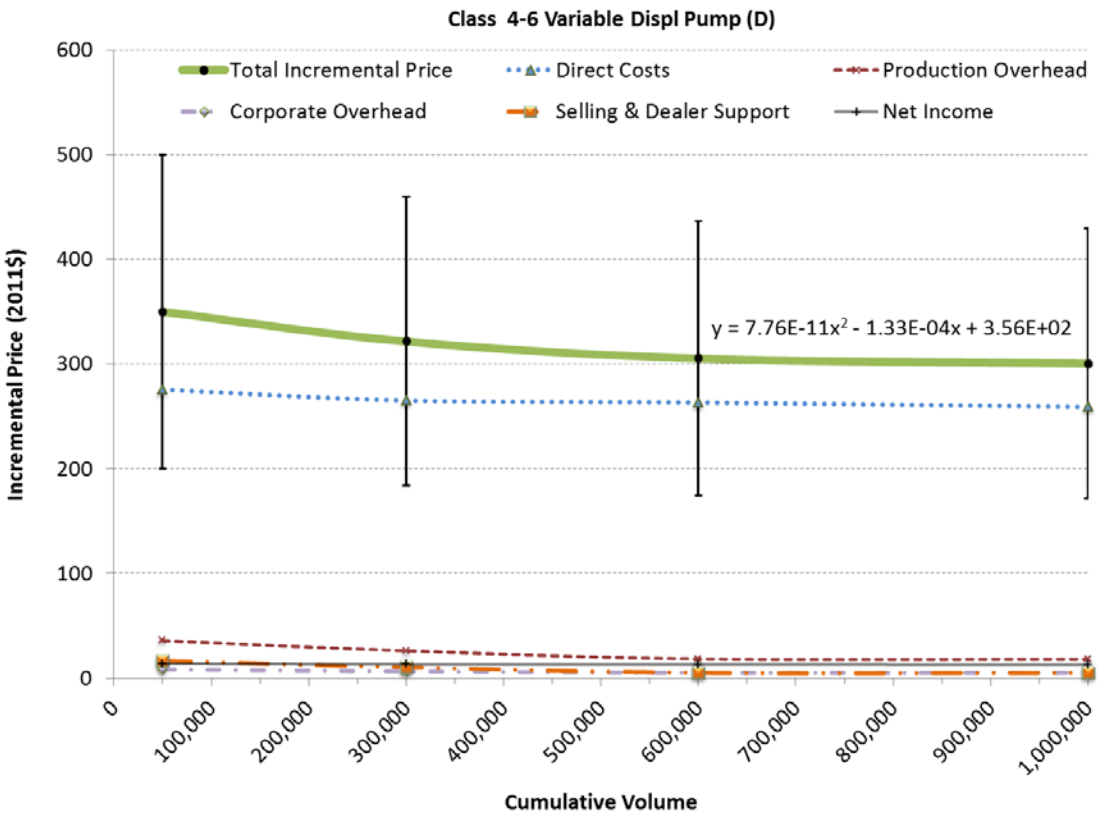
Figure 4. Incremental Price and Breakouts for Class 2b&3 (Diesel) Variable Displacement Pump (Coolant/Oil)



Class 4-6 2-Stage Pump (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$180.00	$165.38	$157.03	$154.52
Direct Costs	$141.73	$136.41	$135.39	$133.23
Production Overhead	$18.43	$13.44	$9.45	$9.30
Corporate Overhead	$4.25	$3.38	$2.71	$2.66
Selling & Dealer Support	$8.50	$5.33	$2.71	$2.66
Net Income	$7.09	$6.82	$6.77	$6.66

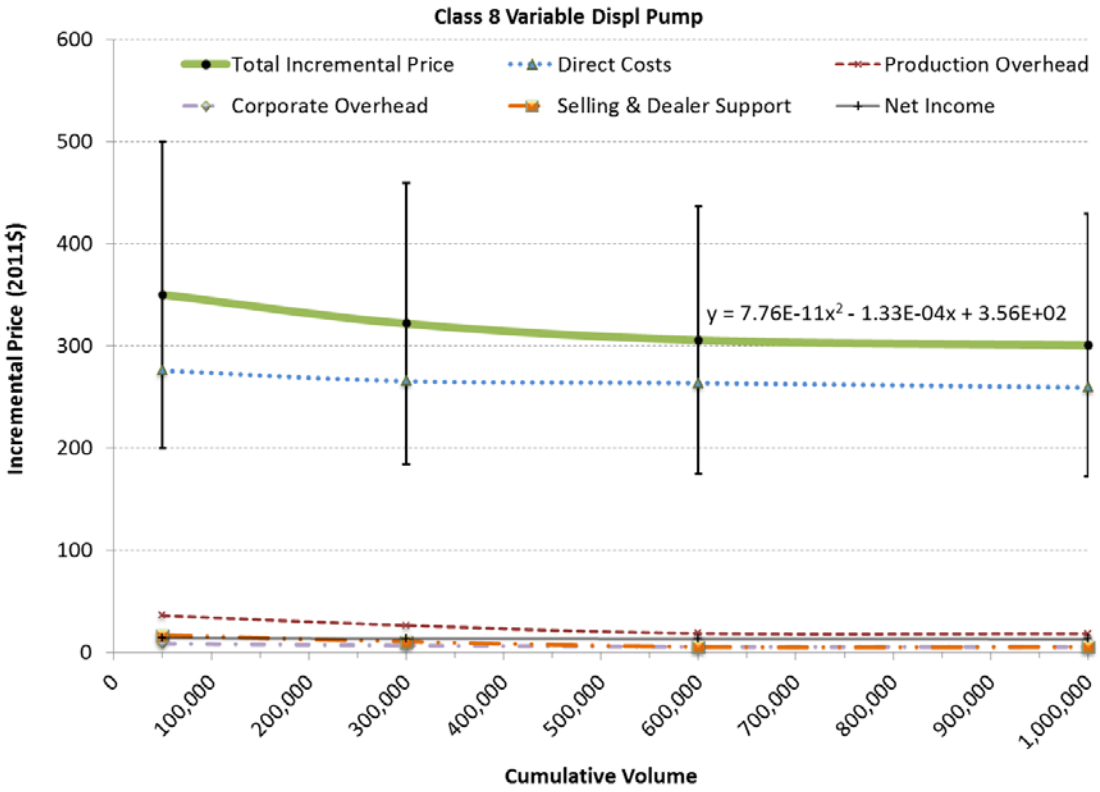
Figure 5. Incremental Price and Breakouts for Vocational (Gasoline) 2-Stage Pump (Coolant/Oil)



Class 4-6 Variable Displ Pump (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$350.00	$321.57	$305.33	$300.46
Direct Costs	$275.59	$265.24	$263.26	$259.06
Production Overhead	$35.83	$26.13	$18.38	$18.08
Corporate Overhead	$8.27	$6.57	$5.27	$5.18
Selling & Dealer Support	$16.54	$10.37	$5.27	$5.18
Net Income	$13.78	$13.26	$13.16	$12.95

Figure 6. Incremental Price and Breakouts for Vocational (Diesel) Variable Displacement Pump (Coolant/Oil)

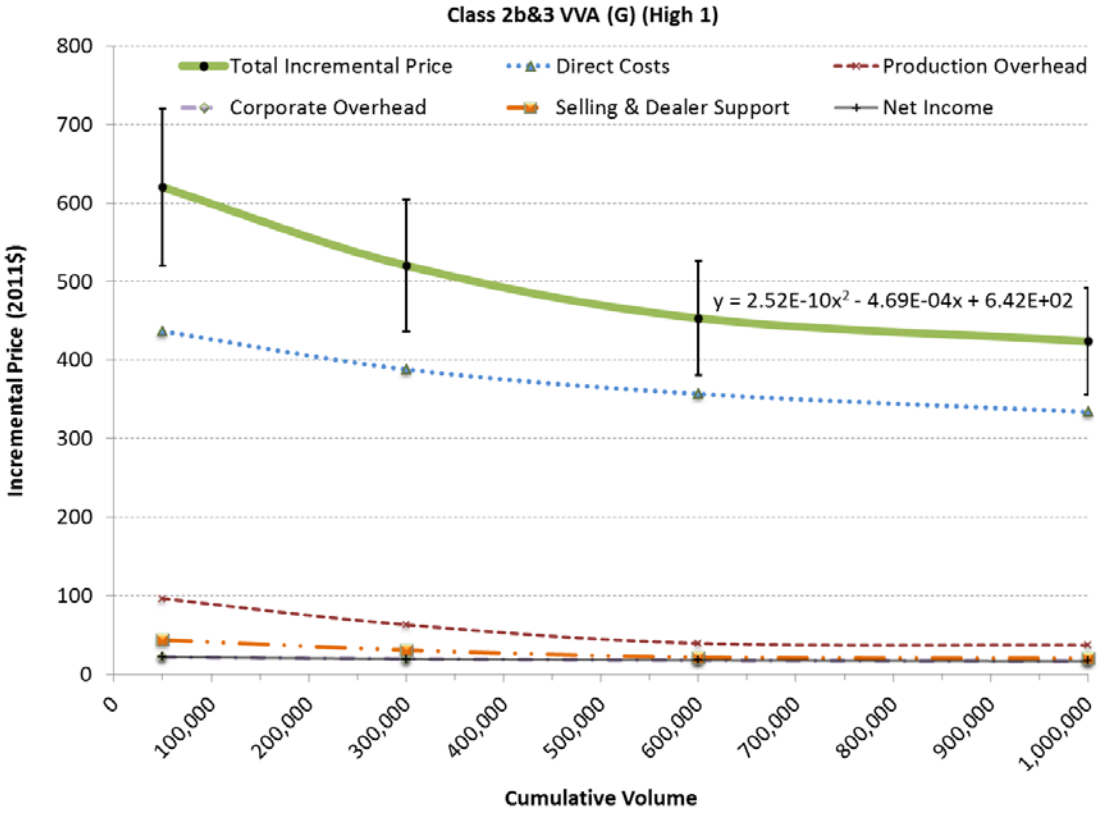


Class 8 Variable Displ Pump

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$350.00	$321.57	$305.33	$300.46
Direct Costs	$275.59	$265.24	$263.26	$259.06
Production Overhead	$35.83	$26.13	$18.38	$18.08
Corporate Overhead	$8.27	$6.57	$5.27	$5.18
Selling & Dealer Support	$16.54	$10.37	$5.27	$5.18
Net Income	$13.78	$13.26	$13.16	$12.95

Figure 7. Incremental Price and Breakouts for Line Haul Variable Displacement Pump (Coolant/Oil)

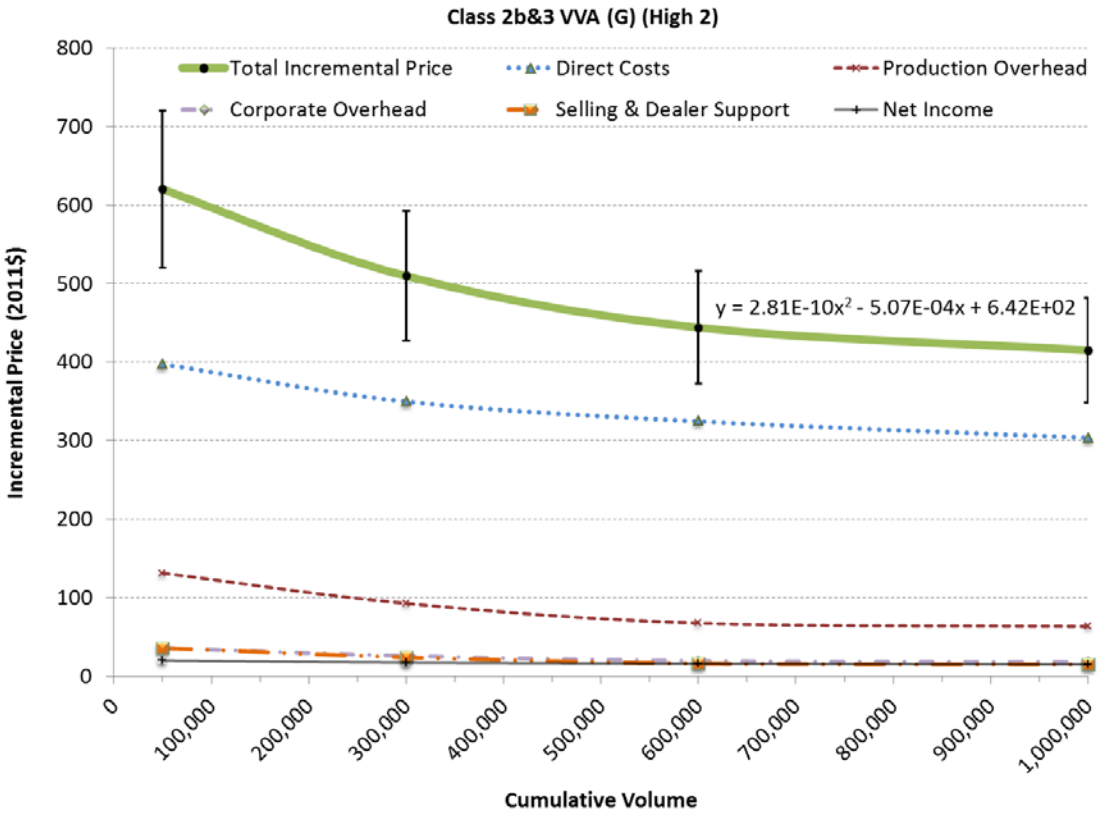
3.3 Variable Valve Actuation (priced per vehicle)



Class 2b&3 VVA (G) (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$620.00	$520.44	$453.38	$423.87
Direct Costs	$436.62	$388.15	$356.99	$333.75
Production Overhead	$96.06	$62.85	$39.27	$36.71
Corporate Overhead	$21.83	$19.41	$17.85	$16.69
Selling & Dealer Support	$43.66	$30.62	$21.42	$20.03
Net Income	$21.83	$19.41	$17.85	$16.69

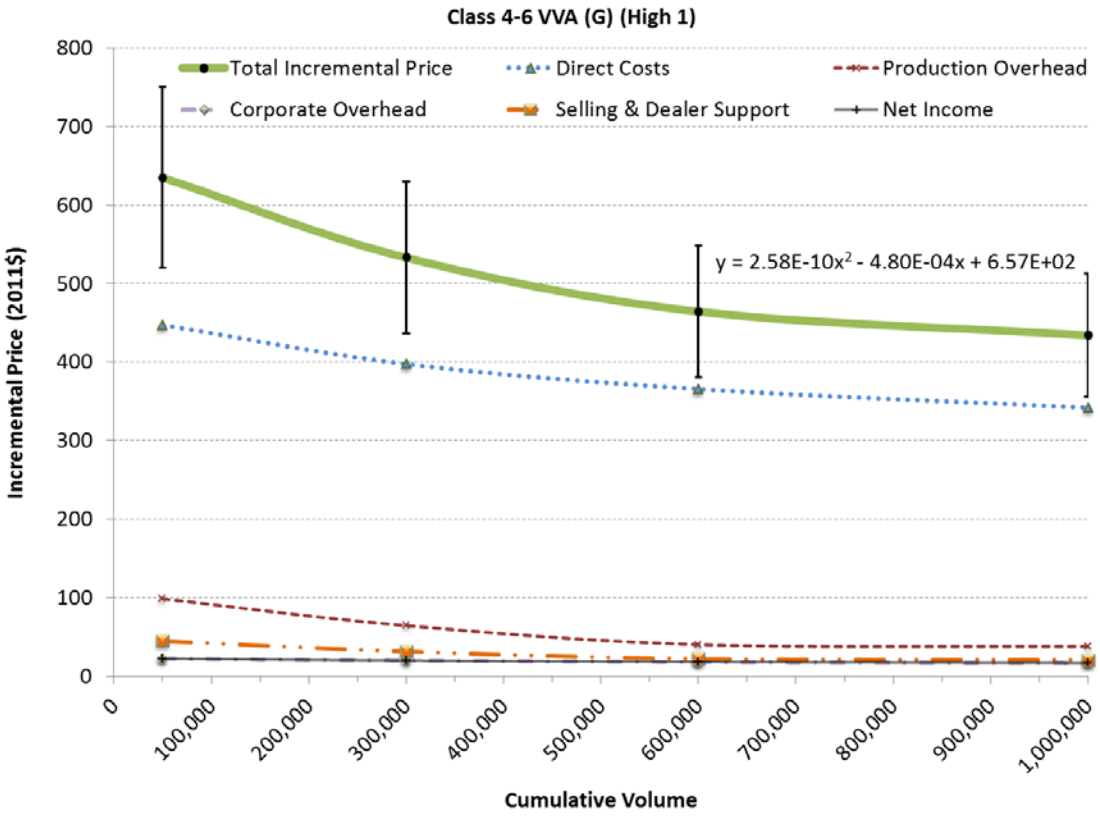
Figure 8. Incremental Price and Breakouts for Class 2b&3 (Gasoline) VVA (High 1 Complexity)



Class 2b&3 VVA (G) (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$620.00	$509.66	$443.98	$415.08
Direct Costs	$397.44	$349.63	$324.55	$303.42
Production Overhead	$131.15	$92.65	$67.51	$63.11
Corporate Overhead	$35.77	$25.88	$19.47	$18.21
Selling & Dealer Support	$35.77	$24.02	$16.23	$15.17
Net Income	$19.87	$17.48	$16.23	$15.17

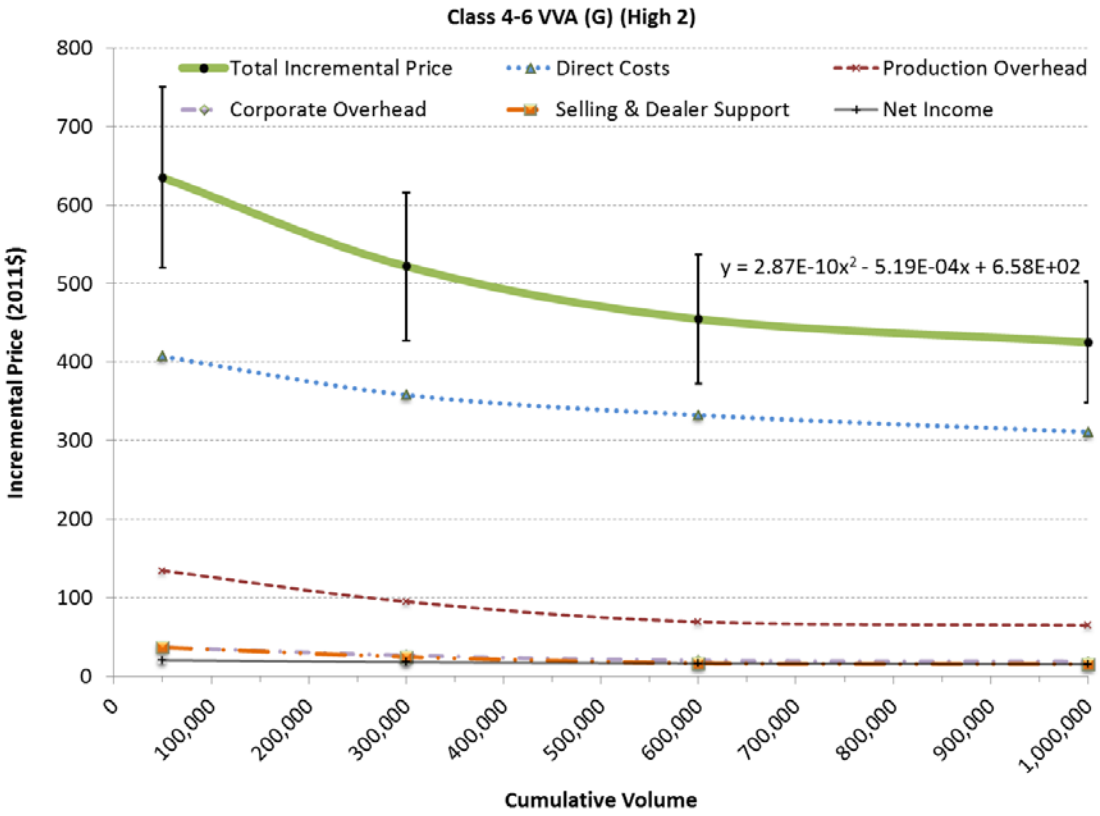
Figure 9. Incremental Price and Breakouts for Class 2b&3 (Gasoline) VVA (High 2 Complexity)



Class 4-6 VVA (G) (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$635.00	$533.03	$464.34	$434.12
Direct Costs	$447.18	$397.54	$365.63	$341.83
Production Overhead	$98.38	$64.38	$40.22	$37.60
Corporate Overhead	$22.36	$19.88	$18.28	$17.09
Selling & Dealer Support	$44.72	$31.36	$21.94	$20.51
Net Income	$22.36	$19.88	$18.28	$17.09

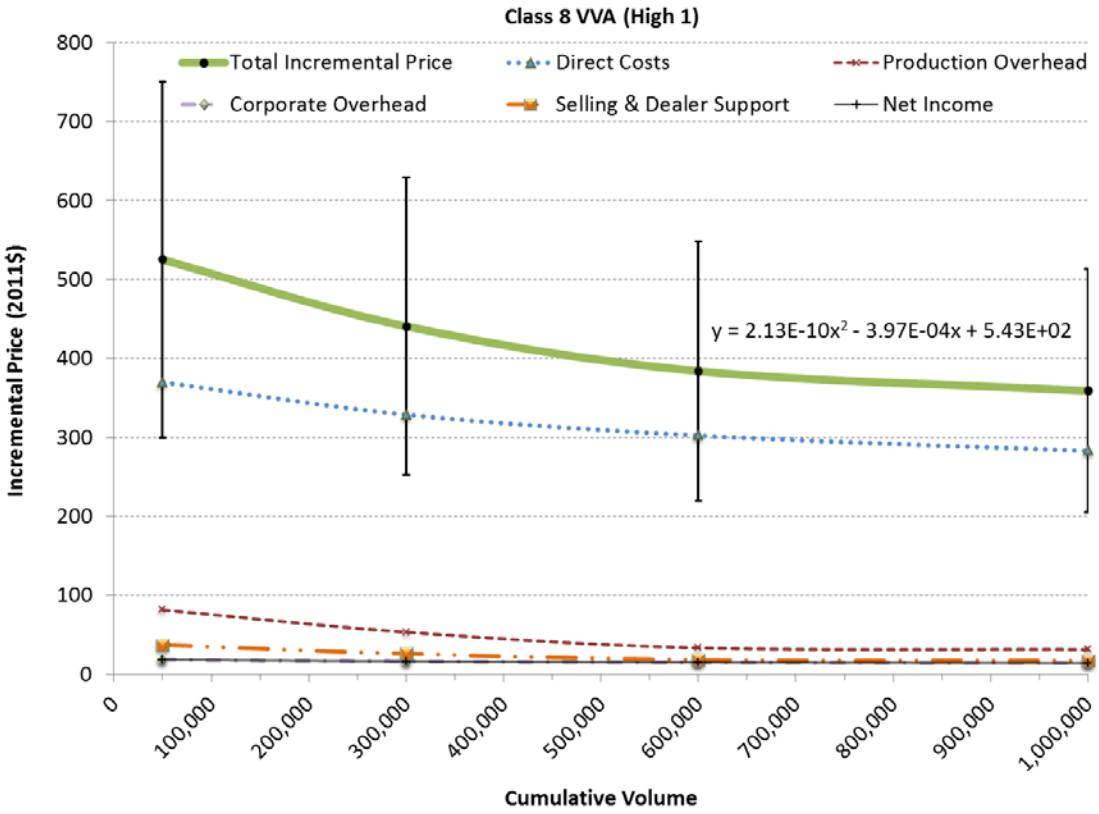
Figure 10. Incremental Price and Breakouts for Vocational (Gasoline) VVA (High 1 Complexity)



Class 4-6 VVA (G) (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$635.00	$521.99	$454.72	$425.13
Direct Costs	$407.05	$358.09	$332.40	$310.77
Production Overhead	$134.33	$94.89	$69.14	$64.64
Corporate Overhead	$36.63	$26.50	$19.94	$18.65
Selling & Dealer Support	$36.63	$24.60	$16.62	$15.54
Net Income	$20.35	$17.90	$16.62	$15.54

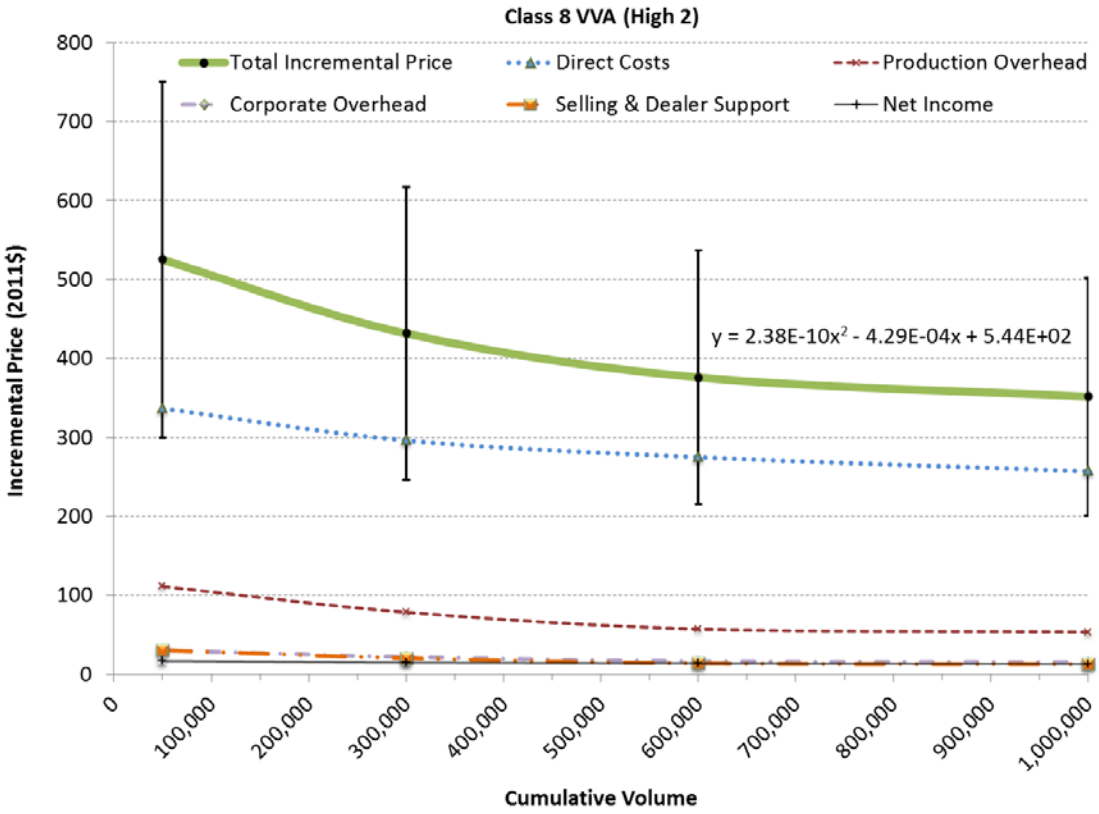
Figure 11. Incremental Price and Breakouts for Vocational (Gasoline) VVA (High 2 Complexity)



Class 8 VVA (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$525.00	$440.70	$383.91	$358.92
Direct Costs	$369.72	$328.68	$302.29	$282.61
Production Overhead	$81.34	$53.22	$33.25	$31.09
Corporate Overhead	$18.49	$16.43	$15.11	$14.13
Selling & Dealer Support	$36.97	$25.93	$18.14	$16.96
Net Income	$18.49	$16.43	$15.11	$14.13

Figure 12. Incremental Price and Breakouts for Line Haul VVA (High 1 Complexity)

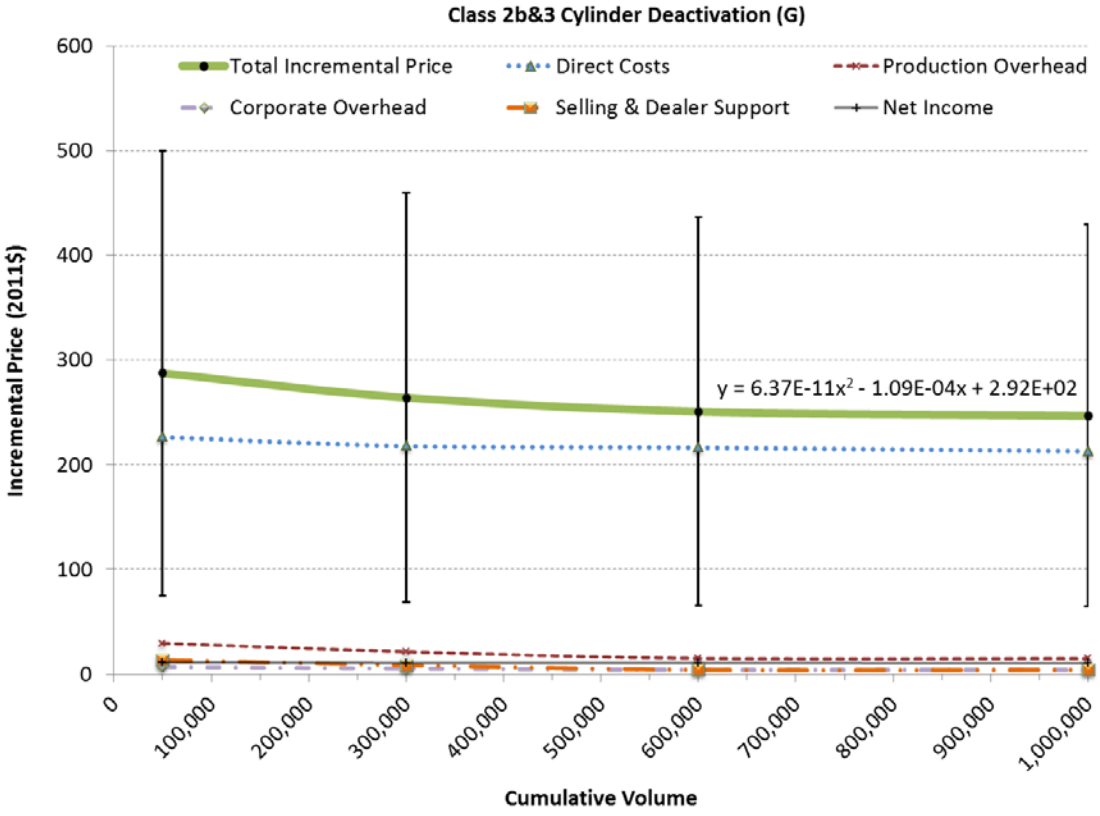


Class 8 VVA (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$525.00	$431.57	$375.95	$351.48
Direct Costs	$336.54	$296.06	$274.82	$256.93
Production Overhead	$111.06	$78.46	$57.16	$53.44
Corporate Overhead	$30.29	$21.91	$16.49	$15.42
Selling & Dealer Support	$30.29	$20.34	$13.74	$12.85
Net Income	$16.83	$14.80	$13.74	$12.85

Figure 13. Incremental Price and Breakouts for Line Haul VVA (High 2 Complexity)

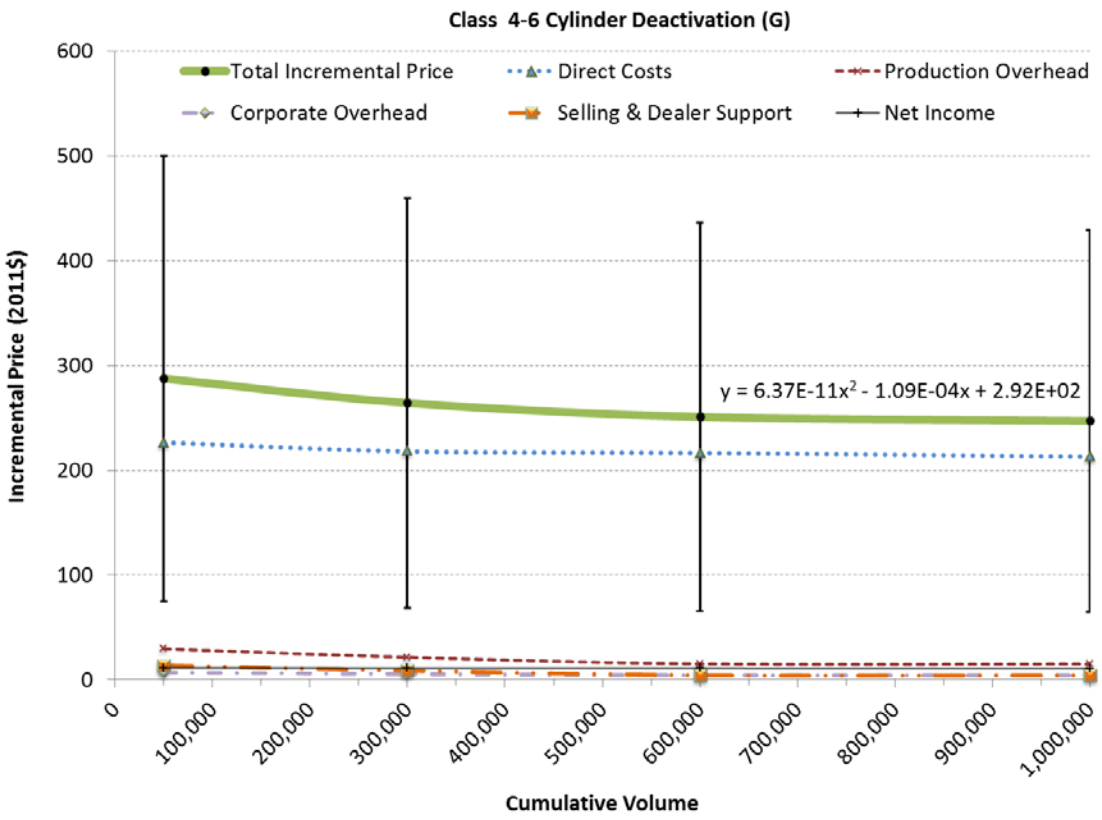
3.4 Cylinder Deactivation



Class 2b&3 Cylinder Deactivation (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$287.50	$264.15	$250.81	$246.81
Direct Costs	$226.38	$217.87	$216.25	$212.80
Production Overhead	$29.43	$21.47	$15.09	$14.85
Corporate Overhead	$6.79	$5.40	$4.33	$4.26
Selling & Dealer Support	$13.58	$8.52	$4.33	$4.26
Net Income	$11.32	$10.89	$10.81	$10.64

Figure 14. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Cylinder Deactivation

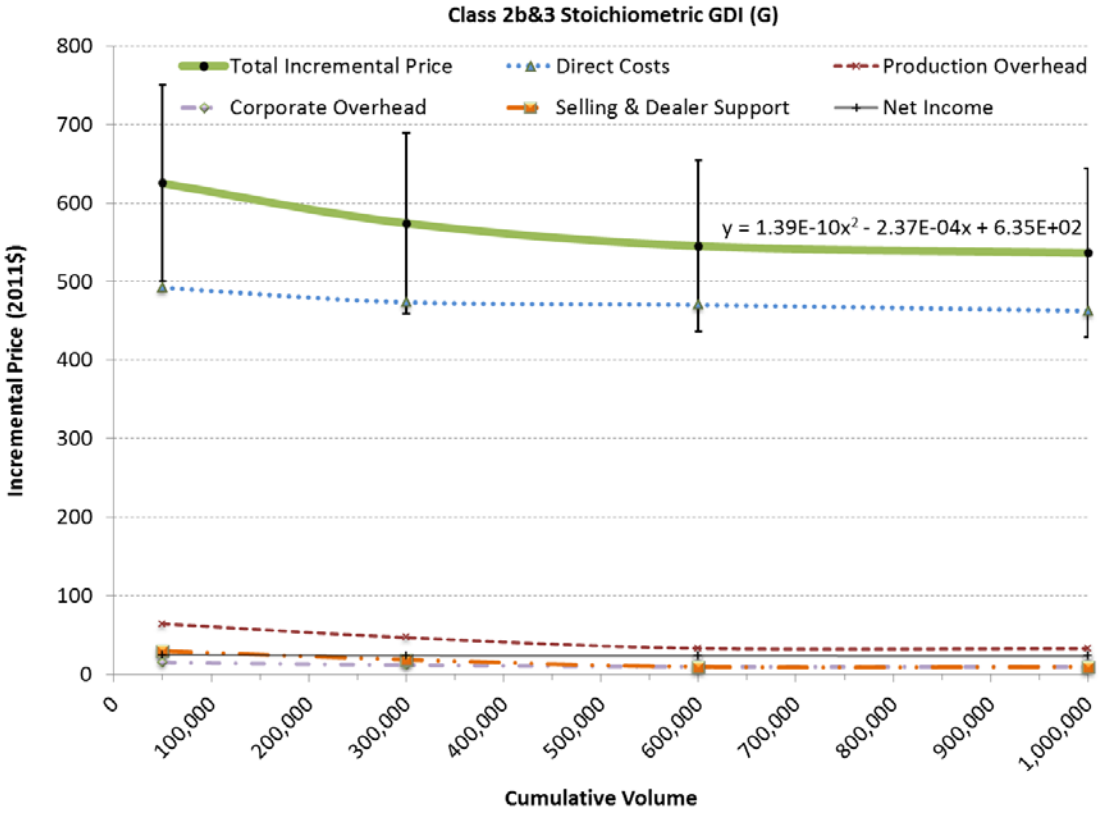


Class 4-6 Cylinder Deactivation (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$287.50	$264.15	$250.81	$246.81
Direct Costs	$226.38	$217.87	$216.25	$212.80
Production Overhead	$29.43	$21.47	$15.09	$14.85
Corporate Overhead	$6.79	$5.40	$4.33	$4.26
Selling & Dealer Support	$13.58	$8.52	$4.33	$4.26
Net Income	$11.32	$10.89	$10.81	$10.64

Figure 15. Incremental Price and Breakouts for Vocational (Gasoline) Cylinder Deactivation

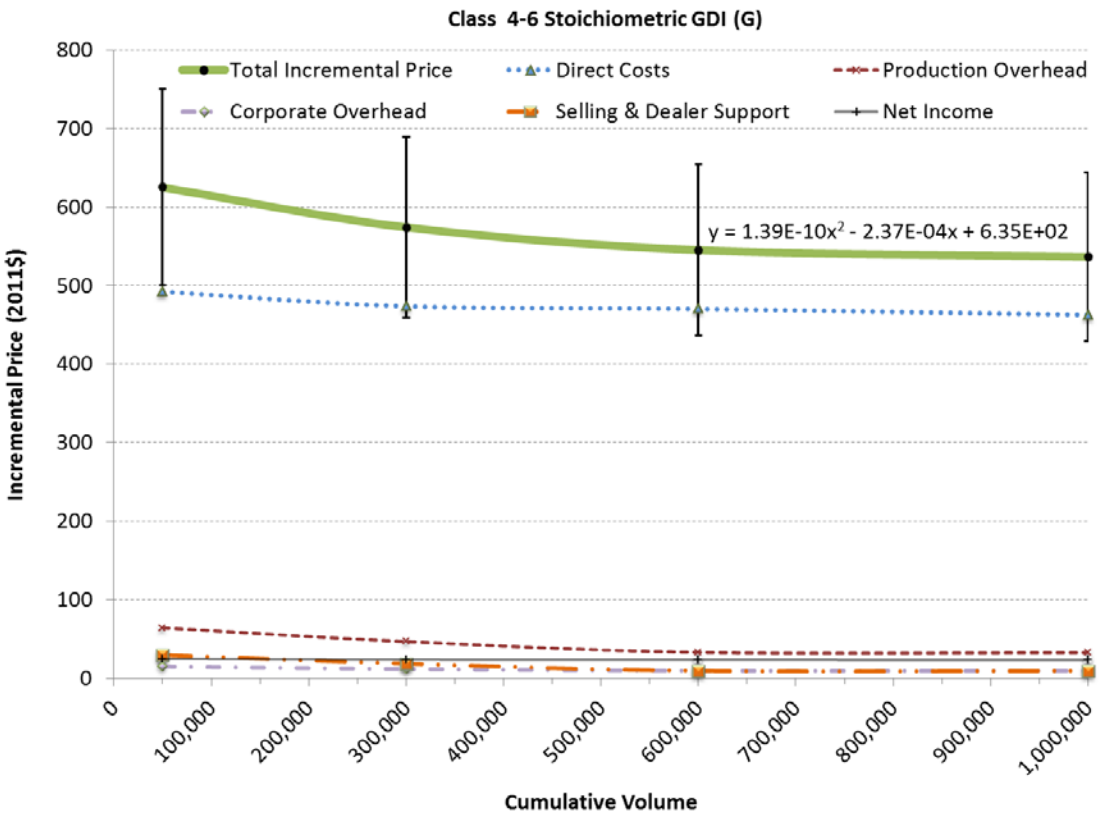
3.5 Stoichiometric GDI



Class 2b&3 Stoichiometric GDI (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$625.00	$574.24	$545.23	$536.53
Direct Costs	$492.13	$473.64	$470.11	$462.61
Production Overhead	$63.98	$46.67	$32.81	$32.29
Corporate Overhead	$14.76	$11.73	$9.40	$9.25
Selling & Dealer Support	$29.53	$18.52	$9.40	$9.25
Net Income	$24.61	$23.68	$23.51	$23.13

Figure 16. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Stoichiometric GDI

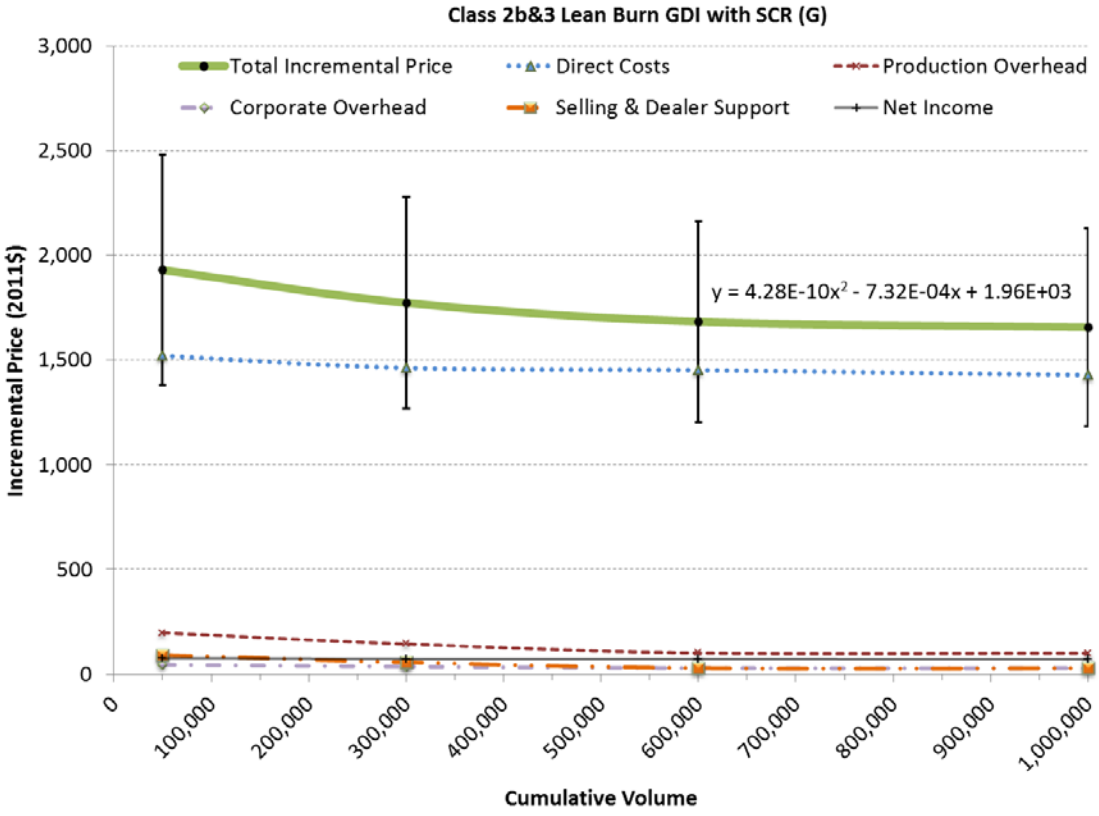


Class 4-6 Stoichiometric GDI (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$625.00	$574.24	$545.23	$536.53
Direct Costs	$492.13	$473.64	$470.11	$462.61
Production Overhead	$63.98	$46.67	$32.81	$32.29
Corporate Overhead	$14.76	$11.73	$9.40	$9.25
Selling & Dealer Support	$29.53	$18.52	$9.40	$9.25
Net Income	$24.61	$23.68	$23.51	$23.13

Figure 17. Incremental Price and Breakouts for Vocational (Gasoline) Stoichiometric GDI

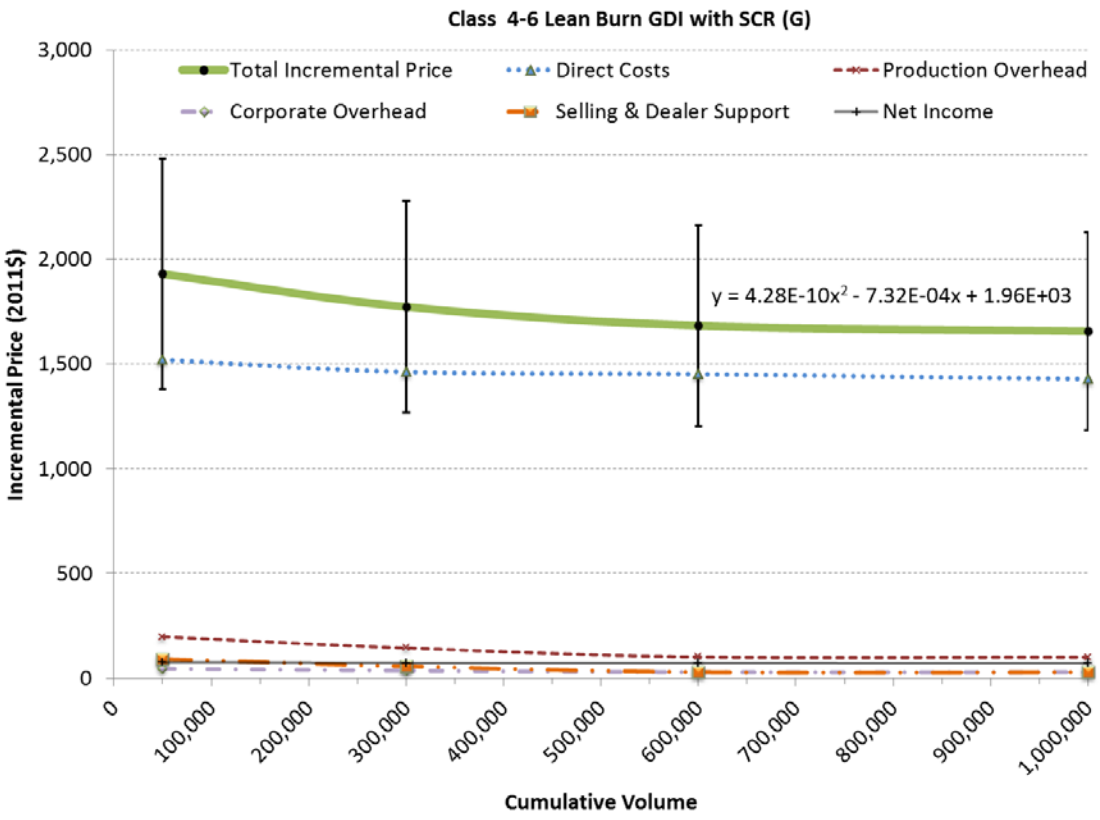
3.6 Lean Burn GDI with SCR



Class 2b&3 Lean Burn GDI with SCR (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,930.00	$1,773.24	$1,683.68	$1,656.81
Direct Costs	$1,519.69	$1,462.59	$1,451.70	$1,428.53
Production Overhead	$197.56	$144.12	$101.33	$99.71
Corporate Overhead	$45.59	$36.23	$29.03	$28.57
Selling & Dealer Support	$91.18	$57.18	$29.03	$28.57
Net Income	$75.98	$73.13	$72.59	$71.43

Figure 18. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Lean Burn GDI with SCR



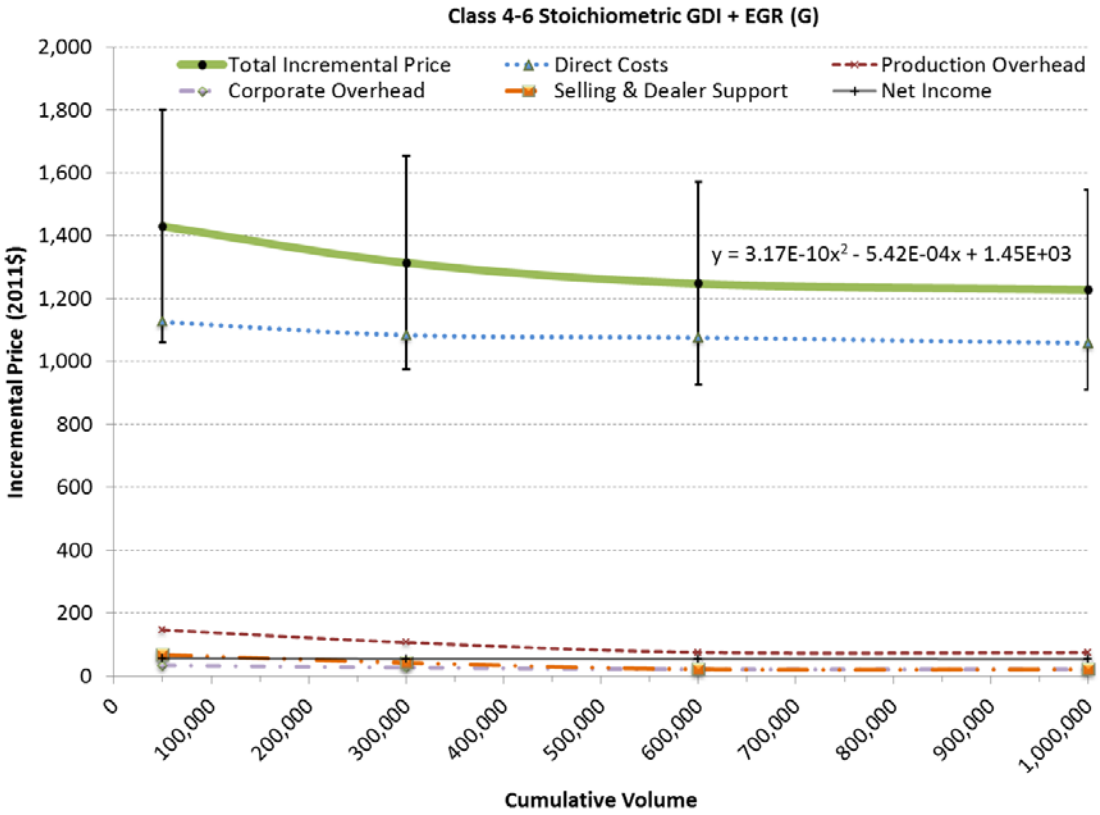
Class 4-6 Lean Burn GDI with SCR (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,930.00	$1,773.24	$1,683.68	$1,656.81
Direct Costs	$1,519.69	$1,462.59	$1,451.70	$1,428.53
Production Overhead	$197.56	$144.12	$101.33	$99.71
Corporate Overhead	$45.59	$36.23	$29.03	$28.57
Selling & Dealer Support	$91.18	$57.18	$29.03	$28.57
Net Income	$75.98	$73.13	$72.59	$71.43

Figure 19. Incremental Price and Breakouts for Vocational (Gasoline) Lean Burn GDI with SCR

3.7 Stoichiometric GDI+EGR

New control strategy concept for Class 2b&3. No costing performed.

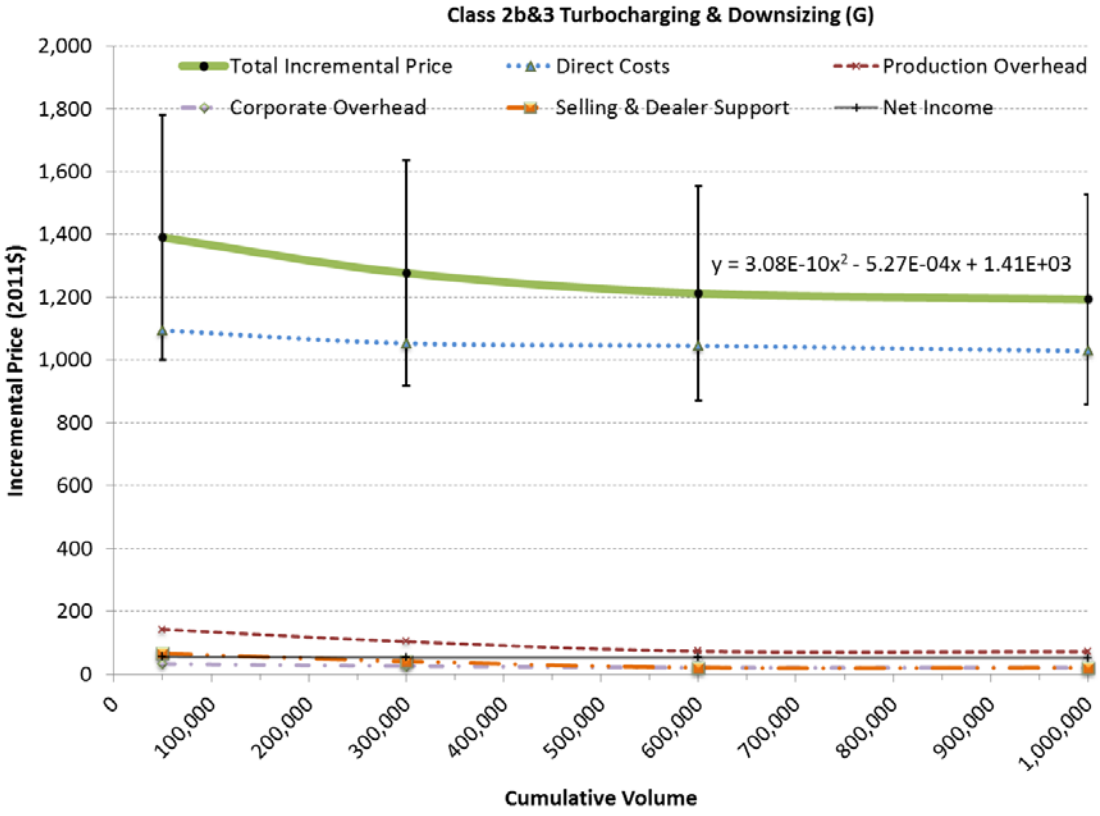


Class 4-6 Stoichiometric GDI + EGR (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,430.00	$1,313.85	$1,247.49	$1,227.59
Direct Costs	$1,125.98	$1,083.68	$1,075.61	$1,058.45
Production Overhead	$146.38	$106.78	$75.08	$73.88
Corporate Overhead	$33.78	$26.85	$21.51	$21.17
Selling & Dealer Support	$67.56	$42.36	$21.51	$21.17
Net Income	$56.30	$54.18	$53.78	$52.92

Figure 20. Incremental Price and Breakouts for Vocational (Gasoline) Stoichiometric GDI+EGR

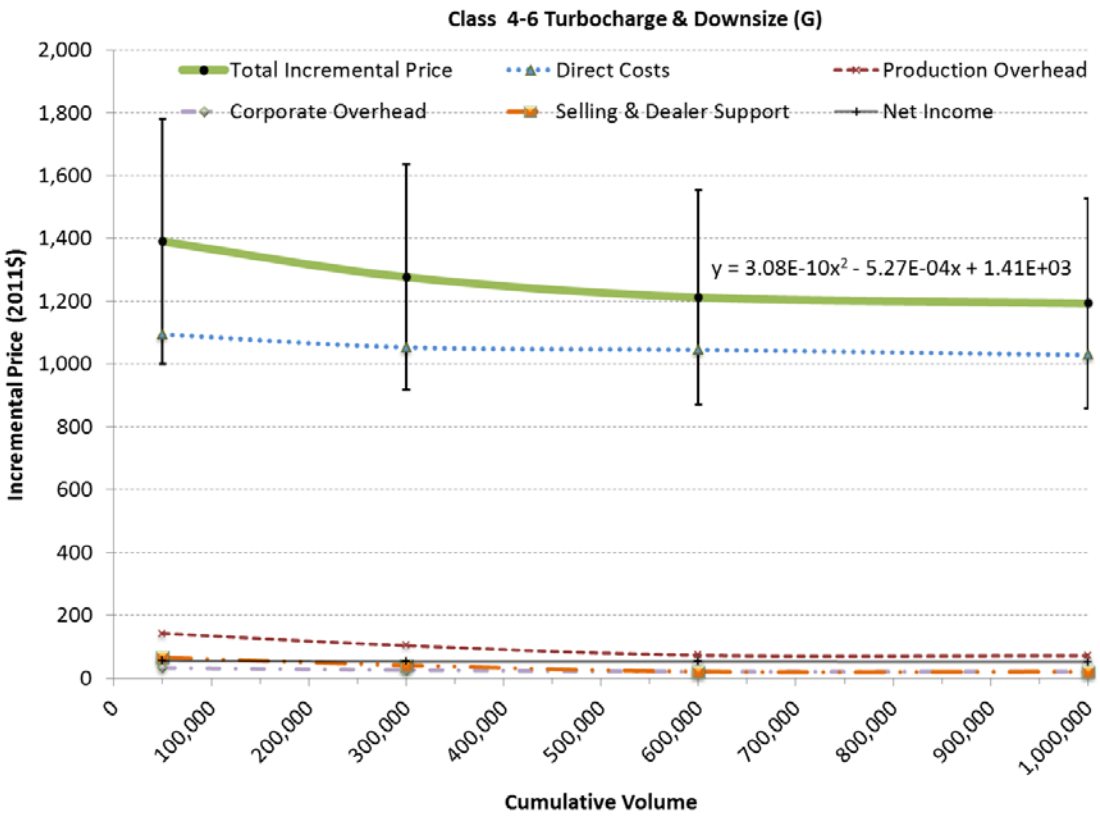
3.8 Turbocharging and Downsizing



Class 2b&3 Turbocharging & Downsizing (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,390.00	$1,277.10	$1,212.60	$1,193.25
Direct Costs	$1,094.49	$1,053.36	$1,045.53	$1,028.84
Production Overhead	$142.28	$103.79	$72.98	$71.81
Corporate Overhead	$32.83	$26.10	$20.91	$20.58
Selling & Dealer Support	$65.67	$41.18	$20.91	$20.58
Net Income	$54.72	$52.67	$52.28	$51.44

Figure 21. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Turbocharging and Downsizing



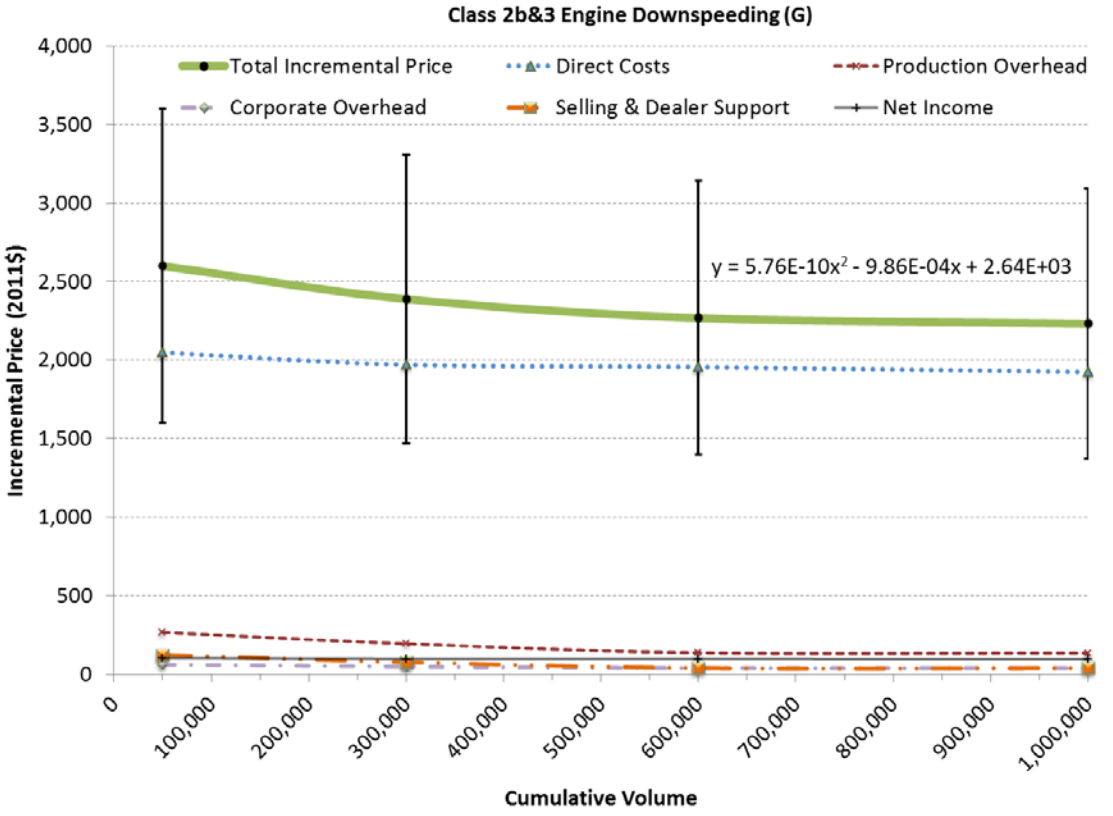
Class 4-6 Turbocharge & Downsize (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,390.00	$1,277.10	$1,212.60	$1,193.25
Direct Costs	$1,094.49	$1,053.36	$1,045.53	$1,028.84
Production Overhead	$142.28	$103.79	$72.98	$71.81
Corporate Overhead	$32.83	$26.10	$20.91	$20.58
Selling & Dealer Support	$65.67	$41.18	$20.91	$20.58
Net Income	$54.72	$52.67	$52.28	$51.44

Figure 22. Incremental Price and Breakouts for Vocational (Gasoline) Turbocharging and Downsizing

No Class 8 costing performed.

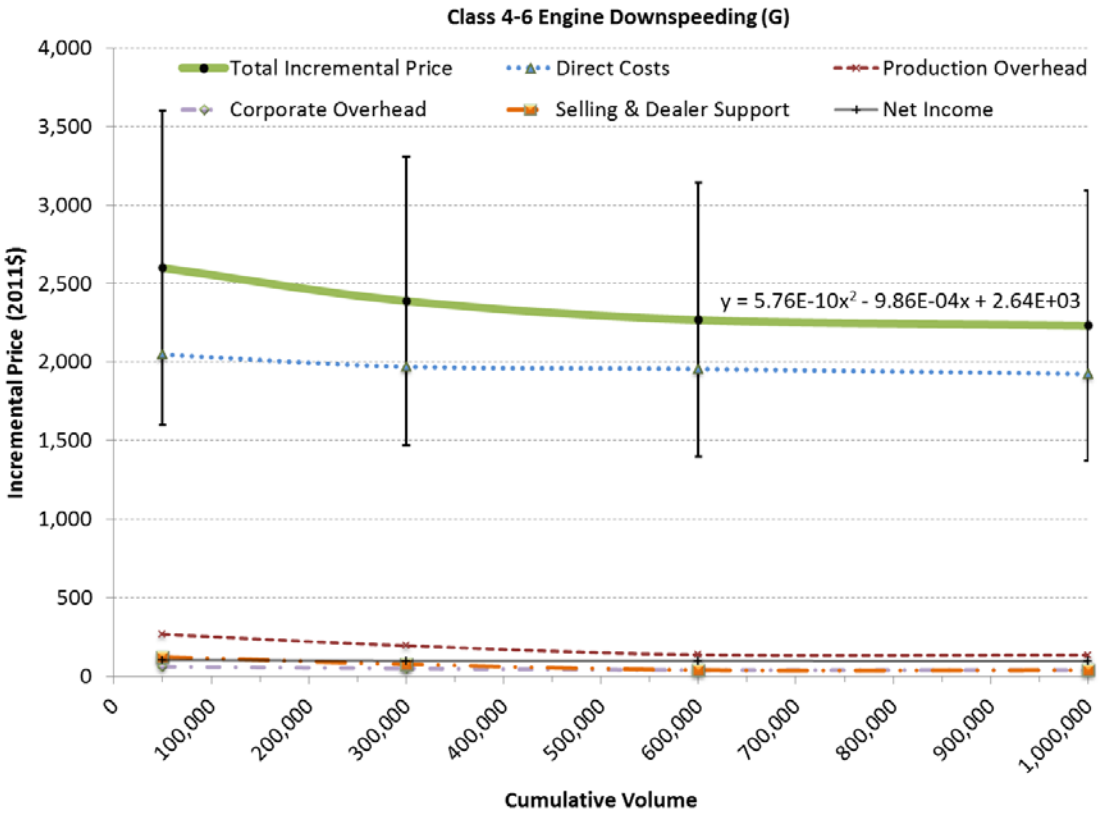
3.9 Engine Downspeeding



Class 2b&3 Engine Downspeeding (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$2,600.00	$2,388.82	$2,268.17	$2,231.98
Direct Costs	$2,047.24	$1,970.32	$1,955.66	$1,924.45
Production Overhead	$266.14	$194.15	$136.50	$134.33
Corporate Overhead	$61.42	$48.81	$39.11	$38.49
Selling & Dealer Support	$122.83	$77.03	$39.11	$38.49
Net Income	$102.36	$98.52	$97.78	$96.22

Figure 23. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Engine Downspeeding



Class 4-6 Engine Downspeeding (G)

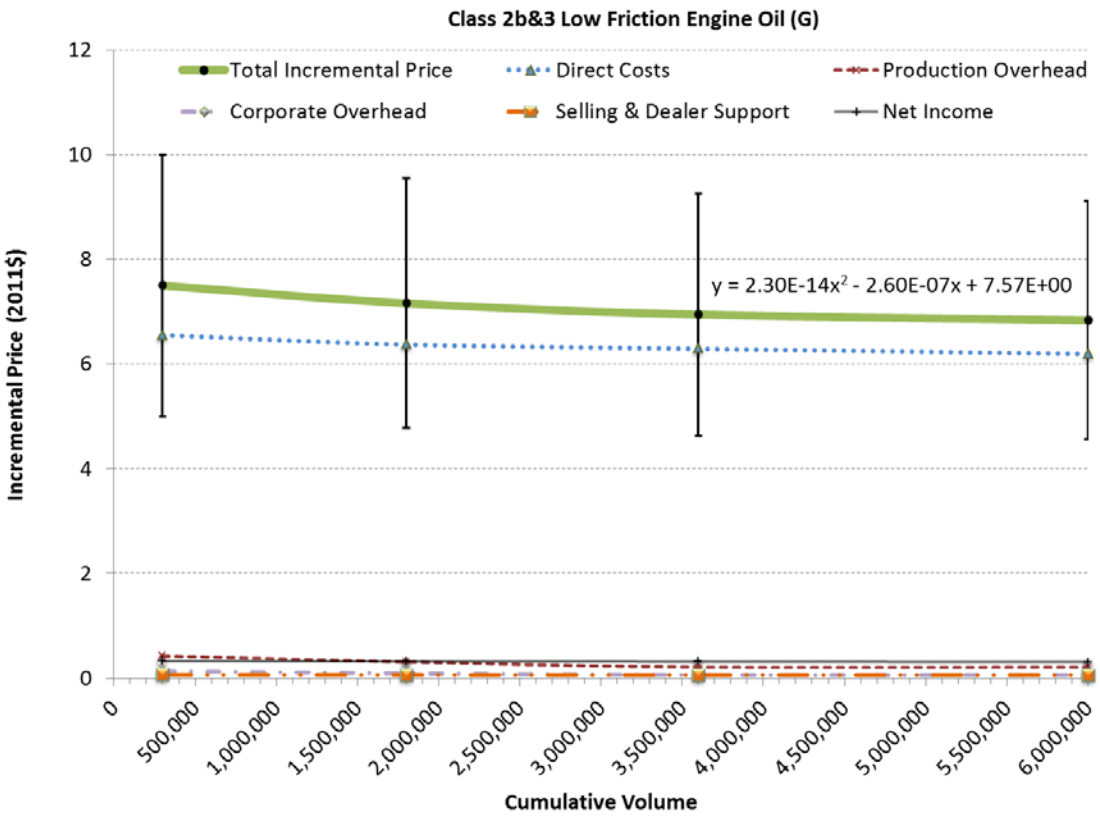
Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$2,600.00	$2,388.82	$2,268.17	$2,231.98
Direct Costs	$2,047.24	$1,970.32	$1,955.66	$1,924.45
Production Overhead	$266.14	$194.15	$136.50	$134.33
Corporate Overhead	$61.42	$48.81	$39.11	$38.49
Selling & Dealer Support	$122.83	$77.03	$39.11	$38.49
Net Income	$102.36	$98.52	$97.78	$96.22

Figure 24. Incremental Price and Breakouts for Vocational (Gasoline) Engine Downspeeding

No Class 8 costing performed.

3.10 Low-Friction Engine Oil (priced per vehicle)

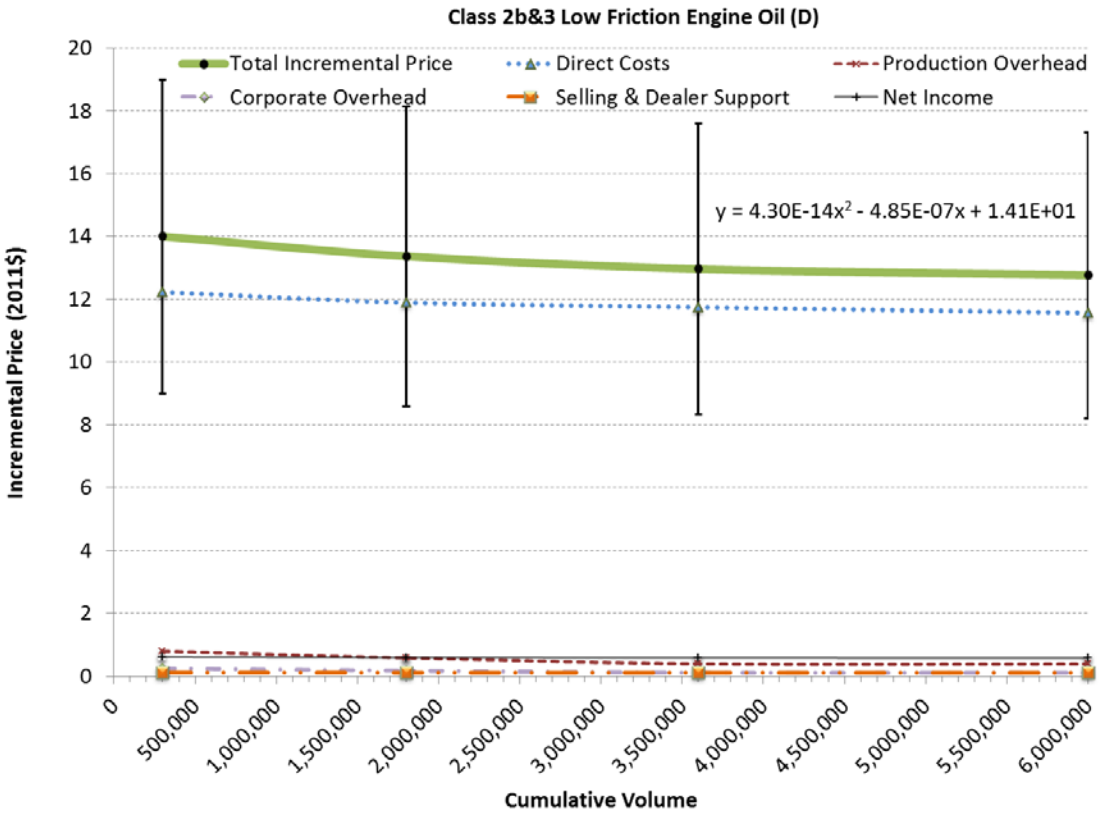
Assumed 7 quarts oil capacity for Class 2b&3 and Vocational gasoline vehicles. Assumed 13 quarts oil capacity for Class 2b&3 and Vocational diesel vehicles. Assumed 47 quarts for Line Haul.



Class 2b&3 Low Friction Engine Oil (G)

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$7.50	$7.16	$6.95	$6.84
Direct Costs	$6.55	$6.37	$6.29	$6.19
Production Overhead	$0.42	$0.31	$0.21	$0.21
Corporate Overhead	$0.13	$0.09	$0.06	$0.06
Selling & Dealer Support	$0.07	$0.06	$0.06	$0.06
Net Income	$0.33	$0.32	$0.31	$0.31

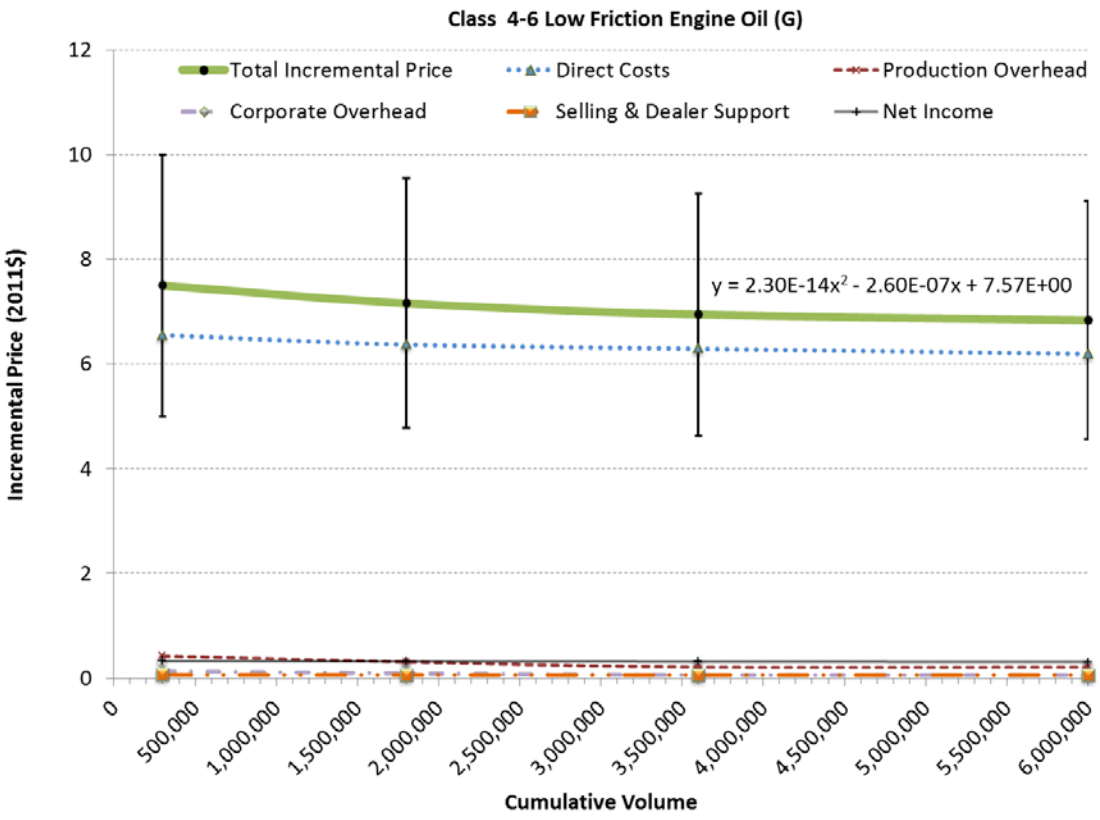
Figure 25. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Low-Friction Engine Oil



Class 2b&3 Low Friction Engine Oil (D)

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$14.00	$13.37	$12.97	$12.76
Direct Costs	$12.23	$11.89	$11.75	$11.56
Production Overhead	$0.79	$0.58	$0.40	$0.39
Corporate Overhead	$0.24	$0.18	$0.12	$0.12
Selling & Dealer Support	$0.12	$0.12	$0.12	$0.12
Net Income	$0.61	$0.59	$0.59	$0.58

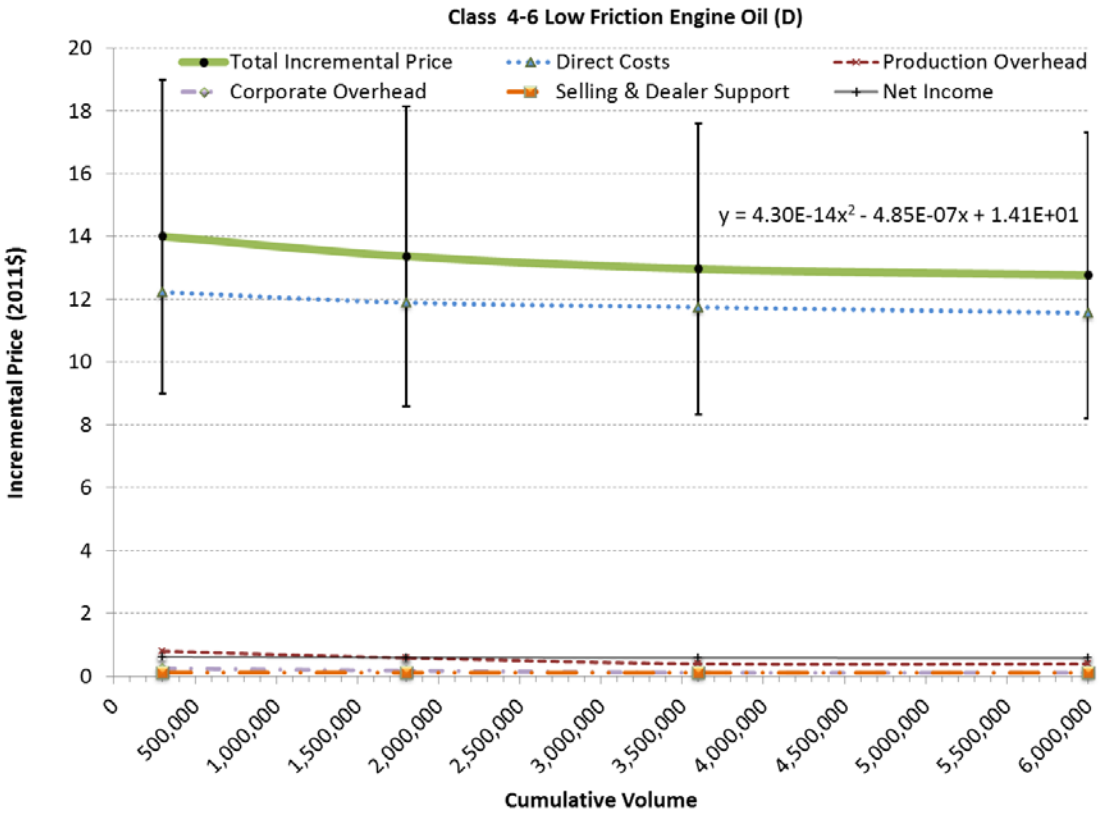
Figure 26. Incremental Price and Breakouts for Class 2b&3 (Diesel) Low-Friction Engine Oil



Class 4-6 Low Friction Engine Oil (G)

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$7.50	$7.16	$6.95	$6.84
Direct Costs	$6.55	$6.37	$6.29	$6.19
Production Overhead	$0.42	$0.31	$0.21	$0.21
Corporate Overhead	$0.13	$0.09	$0.06	$0.06
Selling & Dealer Support	$0.07	$0.06	$0.06	$0.06
Net Income	$0.33	$0.32	$0.31	$0.31

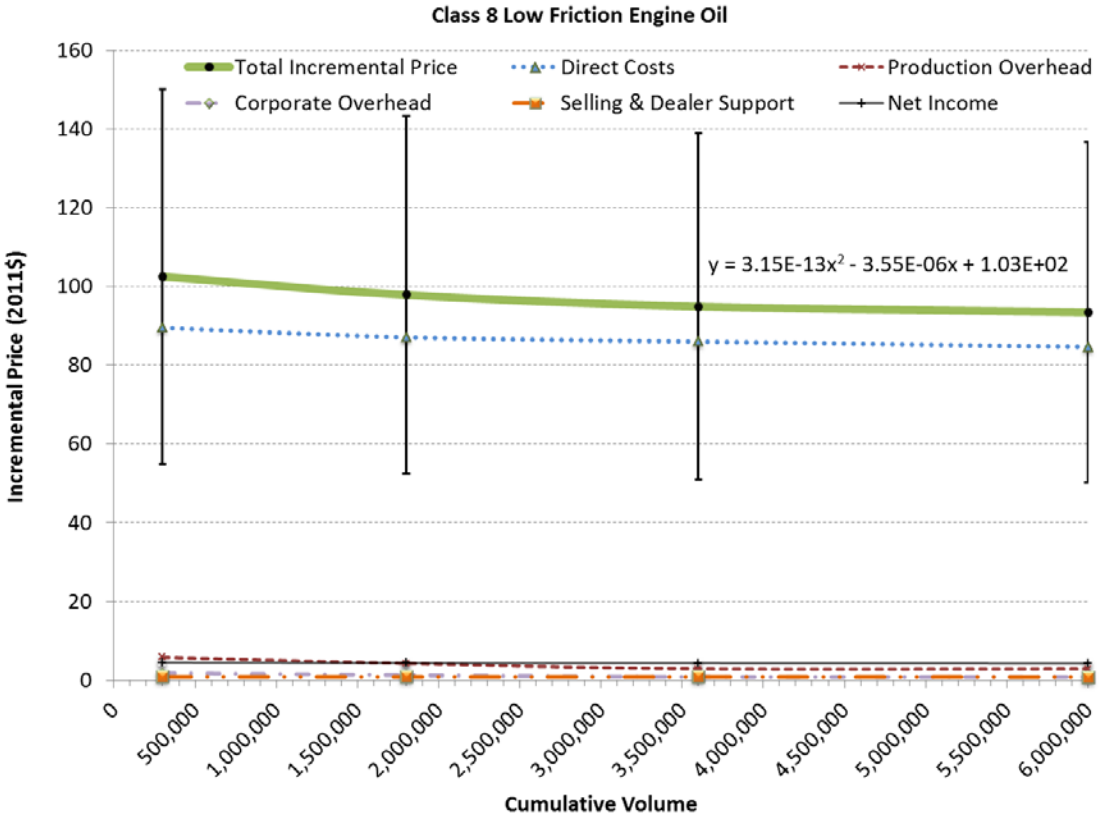
Figure 27. Incremental Price and Breakouts for Vocational (Gasoline) Low-Friction Engine Oil



Class 4-6 Low Friction Engine Oil (D)

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$14.00	$13.37	$12.97	$12.76
Direct Costs	$12.23	$11.89	$11.75	$11.56
Production Overhead	$0.79	$0.58	$0.40	$0.39
Corporate Overhead	$0.24	$0.18	$0.12	$0.12
Selling & Dealer Support	$0.12	$0.12	$0.12	$0.12
Net Income	$0.61	$0.59	$0.59	$0.58

Figure 28. Incremental Price and Breakouts for Vocational (Diesel) Low-Friction Engine Oil

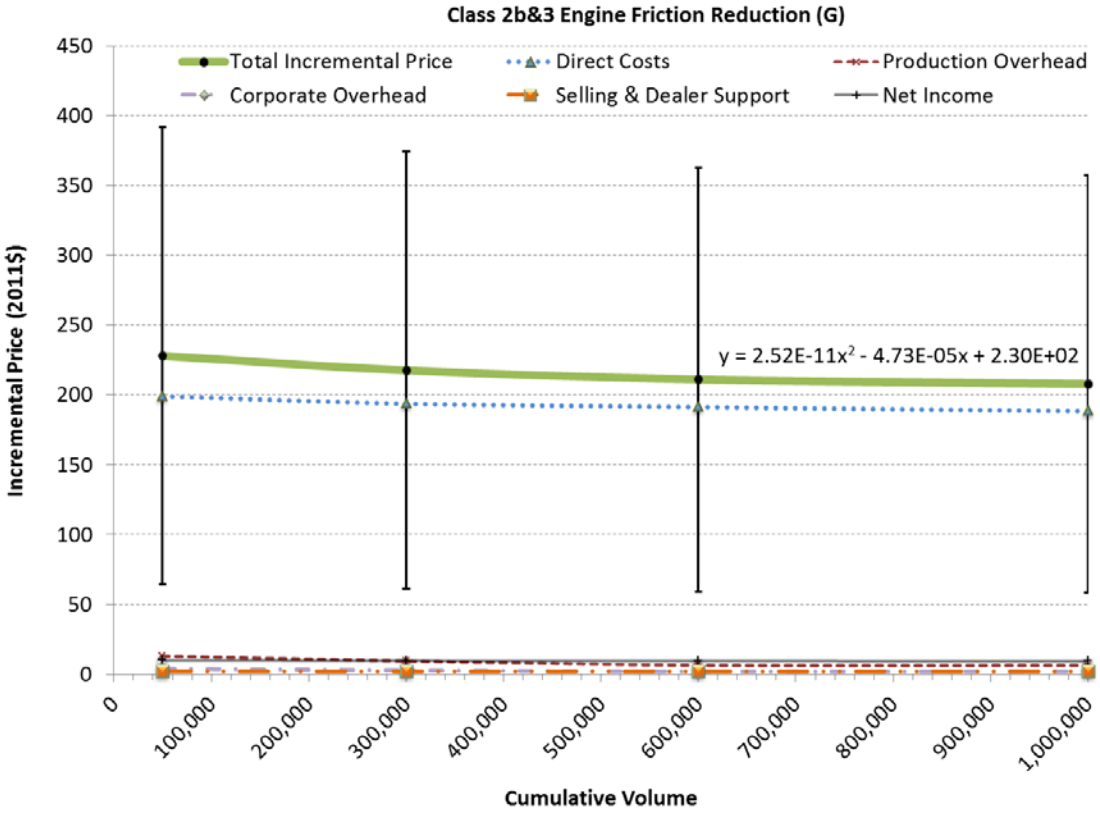


Class 8 Low Friction Engine Oil

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$102.50	$97.88	$94.92	$93.45
Direct Costs	$89.54	$87.08	$86.00	$84.66
Production Overhead	$5.80	$4.27	$2.91	$2.86
Corporate Overhead	$1.79	$1.30	$0.86	$0.85
Selling & Dealer Support	$0.90	$0.87	$0.86	$0.85
Net Income	$4.48	$4.35	$4.30	$4.23

Figure 29. Incremental Price and Breakouts for Line Haul Low-Friction Engine Oil

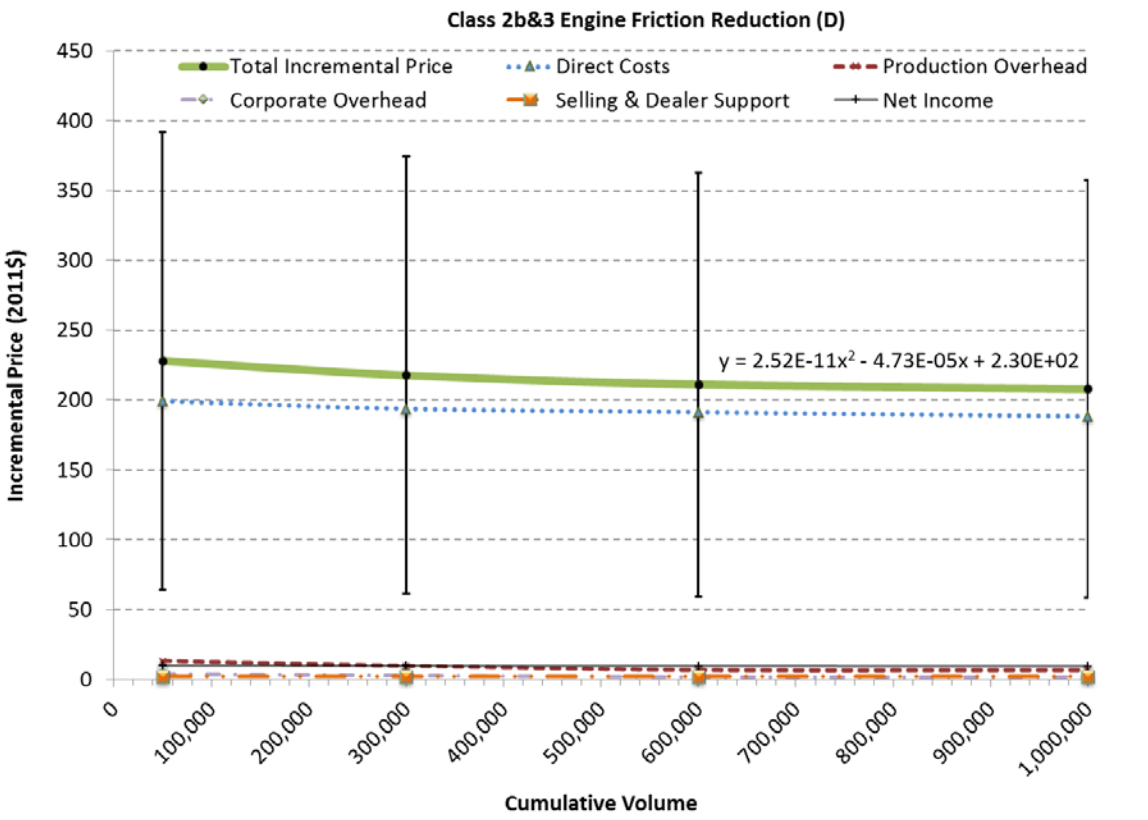
3.11 Engine Friction Reduction



Class 2b&3 Engine Friction Reduction (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$228.00	$217.71	$211.15	$207.87
Direct Costs	$199.16	$193.71	$191.29	$188.32
Production Overhead	$12.91	$9.50	$6.47	$6.37
Corporate Overhead	$3.98	$2.89	$1.91	$1.88
Selling & Dealer Support	$1.99	$1.94	$1.91	$1.88
Net Income	$9.96	$9.69	$9.56	$9.42

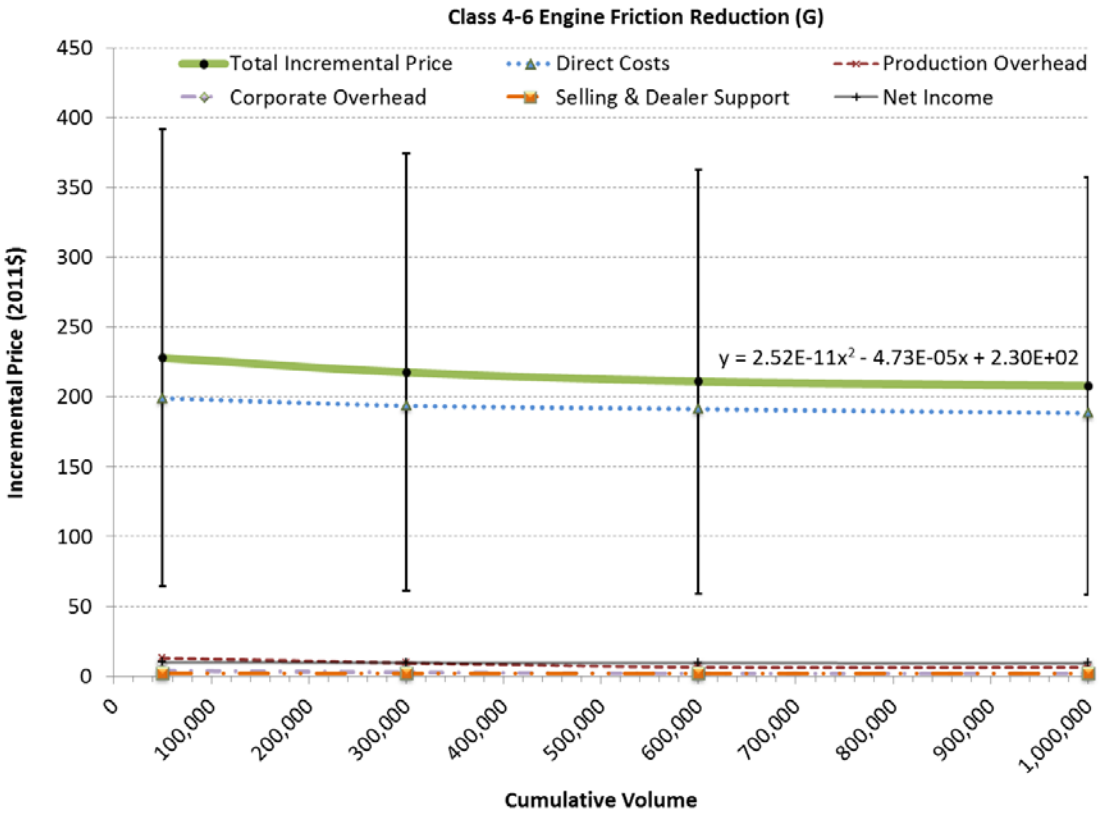
Figure 30. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Engine Friction Reduction



Class 2b&3 Engine Friction Reduction (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$228.00	$217.71	$211.15	$207.87
Direct Costs	$199.16	$193.71	$191.29	$188.32
Production Overhead	$12.91	$9.50	$6.47	$6.37
Corporate Overhead	$3.98	$2.89	$1.91	$1.88
Selling & Dealer Support	$1.99	$1.94	$1.91	$1.88
Net Income	$9.96	$9.69	$9.56	$9.42

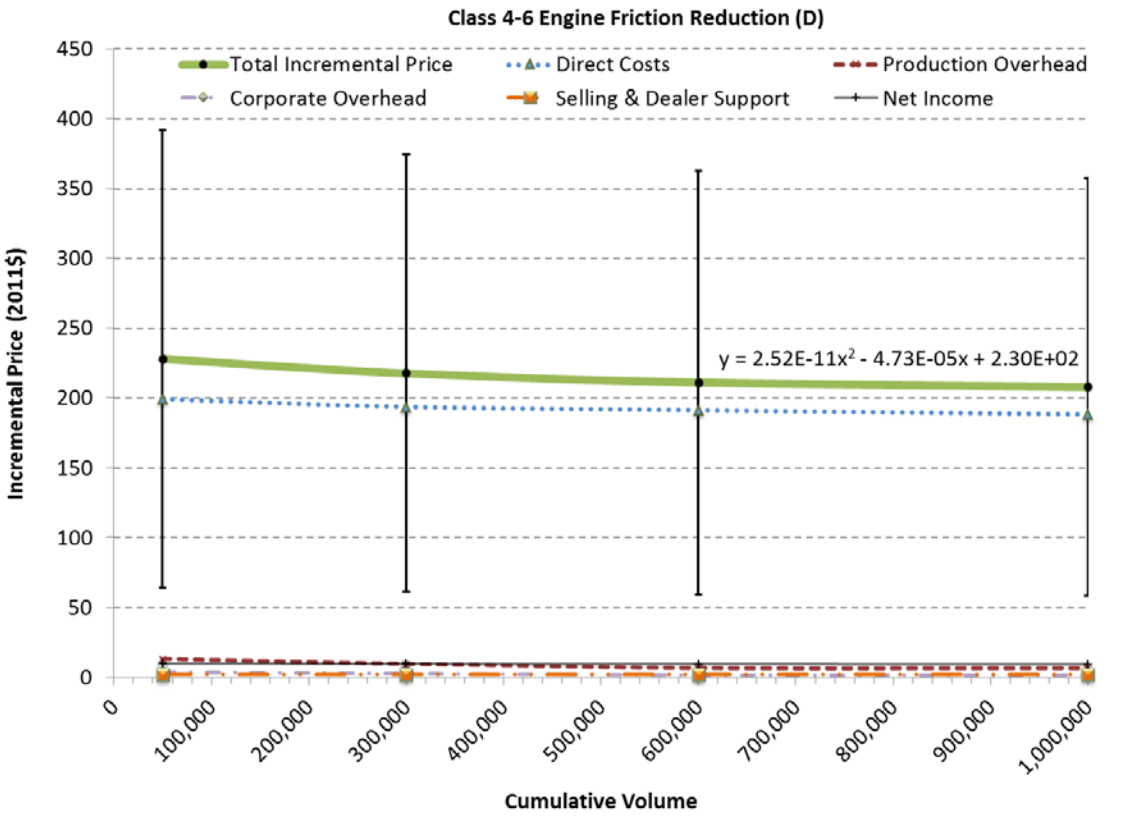
Figure 31. Incremental Price and Breakouts for Class 2b&3 (Diesel) Engine Friction Reduction



Class 4-6 Engine Friction Reduction (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$228.00	$217.71	$211.15	$207.87
Direct Costs	$199.16	$193.71	$191.29	$188.32
Production Overhead	$12.91	$9.50	$6.47	$6.37
Corporate Overhead	$3.98	$2.89	$1.91	$1.88
Selling & Dealer Support	$1.99	$1.94	$1.91	$1.88
Net Income	$9.96	$9.69	$9.56	$9.42

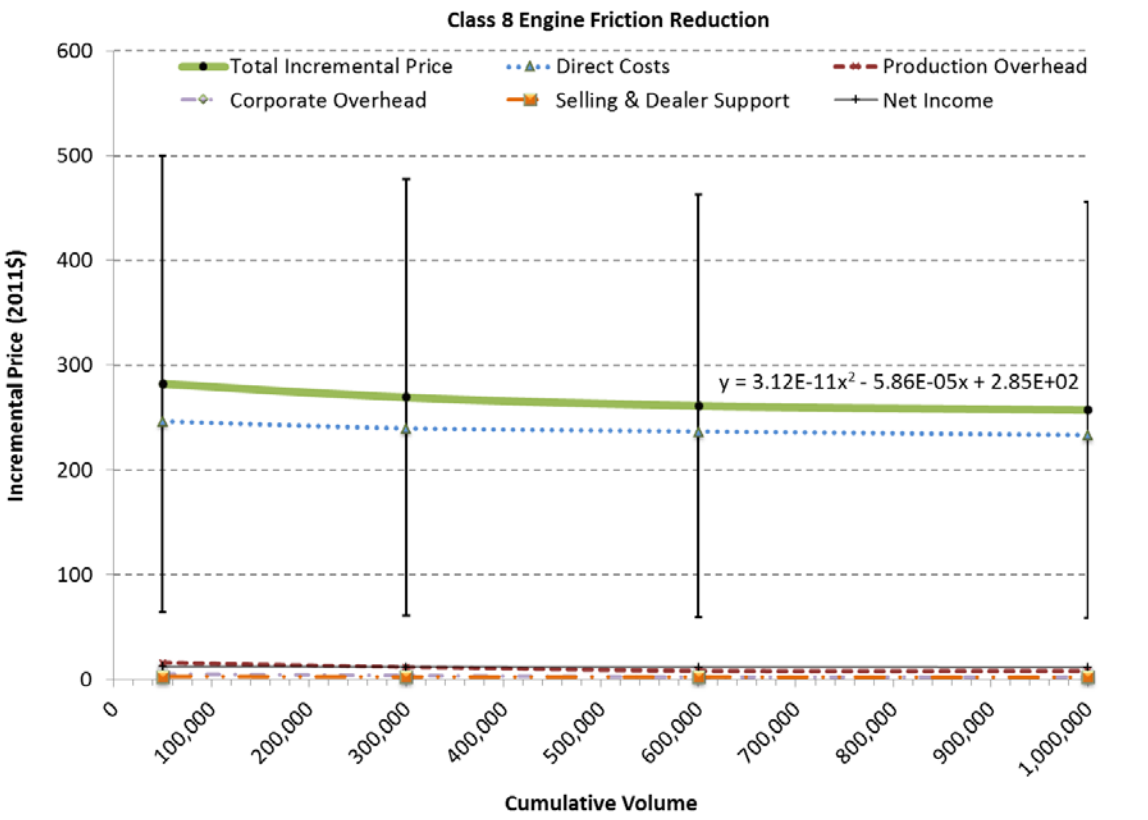
Figure 32. Incremental Price and Breakouts for Vocational (Gasoline) Engine Friction Reduction



Class 4-6 Engine Friction Reduction (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$228.00	$217.71	$211.15	$207.87
Direct Costs	$199.16	$193.71	$191.29	$188.32
Production Overhead	$12.91	$9.50	$6.47	$6.37
Corporate Overhead	$3.98	$2.89	$1.91	$1.88
Selling & Dealer Support	$1.99	$1.94	$1.91	$1.88
Net Income	$9.96	$9.69	$9.56	$9.42

Figure 33. Incremental Price and Breakouts for Vocational (Diesel) Engine Friction Reduction

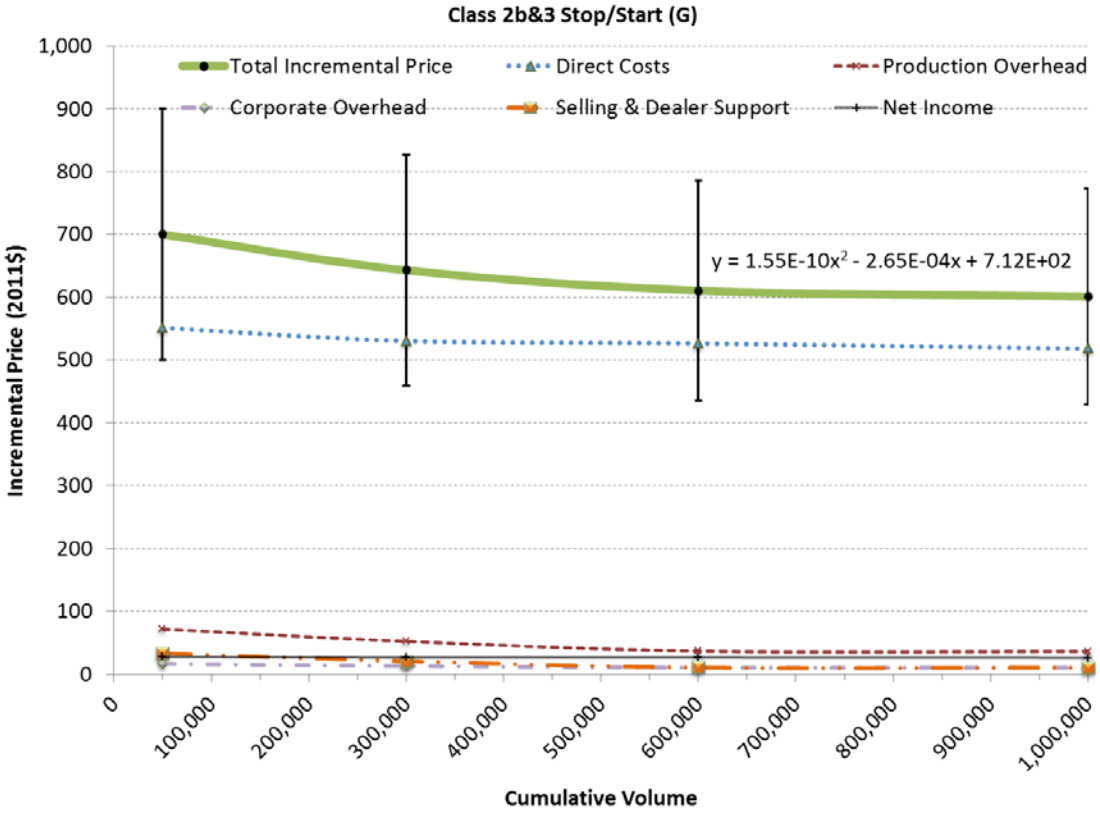


Class 8 Engine Friction Reduction

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$282.00	$269.28	$261.16	$257.10
Direct Costs	$246.33	$239.59	$236.60	$232.92
Production Overhead	$15.96	$11.74	$8.00	$7.87
Corporate Overhead	$4.93	$3.57	$2.37	$2.33
Selling & Dealer Support	$2.46	$2.40	$2.37	$2.33
Net Income	$12.32	$11.98	$11.83	$11.65

Figure 34. Incremental Price and Breakouts for Line Haul Engine Friction Reduction

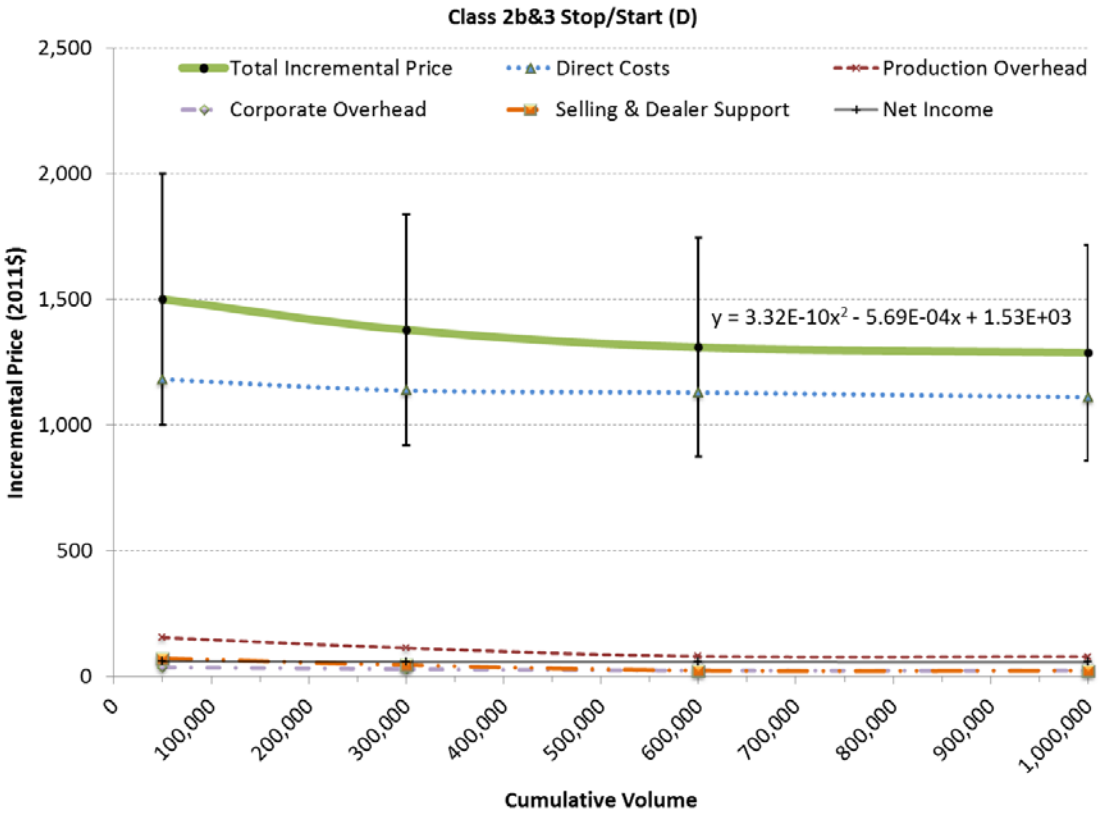
3.12 Stop/Start



Class 2b&3 Stop/Start (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$700.00	$643.14	$610.66	$600.92
Direct Costs	$551.18	$530.47	$526.52	$518.12
Production Overhead	$71.65	$52.27	$36.75	$36.16
Corporate Overhead	$16.54	$13.14	$10.53	$10.36
Selling & Dealer Support	$33.07	$20.74	$10.53	$10.36
Net Income	$27.56	$26.52	$26.33	$25.91

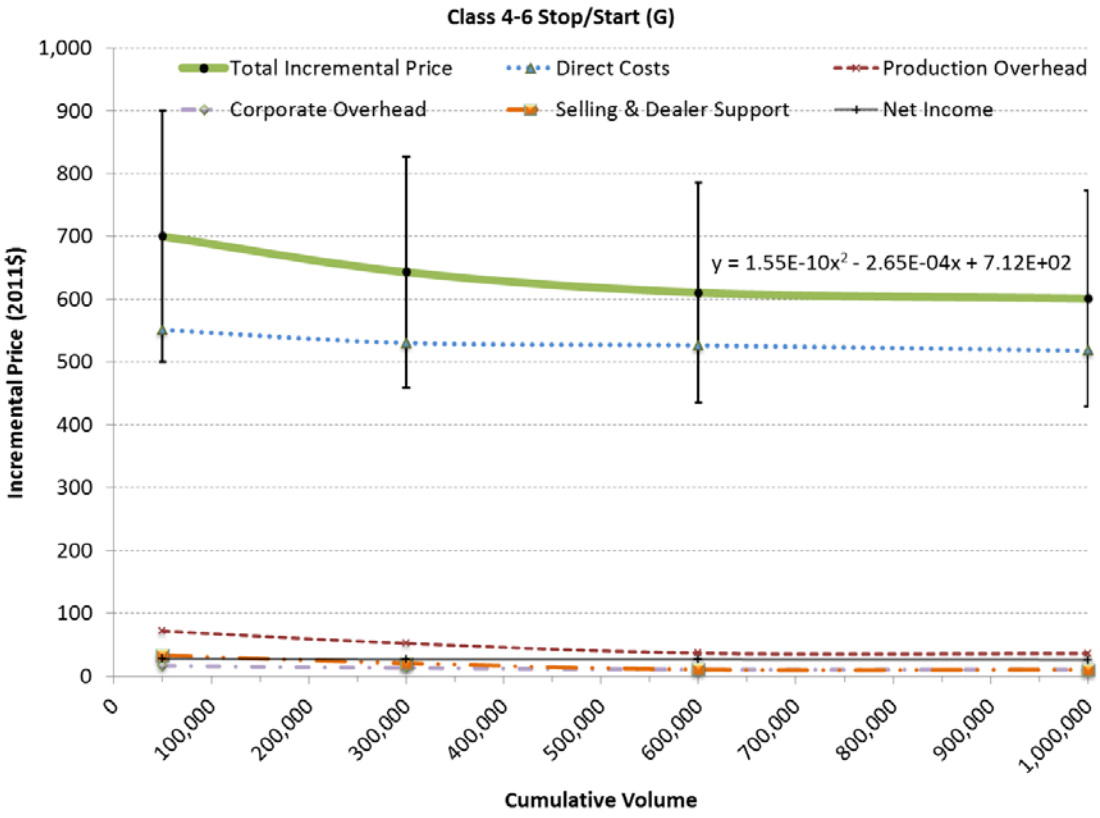
Figure 35. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Stop/Start



Class 2b&3 Stop/Start (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,500.00	$1,378.17	$1,308.56	$1,287.68
Direct Costs	$1,181.10	$1,136.72	$1,128.26	$1,110.26
Production Overhead	$153.54	$112.01	$78.75	$77.50
Corporate Overhead	$35.43	$28.16	$22.57	$22.21
Selling & Dealer Support	$70.87	$44.44	$22.57	$22.21
Net Income	$59.06	$56.84	$56.41	$55.51

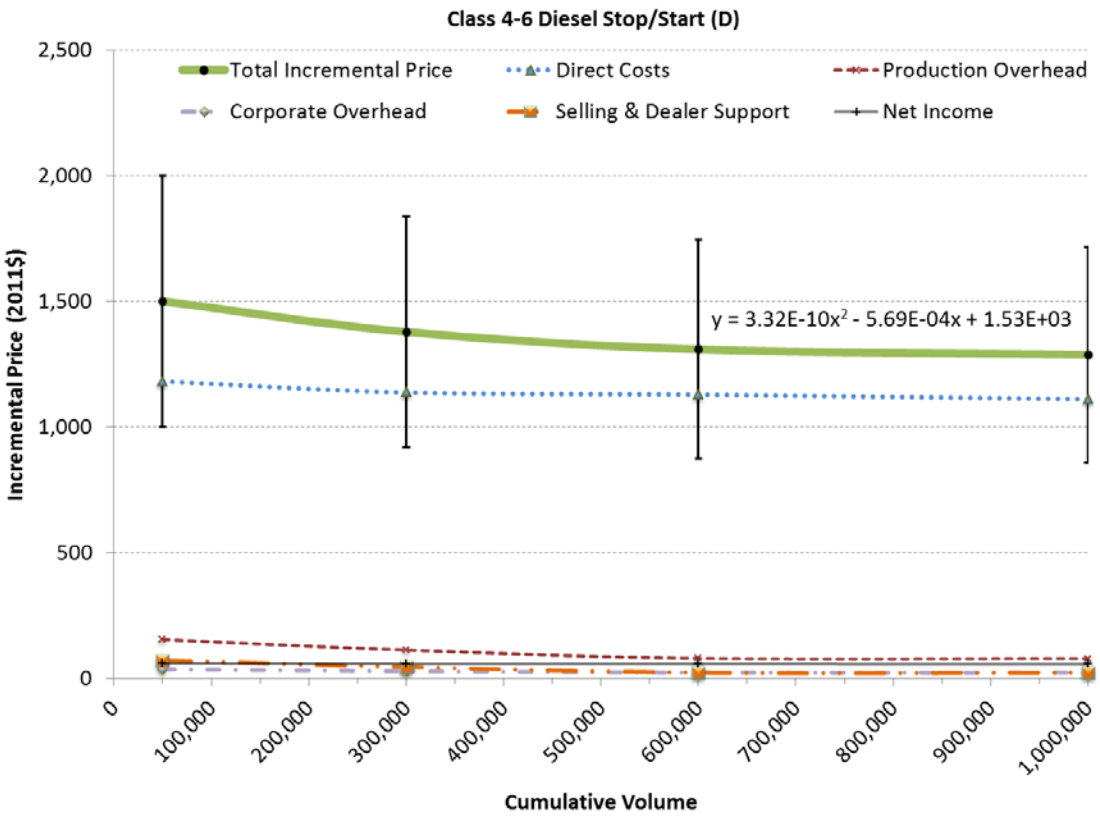
Figure 36. Incremental Price and Breakouts for Class 2b&3 (Diesel) Stop/Start



Class 4-6 Stop/Start (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$700.00	$643.14	$610.66	$600.92
Direct Costs	$551.18	$530.47	$526.52	$518.12
Production Overhead	$71.65	$52.27	$36.75	$36.16
Corporate Overhead	$16.54	$13.14	$10.53	$10.36
Selling & Dealer Support	$33.07	$20.74	$10.53	$10.36
Net Income	$27.56	$26.52	$26.33	$25.91

Figure 37. Incremental Price and Breakouts for Vocational (Gasoline) Stop/Start

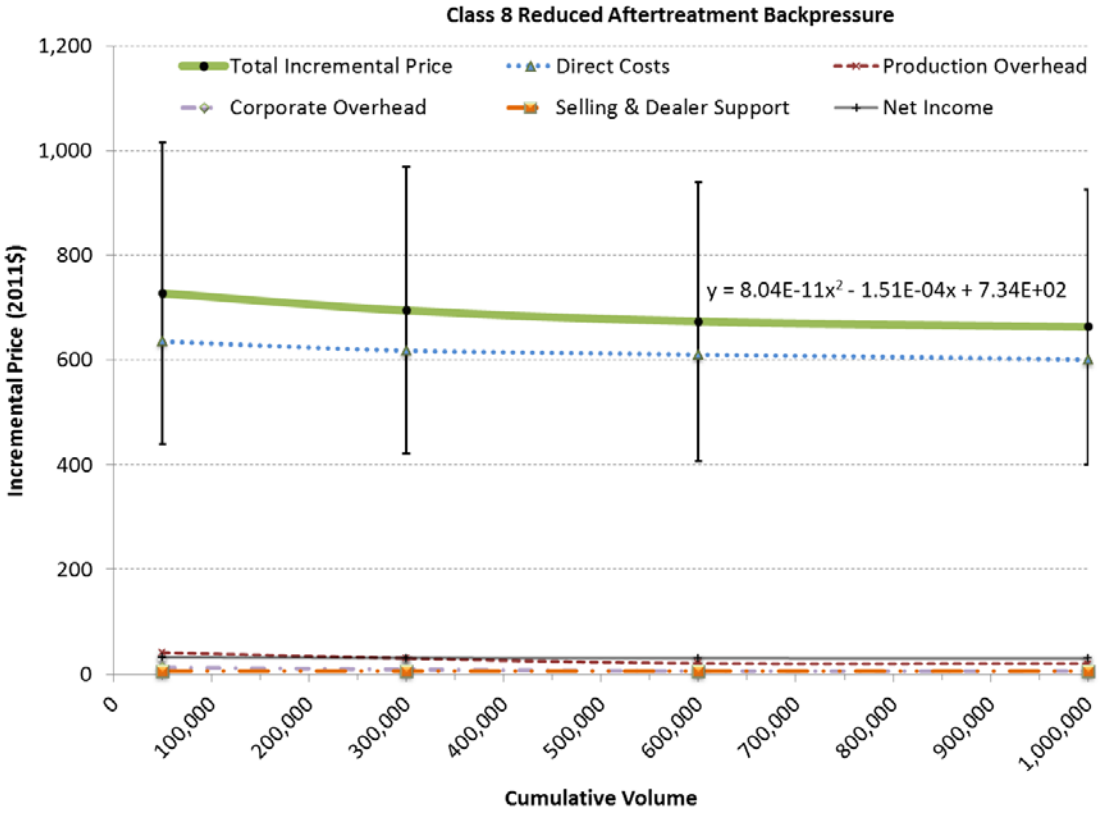


Class 4-6 Diesel Stop/Start (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,500.00	$1,378.17	$1,308.56	$1,287.68
Direct Costs	$1,181.10	$1,136.72	$1,128.26	$1,110.26
Production Overhead	$153.54	$112.01	$78.75	$77.50
Corporate Overhead	$35.43	$28.16	$22.57	$22.21
Selling & Dealer Support	$70.87	$44.44	$22.57	$22.21
Net Income	$59.06	$56.84	$56.41	$55.51

Figure 38. Incremental Price and Breakouts for Vocational (Diesel) Stop/Start

3.13 Reduced Aftertreatment Backpressure

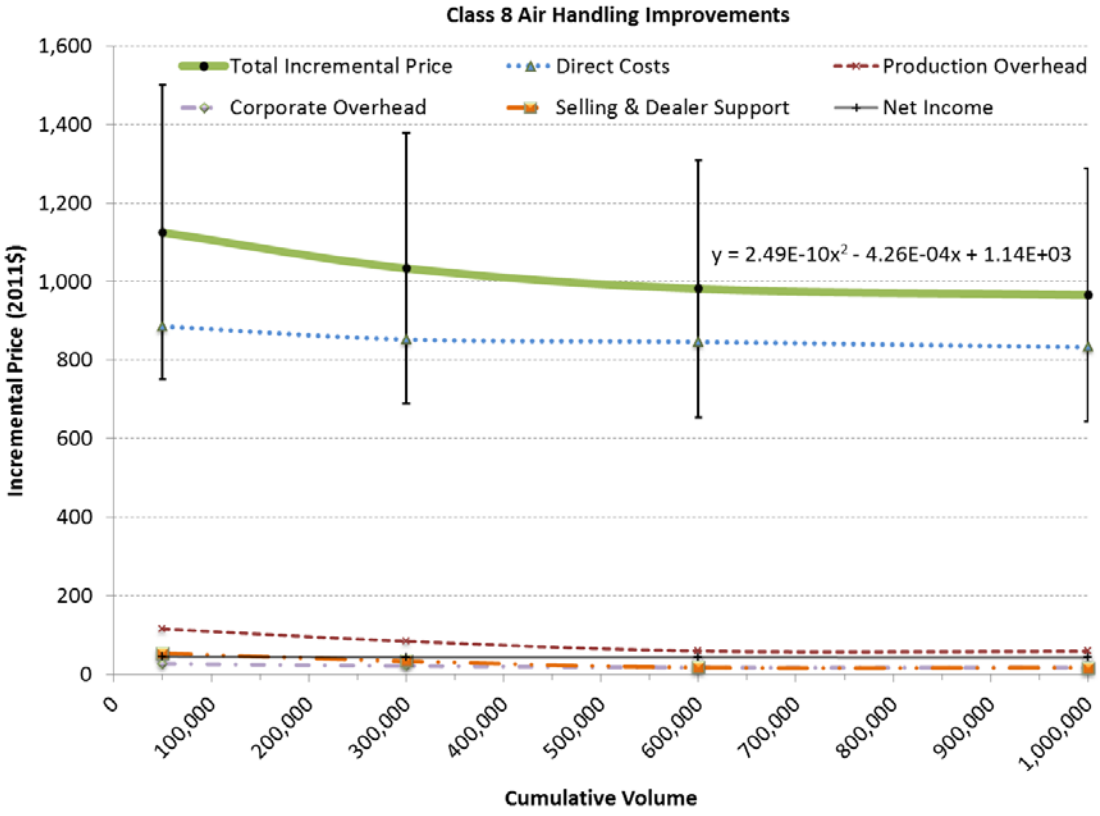


Class 8 Reduced Aftertreatment Backpressure

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$727.50	$694.67	$673.73	$663.26
Direct Costs	$635.48	$618.08	$610.37	$600.89
Production Overhead	$41.18	$30.30	$20.63	$20.31
Corporate Overhead	$12.71	$9.21	$6.10	$6.01
Selling & Dealer Support	$6.35	$6.18	$6.10	$6.01
Net Income	$31.77	$30.90	$30.52	$30.04

Figure 39. Incremental Price and Breakouts for Line Haul Reduced Aftertreatment Backpressure

3.14 Air Handling Improvements

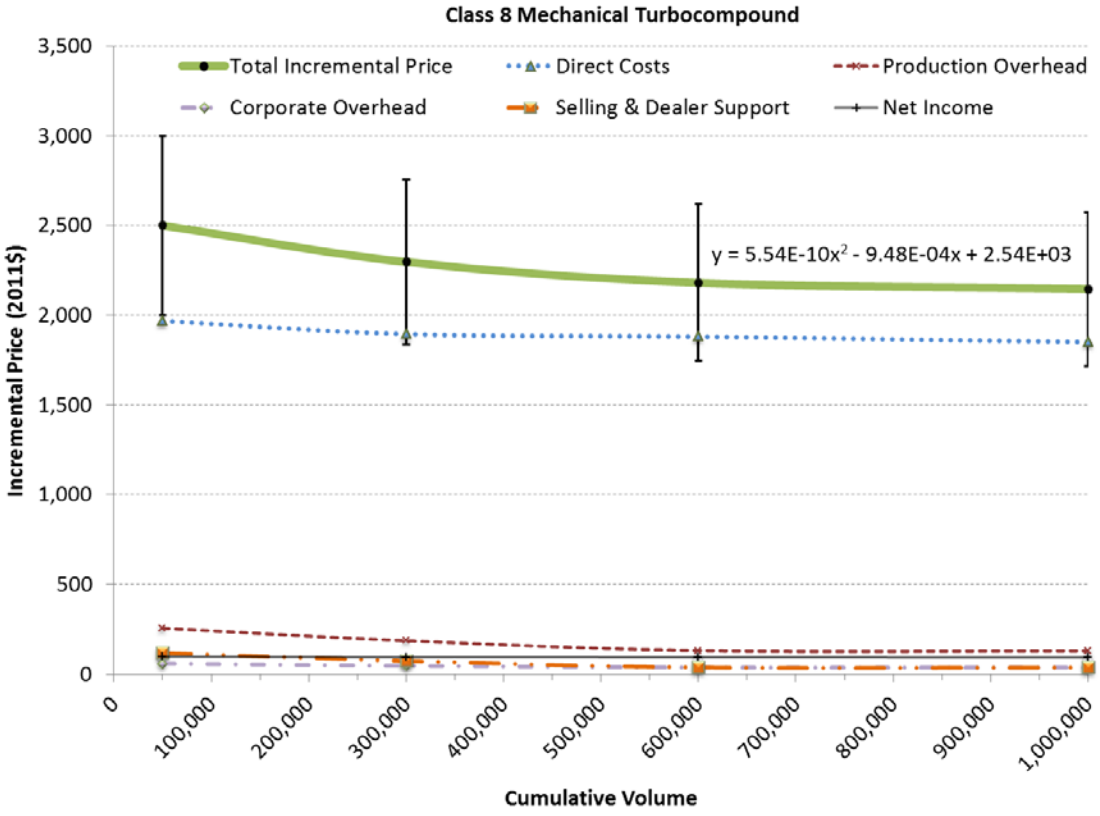


Class 8 Air Handling Improvements

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,125.00	$1,033.62	$981.42	$965.76
Direct Costs	$885.83	$852.54	$846.20	$832.70
Production Overhead	$115.16	$84.01	$59.06	$58.12
Corporate Overhead	$26.57	$21.12	$16.92	$16.65
Selling & Dealer Support	$53.15	$33.33	$16.92	$16.65
Net Income	$44.29	$42.63	$42.31	$41.63

Figure 40. Incremental Price and Breakouts for Line Haul Air Handling Improvements

3.15 Mechanical Turbocompound

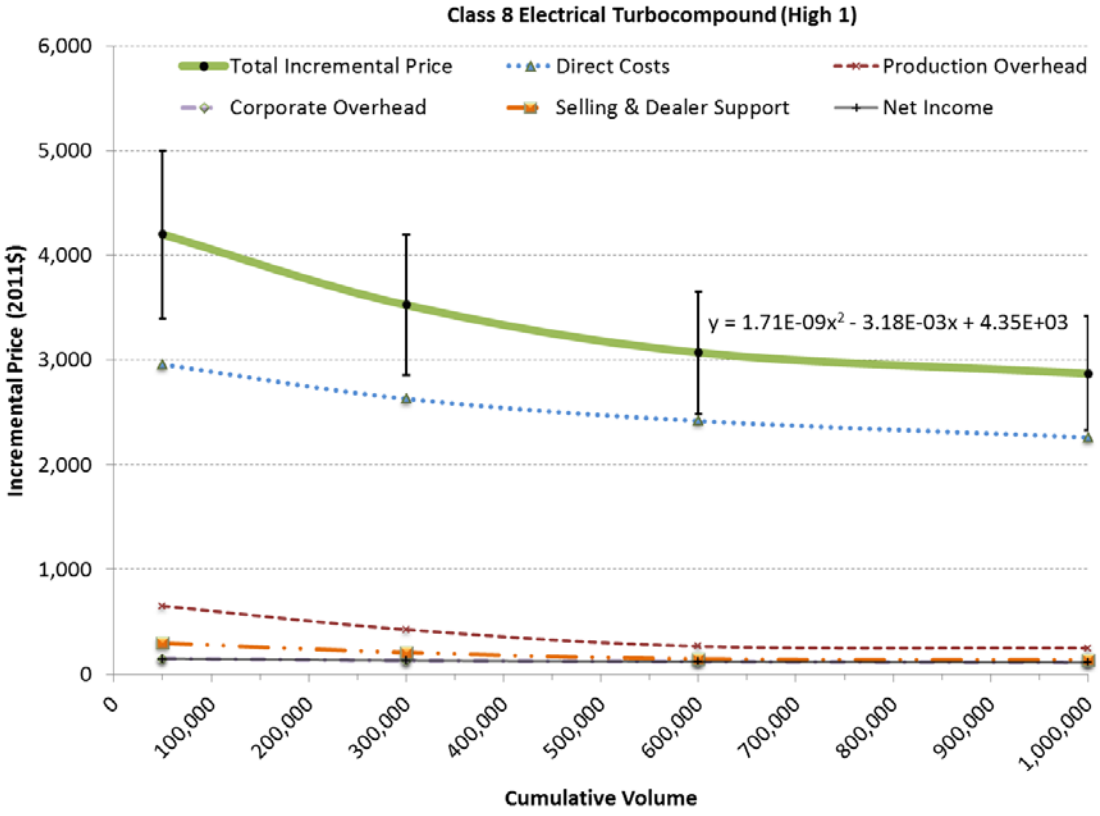


Class 8 Mechanical Turbocompound

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$2,500.00	$2,296.94	$2,180.94	$2,146.13
Direct Costs	$1,968.50	$1,894.54	$1,880.44	$1,850.43
Production Overhead	$255.91	$186.68	$131.25	$129.16
Corporate Overhead	$59.06	$46.93	$37.61	$37.01
Selling & Dealer Support	$118.11	$74.06	$37.61	$37.01
Net Income	$98.43	$94.73	$94.02	$92.52

Figure 41. Incremental Price and Breakouts for Line Haul Mechanical Turbocompound

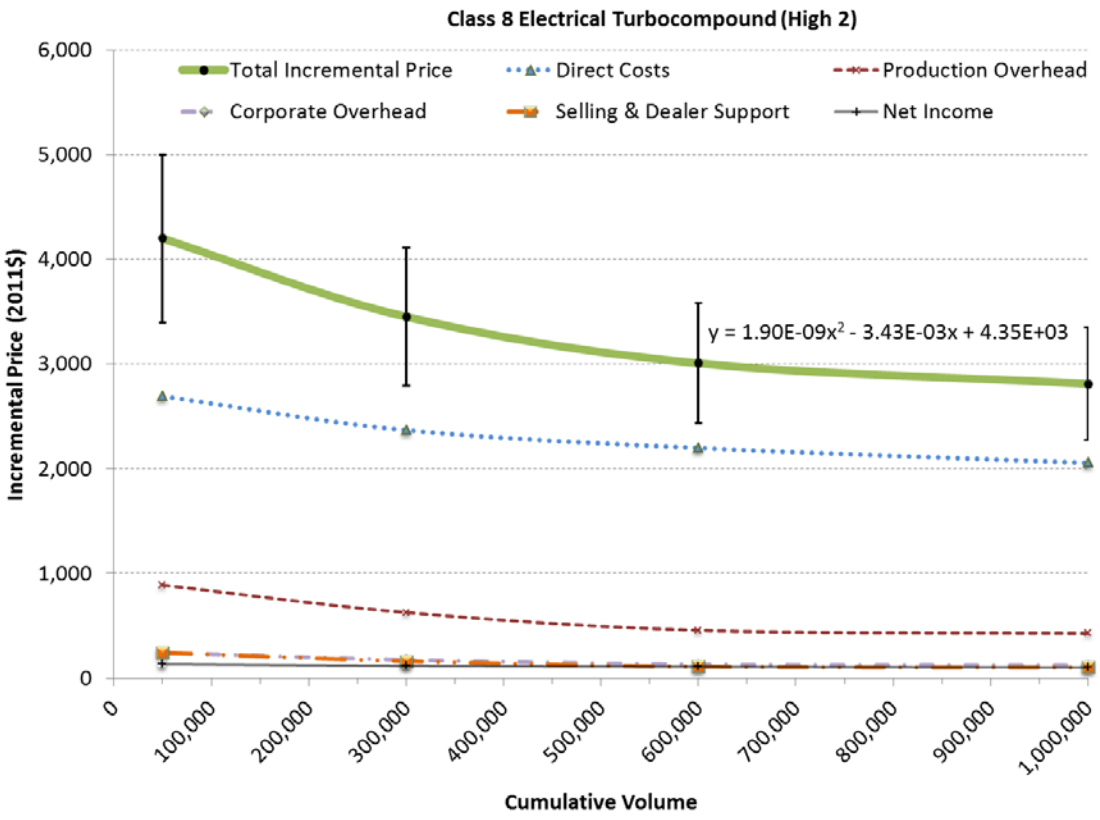
3.16 Electric Turbocompound



Class 8 Electrical Turbocompound (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$4,200.00	$3,525.58	$3,071.25	$2,871.35
Direct Costs	$2,957.75	$2,629.42	$2,418.31	$2,260.90
Production Overhead	$650.70	$425.79	$266.01	$248.70
Corporate Overhead	$147.89	$131.47	$120.92	$113.05
Selling & Dealer Support	$295.77	$207.42	$145.10	$135.65
Net Income	$147.89	$131.47	$120.92	$113.05

Figure 42. Incremental Price and Breakouts for Line Haul Electric Turbocompound (High 1 Complexity)

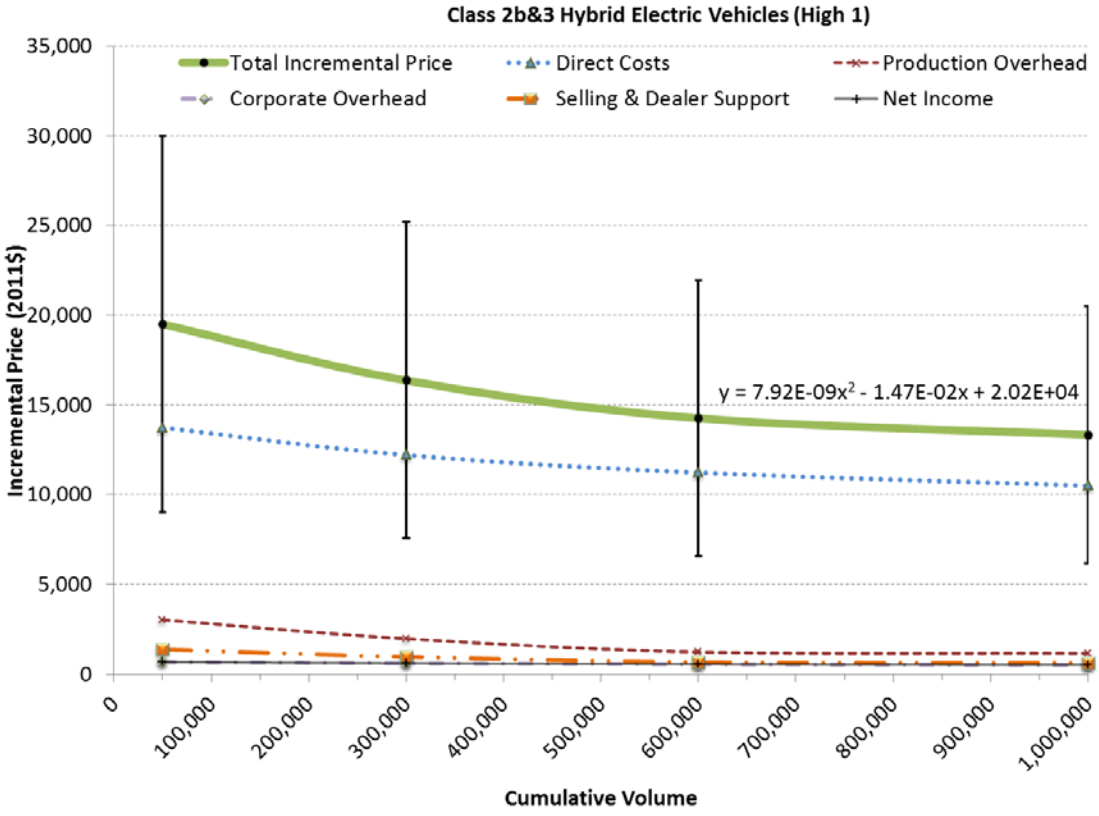


Class 8 Electrical Turbocompound (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$4,200.00	$3,452.54	$3,007.63	$2,811.86
Direct Costs	$2,692.31	$2,368.48	$2,198.56	$2,055.46
Production Overhead	$888.46	$627.65	$457.30	$427.53
Corporate Overhead	$242.31	$175.31	$131.91	$123.33
Selling & Dealer Support	$242.31	$162.69	$109.93	$102.77
Net Income	$134.62	$118.42	$109.93	$102.77

Figure 43. Incremental Price and Breakouts for Line Haul Electric Turbocompound (High 2 Complexity)

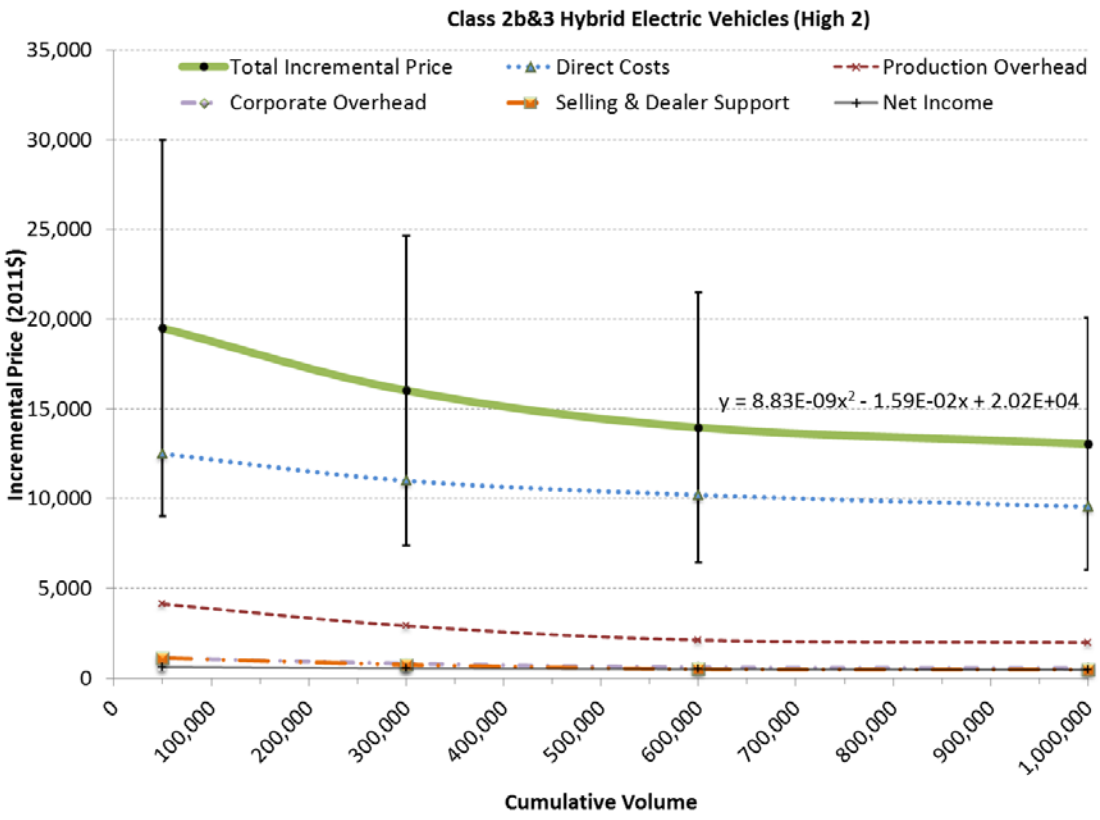
3.17 Hybrid Electric Vehicles



Class 2b&3 Hybrid Electric Vehicles (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$19,500.00	$16,368.75	$14,259.38	$13,331.25
Direct Costs	$13,732.39	$12,208.03	$11,227.85	$10,497.05
Production Overhead	$3,021.13	$1,976.88	$1,235.06	$1,154.68
Corporate Overhead	$686.62	$610.40	$561.39	$524.85
Selling & Dealer Support	$1,373.24	$963.03	$673.67	$629.82
Net Income	$686.62	$610.40	$561.39	$524.85

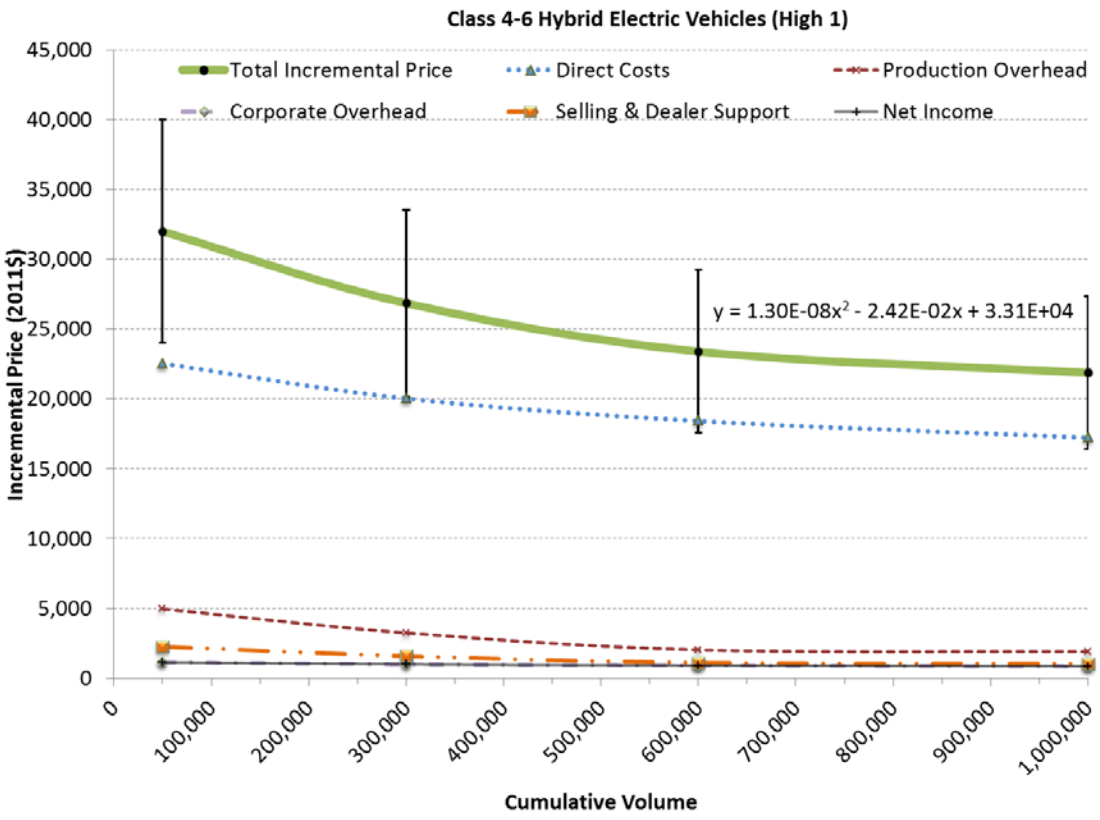
Figure 44. Incremental Price and Breakouts for Class 2b&3 Hybrid Electric Vehicles (High 1)



Class 2b&3 Hybrid Electric Vehicles (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$19,500.00	$16,029.66	$13,963.98	$13,055.08
Direct Costs	$12,500.00	$10,996.51	$10,207.59	$9,543.19
Production Overhead	$4,125.00	$2,914.07	$2,123.18	$1,984.98
Corporate Overhead	$1,125.00	$813.92	$612.46	$572.59
Selling & Dealer Support	$1,125.00	$755.33	$510.38	$477.16
Net Income	$625.00	$549.83	$510.38	$477.16

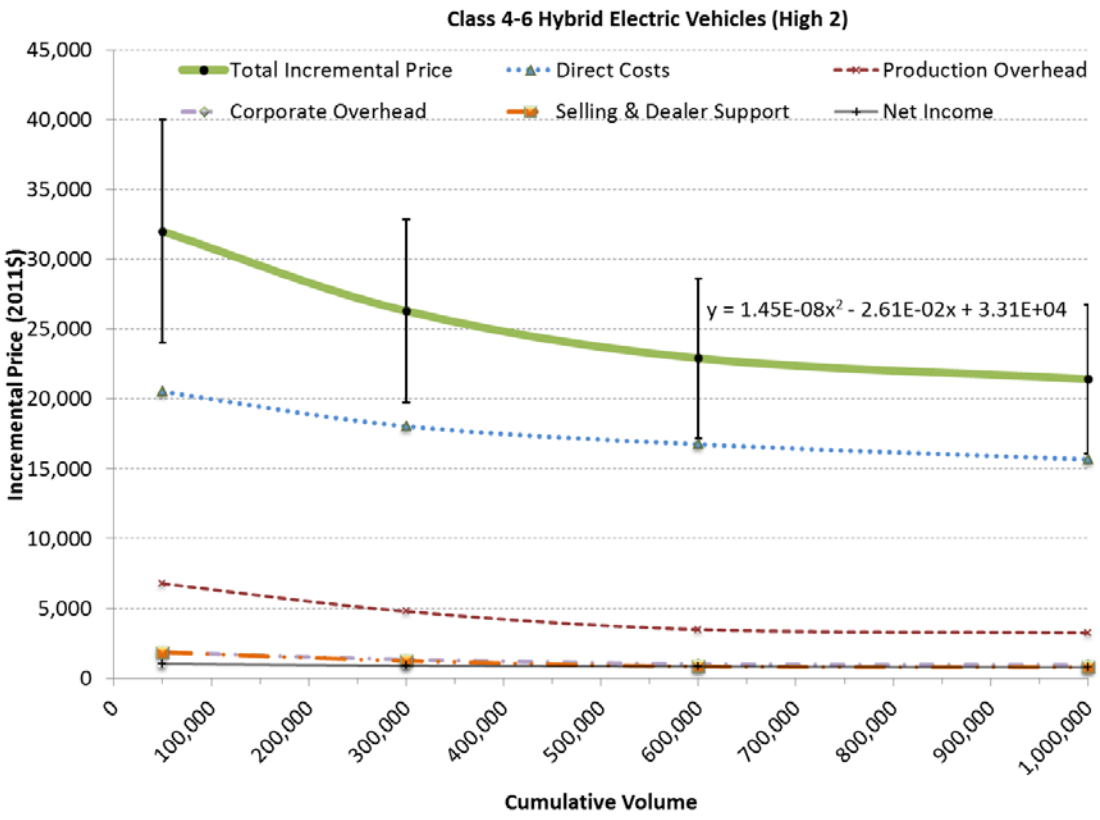
Figure 45. Incremental Price and Breakouts for Class 2b&3 Hybrid Electric Vehicles (High 2)



Class 4-6 Hybrid Electric Vehicles (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$32,000.00	$26,861.54	$23,400.00	$21,876.92
Direct Costs	$22,535.21	$20,033.70	$18,425.20	$17,225.92
Production Overhead	$4,957.75	$3,244.12	$2,026.77	$1,894.85
Corporate Overhead	$1,126.76	$1,001.68	$921.26	$861.30
Selling & Dealer Support	$2,253.52	$1,580.35	$1,105.51	$1,033.56
Net Income	$1,126.76	$1,001.68	$921.26	$861.30

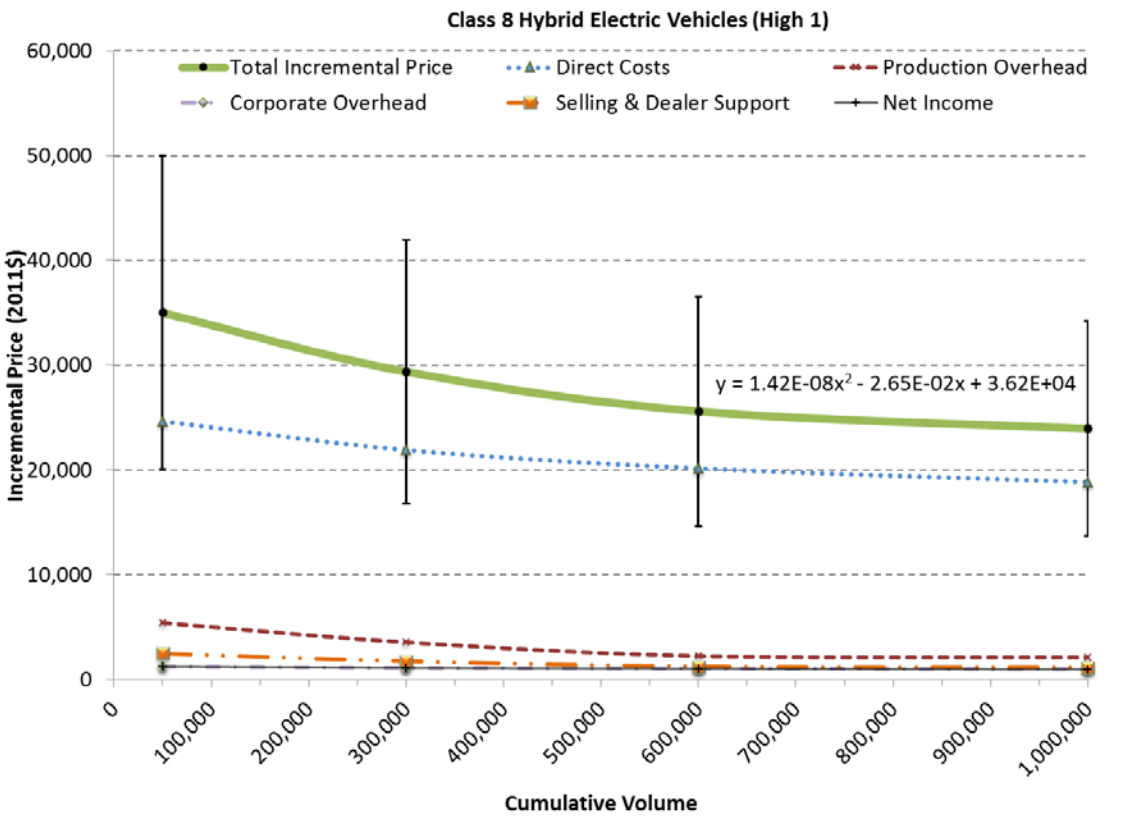
Figure 46. Incremental Price and Breakouts for Vocational Hybrid Electric Vehicles (High 1)



Class 4-6 Hybrid Electric Vehicles (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$32,000.00	$26,305.08	$22,915.25	$21,423.73
Direct Costs	$20,512.82	$18,045.55	$16,750.92	$15,660.62
Production Overhead	$6,769.23	$4,782.07	$3,484.19	$3,257.41
Corporate Overhead	$1,846.15	$1,335.67	$1,005.06	$939.64
Selling & Dealer Support	$1,846.15	$1,239.52	$837.55	$783.03
Net Income	$1,025.64	$902.28	$837.55	$783.03

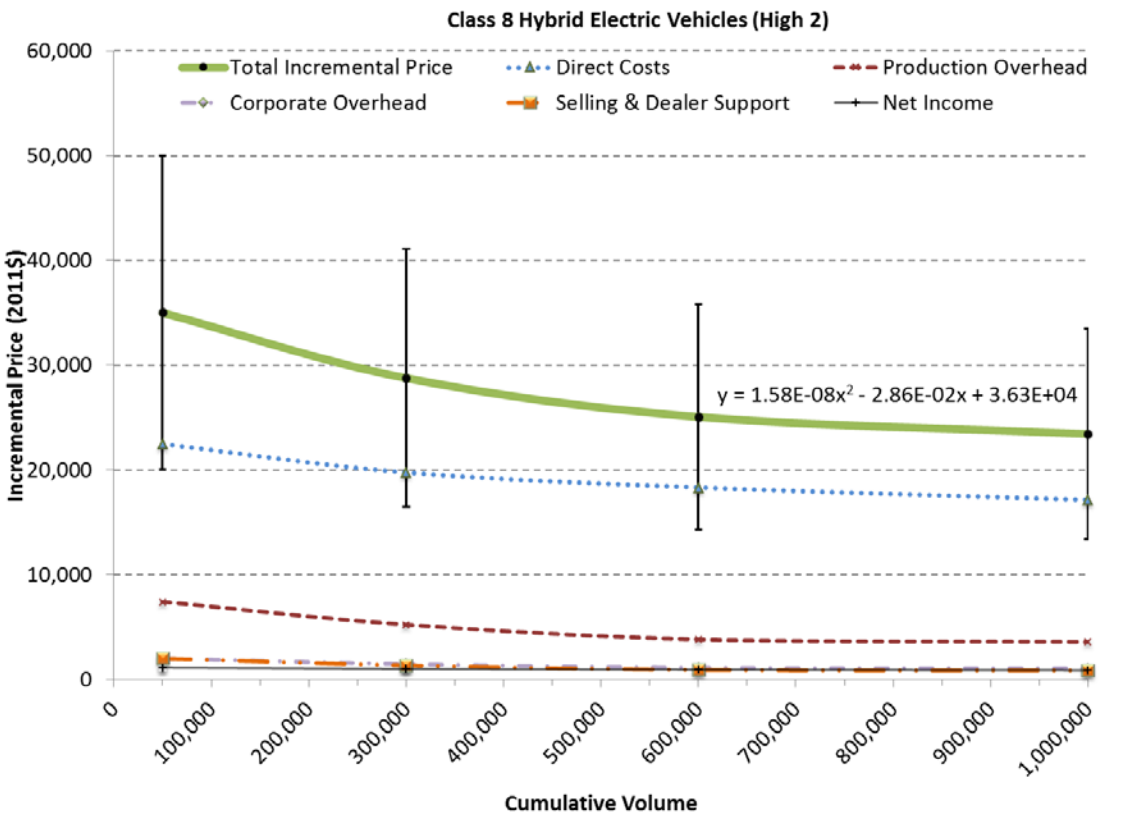
Figure 47. Incremental Price and Breakouts for Vocational Hybrid Electric Vehicles (High 2)



Class 8 Hybrid Electric Vehicles (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$35,000.00	$29,379.81	$25,593.75	$23,927.88
Direct Costs	$24,647.89	$21,911.86	$20,152.56	$18,840.85
Production Overhead	$5,422.54	$3,548.25	$2,216.78	$2,072.49
Corporate Overhead	$1,232.39	$1,095.59	$1,007.63	$942.04
Selling & Dealer Support	$2,464.79	$1,728.51	$1,209.15	$1,130.45
Net Income	$1,232.39	$1,095.59	$1,007.63	$942.04

Figure 48. Incremental Price and Breakouts for Line Haul Hybrid Electric Vehicles (High 1)

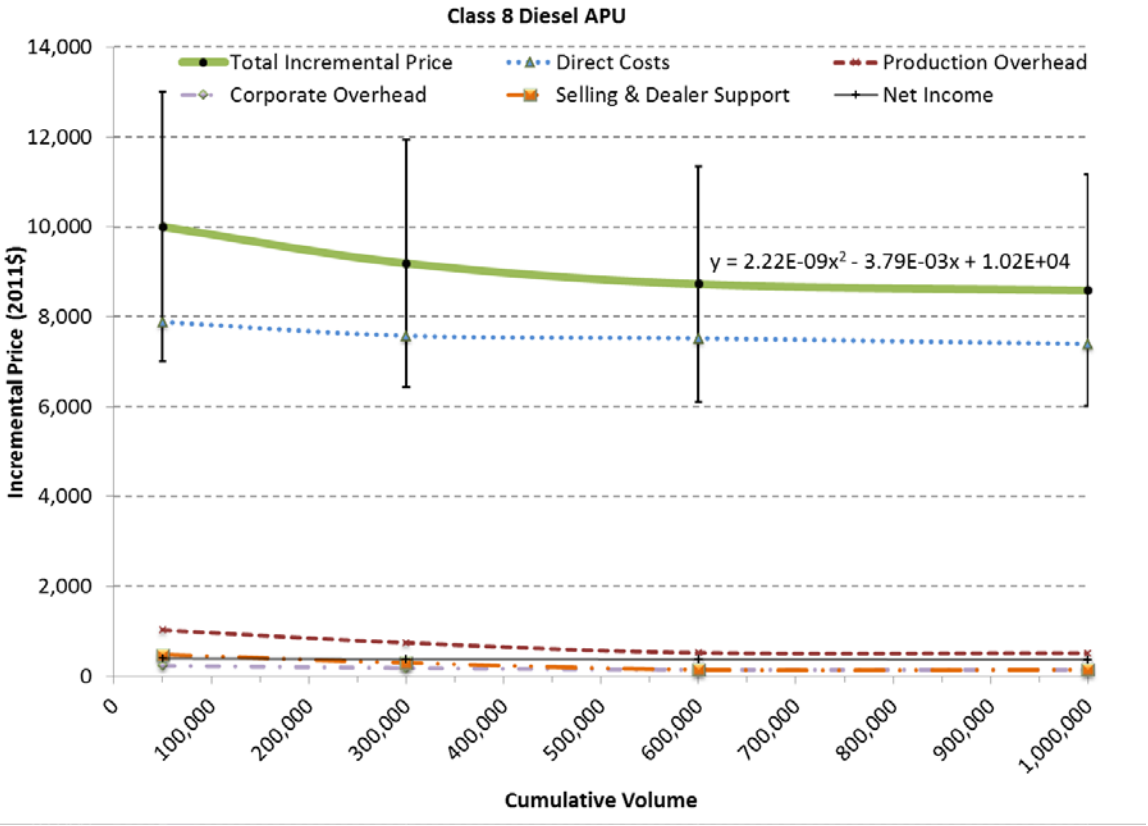


Class 8 Hybrid Electric Vehicles (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$35,000.00	$28,771.19	$25,063.56	$23,432.20
Direct Costs	$22,435.90	$19,737.32	$18,321.32	$17,128.80
Production Overhead	$7,403.85	$5,230.39	$3,810.83	$3,562.79
Corporate Overhead	$2,019.23	$1,460.89	$1,099.28	$1,027.73
Selling & Dealer Support	$2,019.23	$1,355.73	$916.07	$856.44
Net Income	$1,121.79	$986.87	$916.07	$856.44

Figure 49. Incremental Price and Breakouts for Line Haul Hybrid Electric Vehicles (High 2)

3.18 Diesel APU (with DPF)

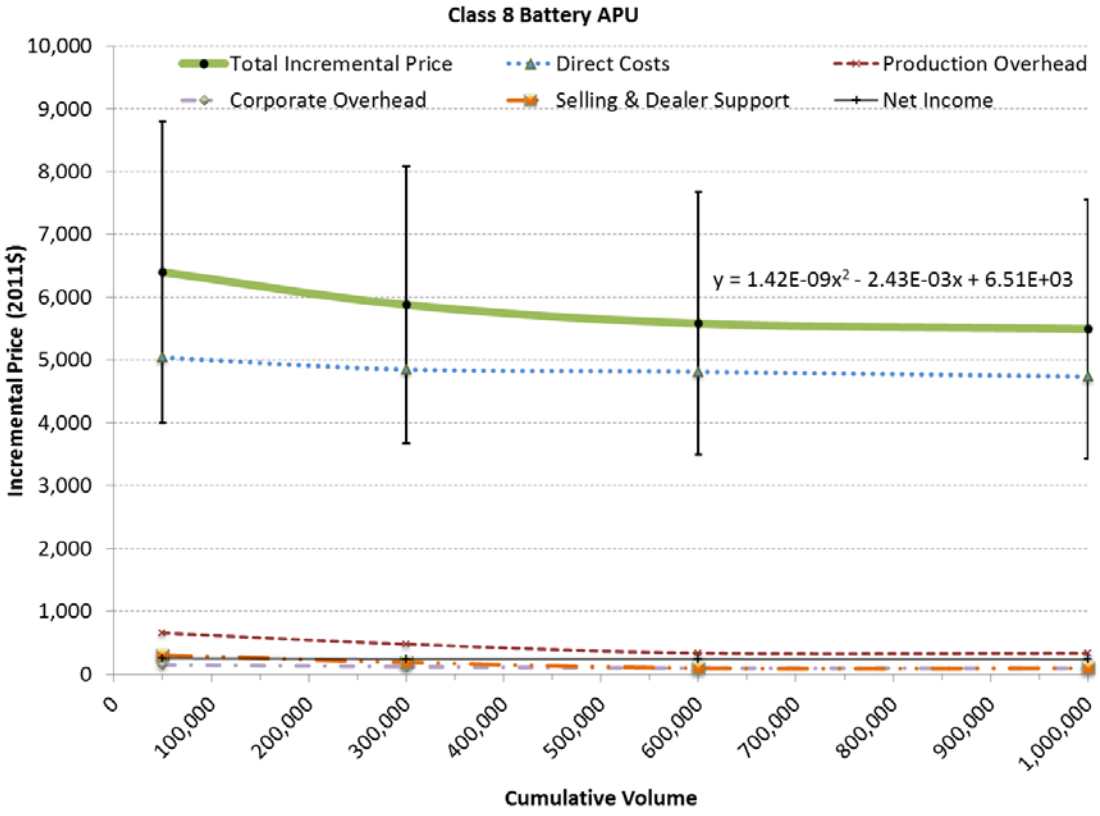


Class 8 Diesel APU

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$10,000.00	$9,187.77	$8,723.74	$8,584.53
Direct Costs	$7,874.02	$7,578.16	$7,521.76	$7,401.74
Production Overhead	$1,023.62	$746.71	$525.02	$516.64
Corporate Overhead	$236.22	$187.74	$150.44	$148.03
Selling & Dealer Support	$472.44	$296.25	$150.44	$148.03
Net Income	$393.70	$378.91	$376.09	$370.09

Figure 50. Incremental Price and Breakouts for Line Haul Diesel APU (w/DPF)

3.19 Battery APU

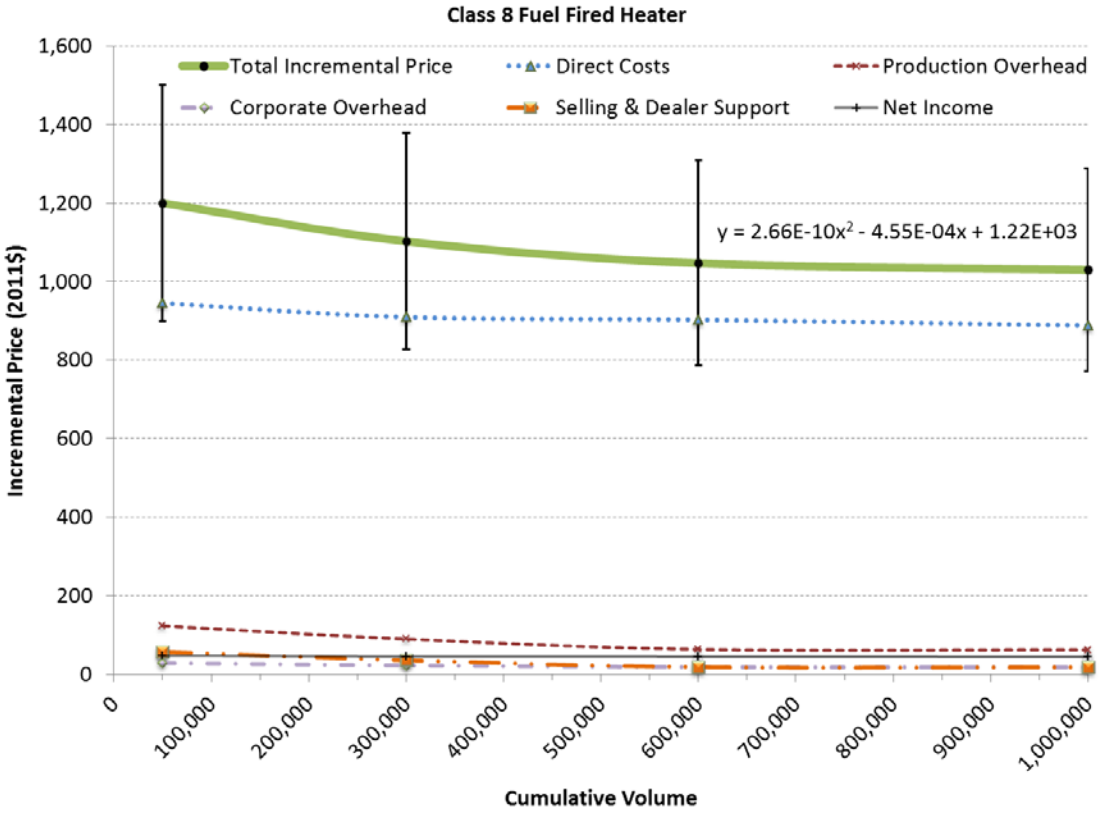


Class 8 Battery APU

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$6,400.00	$5,880.17	$5,583.19	$5,494.10
Direct Costs	$5,039.37	$4,850.02	$4,813.93	$4,737.11
Production Overhead	$655.12	$477.90	$336.01	$330.65
Corporate Overhead	$151.18	$120.15	$96.28	$94.74
Selling & Dealer Support	$302.36	$189.60	$96.28	$94.74
Net Income	$251.97	$242.50	$240.70	$236.86

Figure 51. Incremental Price and Breakouts for Line Haul Battery APU

3.20 Fuel-Fired Heater

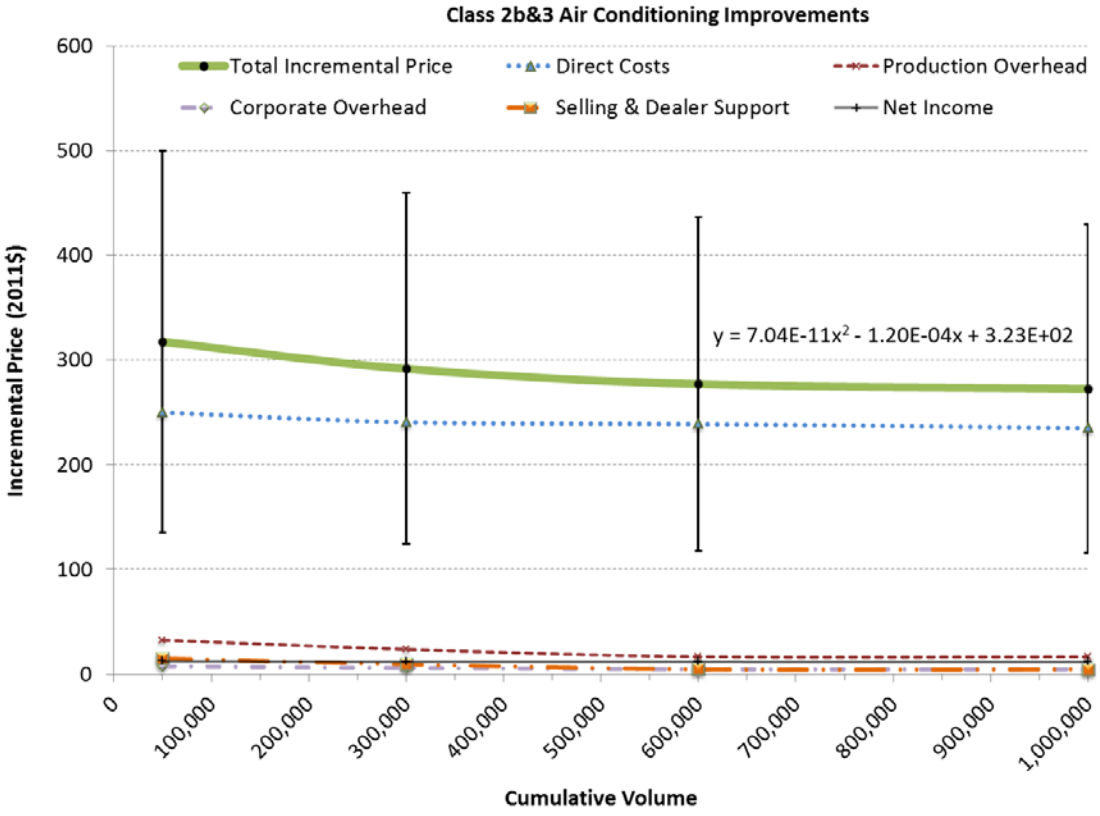


Class 8 Fuel Fired Heater

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,200.00	$1,102.53	$1,046.85	$1,030.14
Direct Costs	$944.88	$909.38	$902.61	$888.21
Production Overhead	$122.83	$89.61	$63.00	$62.00
Corporate Overhead	$28.35	$22.53	$18.05	$17.76
Selling & Dealer Support	$56.69	$35.55	$18.05	$17.76
Net Income	$47.24	$45.47	$45.13	$44.41

Figure 52. Incremental Price and Breakouts for Line Haul Fuel-Fired Heater

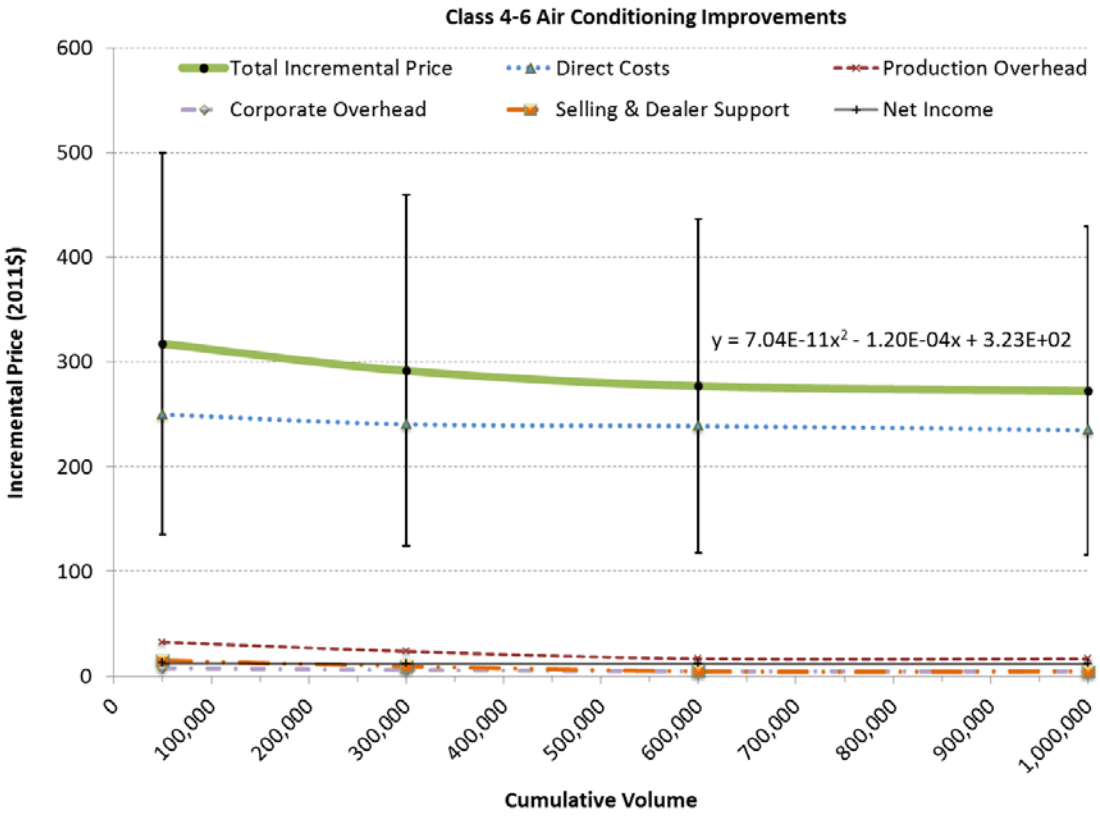
3.21 Air Conditioner System Improvements



Class 2b&3 Air Conditioning Improvements

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$317.50	$291.71	$276.98	$272.56
Direct Costs	$250.00	$240.61	$238.82	$235.01
Production Overhead	$32.50	$23.71	$16.67	$16.40
Corporate Overhead	$7.50	$5.96	$4.78	$4.70
Selling & Dealer Support	$15.00	$9.41	$4.78	$4.70
Net Income	$12.50	$12.03	$11.94	$11.75

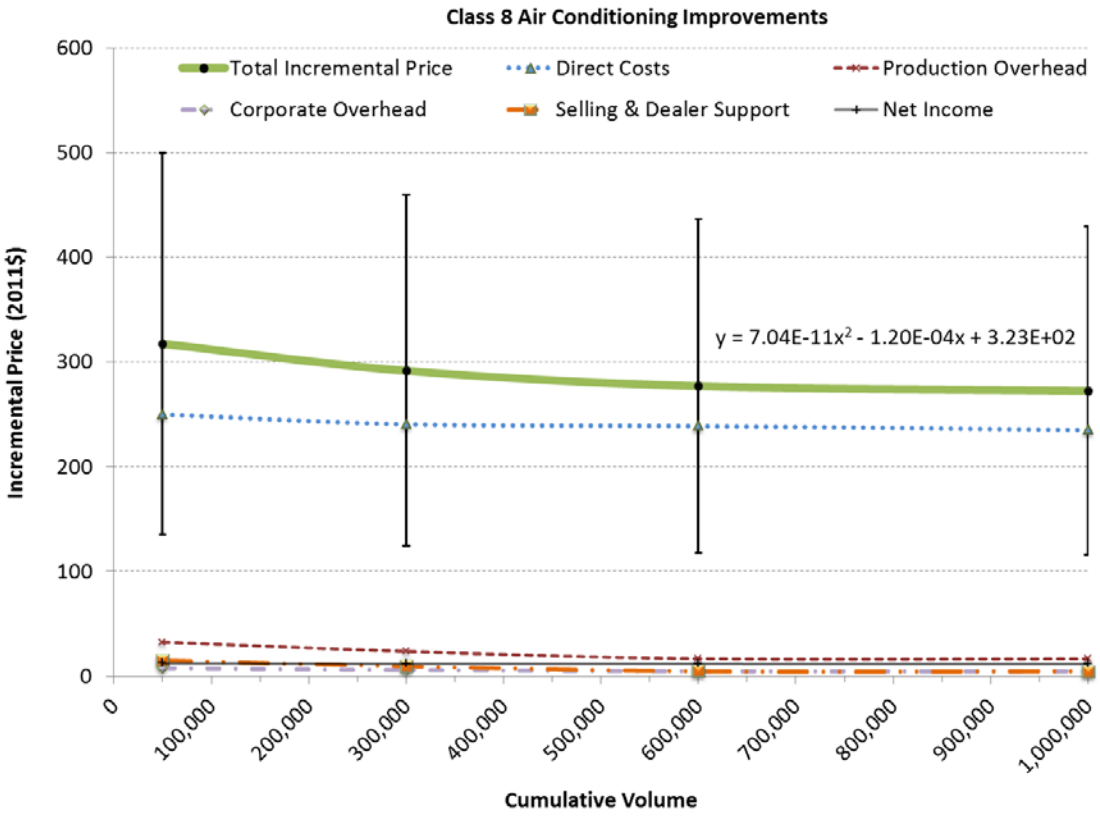
Figure 53. Incremental Price and Breakouts for Class 2b&3 (Gasoline, Diesel) A/C System Improvements



Class 4-6 Air Conditioning Improvements

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$317.50	$291.71	$276.98	$272.56
Direct Costs	$250.00	$240.61	$238.82	$235.01
Production Overhead	$32.50	$23.71	$16.67	$16.40
Corporate Overhead	$7.50	$5.96	$4.78	$4.70
Selling & Dealer Support	$15.00	$9.41	$4.78	$4.70
Net Income	$12.50	$12.03	$11.94	$11.75

Figure 54. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) A/C System Improvements

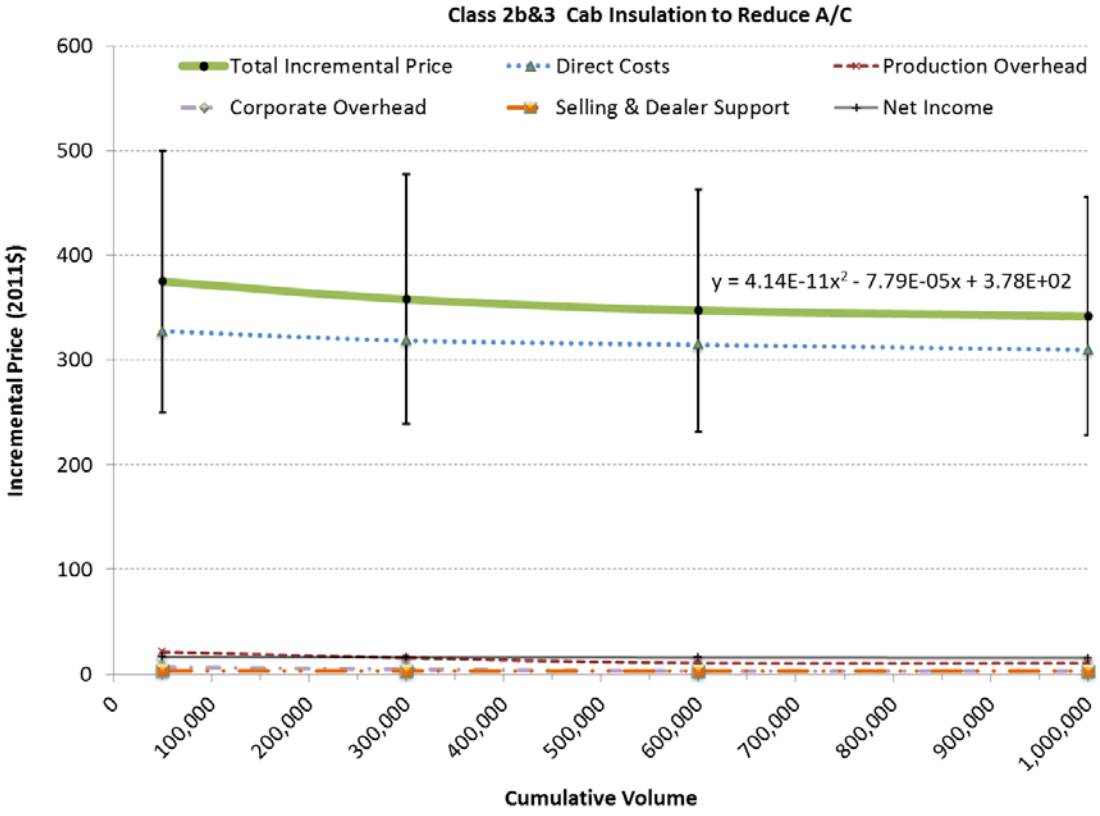


Class 8 Air Conditioning Improvements

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$317.50	$291.71	$276.98	$272.56
Direct Costs	$250.00	$240.61	$238.82	$235.01
Production Overhead	$32.50	$23.71	$16.67	$16.40
Corporate Overhead	$7.50	$5.96	$4.78	$4.70
Selling & Dealer Support	$15.00	$9.41	$4.78	$4.70
Net Income	$12.50	$12.03	$11.94	$11.75

Figure 55. Incremental Price and Breakouts for Line Haul A/C System Improvements

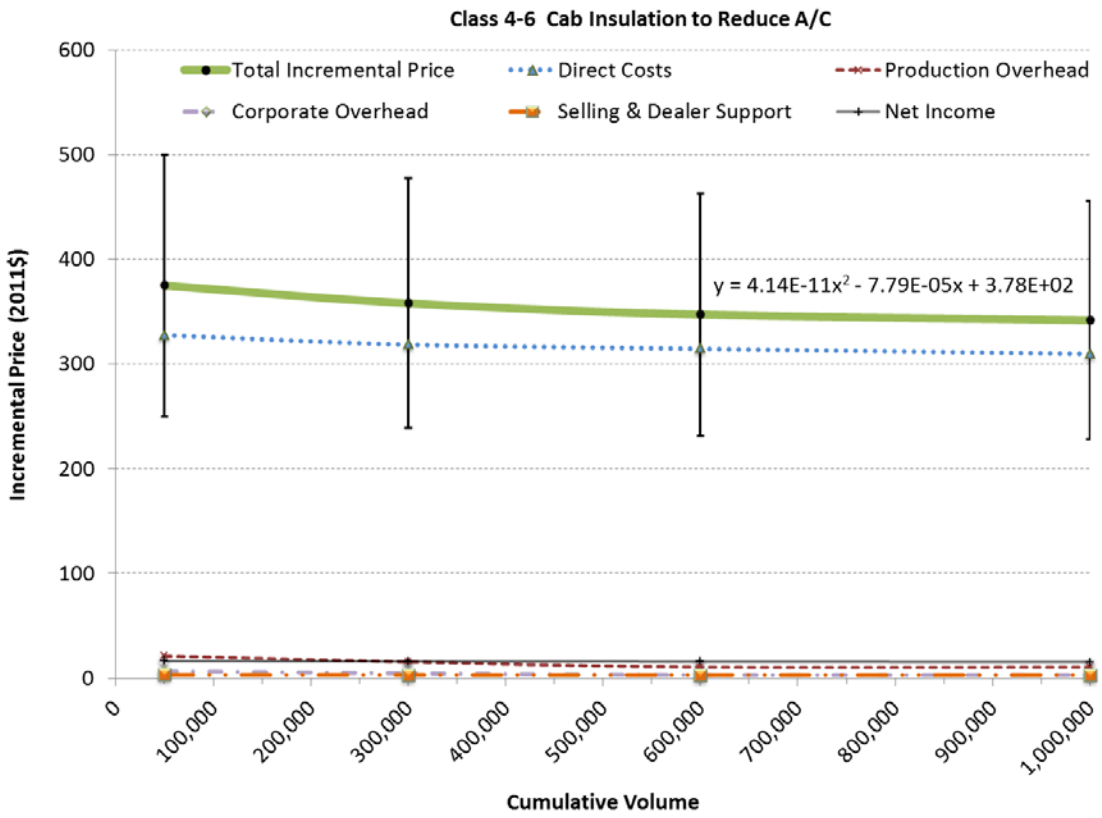
3.22 Cab Insulation to Reduce A/C



Class 2b&3 Cab Insulation to Reduce A/C

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$375.00	$358.08	$347.28	$341.89
Direct Costs	$327.57	$318.60	$314.63	$309.73
Production Overhead	$21.23	$15.62	$10.63	$10.47
Corporate Overhead	$6.55	$4.75	$3.15	$3.10
Selling & Dealer Support	$3.28	$3.19	$3.15	$3.10
Net Income	$16.38	$15.93	$15.73	$15.49

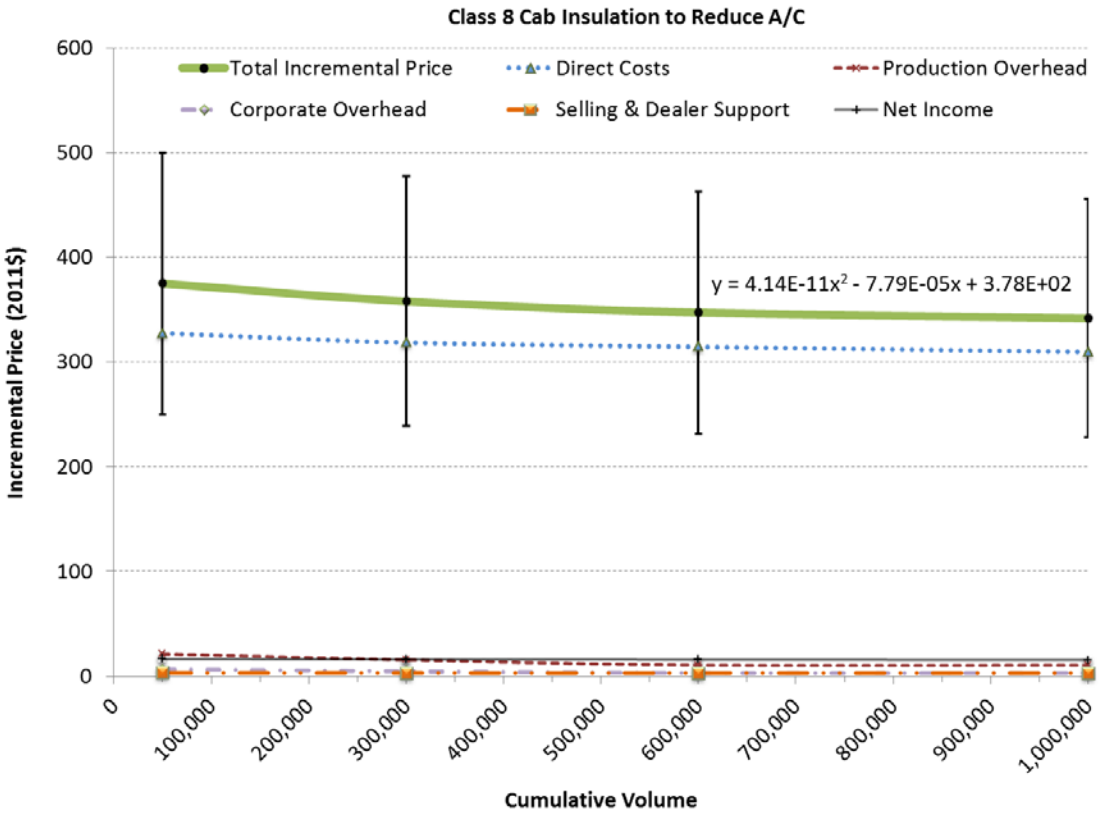
Figure 56. Incremental Price and Breakouts for Class 2b&3 (Gasoline, Diesel) Cab Insulation to Reduce A/C



Class 4-6 Cab Insulation to Reduce A/C

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$375.00	$358.08	$347.28	$341.89
Direct Costs	$327.57	$318.60	$314.63	$309.73
Production Overhead	$21.23	$15.62	$10.63	$10.47
Corporate Overhead	$6.55	$4.75	$3.15	$3.10
Selling & Dealer Support	$3.28	$3.19	$3.15	$3.10
Net Income	$16.38	$15.93	$15.73	$15.49

Figure 57. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) Cab Insulation to Reduce A/C

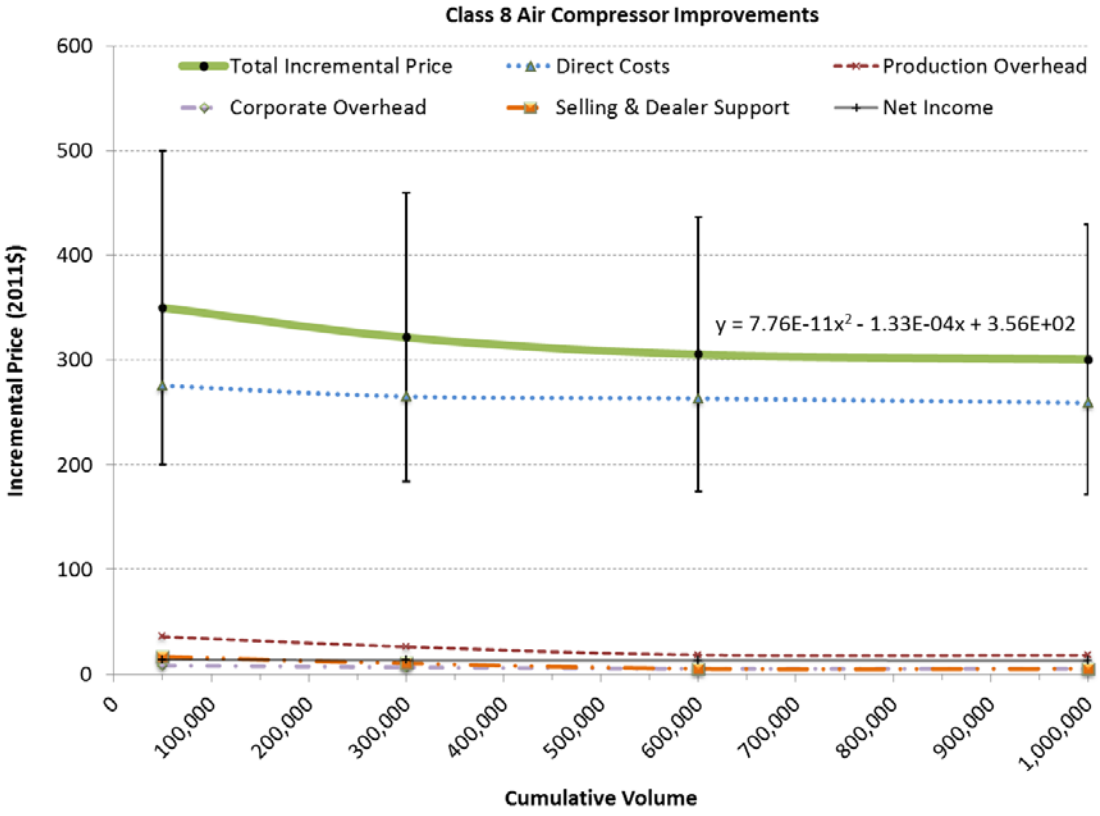


Class 8 Cab Insulation to Reduce A/C

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$375.00	$358.08	$347.28	$341.89
Direct Costs	$327.57	$318.60	$314.63	$309.73
Production Overhead	$21.23	$15.62	$10.63	$10.47
Corporate Overhead	$6.55	$4.75	$3.15	$3.10
Selling & Dealer Support	$3.28	$3.19	$3.15	$3.10
Net Income	$16.38	$15.93	$15.73	$15.49

Figure 58. Incremental Price and Breakouts for Line Haul Cab Insulation to Reduce A/C

3.23 Air Compressor Improvements

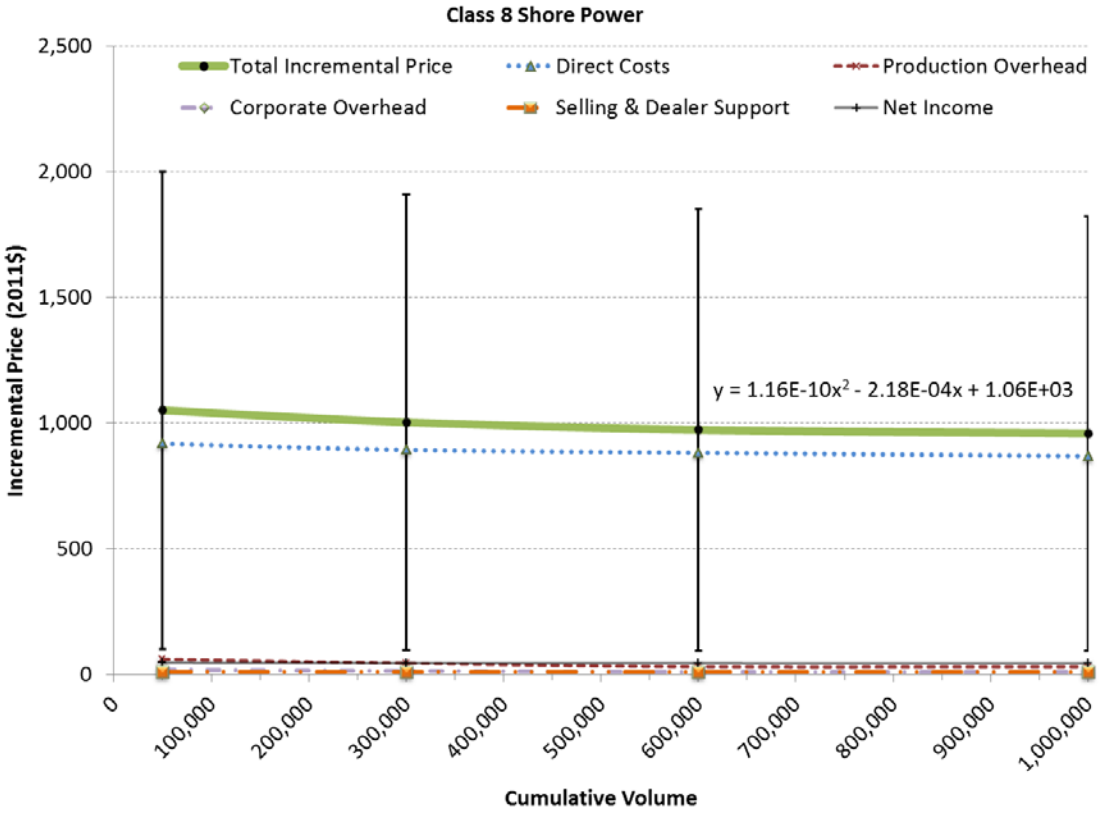


Class 8 Air Compressor Improvements

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$350.00	$321.57	$305.33	$300.46
Direct Costs	$275.59	$265.24	$263.26	$259.06
Production Overhead	$35.83	$26.13	$18.38	$18.08
Corporate Overhead	$8.27	$6.57	$5.27	$5.18
Selling & Dealer Support	$16.54	$10.37	$5.27	$5.18
Net Income	$13.78	$13.26	$13.16	$12.95

Figure 59. Incremental Price and Breakouts for Line Haul Air Compressor Improvements

3.24 Shore Power

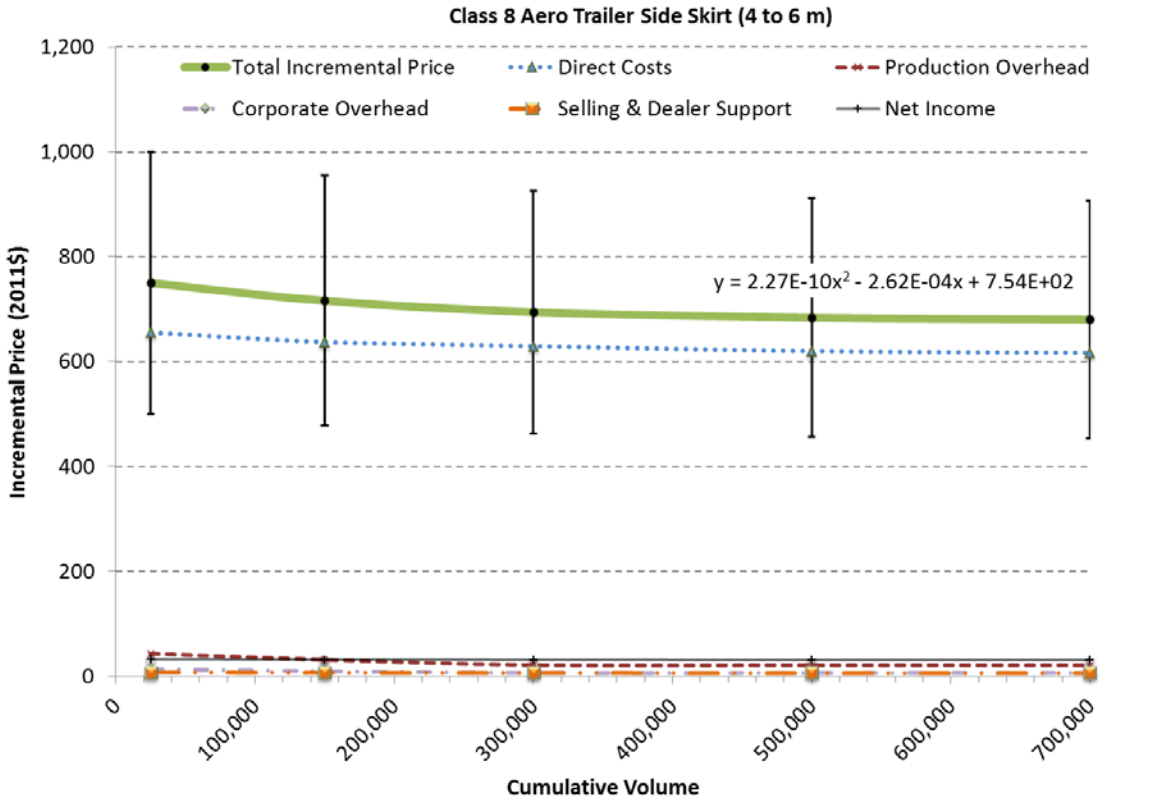


Class 8 Shore Power

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,050.00	$1,002.62	$972.39	$957.28
Direct Costs	$917.19	$892.07	$880.95	$867.26
Production Overhead	$59.43	$43.73	$29.78	$29.31
Corporate Overhead	$18.34	$13.30	$8.81	$8.67
Selling & Dealer Support	$9.17	$8.92	$8.81	$8.67
Net Income	$45.86	$44.60	$44.05	$43.36

Figure 60. Incremental Price and Breakouts for Line Haul Shore Power

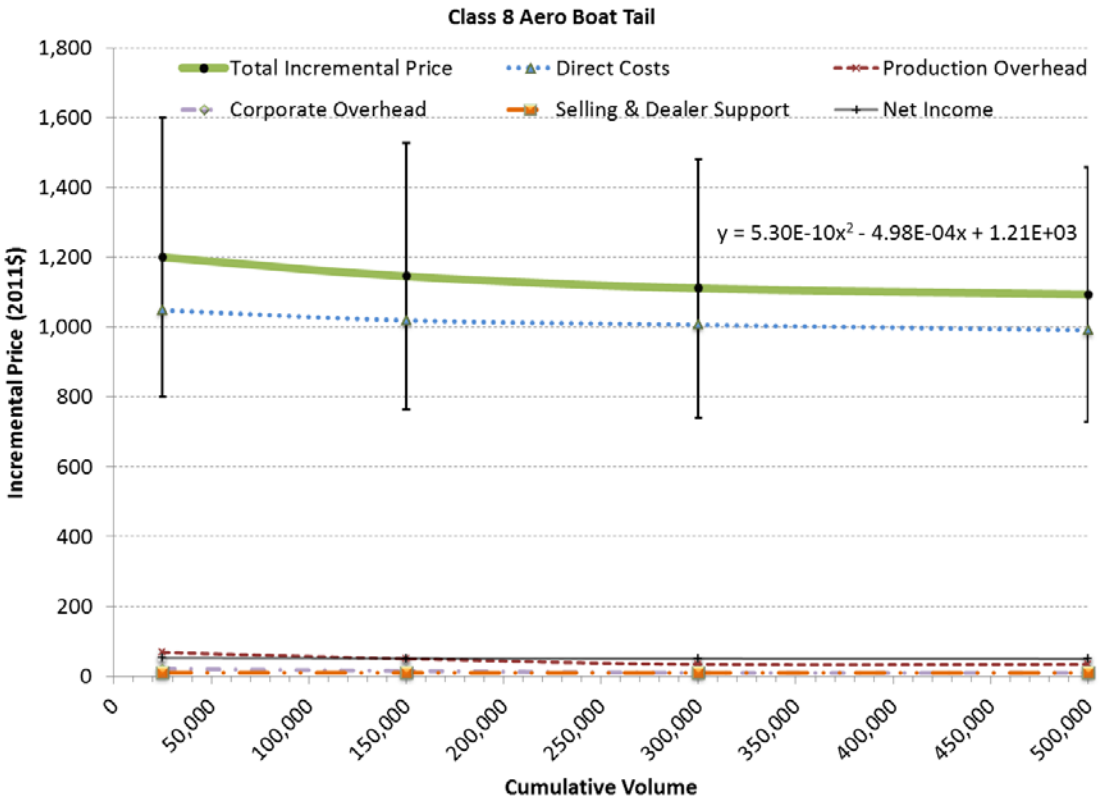
3.25 Aero Bin III



Class 8 Aero Trailer Side Skirt (4 to 6 m)

Volume (units):	25,000	150,000	300,000	500,000	700,000
Total Incremental Price	$750.00	$716.16	$694.57	$683.77	$680.17
Direct Costs	$655.14	$637.19	$629.25	$619.47	$616.21
Production Overhead	$42.45	$31.23	$21.27	$20.94	$20.83
Corporate Overhead	$13.10	$9.50	$6.29	$6.19	$6.16
Selling & Dealer Support	$6.55	$6.37	$6.29	$6.19	$6.16
Net Income	$32.76	$31.86	$31.46	$30.97	$30.81

Figure 61. Incremental Price and Breakouts for Line Haul Aero Trailer Side Skirt (4 to 6 m)

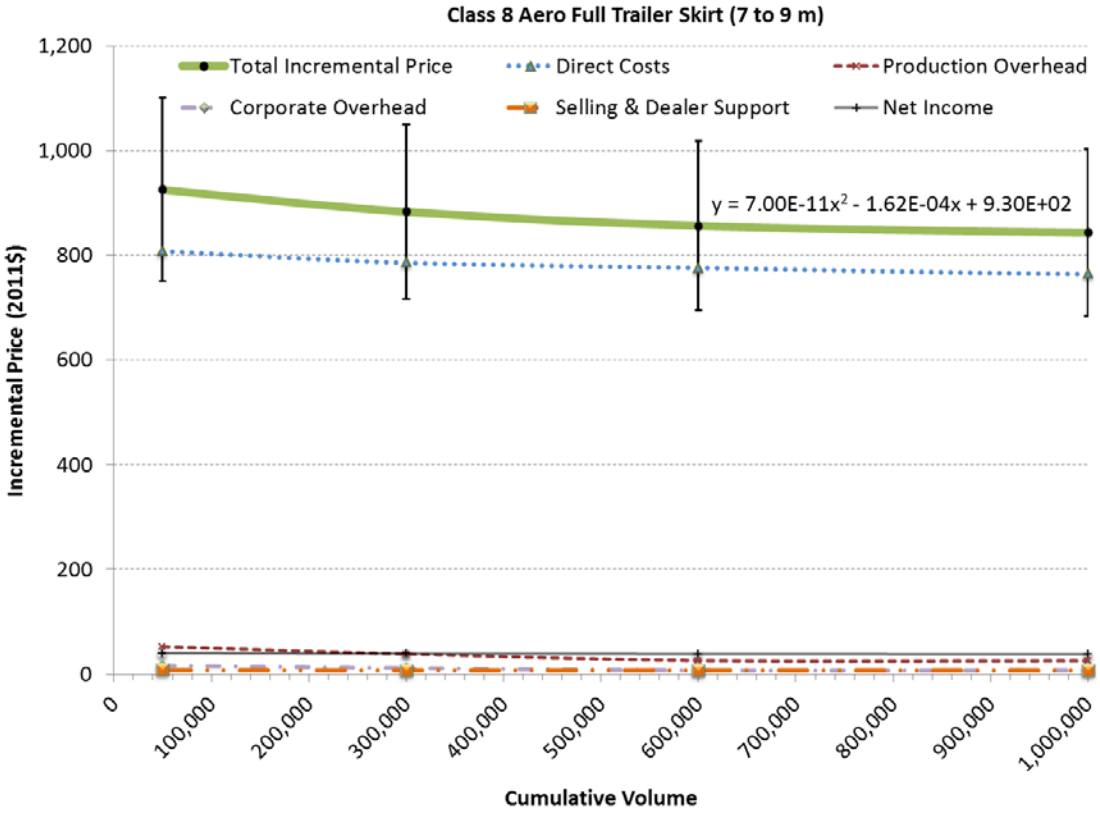


Class 8 Aero Boat Tail

Volume (units):	25,000	150,000	300,000	500,000
Total Incremental Price	$1,200.00	$1,145.85	$1,111.31	$1,094.03
Direct Costs	$1,048.22	$1,019.51	$1,006.80	$991.15
Production Overhead	$67.92	$49.97	$34.03	$33.50
Corporate Overhead	$20.96	$15.20	$10.07	$9.91
Selling & Dealer Support	$10.48	$10.20	$10.07	$9.91
Net Income	$52.41	$50.98	$50.34	$49.56

Figure 62. Incremental Price and Breakouts for Line Haul Aero Boat Tail

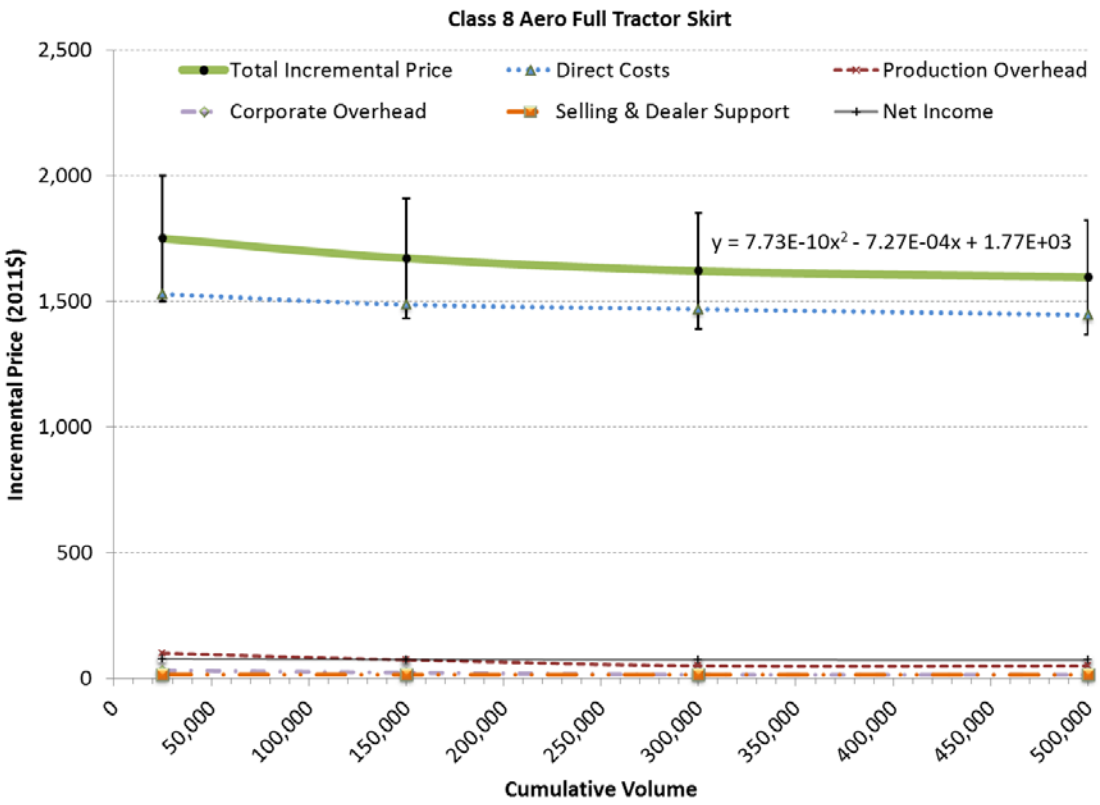
3.26 Aero Bin IV and V



Class 8 Aero Full Trailer Skirt (7 to 9 m)

Volume (units):	50,000	300,000	600,000	1,000,000	1,400,000
Total Incremental Price	$925.00	$883.26	$856.63	$843.32	$838.88
Direct Costs	$808.00	$785.87	$776.08	$764.01	$759.99
Production Overhead	$52.36	$38.52	$26.23	$25.82	$25.69
Corporate Overhead	$16.16	$11.72	$7.76	$7.64	$7.60
Selling & Dealer Support	$8.08	$7.86	$7.76	$7.64	$7.60
Net Income	$40.40	$39.29	$38.80	$38.20	$38.00

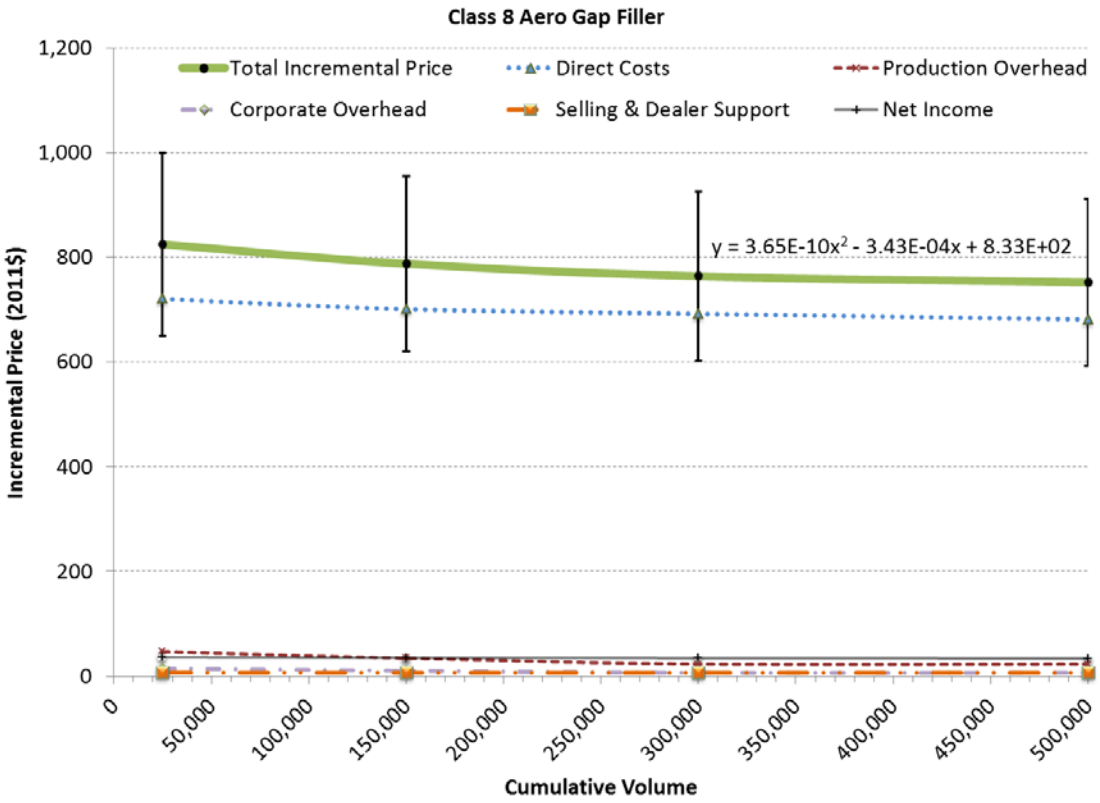
Figure 63. Incremental Price and Breakouts for Line Haul Aero Full Trailer Skirt (7 to 9 m)



Class 8 Aero Full Tractor Skirt

Volume (units):	25,000	150,000	300,000	500,000
Total Incremental Price	$1,750.00	$1,671.04	$1,620.66	$1,595.46
Direct Costs	$1,528.65	$1,486.79	$1,468.25	$1,445.43
Production Overhead	$99.06	$72.88	$49.63	$48.86
Corporate Overhead	$30.57	$22.17	$14.68	$14.45
Selling & Dealer Support	$15.29	$14.87	$14.68	$14.45
Net Income	$76.43	$74.34	$73.41	$72.27

Figure 64. Incremental Price and Breakouts for Line Haul Aero Full Tractor Skirt (over axles)



Class 8 Aero Gap Filler

Volume (units):	25,000	150,000	300,000	500,000
Total Incremental Price	$825.00	$787.78	$764.02	$752.15
Direct Costs	$720.65	$700.91	$692.18	$681.42
Production Overhead	$46.70	$34.36	$23.40	$23.03
Corporate Overhead	$14.41	$10.45	$6.92	$6.81
Selling & Dealer Support	$7.21	$7.01	$6.92	$6.81
Net Income	$36.03	$35.05	$34.61	$34.07

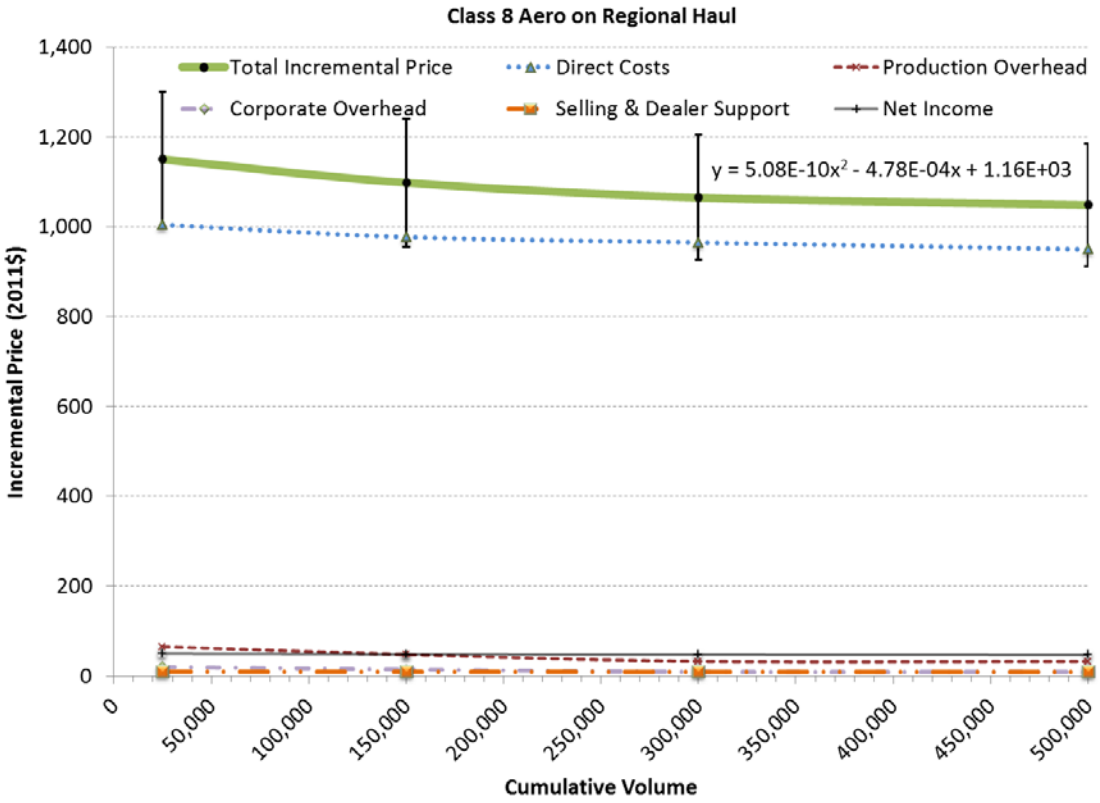
Figure 65. Incremental Price and Breakouts for Line Haul Aero Gap Filler

3.27 Include Trailer C_d and C_{rr} in Rule

The SmartWay Designated trailer must meet the requirements for a trailer equipped with SmartWay verified tires and aerodynamics package. The SmartWay trailers may use one of the following configurations for reduced C_d and $C_{rr:}$[19]

- Trailer Configuration A: Side Skirt; Gap reducer; and Low-rolling resistance tires
- Trailer Configuration B: Side skirt; Boat tail; and Low-rolling resistance tires
- Optional Total Aero Trailer Configuration: Side skirt; Gap reducer; Boat tail; and Low-rolling resistance tires

3.28 Aero on Regional Haul



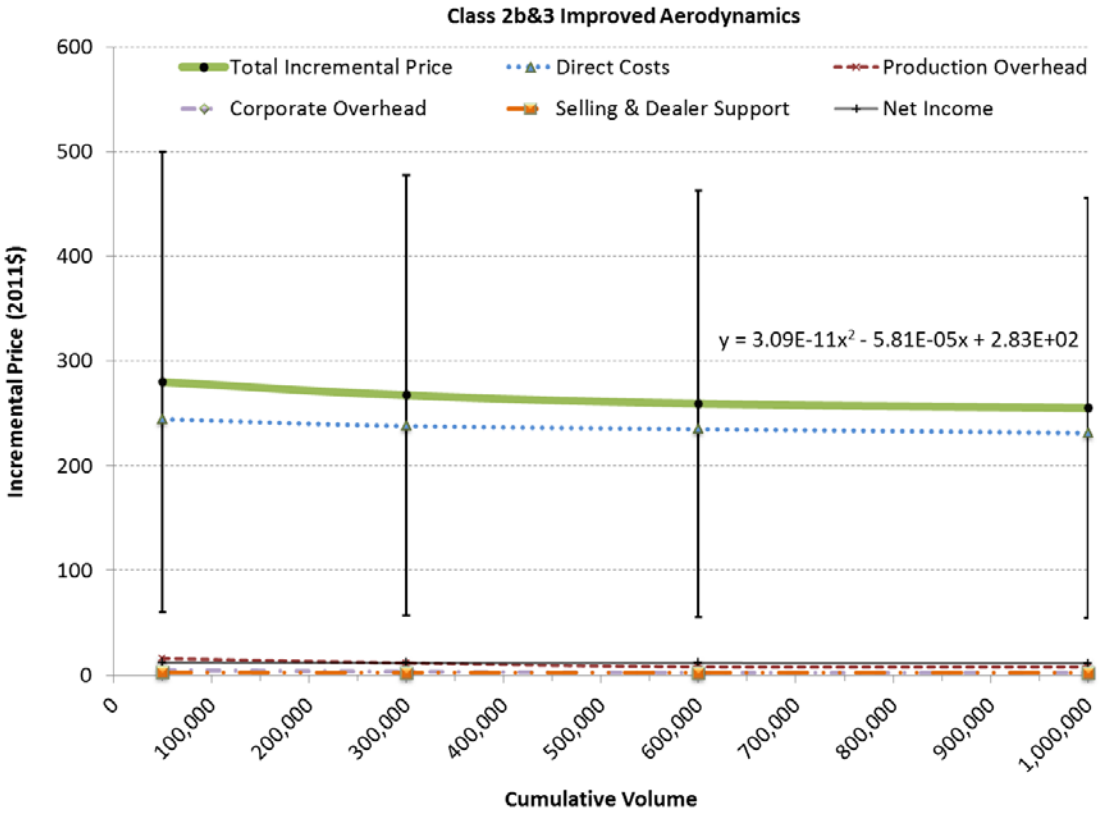
[19] U.S. Environmental Protection Agency, "U.S. EPA Designated SmartWay Mark: License Agreement, Technical Specifications and Requirements, and Graphics Standards and Usage Guide for Tractor and Trailer Manufacturers," Report # EPA420-B11-013, 2011

Class 8 Aero on Regional Haul

Volume (units):	25,000	150,000	300,000	500,000
Total Incremental Price	$1,150.00	$1,098.11	$1,065.00	$1,048.45
Direct Costs	$1,004.54	$977.03	$964.85	$949.85
Production Overhead	$65.09	$47.89	$32.61	$32.11
Corporate Overhead	$20.09	$14.57	$9.65	$9.50
Selling & Dealer Support	$10.05	$9.77	$9.65	$9.50
Net Income	$50.23	$48.85	$48.24	$47.49

Figure 66. Incremental Price and Breakouts for Aero on Regional Haul

3.29 Class 2b&3 Improved Aerodynamics

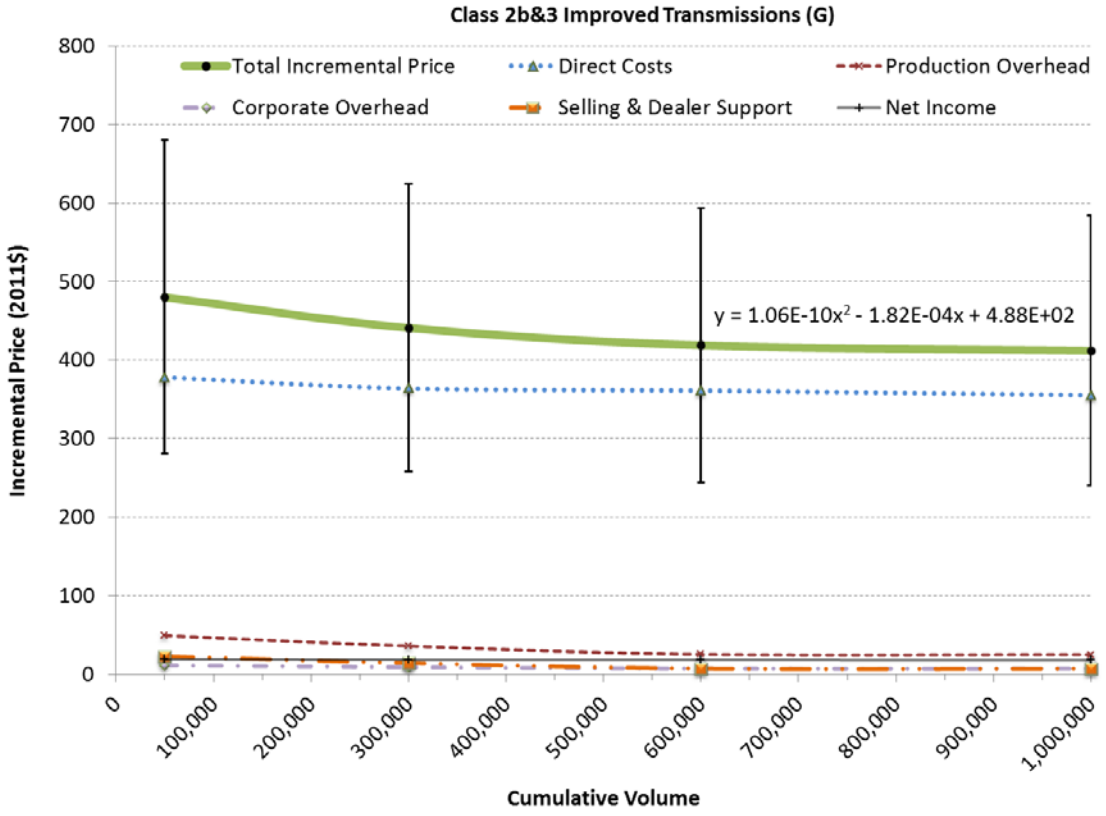


Class 2b&3 Improved Aerodynamics

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$280.00	$267.37	$259.30	$255.27
Direct Costs	$244.58	$237.89	$234.92	$231.27
Production Overhead	$15.85	$11.66	$7.94	$7.82
Corporate Overhead	$4.89	$3.55	$2.35	$2.31
Selling & Dealer Support	$2.45	$2.38	$2.35	$2.31
Net Income	$12.23	$11.89	$11.75	$11.56

Figure 67. Incremental Price and Breakouts for Class 2b&3 (Gasoline, Diesel) Improved Aerodynamics

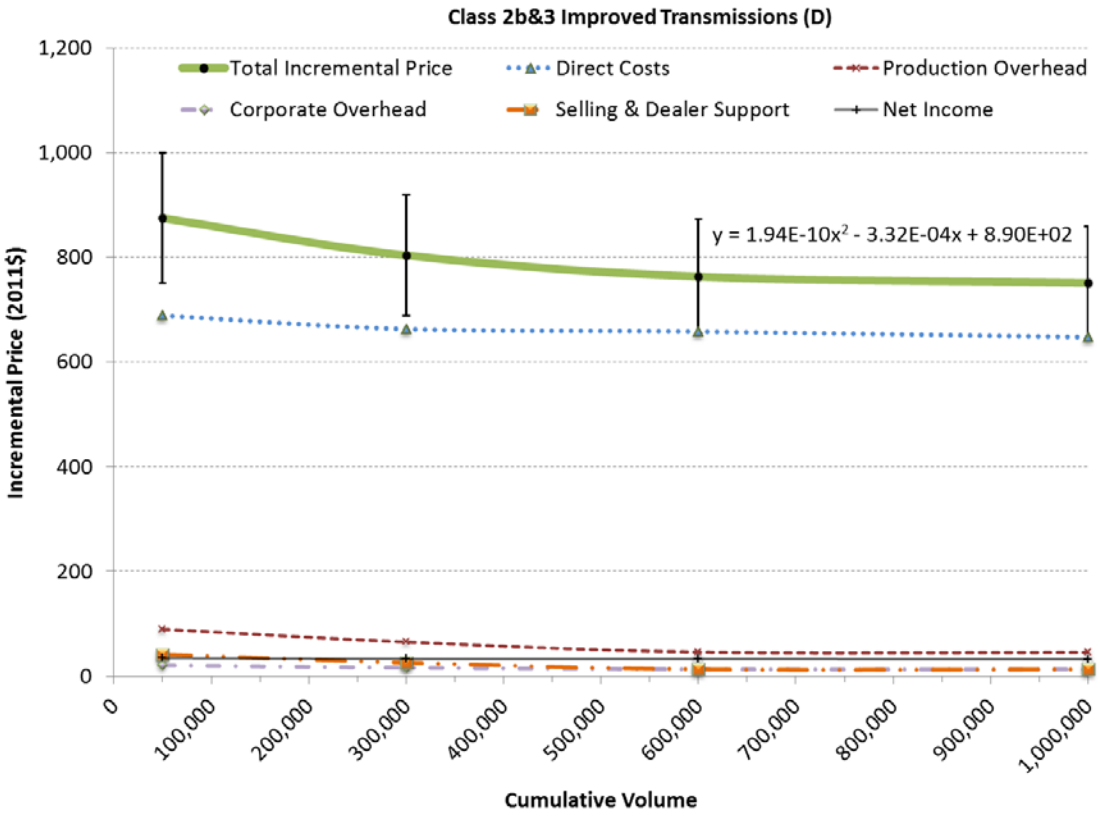
3.30 Improved Transmissions



Class 2b&3 Improved Transmissions (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$480.00	$441.01	$418.74	$412.06
Direct Costs	$377.95	$363.75	$361.04	$355.28
Production Overhead	$49.13	$35.84	$25.20	$24.80
Corporate Overhead	$11.34	$9.01	$7.22	$7.11
Selling & Dealer Support	$22.68	$14.22	$7.22	$7.11
Net Income	$18.90	$18.19	$18.05	$17.76

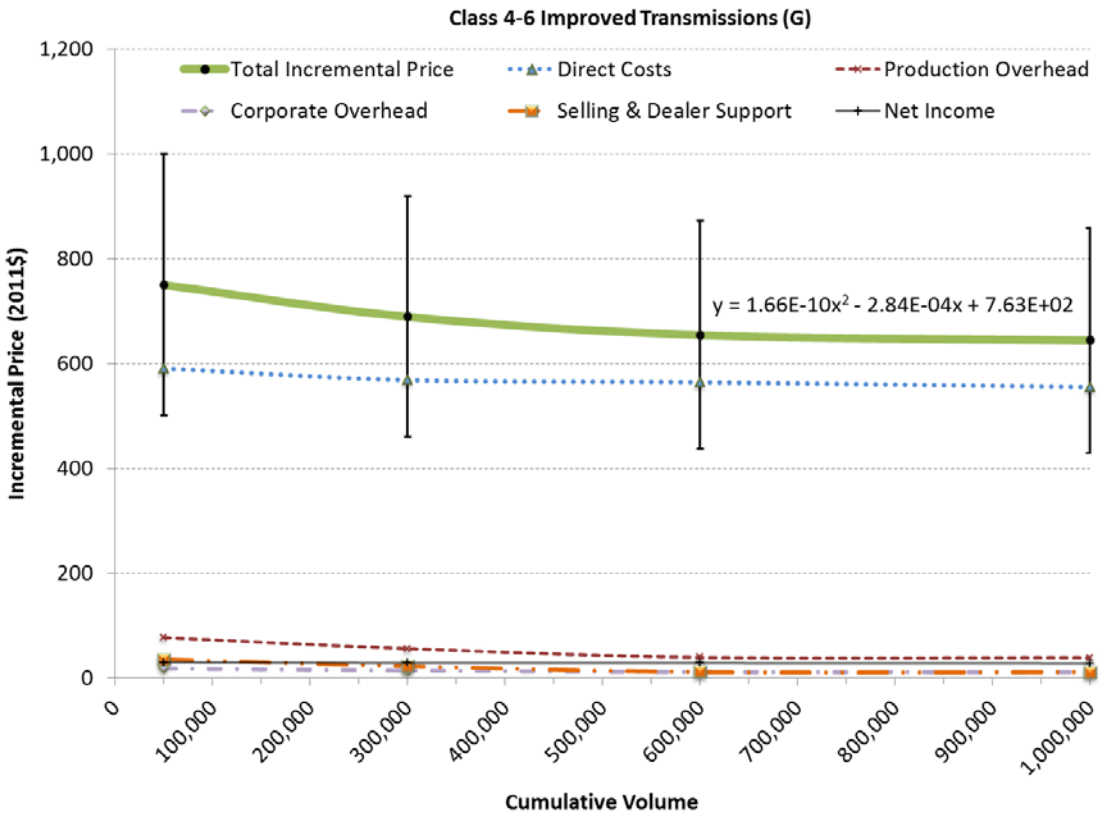
Figure 68. Incremental Price and Breakouts for Class 2b&3 (Gasoline) Improved Transmissions



Class 2b&3 Improved Transmissions (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$875.00	$803.93	$763.33	$751.15
Direct Costs	$688.98	$663.09	$658.15	$647.65
Production Overhead	$89.57	$65.34	$45.94	$45.21
Corporate Overhead	$20.67	$16.43	$13.16	$12.95
Selling & Dealer Support	$41.34	$25.92	$13.16	$12.95
Net Income	$34.45	$33.15	$32.91	$32.38

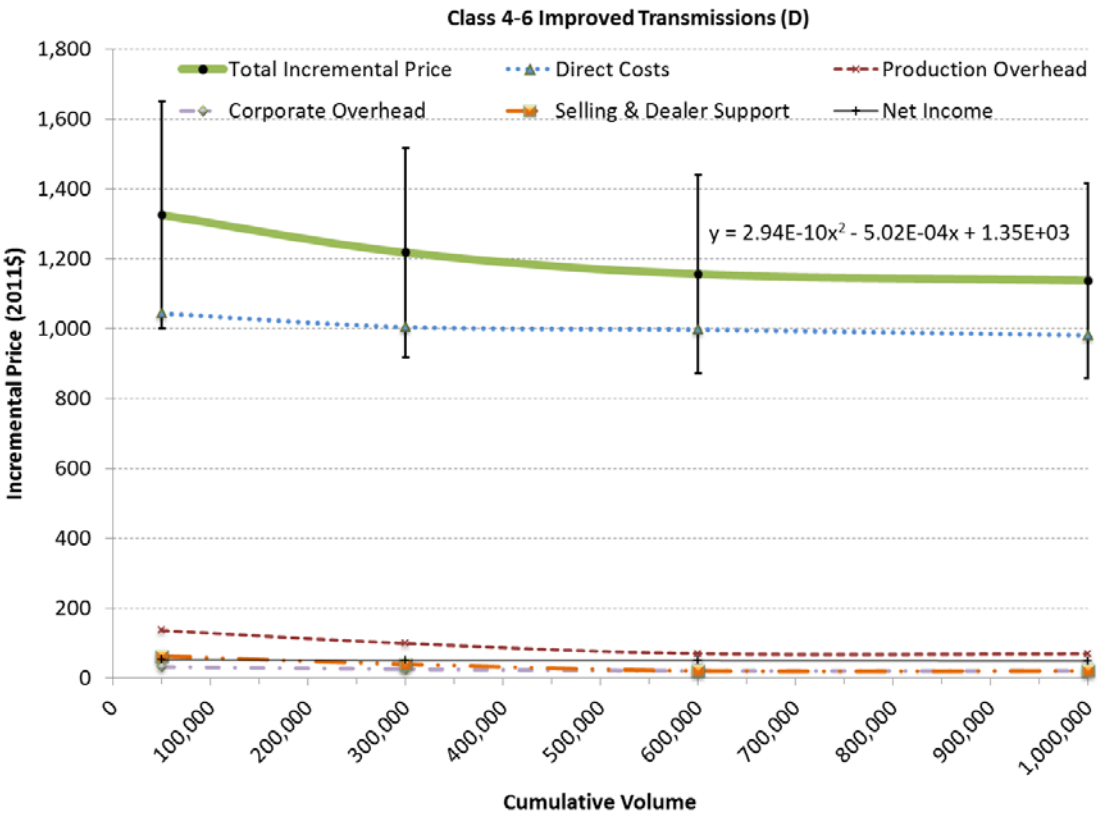
Figure 69. Incremental Price and Breakouts for Class 2b&3 (Diesel) Improved Transmissions



Class 4-6 Improved Transmissions (G)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$750.00	$689.08	$654.28	$643.84
Direct Costs	$590.55	$568.36	$564.13	$555.13
Production Overhead	$76.77	$56.00	$39.38	$38.75
Corporate Overhead	$17.72	$14.08	$11.28	$11.10
Selling & Dealer Support	$35.43	$22.22	$11.28	$11.10
Net Income	$29.53	$28.42	$28.21	$27.76

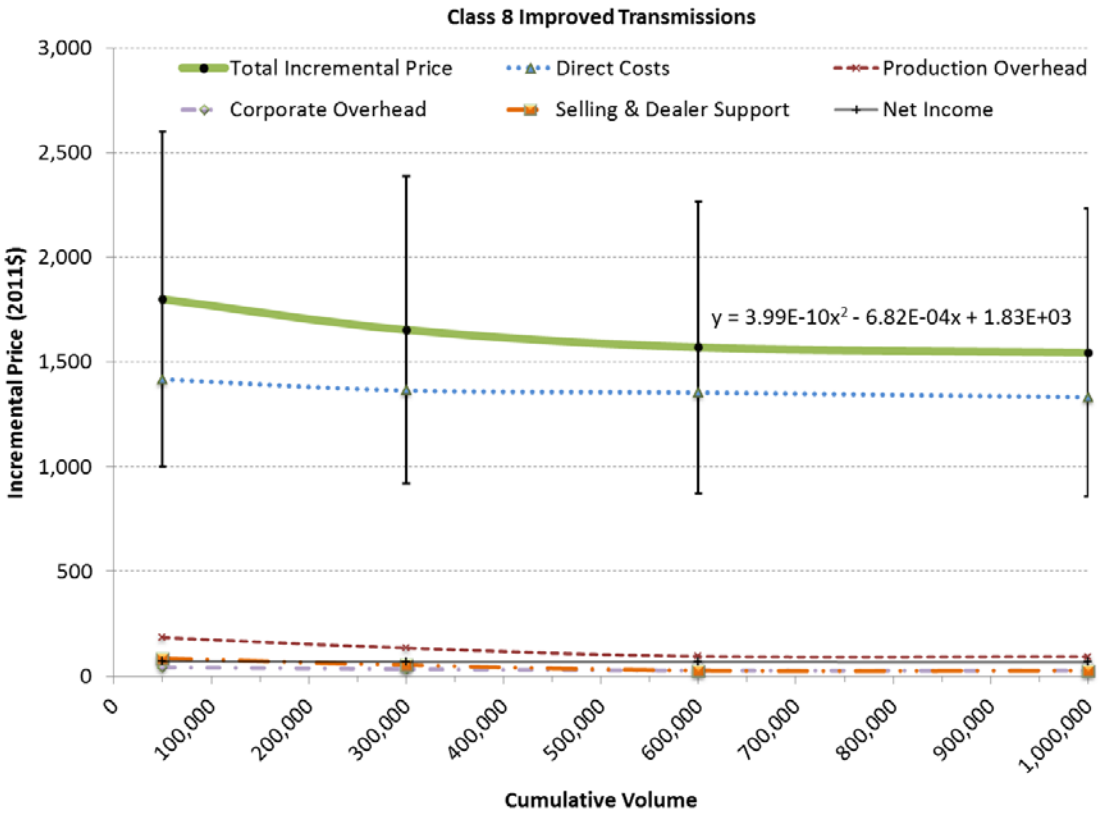
Figure 70. Incremental Price and Breakouts for Vocational (Gasoline) Improved Transmissions



Class 4-6 Improved Transmissions (D)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,325.00	$1,217.38	$1,155.90	$1,137.45
Direct Costs	$1,043.31	$1,004.11	$996.63	$980.73
Production Overhead	$135.63	$98.94	$69.57	$68.45
Corporate Overhead	$31.30	$24.87	$19.93	$19.61
Selling & Dealer Support	$62.60	$39.25	$19.93	$19.61
Net Income	$52.17	$50.21	$49.83	$49.04

Figure 71. Incremental Price and Breakouts for Vocational (Diesel) Improved Transmissions

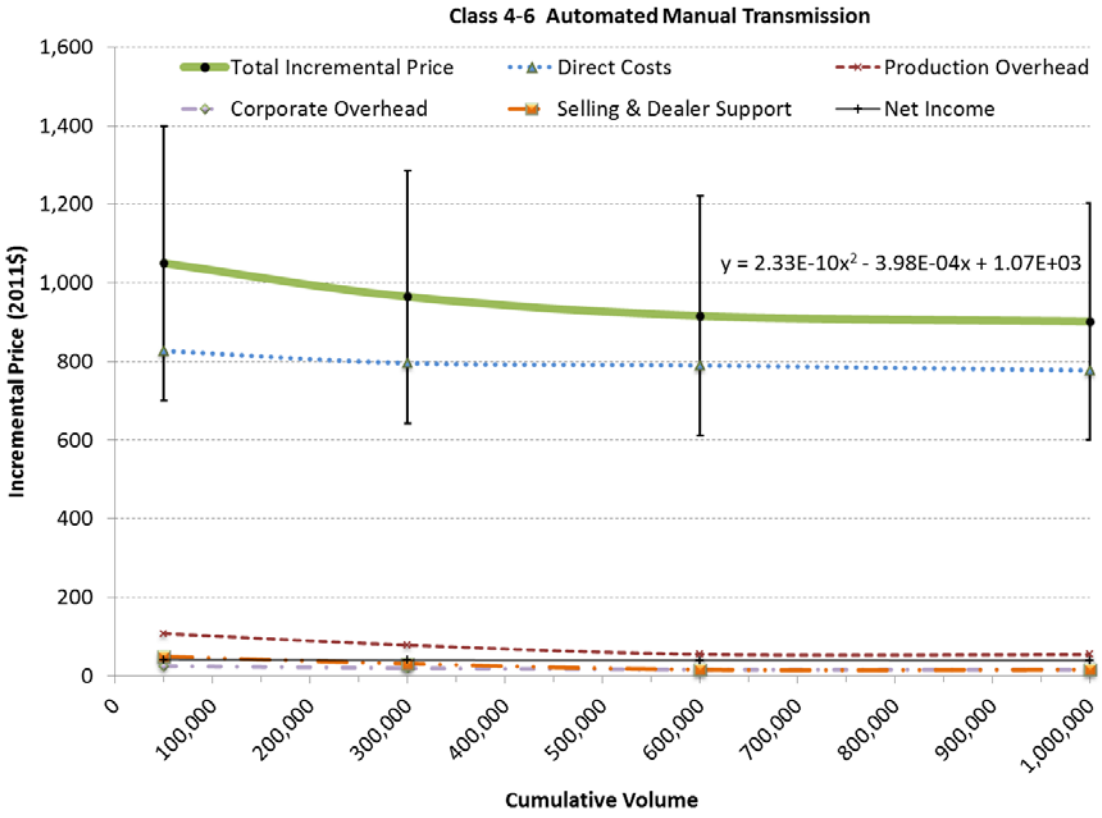


Class 8 Improved Transmissions

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,800.00	$1,653.80	$1,570.27	$1,545.22
Direct Costs	$1,417.32	$1,364.07	$1,353.92	$1,332.31
Production Overhead	$184.25	$134.41	$94.50	$93.00
Corporate Overhead	$42.52	$33.79	$27.08	$26.65
Selling & Dealer Support	$85.04	$53.33	$27.08	$26.65
Net Income	$70.87	$68.20	$67.70	$66.62

Figure 72. Incremental Price and Breakouts for Line Haul Improved Transmissions

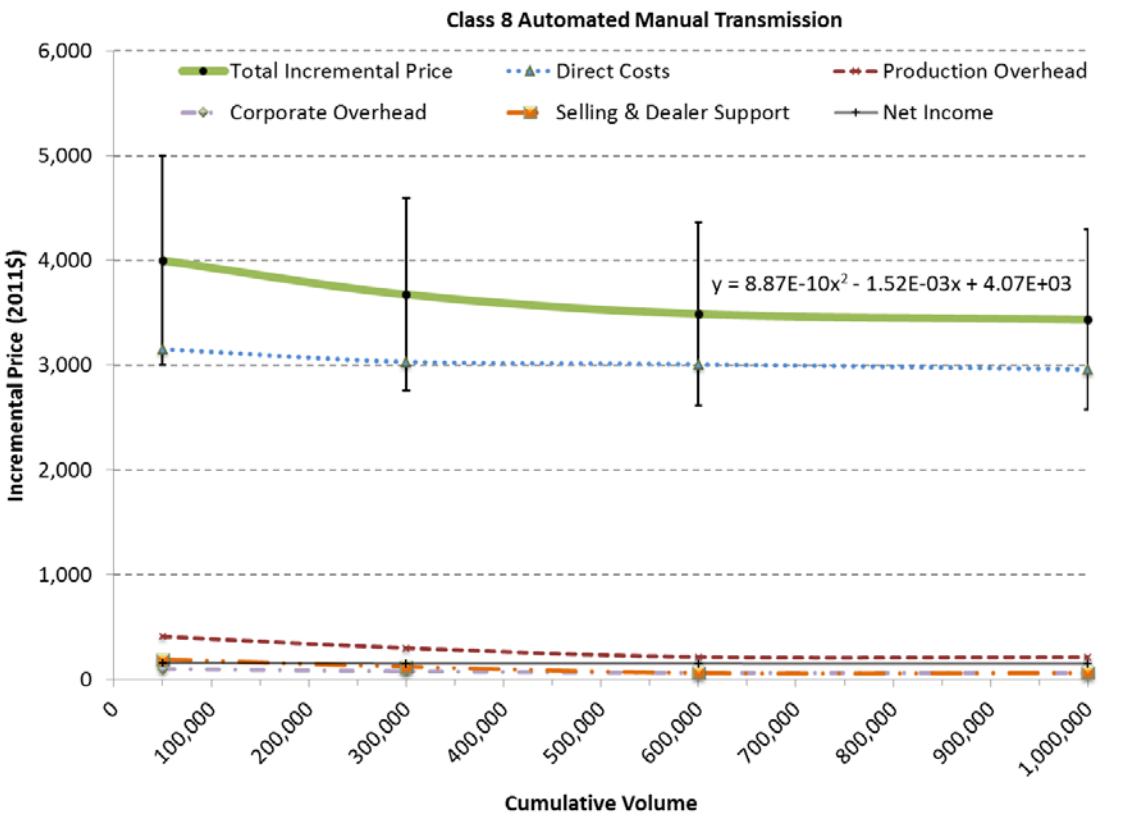
3.31 Automated Manual Transmission



Class 4-6 Automated Manual Transmission

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,050.00	$964.72	$915.99	$901.38
Direct Costs	$826.77	$795.71	$789.79	$777.18
Production Overhead	$107.48	$78.40	$55.13	$54.25
Corporate Overhead	$24.80	$19.71	$15.80	$15.54
Selling & Dealer Support	$49.61	$31.11	$15.80	$15.54
Net Income	$41.34	$39.79	$39.49	$38.86

Figure 73. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) AMT

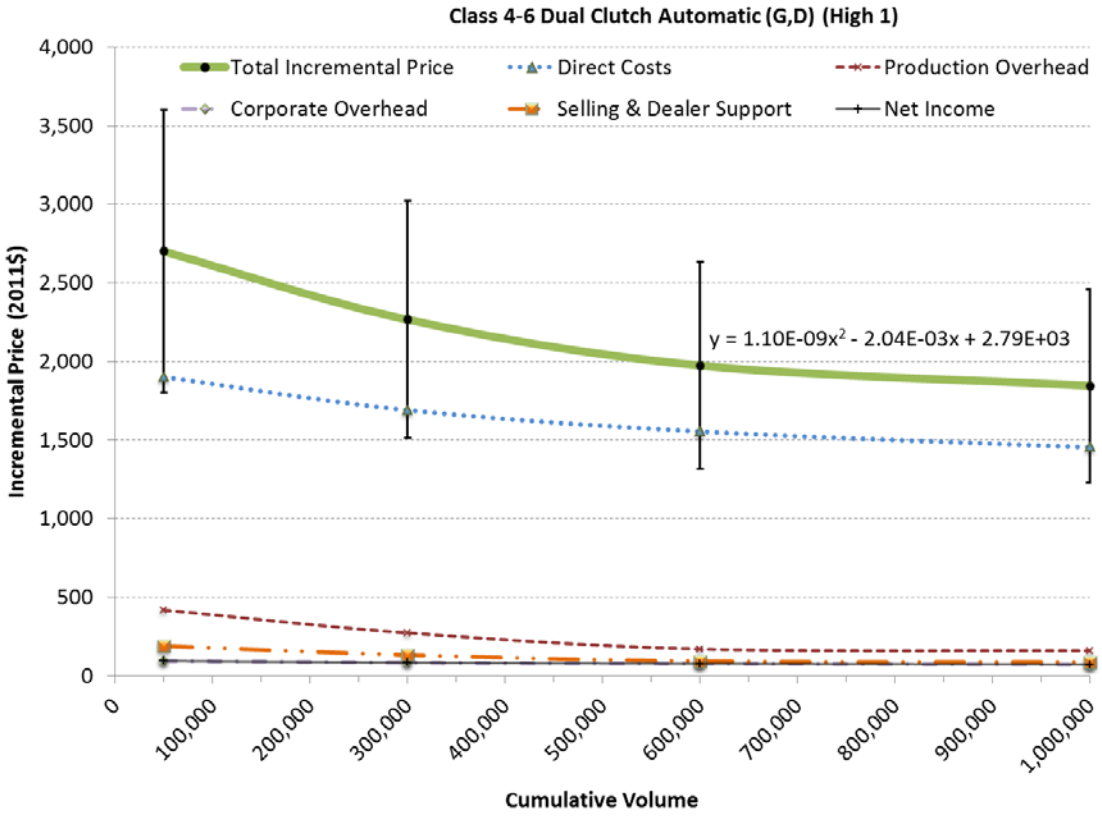


Class 8 Automated Manual Transmission

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$4,000.00	$3,675.11	$3,489.50	$3,433.81
Direct Costs	$3,149.61	$3,031.26	$3,008.71	$2,960.69
Production Overhead	$409.45	$298.69	$210.01	$206.66
Corporate Overhead	$94.49	$75.09	$60.17	$59.21
Selling & Dealer Support	$188.98	$118.50	$60.17	$59.21
Net Income	$157.48	$151.56	$150.44	$148.03

Figure 74. Incremental Price and Breakouts for Line Haul AMT

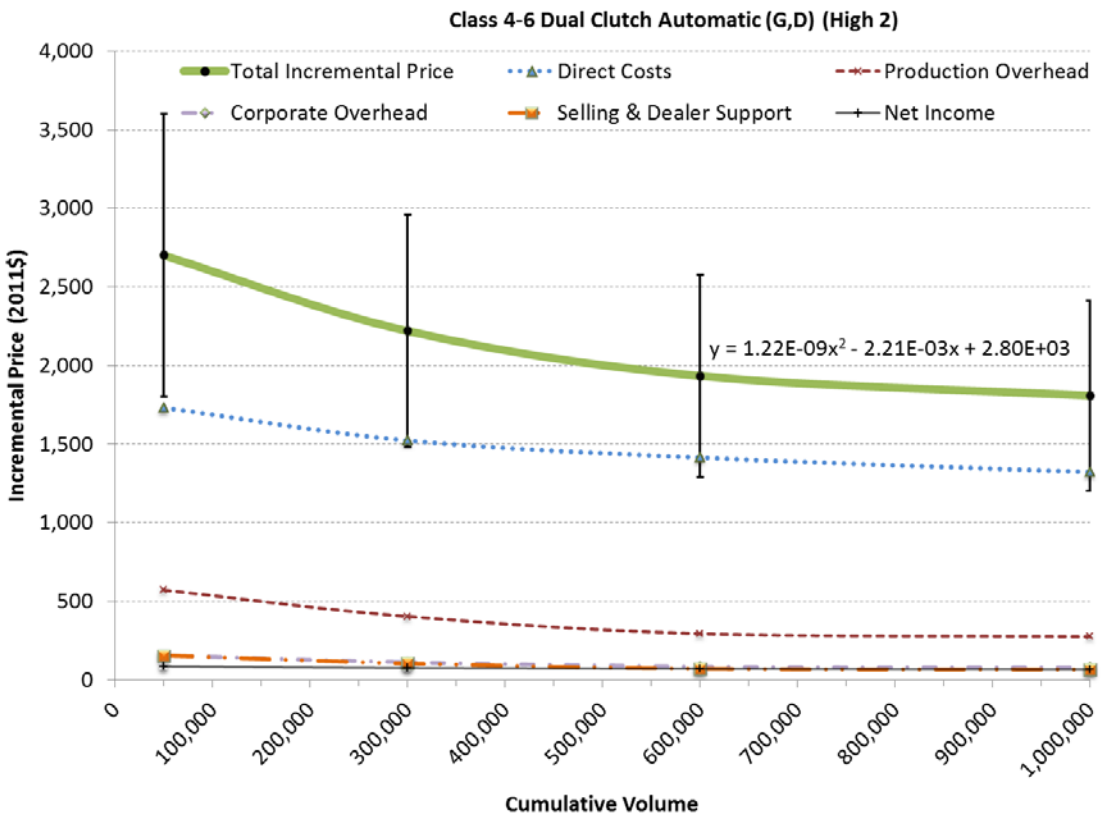
3.32 Dual Clutch Automatic



Class 4-6 Dual Clutch Automatic (G,D) (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$2,700.00	$2,266.44	$1,974.38	$1,845.87
Direct Costs	$1,901.41	$1,690.34	$1,554.63	$1,453.44
Production Overhead	$418.31	$273.72	$171.01	$159.88
Corporate Overhead	$95.07	$84.52	$77.73	$72.67
Selling & Dealer Support	$190.14	$133.34	$93.28	$87.21
Net Income	$95.07	$84.52	$77.73	$72.67

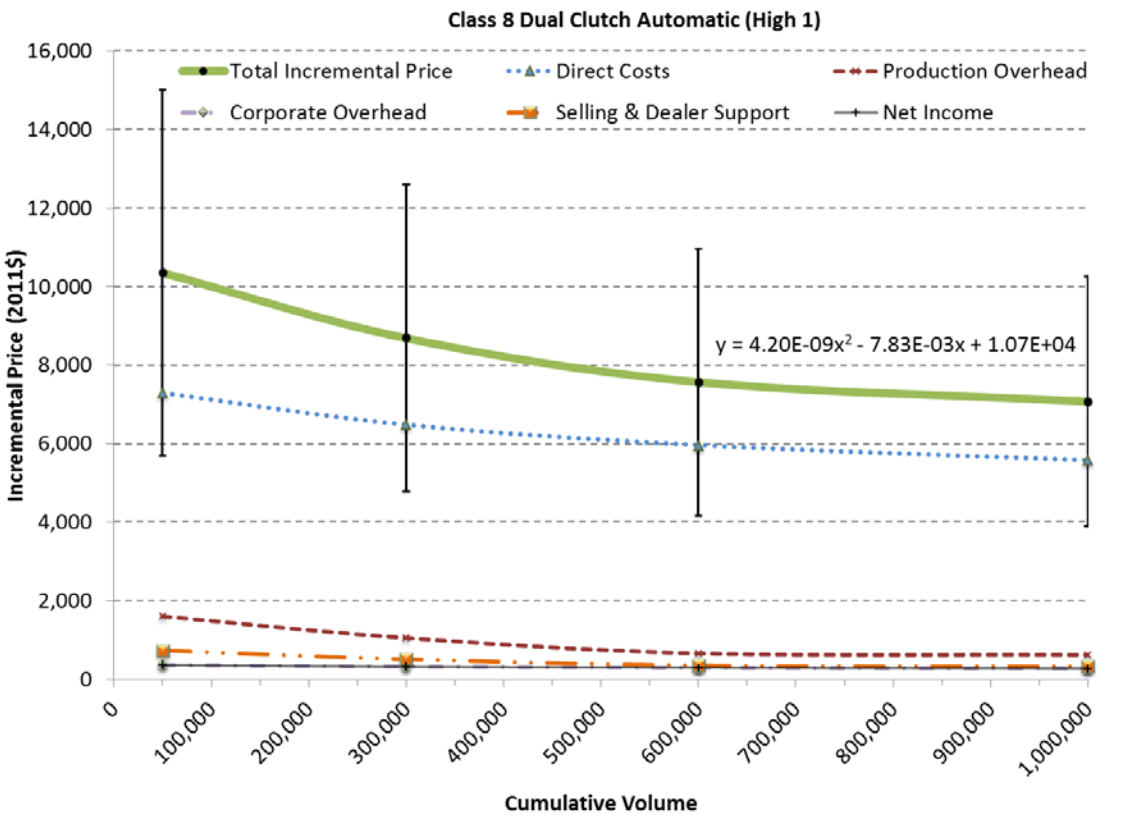
Figure 75. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) Dual Clutch Automatic (High 1)



Class 4-6 Dual Clutch Automatic (G,D) (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$2,700.00	$2,219.49	$1,933.47	$1,807.63
Direct Costs	$1,730.77	$1,522.59	$1,413.36	$1,321.36
Production Overhead	$571.15	$403.49	$293.98	$274.84
Corporate Overhead	$155.77	$112.70	$84.80	$79.28
Selling & Dealer Support	$155.77	$104.58	$70.67	$66.07
Net Income	$86.54	$76.13	$70.67	$66.07

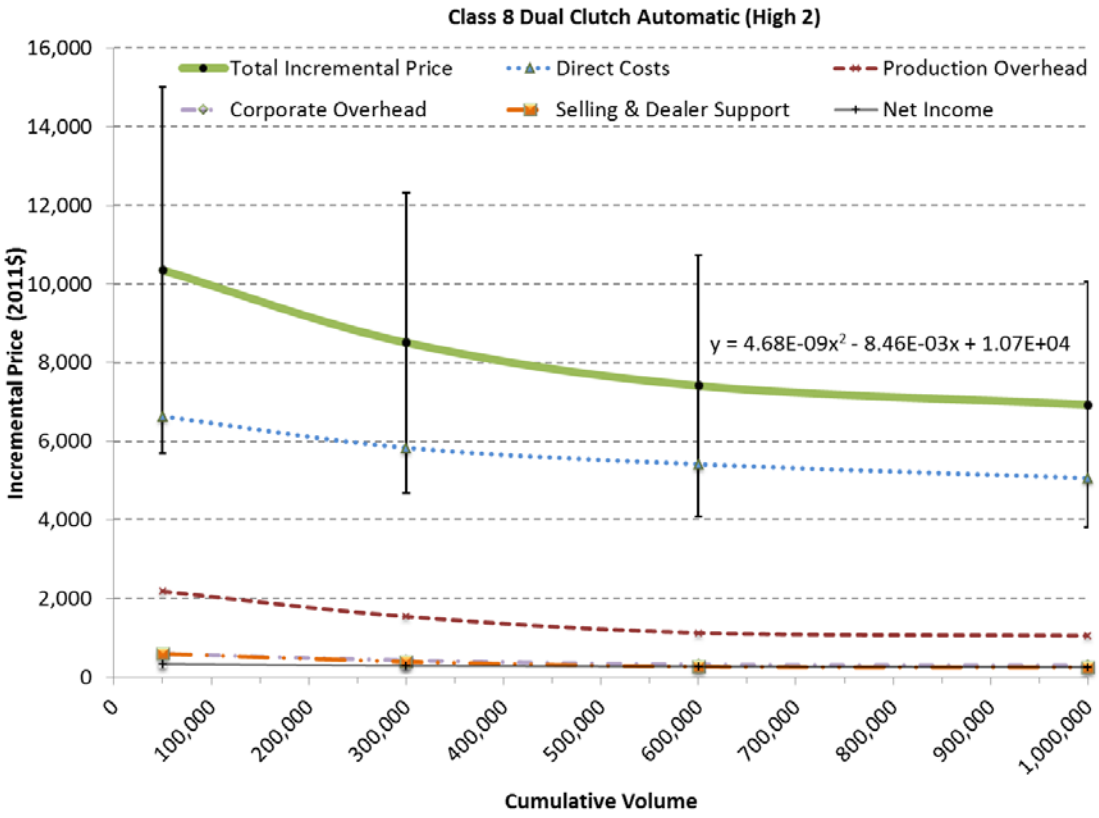
Figure 76. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) Dual Clutch Automatic (High 2)



Class 8 Dual Clutch Automatic (High 1)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$10,350.00	$8,688.03	$7,568.44	$7,075.82
Direct Costs	$7,288.73	$6,479.65	$5,959.40	$5,571.51
Production Overhead	$1,603.52	$1,049.27	$655.53	$612.87
Corporate Overhead	$364.44	$323.98	$297.97	$278.58
Selling & Dealer Support	$728.87	$511.15	$357.56	$334.29
Net Income	$364.44	$323.98	$297.97	$278.58

Figure 77. Incremental Price and Breakouts for Line Haul Dual Clutch Automatic (High 1)

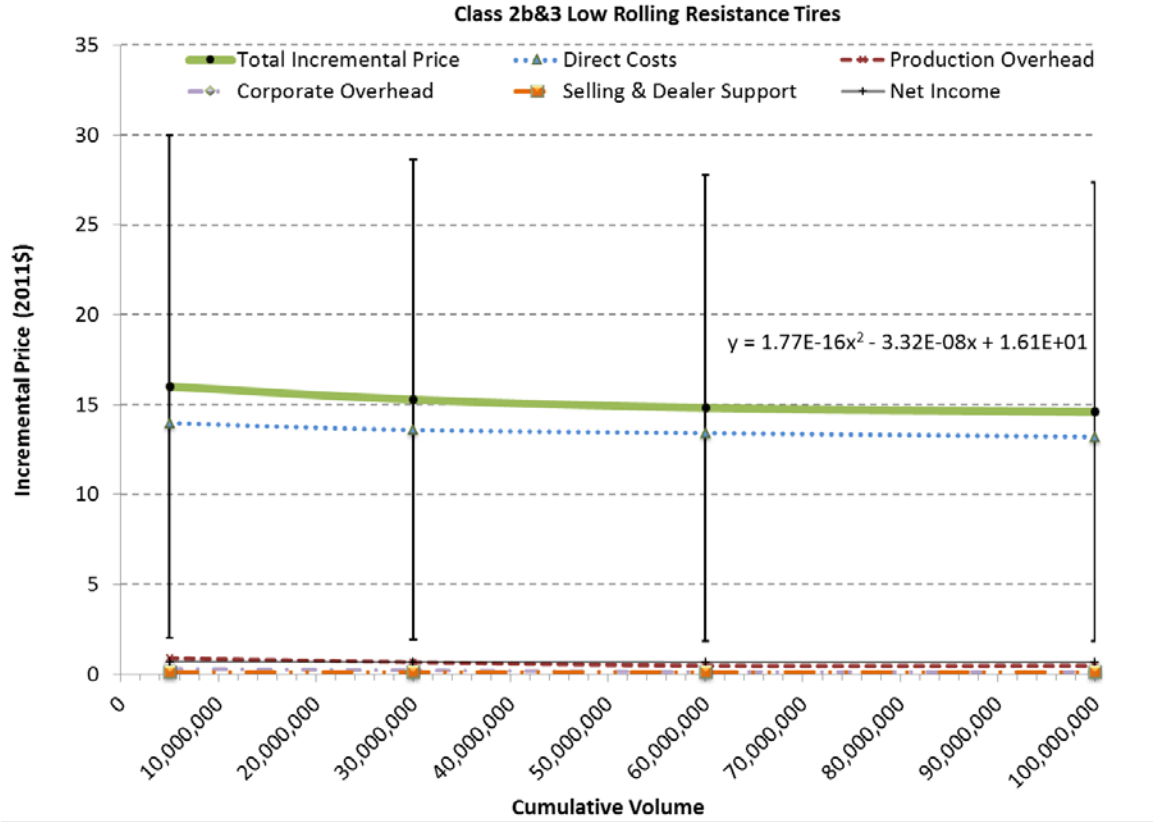


Class 8 Dual Clutch Automatic (High 2)

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$10,350.00	$8,508.05	$7,411.65	$6,929.24
Direct Costs	$6,634.62	$5,836.61	$5,417.87	$5,065.23
Production Overhead	$2,189.42	$1,546.70	$1,126.92	$1,053.57
Corporate Overhead	$597.12	$432.00	$325.07	$303.91
Selling & Dealer Support	$597.12	$400.91	$270.89	$253.26
Net Income	$331.73	$291.83	$270.89	$253.26

Figure 78. Incremental Price and Breakouts for Line Haul Dual Clutch Automatic (High 2)

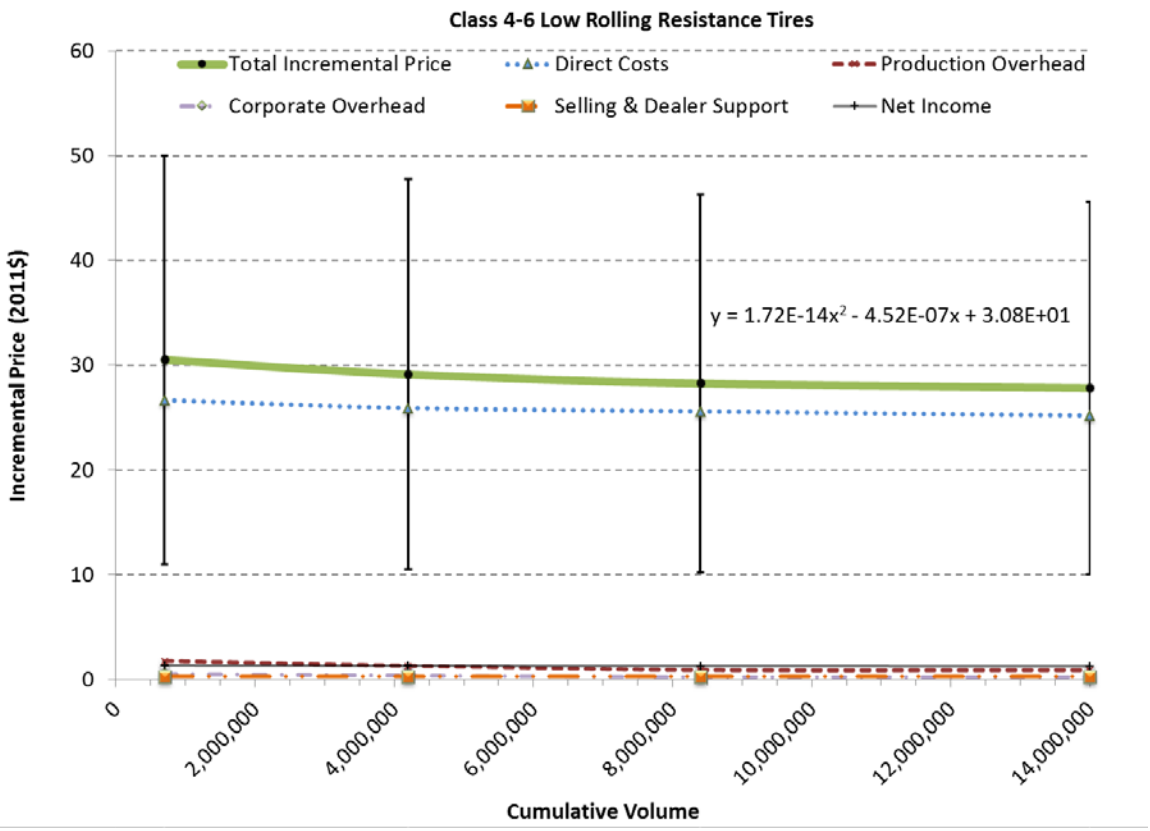
3.33 Low Rolling Resistance Tires (priced per tire)



Class 2b&3 Low Rolling Resistance Tires

Volume (units):	5,000,000	30,000,000	60,000,000	100,000,000
Total Incremental Price	$16.00	$15.28	$14.82	$14.59
Direct Costs	$13.98	$13.59	$13.42	$13.22
Production Overhead	$0.91	$0.67	$0.45	$0.45
Corporate Overhead	$0.28	$0.20	$0.13	$0.13
Selling & Dealer Support	$0.14	$0.14	$0.13	$0.13
Net Income	$0.70	$0.68	$0.67	$0.66

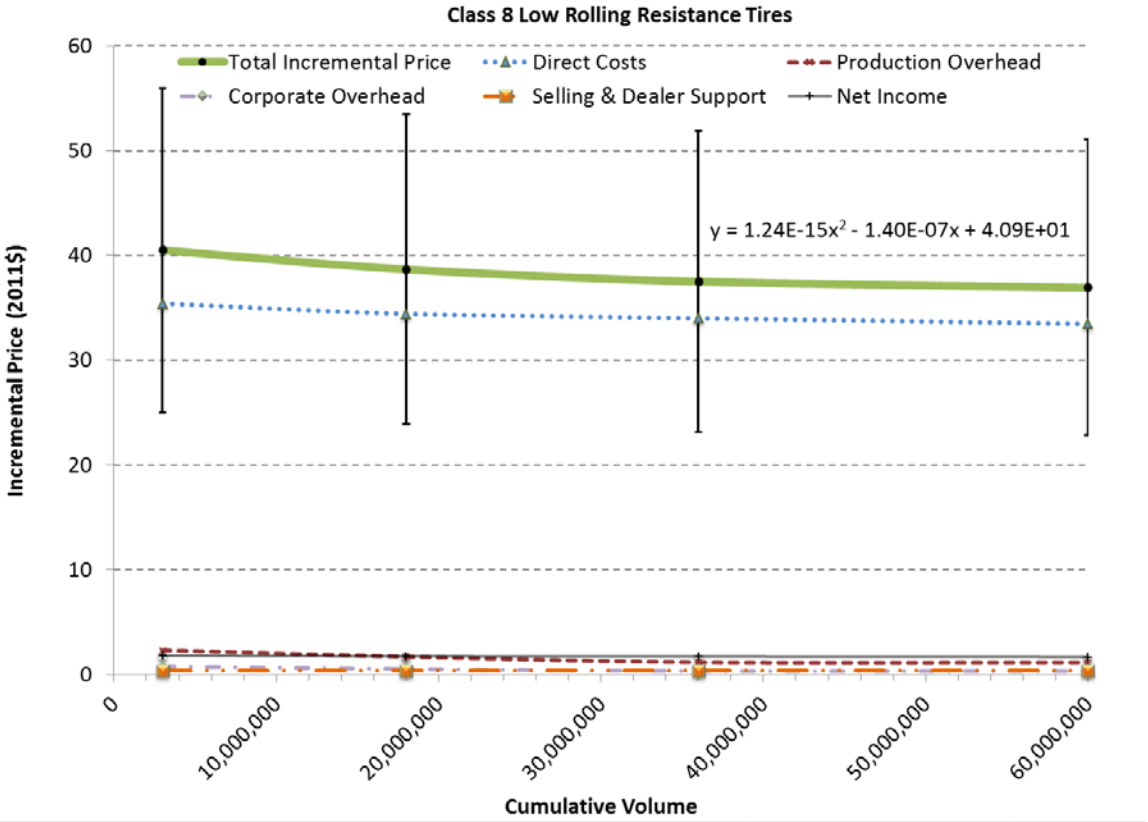
Figure 79. Incremental Price and Breakouts for Class 2b&3 (Gasoline, Diesel) LRR Tires



Class 4-6 Low Rolling Resistance Tires

Volume (units):	700,000	4,200,000	8,400,000	14,000,000
Total Incremental Price	$30.50	$29.12	$28.25	$27.81
Direct Costs	$26.64	$25.91	$25.59	$25.19
Production Overhead	$1.73	$1.27	$0.86	$0.85
Corporate Overhead	$0.53	$0.39	$0.26	$0.25
Selling & Dealer Support	$0.27	$0.26	$0.26	$0.25
Net Income	$1.33	$1.30	$1.28	$1.26

Figure 80. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) LRR Tires

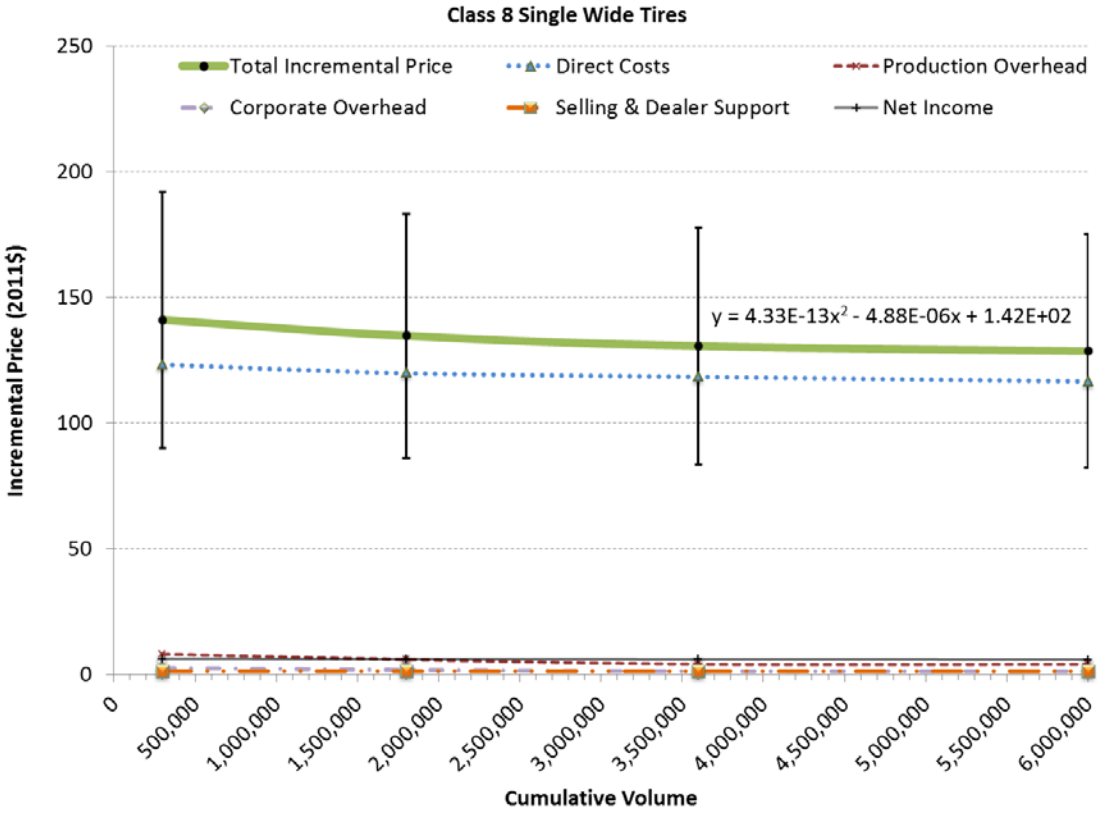


Class 8 Low Rolling Resistance Tires

Volume (units):	3,000,000	18,000,000	36,000,000	60,000,000
Total Incremental Price	$40.50	$38.67	$37.51	$36.92
Direct Costs	$35.38	$34.41	$33.98	$33.45
Production Overhead	$2.29	$1.69	$1.15	$1.13
Corporate Overhead	$0.71	$0.51	$0.34	$0.33
Selling & Dealer Support	$0.35	$0.34	$0.34	$0.33
Net Income	$1.77	$1.72	$1.70	$1.67

Figure 81. Incremental Price and Breakouts for Line Haul Low Rolling Resistance Tires

3.34 Single Wide Tires (priced per tire/wheel replacing 2 standard width tires/wheels)

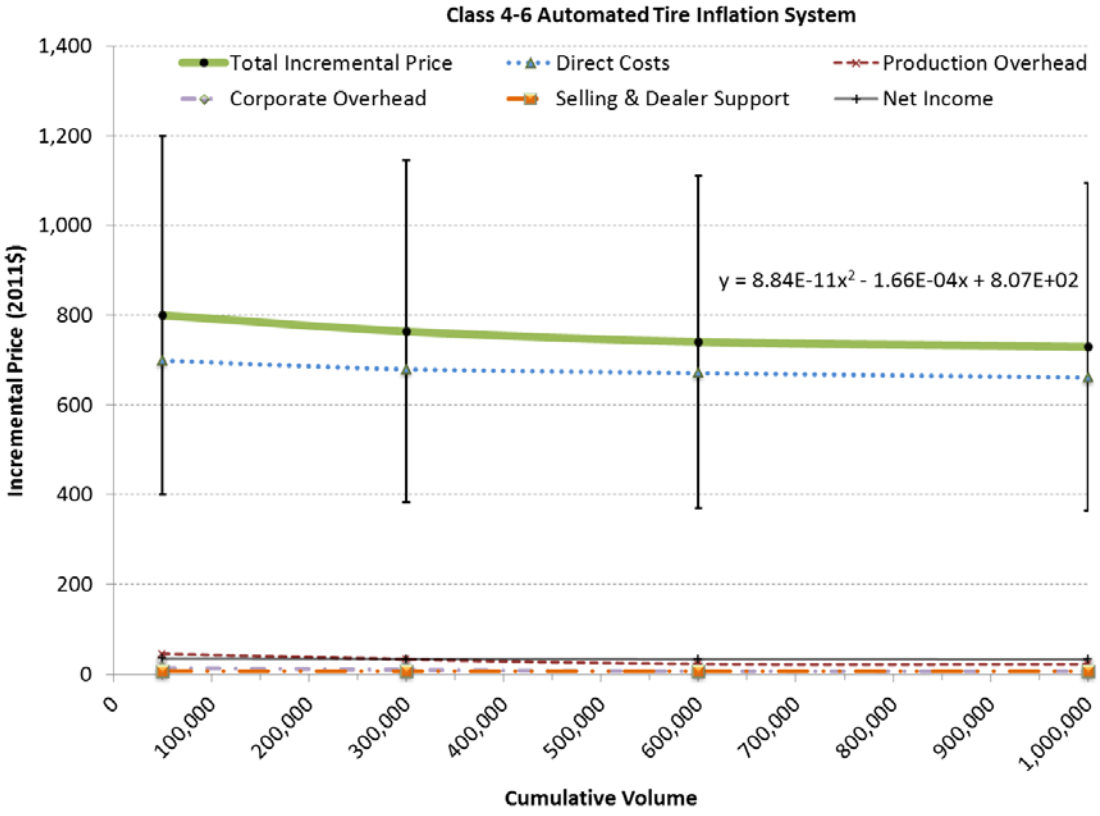


Class 8 Single Wide Tires

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$141.00	$134.64	$130.58	$128.55
Direct Costs	$123.17	$119.79	$118.30	$116.46
Production Overhead	$7.98	$5.87	$4.00	$3.94
Corporate Overhead	$2.46	$1.79	$1.18	$1.16
Selling & Dealer Support	$1.23	$1.20	$1.18	$1.16
Net Income	$6.16	$5.99	$5.91	$5.82

Figure 82. Incremental Price and Breakouts for Line Haul Single Wide Tires

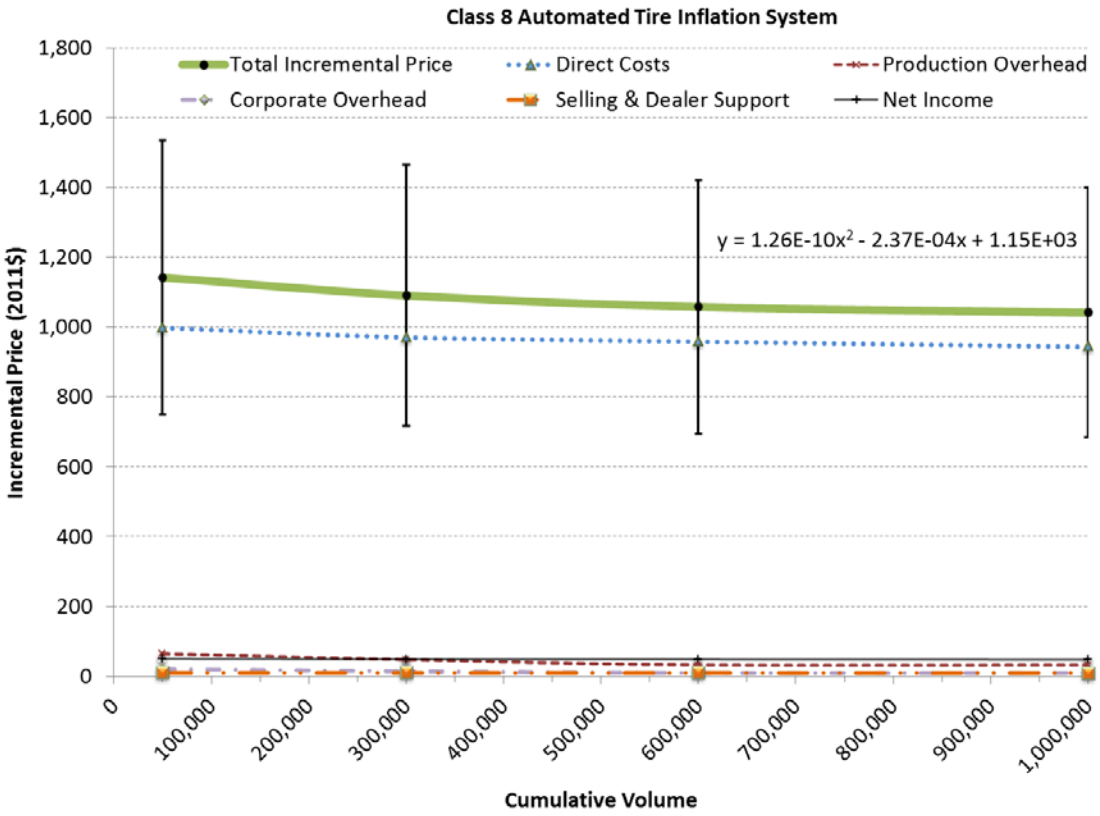
3.35 Automatic Tire Inflation System



Class 4-6 Automated Tire Inflation System

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$800.00	$763.90	$740.87	$729.35
Direct Costs	$698.81	$679.67	$671.20	$660.77
Production Overhead	$45.28	$33.32	$22.69	$22.33
Corporate Overhead	$13.98	$10.13	$6.71	$6.61
Selling & Dealer Support	$6.99	$6.80	$6.71	$6.61
Net Income	$34.94	$33.98	$33.56	$33.04

Figure 83. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) ATI

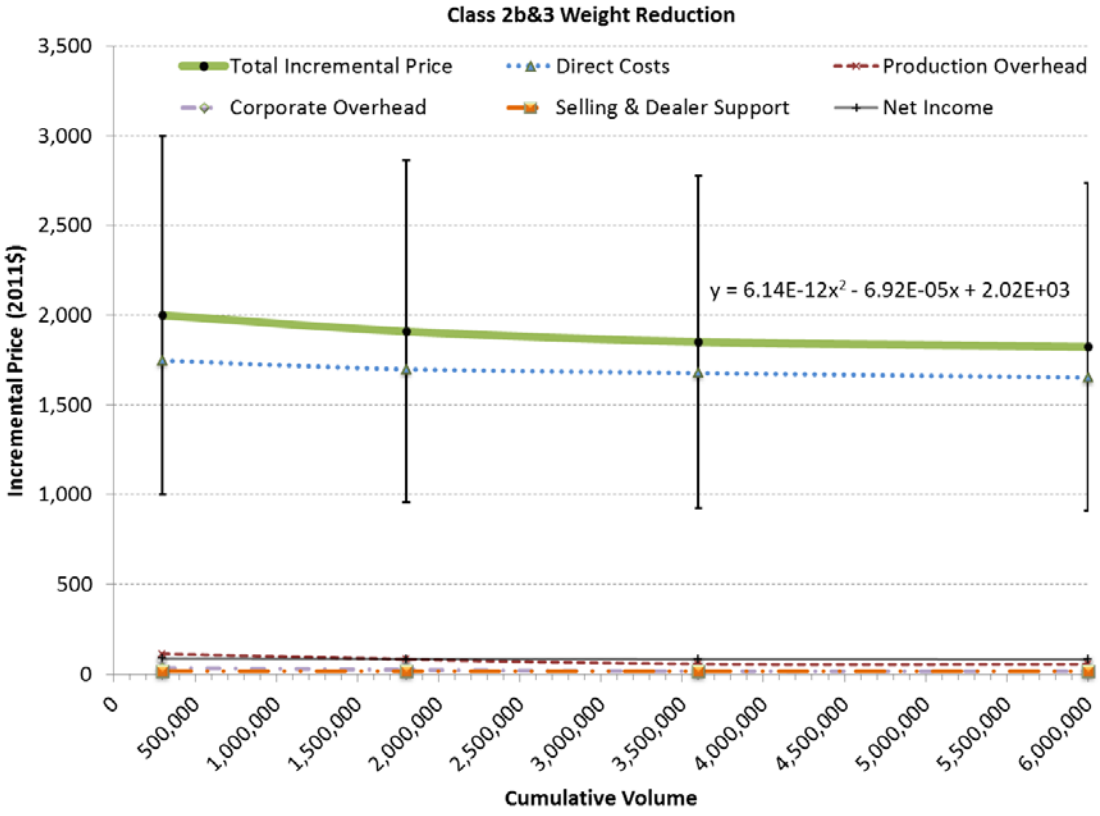


Class 8 Automated Tire Inflation System

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$1,142.50	$1,090.95	$1,058.06	$1,041.61
Direct Costs	$997.99	$970.66	$958.56	$943.66
Production Overhead	$64.67	$47.58	$32.40	$31.90
Corporate Overhead	$19.96	$14.47	$9.59	$9.44
Selling & Dealer Support	$9.98	$9.71	$9.59	$9.44
Net Income	$49.90	$48.53	$47.93	$47.18

Figure 84. Incremental Price and Breakouts for Line Haul ATI

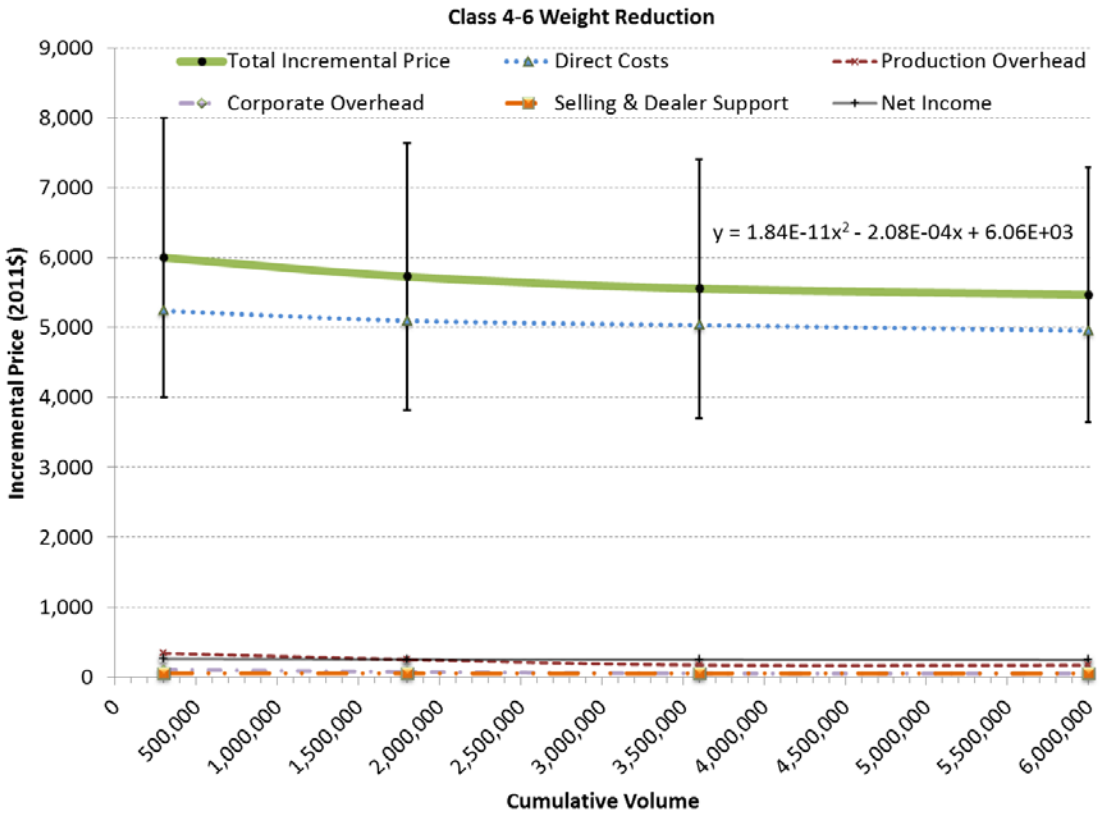
3.36 Weight Reduction



Class 2b&3 Weight Reduction

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$2,000.00	$1,909.76	$1,852.18	$1,823.39
Direct Costs	$1,747.03	$1,699.18	$1,678.00	$1,651.92
Production Overhead	$113.21	$83.29	$56.72	$55.83
Corporate Overhead	$34.94	$25.33	$16.78	$16.52
Selling & Dealer Support	$17.47	$16.99	$16.78	$16.52
Net Income	$87.35	$84.96	$83.90	$82.60

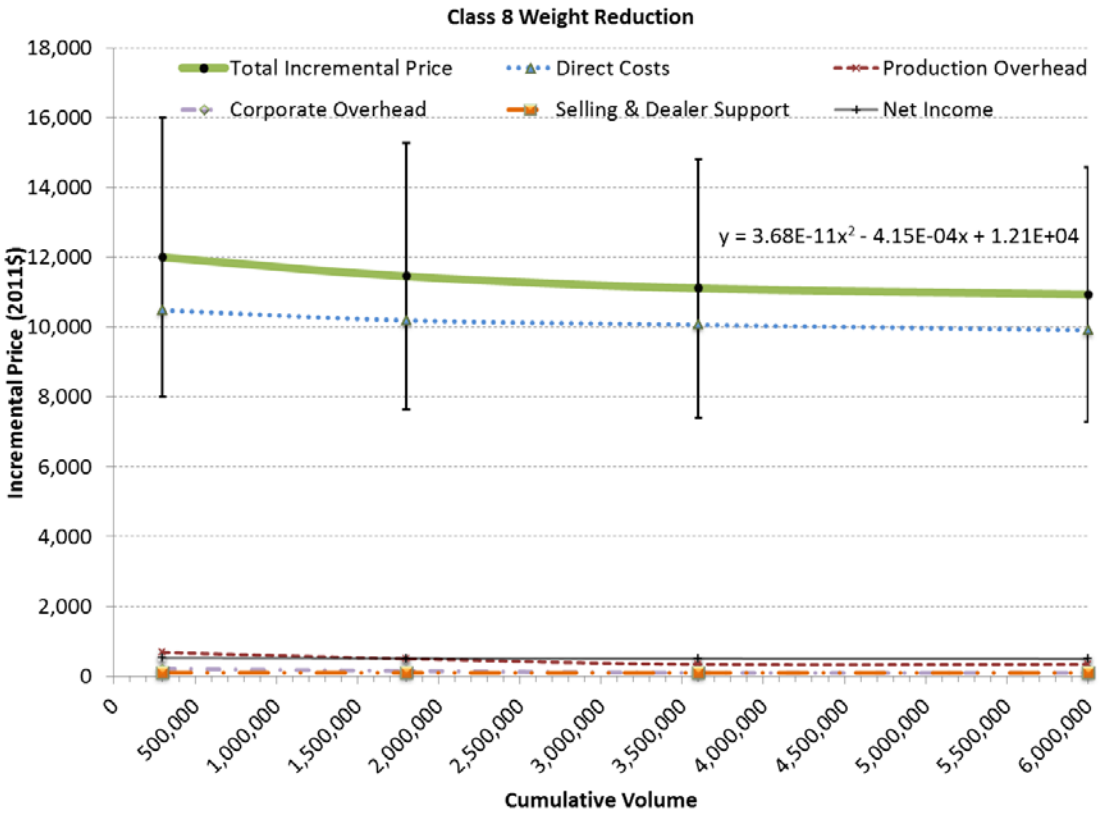
Figure 85. Incremental Price and Breakouts for Class 2b&3 (Gasoline, Diesel) Weight Reduction



Class 4-6 Weight Reduction

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$6,000.00	$5,729.27	$5,556.53	$5,470.16
Direct Costs	$5,241.09	$5,097.55	$5,034.00	$4,955.75
Production Overhead	$339.62	$249.87	$170.15	$167.50
Corporate Overhead	$104.82	$76.00	$50.34	$49.56
Selling & Dealer Support	$52.41	$50.98	$50.34	$49.56
Net Income	$262.05	$254.88	$251.70	$247.79

Figure 86. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) Weight Reduction

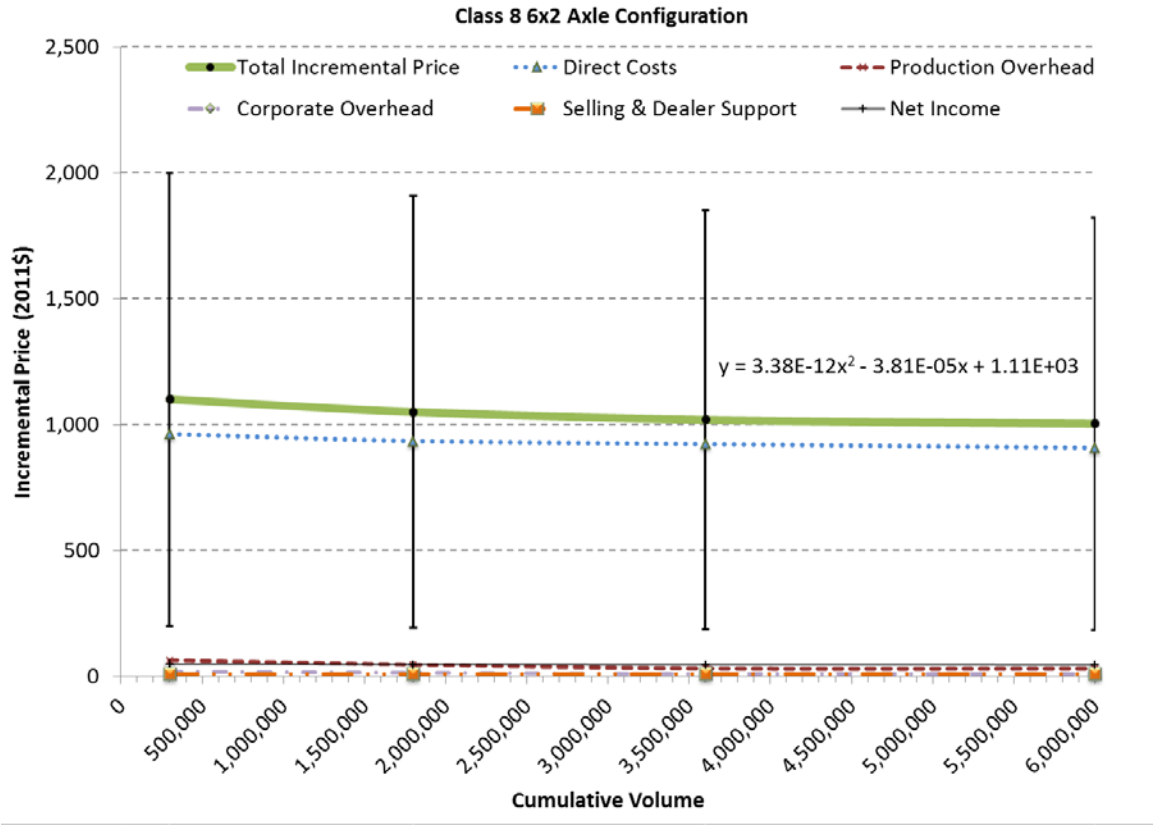


Class 8 Weight Reduction

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$12,000.00	$11,458.55	$11,113.06	$10,940.32
Direct Costs	$10,482.18	$10,195.11	$10,068.01	$9,911.51
Production Overhead	$679.25	$499.74	$340.30	$335.01
Corporate Overhead	$209.64	$152.00	$100.68	$99.12
Selling & Dealer Support	$104.82	$101.95	$100.68	$99.12
Net Income	$524.11	$509.76	$503.40	$495.58

Figure 87. Incremental Price and Breakouts for Line Haul Weight Reduction

3.37 6x2 Tractors

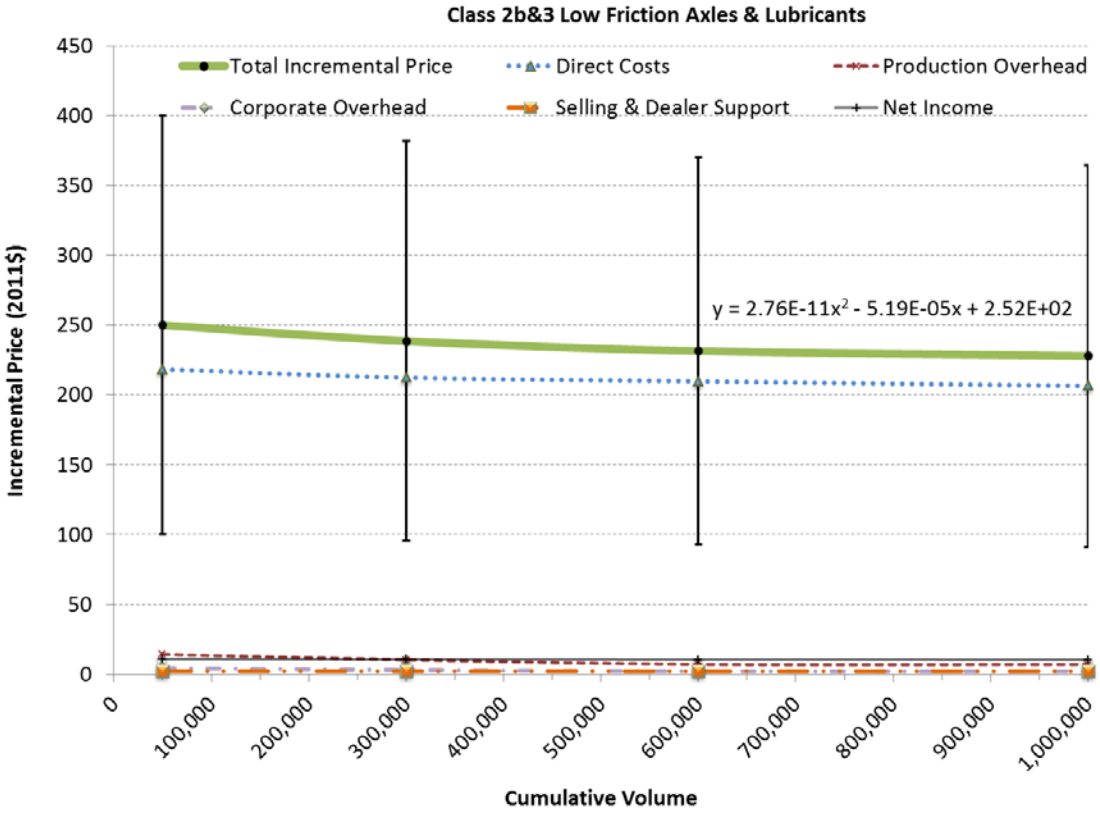


Class 8 6x2 Axle Configuration

Volume (units):	300,000	1,800,000	3,600,000	6,000,000
Total Incremental Price	$1,100.00	$1,050.37	$1,018.70	$1,002.86
Direct Costs	$960.87	$934.55	$922.90	$908.55
Production Overhead	$62.26	$45.81	$31.19	$30.71
Corporate Overhead	$19.22	$13.93	$9.23	$9.09
Selling & Dealer Support	$9.61	$9.35	$9.23	$9.09
Net Income	$48.04	$46.73	$46.15	$45.43

Figure 88. Incremental Price and Breakouts for Line Haul 6x2 Tractors

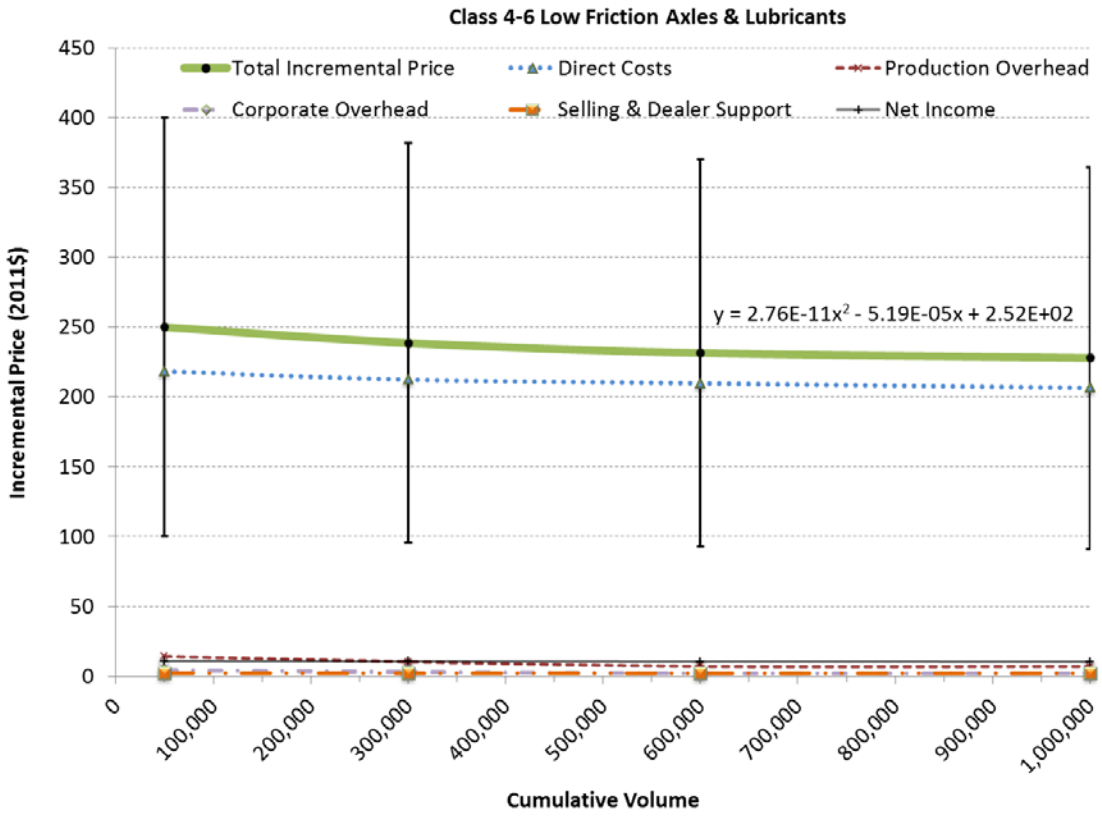
3.38 Chassis Friction Reduction and Improved Lube



Class 2b&3 Low Friction Axles & Lubricants

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$250.00	$238.72	$231.52	$227.92
Direct Costs	$218.38	$212.40	$209.75	$206.49
Production Overhead	$14.15	$10.41	$7.09	$6.98
Corporate Overhead	$4.37	$3.17	$2.10	$2.06
Selling & Dealer Support	$2.18	$2.12	$2.10	$2.06
Net Income	$10.92	$10.62	$10.49	$10.32

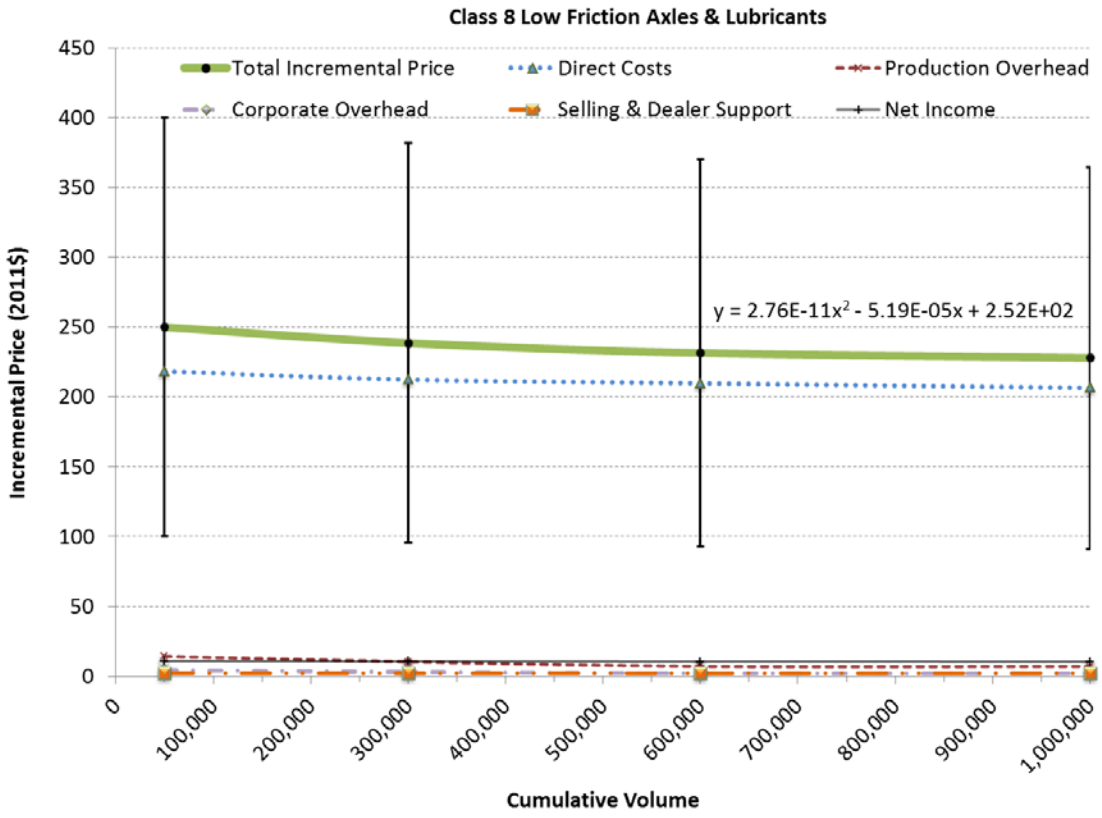
Figure 89. Incremental Price and Breakouts for Class 2b&3 (Gasoline, Diesel) Chassis Friction Reduction and Improved Lube



Class 4-6 Low Friction Axles & Lubricants

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$250.00	$238.72	$231.52	$227.92
Direct Costs	$218.38	$212.40	$209.75	$206.49
Production Overhead	$14.15	$10.41	$7.09	$6.98
Corporate Overhead	$4.37	$3.17	$2.10	$2.06
Selling & Dealer Support	$2.18	$2.12	$2.10	$2.06
Net Income	$10.92	$10.62	$10.49	$10.32

Figure 90. Incremental Price and Breakouts for Vocational (Gasoline, Diesel) Chassis Friction Reduction and Improved Lube



Class 8 Low Friction Axles & Lubricants

Volume (units):	50,000	300,000	600,000	1,000,000
Total Incremental Price	$250.00	$238.72	$231.52	$227.92
Direct Costs	$218.38	$212.40	$209.75	$206.49
Production Overhead	$14.15	$10.41	$7.09	$6.98
Corporate Overhead	$4.37	$3.17	$2.10	$2.06
Selling & Dealer Support	$2.18	$2.12	$2.10	$2.06
Net Income	$10.92	$10.62	$10.49	$10.32

Figure 91. Incremental Price and Breakouts for Line Haul Chassis Friction Reduction and Improved Lube

4 Life Cycle Cost Elements

Incremental retail prices are placed into the vehicle life context by examining life cycle cost elements. This section presents the information currently available on the vehicle life cycle impacts of the identified technologies in the various vehicle categories. Fuel savings are determined from SwRI modeling of technology performance and are not included here. O&M impacts and technology replacement requirements are described in terms of their costs or benefits and corresponding intervals during the vehicle life. Residual value is assessed as the incremental residual value provided by the technology (negative residual value represents having a lower resale value). Phase 2 GHG regulations only apply to new vehicles and would not affect the sales of used vehicles.

In the case of 6x2 Axle technology, the benefit is in fuel savings, and the penalty is primarily in terms of reduced traction under slippery road conditions. Many 6x2 setups have taken steps to mitigate the traction issue, but there isn't a lot of field experience with them yet. Today, the used truck market is wary of the traction issue due to the newness of the technology. They may become more or less comfortable with this issue over time as experience is gained. This could then affect the resale value of 6x2 trucks up or down. See the referenced 2014 NACFE report "Confidence Report on 6x2 Axles" for more detail.

As noted earlier, life cycle cost elements reported here are intended to inform separate full life cycle analysis, which will also make use of inputs outside the scope of this report. TBD and NNI were entered into the following tables when data was not available (if data was available, it was entered in the units that were reported by the sources). NNI represented assumptions that there will be no net increase, but little data was available to support this assumption. There is limited maintenance, replacement, and residual value data due to the technologies being new and not being widely deployed for long periods of time.

4.1 Advanced Bottoming Cycle

Table 12. Life Cycle Cost Elements of Line Haul Advanced Bottoming Cycle

Class 8 Advanced Bottoming Cycle

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2015	0	$0.003/mi	TBD	TBD
Interval			n/a	n/a	End of first owner life

4.2 Coolant/Oil Pump

Table 13. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Coolant/Oil Pump

Class 2b&3 2-Stage Pump (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	TBD	TBD
Interval			n/a	100,000 miles	End of first owner life

Class 2b&3 Variable Displ Pump (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	TBD	TBD
Interval			n/a	100,000 miles	End of first owner life

Class 4-6 2-Stage Pump (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	TBD	TBD
Interval			n/a	100,000 miles	End of first owner life

Class 4-6 Variable Displ Pump (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	TBD	TBD
Interval			n/a	100,000 miles	End of first owner life

Class 8 Variable Displ Pump

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	2012	20,000	TBD	TBD	TBD
Interval			n/a	n/a	End of first owner life

4.3 Variable Valve Actuation

Table 14. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul VVA

Class 2b&3 VVA (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	2008MY	TBD	10% increase	NNI	NNI
Interval			100,000 mile valve job	n/a	End of first owner life

Class 4-6 VVA (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	2008MY	TBD	10% increase	NNI	NNI
Interval			100,000 mile valve job	n/a	End of first owner life

Class 8 VVA

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	20014MY	0	10% increase	NNI	NNI
Interval			100,000 mile valve job	n/a	End of first owner life

4.4 Cylinder Deactivation

Table 15. Life Cycle Cost Elements of Class 2b&3 and Vocational Cylinder Deactivation

Class 2b&3 Cylinder Deactivation (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 4-6 Cylinder Deactivation (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.5 Stoichiometric GDI

Table 16. Life Cycle Cost Elements of Class 2b&3 and Vocational Stoichiometric GDI

Class 2b&3 Stoichiometric GDI (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 4-6 Stoichiometric GDI (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.6 Lean Burn GDI with SCR

Table 17. Life Cycle Cost Elements of Class 2b&3 and Vocational Lean Burn GDI with SCR

Class 2b&3 Lean Burn GDI with SCR (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2016	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 4-6 Lean Burn GDI with SCR (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2016	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.7 Stoichiometric GDI+EGR

Table 18. Life Cycle Cost Elements of Vocational Stoichiometric GDI+EGR

Class 4-6 Stoichiometric GDI + EGR (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.8 Turbocharging and Downsizing

Table 19. Life Cycle Cost Elements of Class 2b&3 and Vocational Turbocharging and Downsizing

Class 2b&3 Turbocharging & Downsizing (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 4-6 Turbocharging & Downsizing (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.9 Engine Downspeeding

Table 20. Life Cycle Cost Elements of Class 2b&3 and Vocational Engine Downspeeding

Class 2b&3 Engine Downspeeding (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 4-6 Engine Downspeeding (G)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.10 Low-Friction Engine Oil

Table 21. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Low-Friction Engine Oil

Class 2b&3 Low Friction Engine Oil (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			5,000 mile	n/a	End of first owner life

Class 2b&3 Low Friction Engine Oil (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			15,000 mile	n/a	End of first owner life

Class 4-6 Low Friction Engine Oil (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			5,000 mile	n/a	End of first owner life

Class 4-6 Low Friction Engine Oil (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			15,000 mile	n/a	End of first owner life

Class 8 Low Friction Engine Oil

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			25,000 mile	n/a	End of first owner life

4.11 Engine Friction Reduction

Table 22. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Engine Friction Reduction

Class 2b&3 Engine Friction Reduction (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	TBD	NNI	NNI
Interval			n/a	n/a	End of first owner life

Class 4-6 Engine Friction Reduction (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	TBD	NNI	NNI
Interval			n/a	n/a	End of first owner life

Class 8 Engine Friction Reduction

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	TBD	NNI	NNI
Interval			n/a	n/a	End of first owner life

4.12 Stop/Start

Table 23. Life Cycle Cost Elements of Class 2b&3 and Vocational Stop/Start

Class 2b&3 Stop/Start (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	$455 for battery	Portion of remaining battery life
Interval			45,000 miles	100,000 miles	End of first owner life

Class 2b&3 Stop/Start (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	$455 for battery	Portion of remaining battery life
Interval			45,000 miles	100,000 miles	End of first owner life

Class 4-6 Stop/Start (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	$455 for battery	Portion of remaining battery life
Interval			45,000 miles	100,000 miles	End of first owner life

Class 4-6 Diesel Stop/Start (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	$455 for battery	Portion of remaining battery life
Interval			45,000 miles	100,000 miles	End of first owner life

4.13 Reduce Aftertreatment Backpressure

Table 24. Life Cycle Cost Elements of Line Haul Reduced Aftertreatment Backpressure

Class 8 Reduced Aftertreatment Backpressure

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	TBD	NNI	NNI
Interval			TBD	n/a	End of first owner life

4.14 Air Handling Improvements

Table 25. Life Cycle Cost Elements of Line Haul Air Handling Improvements

Class 8 Air Handling Improvements

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.15 Mechanical Turbocompound

Table 26. Life Cycle Cost Elements of Line Haul Mechanical Turbocompound

Class 8 Mechanical Turbocompound

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	2010	TBD	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.16 Electric Turbocompound

Table 27. Life Cycle Cost Elements of Line Haul Electric Turbocompound

Class 8 Electrical Turbocompound

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	2014?	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.17 Hybrid Electric Vehicle

Table 28. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Hybrid Electric Vehicle

Class 2b&3 Hybrid Electric Vehicles

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing		NNI	$0.006/mi	NNI
Interval			n/a	6 year battery life	End of first owner life

Class 4-6 Hybrid Electric Vehicles

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing		NNI	$0.006/mi	NNI
Interval			n/a	6 year battery life	End of first owner life

Class 8 Hybrid Electric Vehicles

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing		NNI	$0.006/mi	NNI
Interval			n/a	6 year battery life	End of first owner life

4.18 Diesel APU

Table 29. Life Cycle Cost Elements of Line Haul Diesel APU

Class 8 Diesel APU

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	2012	20,000	$400/yr	NNI	1,000
Interval			500-2,000 hrs	n/a	End of first owner life

4.19 Battery APU

Table 30. Life Cycle Cost Elements of Line Haul Battery APU

Class 8 Battery APU

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	10,000	$200/yr	$220	NNI
Interval			annual	Batteries every 2 yrs	End of first owner life

4.20 Fuel-Fired Heater

Table 31. Life Cycle Cost Elements of Line Haul Fuel-Fired Heater

Class 8 Fuel Fired Heater

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	50,000	$110/yr	TBD	NNI
Interval			annual	n/a	End of first owner life

4.21 Air Conditioning System Improvements

Table 32. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul A/C System Improvements

Class 2b&3 Air Conditioning Improvements

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 4-6 Air Conditioning Improvements

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 8 Air Conditioning Improvements

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.22 Cab Insulation to Reduce A/C

Table 33. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Cab Insulation to Reduce A/C

Class 2b&3 Cab Insulation to Reduce A/C

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	TBD	$1,000 - $1,700	NNI
Interval			TBD	replace when damaged	End of first owner life

Class 4-6 Cab Insulation to Reduce A/C

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	TBD	$1,000 - $1,700	NNI
Interval			TBD	replace when damaged	End of first owner life

Class 8 Cab Insulation to Reduce A/C

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	TBD	$1,000 - $1,700	NNI
Interval			TBD	replace when damaged	End of first owner life

4.23 Air Compressor Improvements

Table 34. Life Cycle Cost Elements of Line Haul Air Compressor Improvements

Class 8 Air Compressor Improvements

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	2012	20,000	NNI	NNI	NNI
Interval			n/a	n/a	End of first owner life

4.24 Shore Power

Table 35. Life Cycle Cost Elements of Line Haul Shore Power

Class 8 Shore Power

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	40,000	NNI	TBD	NNI
Interval			n/a	n/a	End of first owner life

4.25 Aero Bin III

Table 36. Life Cycle Cost Elements of Line Haul Aero Bin III

Class 8 Aero Trailer Side Skirt (4 to 6 m)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

Class 8 Aero Boat Tail

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

4.26 Aero Bin IV and V

Table 37. Life Cycle Cost Elements of Line Haul Aero Bin IV and V

Class 8 Aero Full Trailer Skirt (7 to 9 m)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	50,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

Class 8 Aero Full Tractor Skirt

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

Class 8 Aero Gap Filler

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

4.27 Aero on Regional Haul

Table 38. Life Cycle Cost Elements of Aero on Regional Haul

Class 8 Aero on Regional Haul

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

4.28 Class 2b&3 Improved Aerodynamics

Table 39. Life Cycle Cost Elements of Class 2b&3 Improved Aerodynamics

Class 2b&3 Improved Aerodynamics

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	25,000	10% of incremental	Full Incremental	NNI
Interval			annual	10 year life	End of first owner life

4.29 Improved Transmissions

Table 40. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Improved Transmissions

Class 2b&3 Improved Transmissions (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	NNI	NNI	NNI
Interval			n/a	n/a	End of first owner life

Class 2b&3 Improved Transmissions (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	NNI	NNI	NNI
Interval			n/a	n/a	End of first owner life

Class 4-6 Improved Transmissions (G)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	NNI	NNI	NNI
Interval			n/a	n/a	End of first owner life

Class 4-6 Improved Transmissions (D)

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	NNI	NNI	NNI
Interval			n/a	n/a	End of first owner life

Class 8 Improved Transmissions

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	NNI	NNI	NNI
Interval			n/a	n/a	End of first owner life

4.30 Automated Manual Transmission

Table 41. Life Cycle Cost Elements of Vocational and Line Haul AMT

Class 4-6 Automated Manual Transmission

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 8 Automated Manual Transmission

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			300,000 mile	n/a	End of first owner life

4.31 Dual Clutch Automatic

Table 42. Life Cycle Cost Elements of Vocational and Line Haul Dual Clutch Automatic

Class 4-6 Dual Clutch Automatic (G,D)

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

Class 8 Dual Clutch Automatic

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production	Maintenance	Replacement	Residual Value
Value	~2014	0	TBD	NNI	NNI
Interval			100,000 mile	n/a	End of first owner life

4.32 Low Rolling Resistance Tires

Table 43. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul LRR Tires

Class 2b&3 Low Rolling Resistance Tires

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	5,400,000	Full Incremental	NNI	NNI
Interval			40,000 mile	n/a	End of first owner life

Class 4-6 Low Rolling Resistance Tires

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	700,000	Full Incremental	NNI	NNI
Interval			40,000 mile	n/a	End of first owner life

Class 8 Low Rolling Resistance Tires

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	3,000,000	NNI	$40/tire	NNI
Interval			40,000 mile	125,000 mile	End of first owner life

4.33 Single Wide Tires

Table 44. Life Cycle Cost Elements of Line Haul Single Wide Tires

Class 8 Single Wide Tires

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	300,000	NNI	$30/tire	NNI
Interval			40,000 mile (tire)	125,000 mile (tire)	End of first owner life
			450,000 mile (wheel)	450,000 mile (wheel)	

4.34 Automated Tire Inflation System

Table 45. Life Cycle Cost Elements of Vocational and Line Haul ATI

Class 4-6 Automated Tire Inflation System

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	20014MY	0	TBD	NNI	NNI
Interval			TBD	n/a	End of first owner life

Class 8 Automated Tire Inflation System

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	20014MY	0	TBD	NNI	NNI
Interval			TBD	n/a	End of first owner life

4.35 Weight Reduction

Table 46. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Weight Reduction

Class 2b&3 Weight Reduction

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	NNI	NNI	NNI
Interval			450,000 mile	450,000 mile	End of first owner life

Class 4-6 Weight Reduction

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	NNI	NNI	NNI
Interval			450,000 mile	450,000 mile	End of first owner life

Class 8 Weight Reduction

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	NNI	NNI	NNI
Interval			450,000 mile	450,000 mile	End of first owner life

4.36 6x2 Tractors

Table 47. Life Cycle Cost Elements of Line Haul 6x2 Tractors

Class 8 6x2 Axle Configuration

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	NNI	NNI	($4,000)
Interval			450,000 mile	450,000 mile	End of first owner life

Negative residual value represents the lower resale value of a 6x2 tractor when compared to 6x4 tractors.

4.37 Chassis Friction Reduction and Improved Lube

Table 48. Life Cycle Cost Elements of Class 2b&3, Vocational, and Line Haul Chassis Friction Reduction and Improved Lube

Class 2b&3 Low Friction Axles & Lubricants

Life Cycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			10,000 mile	n/a	End of first owner life

Class 4-6 Low Friction Axles & Lubricants

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			180,000 mile	n/a	End of first owner life

Class 8 Low Friction Axles & Lubricants

Lifecycle Cost Element:	Start of Production	Estimated 2012 Production Volume	Maintenance	Replacement	Residual Value
Value	Ongoing	TBD	Full Incremental	NNI	NNI
Interval			500,000 mile	n/a	End of first owner life

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6 Appendix A: Reference Data

The following tables provide detailed information for the specific data gathered from the listed references. The incremental prices and life cycle costs are in this report are derived from these data, which are presented by vehicle category and technology and include assumptions regarding baselines and prior technologies.

6.1 Advanced Bottoming Cycle

Table 49. Reference Data for Line Haul Advanced Bottoming Cycle

Class 8 Advanced Bottoming Cycle

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$7,200 to $30,200	7, 54, 58, 69	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2015 Introduction	11-15L diesel with bottoming cycle. Steam cycle. 30 kW.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Advanced Bottoming Cycle

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$15,100 to $30,200	Bottoming cycle includes electric bottoming cycle expander connected to a generator.	Steam cycle. 30 kW. Accessory power demand on the engine is reduced from an average of 5 kW to 3 kW.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$23,000	Advanced 11-15L diesel with bottoming cycle	
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$7,200 to $15,100	Advanced 11-15L diesel with bottoming cycle.	Steam Cycle 15 to 60 kW
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$7,200 to $15,100	Advanced 11-15L diesel with bottoming cycle.	Steam Cycle 32 kW

6.2 Coolant/Oil Pump

Table 50. Reference Data for Class 2b&3 (Gasoline) 2-Stage Pump

Class 2b&3 2-Stage Pump (G)						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$120 to $240	54, 55, 57	6.2 V-8: gasoline PFI, fixed valve	2011$	2014 introduction	Viscous drive clutch, actuator pin-out on ECM, wiring (see 2013 DD15 and DD13): combined coolant/oil pump tech to 2-stage oil pump for gasoline engines, variable displacement for diesels.

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 2-Stage Pump (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Accessory Electrification -- Electric Auxiliaries (air comp, ps pump, air cond, fan, alt, water pump); in combination with upgrade to 42V electrical system or hybrid.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$120	Improved accessories	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$822	Improved Accessories—Level 1 (IACC1) (shown in package cost)	Included in pacakge with Auto 4VDV6 +EFR2 +ASL2 +LDB +IACC1 +EPS +Aero1 +LRRT1 +HEG +DCP +WR5% +6sp.

Table 51. Reference Data for Class 2b&3 (Diesel) Variable Displacement Pump

Class 2b&3 Variable Displ Pump (D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$200 to $500	54, 55, 57	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	2014 introduction	Viscous drive clutch, actuator pin-out on ECM, wiring (see 2013 DD15 and DD13): combined coolant/oil pump tech to 2-stage oil pump for gasoline engines, variable displacement for diesels.

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Variable Displ Pump (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Accessory Electrification -- Electric Auxiliaries (air comp, ps pump, air cond, fan, alt, water pump); in combination with upgrade to 42V electrical system or hybrid.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$120	Improved accessories	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$822	Improved Accessories—Level 1 (IACC1) (shown in package cost)	Included in pacakge with Auto 4VDV6 +EFR2 +ASL2 +LDB +IACC1 +EPS +Aero1 +LRRT1 +HEG +DCP +WR5% +6sp.

Table 52. Reference Data for Vocational (Gasoline) 2-Stage Pump

Class 4-6 2-Stage Pump (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$120 to $240	54, 55, 57	6.2 V-8: gasoline PFI, fixed valve	2011$	2014 introduction	Viscous drive clutch, actuator pin-out on ECM, wiring (see 2013 DD15 and DD13): combined coolant/oil pump tech to 2-stage oil pump for gasoline engines, variable displacement for diesels.

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission
Prior Technology: None additional required

Class 4-6 2-Stage Pump (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Accessory Electrification -- Electric Auxiliaries (air comp, ps pump, air cond, fan, alt, water pump); in combination with upgrade to 42V electrical system or hybrid.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$120	Improved accessories	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$822	Improved Accessories—Level 1 (IACC1) (shown in package cost)	Included in pacakge with Auto 4VDV6 +EFR2 +ASL2 +LDB +IACC1 +EPS +Aero1 +LRRT1 +HEG +DCP +WR5% +6sp.

Table 53. Reference Data for Vocational (Diesel) Variable Displacement Pump

Class 4-6 Variable Displ Pump (D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$200 to $500	54, 55, 57	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	2014 introduction	Viscous drive clutch, actuator pin-out on ECM, wiring (see 2013 DD15 and DD13): combined coolant/oil pump tech to 2-stage oil pump for gasoline engines, variable displacement for diesels.

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission
Prior Technology: None additional required

Class 4-6 Variable Displ Pump (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Accessory Electrification -- Electric Auxiliaries (air comp, ps pump, air cond, fan, alt, water pump); in combination with upgrade to 42V electrical system or hybrid.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$120	Improved accessories	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$822	Improved Accessories—Level 1 (IACC1) (shown in package cost)	Included in pacakge with Auto 4VDV6 +EFR2 +ASL2 +LDB +IACC1 +EPS +Aero1 +LRRT1 +HEG +DCP +WR5% +6sp.

Table 54. Reference Data for Line Haul Variable Displacement Pump

Class 8 Variable Displ Pump

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$200 to $500	54, 55, 57, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2012 introduction	Viscous drive clutch, actuator pin-out on ECM, wiring, variable displacement pump

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Variable Displ Pump

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Accessory Electrification -- Electric Auxiliaries (air comp, ps pump, air cond, fan, alt, water pump); in combination with upgrade to 42V electrical system or hybrid.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$120	Improved accessories	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$822	Improved Accessories—Level 1 (IACC1) (shown in package cost)	Included in pacakge with Auto 4VDV6 +EFR2 +ASL2 +LDB +IACC1 +EPS +Aero1 +LRRT1 +HEG +DCP +WR5% +6sp.
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Belt-driven mechanical accessories

6.3 Variable Valve Actuation

Table 55. Reference Data for Class 2b&3 (Gasoline) VVA

Class 2b&3 VVA (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$520 to $720	11, 54, 55, 57	6.2 V-8: gasoline PFI, fixed valve	2011$	2008 introduction	Variable valve lift and timing mechanism similar to BMW Valvetronic, Sturman is an option for diesel

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required (VVT and VVL packaged together)

Class 2b&3 VVA (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54, 11	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$122	Gasoline, PFI, fixed valve VVT	Cost of VVT only
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$520-$720	Gasoline, PFI	including $120 for VVT
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$105	Gasoline, PFI, fixed valve	VVT - Dual Cam Phasing (DCP)
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$555	Gasoline, PFI, VVT	Continuously Variable Valve Lift (CVVL)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$326	LT V8 Gasoline Engine	Discrete variable valve lift (DVVL) on DOHC
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	?	LT V8 Gasoline Engine	Continuously Variable Valve Lift (CVVL)

Table 56. Reference Data for Vocational (Gasoline) VVA

Class 4-6 VVA (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$520 to $750	11, 54, 55, 57	6.2 V-8: gasoline PFI, fixed valve	2011$	2008 introduction	Variable valve lift and timing mechanism similar to BMW Valvetronic, Sturman is an option for diesel

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 VVA (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54, 11	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$122	Gasoline, PFI, fixed valve VVT	Cost of VVT only
3, 4, 5, 7	TIAX site visits during research for Source 54	$500 to $750	6-9L Diesel Engines	VVA
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$326	LT V8 Gasoline Engine	Discrete variable valve lift (DVVL) on DOHC
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.:	$300	11 to 15L Engines	We think that VVA would work best when combined with turbocompound. (50$/cyl)
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,500	Class 7 and Class 8 Truck Technologies	Improved injectors and more efficient combustion
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$300	11 to 15L Engines	Costs & benefits from SwRI/TIAX; reasonable to reviewers
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$555	V8	Continuously Variable Valve Lift (CVVL)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$326	LT V8 Gasoline Engine	Discrete variable valve lift (DVVL) on DOHC
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$300	11 to 15L Engines	11-15 Liter Engine Diesel Technology Matrix

Table 57. Reference Data for Line Haul VVA

Class 8 VVA						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$300 to $750	7, 28, 54, 55, 57, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2014 introduction	Variable valve lift and timing mechanism similar to BMW Valvetronic, Sturman is an option for diesel

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required (VVT and VVL packaged together)

Class 8 VVA

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$300	11 to 15L Engines	We think that VVA would work best when combined with turbocompound. (50$/cyl)
3, 4, 5, 7	TIAX site visits during research for Source 54	$500 to $750	6-9L Diesel Engines	VVA
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$1,500	Class 7 and Class 8 Truck Technologies	Improved injectors and more efficient combustion
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$300	11 to 15L Engines	Costs & benefits from SwRI/TIAX; reasonable to reviewers
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$555	V8	Continuously Variable Valve Lift (CVVL)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$326	LT V8 Gasoline Engine	Discrete variable valve lift (DVVL) on DOHC
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$300	11 to 15L Engines	11-15 Liter Engine Diesel Technology Matrix

6.4 Cylinder Deactivation

Table 58. Reference Data for Class 2b&3 (Gasoline) Cylinder Deactivation

Class 2b&3 Cylinder Deactivation (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$75 to $500	54, 55, 57	6.2 V-8: gasoline PFI, VVA, friction reductionI, OHV to DOHC	2011$	2014 introduction	Cost range to cover OHV to DOHC configurations

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: VVA (VVT + VVL); engine friction reduction

Class 2b&3 Cylinder Deactivation (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$75	6.2 V-8 (OHC)	Baseline + VVL and VVT + reduced friction ($110-$500)
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$400	6.2 V-8 (OHV)	Baseline + VVL and VVT
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$383	V8	Cylinder Deactivation, OHV
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$583	V8	Cylinder Deactivation, SOHC
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$208	LT V8 Gasoline Engine	Baseline + VVL and VVT + reduced friction

Table 59. Reference Data for Vocational (Gasoline) Cylinder Deactivation

Class 4-6 Cylinder Deactivation (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$75 to $500	54, 55, 57	6.2 V-8: gasoline PFI, VVA, friction reductionI, OHV to DOHC	2011$	2014 introduction	Cost range to cover OHV to DOHC configurations

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: VVA (VVT + VVL); engine friction reduction

Class 4-6 Cylinder Deactivation (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$75	6.2 V-8 (OHC)	Baseline + VVL and VVT + reduced friction ($110-$500)
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$400	6.2 V-8 (OHV)	Baseline + VVL and VVT
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$383	V8	Cylinder Deactivation, OHV
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$583	V8	Cylinder Deactivation, SOHC
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$208	LT V8 Gasoline Engine	Baseline + VVL and VVT + reduced friction

6.5 Stoichiometric GDI

Table 60. Reference Data for Class 2b&3 (Gasoline) Stoichiometric GDI

Class 2b&3 Stoichiometric GDI (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$500 to $750	28, 47, 54, 55, 57	6.2 V-8: gasoline PFI, VVA, friction reduction	2011$	2014 introduction	GDI without Nox aftertreatment

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: VVA (VVT + VVL); engine friction reduction

Class 2b&3 Stoichiometric GDI (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$700	V8 Gasoline	unknown baseline
47	Ricardo. “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies.” Prepared for U.S. Environmental Protection Agency. December 21, 2007.	?	5.4L V8 gasoline	Applied to engines with and without VVL + VVT
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$512 to $930	5-8L Gasoline Engine	VVT + VVL + Cylinder deactivation
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$485	V8	Does not include VVL + VVT
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$537	LT V8 OHV Gasoline Engine	Baseline + VVL and VVT + reduced friction

Table 61. Reference Data for Vocational (Gasoline) Stoichiometric GDI

Class 4-6 Stoichiometric GDI (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$500 to $750	28, 47, 54, 55, 57	6.2 V-8: gasoline PFI, VVA, friction reduction	2011$	2014 introduction	GDI without NOx aftertreatment

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: VVA (VVT + VVL); engine friction reduction

Class 4-6 Stoichiometric GDI (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$700	V8 Gasoline	unknown baseline
47	Ricardo. “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies.” Prepared for U.S. Environmental Protection Agency. December 21, 2007.	?	5.4L V8 gasoline	Applied to engines with and without VVL + VVT
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$512 to $930	5-8L Gasoline Engine	VVT + VVL + Cylinder deactivation
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$485	V8	Does not include VVL + VVT
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$537	LT V8 OHV Gasoline Engine	Baseline + VVL and VVT + reduced friction

6.6 Lean Burn GDI with SCR

Table 62. Reference Data for Class 2b&3 (Gasoline) Lean Burn GDI with SCR

Class 2b&3 Lean Burn GDI with SCR (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,380 to $2,480	11, 28, 47, 54, 55, 57, 58	6.2 V-8: gasoline PFI, GDI, VVA, friction reduction	2011$	2016 introduction	GDI with SCR NOx aftertreatment

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: Stoichiometric GDI; VVA (VVT + VVL); engine friction reduction

Class 2b&3 Lean Burn GDI with SCR (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$480	LT V8 Gasoline Engine	Stoich GDI w/ DPF
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$250	V8 Gasoline	Improved DOC
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$75	V8 Gasoline	O2 Sensor
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000	V8 Gasoline	Nox Adsorber; NOx adsorber (integrated) system
54, 47	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	?	6.2 V-8 (OHC)	Lean Burn GDI w/ SCR; add SCR system similar to that used on diesel pickup trucks
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$750	5-8L Gasoline Engine	Lean Burn GDI; aove + VVL + Cylinder deactivation + Stoich GDI
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$6,000 to $8,000	6-9L diesel	Add SCR system - Diesel Engine; only SCR priced near class recently
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$270	3.5L gasoline	Stoich GDI w/ DPF; adv. cordierite brick & can; coated DPF
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$274	3.5L gasoline	SCR brick and Can
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$363	3.5L gasoline	SCR dosing system
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$3,250 to $4,350	5-8L Gasoline Engine	Lean burn GDI; requires low sulfur gasoline

Table 63. Reference Data for Vocational (Gasoline) Lean Burn GDI with SCR

Class 4-6 Lean Burn GDI with SCR (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,380 to $2,480	11, 28, 47, 54, 55, 57, 58	6.2 V-8: gasoline PFI, GDI, VVA, friction reduction	2011$	2016 introduction	GDI with SCR NOx aftertreatment

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: Stoichiometric GDI; VVA (VVT + VVL); engine friction reduction

Class 4-6 Lean Burn GDI with SCR (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$480	LT V8 Gasoline Engine	Stoich GDI w/ DPF
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$250	V8 Gasoline	Improved DOC
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$75	V8 Gasoline	O2 Sensor
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000	V8 Gasoline	Nox Adsorber; NOx adsorber (integrated) system
54, 47	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	?	6.2 V-8 (OHC)	Lean Burn GDI w/ SCR; add SCR system similar to that used on diesel pickup trucks
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$750	5-8L Gasoline Engine	Lean Burn GDI; aove + VVL + Cylinder deactivation + Stoich GDI
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$6,000 to $8,000	6-9L diesel	Add SCR system - Diesel Engine; only SCR priced near class recently
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$270	3.5L gasoline	Stoich GDI w/ DPF; adv. cordierite brick & can; coated DPF
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$274	3.5L gasoline	SCR brick and Can
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$363	3.5L gasoline	SCR dosing system
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$3,250 to $4,350	5-8L Gasoline Engine	Lean burn GDI; requires low sulfur gasoline

6.7 Stoichiometric GDI+EGR

Table 64. Reference Data for Vocational (Gasoline) Stoichiometric GDI+EGR

Class 4-6 Stoichiometric GDI + EGR (G)						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$1060 to $1800	28, 47, 54, 55, 57	6.2 V-8: gasoline PFI, VVA, friction reduction	2011$	2014 introduction	GDI without NOx aftertreatment

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: Variable Valve Actuation (VVT + VVL), Engine Friction Reduction

Class 4-6 Stoichiometric GDI + EGR (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$700	V8 Gasoline	unknown baseline
47	Ricardo. "A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies." Prepared for U.S. EPA. Report #EPA420-R-08-004a. June 2008.	?	5.4L V8 gasoline	Applied to engines with and without VVL + VVT
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$512 to $930	5-8L Gasoline Engine	VVT + VVL + Cylinder deactivation
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$485	V8	Does not include VVL + VVT
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$537	LT V8 OHV Gasoline Engine	Baseline + VVL and VVT + reduced friction
70	"European Union Greenhouse Gas Reduction Potential for Heavy-Duty Vehicles", TIAX report to The International Council on Clean Transportation, Dec, 2011	$3,728	2020 Engine Class 3	Advanced 6-9L 2020 engine (220 to 230 bar cylinder pressure, 3,000 bar fuel injection, electrically boosted dual-stage variable geometry turbocharger, improved closed-loop engine controls, electric accessories, peak thermal efficiency 46 to 49%)*
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$336	Cooled Exhaust Gas Recirculation (EGR)— Level 1 (24 bar BMEP).	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$3,250 to $4,350	Lean burn GDI	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$750	Advanced EGR	High-rate EGR
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$500 - $750	High-rate EGR	
	internet searches, no realiable source found yet	$10-$50/plg	Advanced Corona Ignition System (ACIS)	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$537	LT V8 OHV Gasoline Engine	Baseline + VVL and VVT + reduced friction

6.8 Turbocharging and Downsizing

Table 65. Reference Data for Class 2b&3 (Gasoline) Turbocharging and Downsizing

Class 2b&3 Turbocharging & Downsizing (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,000 to $1,780	54, 55, 57, 58	6.2 V-8: gasoline PFI, GDI, VVA, friction reduction	2011$	2014 introduction	System cost includes turbocharging engine, higher BMEP capability

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: Stoichiometric GDI; VVA (VVT + VVL); engine friction reduction

Class 2b&3 Turbocharging & Downsizing (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$3,000 to $4,200 Package cost	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$1,000 to $2,000	5-8L Gasoline Engine	added to the cost of VVT, VVL, and GDI
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$1,229	5-8L Gasoline Engine	Above + VVL + Cylinder deactivation + Stoich GDI
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$986	V8	Gasoline, PFI, VVT, VVL, GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,339	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 1 18-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,781	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 2 24-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$2500 to $3600	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT

Table 66. Reference Data for Vocational (Gasoline) Turbocharging and Downsizing

Class 4-6 Turbocharging & Downsizing (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,000 to $1,780	54, 55, 57, 58	6.2 V-8: gasoline PFI, GDI, VVA, friction reduction	2011$	2014 introduction	System cost includes turbocharging engine, higher BMEP capability

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: Stoichiometric GDI; VVA (VVT + VVL); engine friction reduction

Class 4-6 Turbocharging & Downsizing (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$3,000 to $4,200 Package cost	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $2,000	5-8L Gasoline Engine	added to the cost of VVT, VVL, and GDI
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,229	5-8L Gasoline Engine	Above + VVL + Cylinder deactivation + Stoich GDI
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$986	V8	Gasoline, PFI, VVT, VVL, GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,339	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 1 18-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,781	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 2 24-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$2500 to $3600	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT

6.9 Engine Downspeeding

Table 67. Reference Data for Class 2b&3 (Gasoline) Engine Downspeeding

Class 2b&3 Engine Downspeeding (G)						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$1,600 to $3,600	11, 28, 54, 55, 57, 58, 69	6.2 V-8: gasoline PFI, GDI, VVA, friction reduction	2011$	2015 introduction	High BMEP V-6 with EGR plus Higher Speed Transmission

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission
Prior Technology: Stoichiometric GDI; VVA (VVT + VVL); engine friction reduction

Class 2b&3 Engine Downspeeding (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$3,000 to $4,200 Package cost	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $2,000	5-8L Gasoline Engine	added to the cost of VVT, VVL, and GDI
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,229	5-8L Gasoline Engine	Above + VVL + Cylinder deactivation + Stoich GDI
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$986	V8	Gasoline, PFI, VVT, VVL, GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,339	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 1 18-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,781	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 2 24-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$2500 to $3600	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix

54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$251	High Efficiency Gearbox	combined w. 6-speed auto with inmproved internals
11	NHTSA LDV Rulemaking -- primarily tables on Pp 334-341, plus supporting text	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$638	8-spd AT	V8
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$500-$1500	6-9L Diesel engine Increase cyliner pressure	20 to 23 Bar
	Research Notes	$500-$2000	6-9L Diesel engine Increase cyliner pressure	Eckerle (Cummins) identified this as a higher cost process; requires new materials, higher maching costs; Frey has this at $1,000; TIAX/Global insights has this + FI at $2,200
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$638	8-spd AT	V8

Table 68. Reference Data for Vocational (Gasoline) Engine Downspeeding

Class 4-6 Engine Downspeeding (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$1,600 to $3,600	11, 28, 54, 55, 57, 58, 69	6.2 V-8: gasoline PFI, GDI, VVA, friction reduction	2011$	2015 introduction	High BMEP V-6 with EGR plus Higher Speed Transmission

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: Stoichiometric GDI; VVA (VVT + VVL); engine friction reduction

Class 4-6 Engine Downspeeding (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$3,000 to $4,200 Package cost	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $2,000	5-8L Gasoline Engine	added to the cost of VVT, VVL, and GDI
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,229	5-8L Gasoline Engine	Above + VVL + Cylinder deactivation + Stoich GDI
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$986	V8	Gasoline, PFI, VVT, VVL, GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,339	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 1 18-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$1,781	LT V8 OHV Gasoline Engine	Turbocharging and Downsizing—Level 2 24-bar BMEP with downsize from V8 OHV to V6 DOHC - Total package cost including VVT, VVL, and GDI
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$2500 to $3600	5-8L Gasoline Engine	Package 3: Turbo-charged gasoline, down-sized engine; Includes SGDI, VVLT
28	Vyas, A., C. Saricks, F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix

54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$251	High Efficiency Gearbox	combined w. 6-speed auto with inmproved internals
11	NHTSA LDV Rulemaking -- primarily tables on Pp 334-341, plus supporting text	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$638	8-spd AT	V8
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$500-$1500	6-9L Diesel engine Increase cyliner pressure	20 to 23 Bar
	Research Notes	$500-$2000	6-9L Diesel engine Increase cyliner pressure	Eckerle (Cummins) identified this as a higher cost process; requires new materials, higher maching costs; Frey has this at $1,000; TIAX/Global insights has this + FI at $2,200
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$638	8-spd AT	V8

6.10 Low-Friction Engine Oil

Table 69. Reference Data for Class 2b&3 (Gasoline) Low-Friction Engine Oil

Class 2b&3 Low Friction Engine Oil (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$5 to $10	11, 42, 54, 55, 57	6.2 V-8: gasoline PFI	2011$	continuous improvement	Low Friction Engine Oil only

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Low Friction Engine Oil (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$8-$11	3.5L gasoline	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	11 to 15L Engines estimate	
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$100 to $400	5-8L Gasoline Engine	Packaged with all Engine Friction Reduction
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$6	3.5L gasoline	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$5	LT V8 Gasoline Engine	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$35 to $55		synthetic lube in tandem-drive axles
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$4	LT V8 Gasoline Engine	Low Friction Lubricants—Level 1

Table 70. Reference Data for Class 2b&3 (Diesel) Low-Friction Engine Oil

Class 2b&3 Low Friction Engine Oil (D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$9 to $19	11, 42, 54, 55, 57	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	continuous improvement	Low Friction Engine Oil only

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Low Friction Engine Oil (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$8-$11	3.5L gasoline	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	11 to 15L Engines estimate	
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$100 to $400	5-8L Gasoline Engine	Packaged with all Engine Friction Reduction
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$0 to $500	6-9L Diesel Engines	Packaged with all Engine Friction Reduction
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$6	3.5L gasoline	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$5	LT V8 Gasoline Engine	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$35 to $55		synthetic lube in tandem-drive axles
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$4	LT V8 Gasoline Engine	Low Friction Lubricants—Level 1

Table 71. Reference Data for Vocational (Gasoline) Low-Friction Engine Oil

Class 4-6 Low Friction Engine Oil (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$5 to $10	11, 42, 54, 55, 57	6.2 V-8: gasoline PFI	2011$	continuous improvement	Low Friction Engine Oil only

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Low Friction Engine Oil (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$8-$11	3.5L gasoline	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	11 to 15L Engines estimate	
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$100 to $400	5-8L Gasoline Engine	Packaged with all Engine Friction Reduction
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$6	3.5L gasoline	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$5	LT V8 Gasoline Engine	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$35 to $55		synthetic lube in tandem-drive axles
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$4	LT V8 Gasoline Engine	Low Friction Lubricants—Level 1

Table 72. Reference Data for Vocational (Diesel) Low-Friction Engine Oil

Class 4-6 Low Friction Engine Oil (D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$9 to $19	11, 42, 54, 55, 57	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	continuous improvement	Low Friction Engine Oil only

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Low Friction Engine Oil (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$8-$11	3.5L gasoline	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	11 to 15L Engines estimate	
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$100 to $400	5-8L Gasoline Engine	Packaged with all Engine Friction Reduction
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$0 to $500	6-9L Diesel Engines	Packaged with all Engine Friction Reduction
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$6	3.5L gasoline	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$5	LT V8 Gasoline Engine	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$35 to $55		synthetic lube in tandem-drive axles
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$4	LT V8 Gasoline Engine	Low Friction Lubricants—Level 1

Table 73. Reference Data for Line Haul Low-Friction Engine Oil

Class 8 Low Friction Engine Oil

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$55 to $150	11, 28, 42, 54, 57	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Low Friction Engine Oil only

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Low Friction Engine Oil

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$8-$11	3.5L gasoline	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	11 to 15L Engines estimate	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$500	Class7 & 8	Internal friction reduction through better lubricants and improved bearings.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$100 to $400	5-8L Gasoline Engine	Packaged with all Engine Friction Reduction
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$35 to $55		synthetic lube in tandem-drive axles
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$54-$75	Scaled from 11	3.5L: 6.2 Quarts or 5.9 Litres is the oil capacity (including filter); MaxxForce 11L and 13L: Lub Capacity 40L (42 quarts)

6.11 Engine Friction Reduction

Table 74. Reference Data for Class 2b&3 (Gasoline) Engine Friction Reduction

Class 2b&3 Engine Friction Reduction (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$64 to $392	11, 55, 69	6.2 V-8: gasoline PFI	2011$	continuous improvement	Improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology:

Class 2b&3 Engine Friction Reduction (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$52 to $196	4 cylinder gasoline or diesel engine	improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.
		$78 to $294	6 cylinder gasoline or diesel engine	
		$104 to $392	8 cylinder gasoline or diesel engine	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$32 to $52	4 cylinder gasoline or diesel engine	Improvements of surface engineering (surface coatings, material substitutions, selective surface hardening and surface topography control).
		$48 to $78	6 cylinder gasoline or diesel engine	
		$64 to $104	8 cylinder gasoline or diesel engine	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$0 to $500	Up to 8 cylinders	Friction Reduction (lubricants, bearings, materials, coatings, etc)

Table 75. Reference Data for Class 2b&3 (Diesel) Engine Friction Reduction

Class 2b&3 Engine Friction Reduction (D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$48 to $294	11, 55, 69	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	continuous improvement	Improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology:

Class 2b&3 Engine Friction Reduction (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$52 to $196	4 cylinder gasoline or diesel engine	improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.
		$78 to $294	6 cylinder gasoline or diesel engine	
		$104 to $392	8 cylinder gasoline or diesel engine	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$32 to $52	4 cylinder gasoline or diesel engine	Improvements of surface engineering (surface coatings, material substitutions, selective surface hardening and surface topography control).
		$48 to $78	6 cylinder gasoline or diesel engine	
		$64 to $104	8 cylinder gasoline or diesel engine	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$0 to $500	Up to 8 cylinders	Friction Reduction (lubricants, bearings, materials, coatings, etc)

Table 76. Reference Data for Vocational (Gasoline) Engine Friction Reduction

Class 4-6 Engine Friction Reduction (G)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$64 to $392	11, 55, 69	6.2 V-8: gasoline PFI	2011$	continuous improvement	Improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology:

Class 4-6 Engine Friction Reduction (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$52 to $196	4 cylinder gasoline or diesel engine	improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.
		$78 to $294	6 cylinder gasoline or diesel engine	
		$104 to $392	8 cylinder gasoline or diesel engine	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$32 to $52	4 cylinder gasoline or diesel engine	Improvements of surface engineering (surface coatings, material substitutions, selective surface hardening and surface topography control).
		$48 to $78	6 cylinder gasoline or diesel engine	
		$64 to $104	8 cylinder gasoline or diesel engine	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$0 to $500	Up to 8 cylinders	Friction Reduction (lubricants, bearings, materials, coatings, etc)

Table 77. Reference Data for Vocational (Diesel) Engine Friction Reduction

Class 4-6 Engine Friction Reduction (D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$48 to $294	11, 55, 69	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	continuous improvement	Improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology:

Class 4-6 Engine Friction Reduction (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$52 to $196	4 cylinder gasoline or diesel engine	improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.
		$78 to $294	6 cylinder gasoline or diesel engine	
		$104 to $392	8 cylinder gasoline or diesel engine	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$32 to $52	4 cylinder gasoline or diesel engine	Improvements of surface engineering (surface coatings, material substitutions, selective surface hardening and surface topography control).
		$48 to $78	6 cylinder gasoline or diesel engine	
		$64 to $104	8 cylinder gasoline or diesel engine	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$0 to $500	Up to 8 cylinders	Friction Reduction (lubricants, bearings, materials, coatings, etc)

Table 78. Reference Data for Line Haul Engine Friction Reduction

Class 8 Engine Friction Reduction

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$48 to $294	11, 55, 69	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Engine Friction Reduction

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$52 to $196	4 cylinder gasoline or diesel engine	improve low-tension piston rings, roller cam followers, crankshaft design/bearings, material substitution, and piston/cylinder surface treatments.
		$78 to $294	6 cylinder gasoline or diesel engine	
		$104 to $392	8 cylinder gasoline or diesel engine	
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$32 to $52	4 cylinder gasoline or diesel engine	Improvements of surface engineering (surface coatings, material substitutions, selective surface hardening and surface topography control).
		$48 to $78	6 cylinder gasoline or diesel engine	
		$64 to $104	8 cylinder gasoline or diesel engine	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$0 to $500	Up to 8 cylinders	Friction Reduction (lubricants, bearings, materials, coatings, etc)

6.12 Stop/Start

Table 79. Reference Data for Class 2b&3 (Gasoline) Stop/Start

Class 2b&3 Stop/Start (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$500 to $900	54, 55, 28, 47	6.2 V-8: gasoline PFI, fixed valve	2011$	2014 introduction	More capable vehicle battery and starter, control system development, Belt driven generator only
Battery replacement	$455	56	Varta stop/start battery	2013$		Stop/start capable battery

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Stop/Start (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,200	Focus on Diesel engines	Belt driven 42V system
47	Ricardo. “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies.” Prepared for U.S. Environmental Protection Agency. December 21, 2007.	No cost analysis in study	belt driven or ISG 42V	Only discussion of system characteristics
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $2,000	belt driven or ISG 42V	Need volume to get costs down; probably requires 42V alternator
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$720 to $880	Belt driven Alterntor	12V BAS Micro-Hybrid
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/5809	455	Stop/Start capable battery	used as replacement cost (full cost)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	480	12V Micro Hybrid	12V BAS Micro-Hybrid

Table 80. Reference Data for Class 2b&3 (Diesel) Stop/Start

Class 2b&3 Stop/Start (D)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,000 to $2,000	54, 55, 28, 47	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	2014 introduction	More capable vehicle battery and starter, control system development, ISG only
Battery replacement	$455	56	Varta stop/start battery	2013$		Stop/start capable battery

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Stop/Start (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,200	Focus on Diesel engines	Belt driven 42V system
47	Ricardo. “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies.” Prepared for U.S. EPA. Report #EPA420-R-08-004a. June 2008.	No cost analysis in study	belt driven or ISG 42V	Only discussion of system characteristics
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $2,000	belt driven or ISG 42V	Need volume to get costs down; probably requires 42V alternator
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$720 to $880	Belt driven Alterntor	12V BAS Micro-Hybrid
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/580901-(f21).html. Accessed July 2013.	455	Stop/Start capable battery	used as replacement cost (full cost)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	976	Mild Hybrid	ISG
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$3,111	Strong Hybrid (Level 2)	Strong Hybrid

Table 81. Reference Data for Vocational (Gasoline) Stop/Start

Class 4-6 Stop/Start (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$500 to $900	54, 55, 28, 47	6.2 V-8: gasoline PFI, fixed valve	2011$	2014 introduction	More capable vehicle battery and starter, control system development, Belt driven generator only
Battery replacement	$455	56	Varta stop/start battery	2013$		Stop/start capable battery

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Stop/Start (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,200	Focus on Diesel engines	Belt driven 42V system
47	Ricardo. “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies.” Prepared for U.S. Environmental Protection Agency. December 21, 2007.	No cost analysis in study	belt driven or ISG 42V	Only discussion of system characteristics
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $2,000	belt driven or ISG 42V	Need volume to get costs down; probably requires 42V alternator
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2010.	$720 to $880	Belt driven Alterntor	12V BAS Micro-Hybrid
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/5809	455	Stop/Start capable battery	used as replacement cost (full cost)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	480	12V Micro Hybrid	12V BAS Micro-Hybrid

Table 82. Reference Data for Vocational (Diesel) Stop/Start

Class 4-6 Stop/Start (D)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,000 to $2,000	54, 55, 28, 47	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$	2014 introduction	More capable vehicle battery and starter, control system development, ISG only
Battery replacement	$455	56	Varta stop/start battery	2013$		Stop/start capable battery

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Diesel Stop/Start (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,200	Focus on Diesel engines	Belt driven 42V system
47	Ricardo. “A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies.” Prepared for U.S. EPA. Report #EPA420-R-08-004a. June 2008.	No cost analysis in study	belt driven or ISG 42V	Only discussion of system characteristics
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $2,000	belt driven or ISG 42V	Need volume to get costs down; probably requires 42V alternator
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$720 to $880	Belt driven Alterntor	12V BAS Micro-Hybrid
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/580901-(f21).html. Accessed July 2013.	455	Stop/Start capable battery	used as replacement cost (full cost)
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	976	Mild Hybrid	ISG
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$3,111	Strong Hybrid (Level 2)	Strong Hybrid

6.13 Reduced Aftertreatment Backpressure

Table 83. Reference Data for Line Haul Reduced Aftertreatment Backpressure

Class 8 Reduced Aftertreatment Backpressure						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$440 to $1015	11, 28, 54, 55, 74	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Increase catalyst volume by 50% to reduce backpressure

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Reduced Aftertreatment Backpressure

Reference Number	Reference	Value from Reference	Description	Additional Notes
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$480	LT V8 Gasoline Engine	Stoich GDI w/ DPF
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$250	V8 Gasoline	Improved DOC
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$75	V8 Gasoline	O2 Sensor
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000	V8 Gasoline	Nox Adsorber; NOx adsorber (integrated) system
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$750	5-8L Gasoline Engine	Lean Burn GDI; aove + VVL + Cylinder deactivation + Stoich GDI
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$6,000 to $8,000	6-9L diesel	Add SCR system - Diesel Engine; only SCR priced near class recently
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$270	3.5L gasoline	Stoich GDI w/ DPF; adv. cordierite brick & can; coated DPF
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$274	3.5L gasoline	SCR brick and Can
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$363	3.5L gasoline	SCR dosing system
74	TIAX Offroad Engine Manufacturers Association Study, not published	$440 - $1015	DPF and DOC volume increase by 50%	Catalyst substrates for diesel truck applications are usually about 180-250 mm (7-10") in diameter and 150-180 mm (6-7") in length. Smaller substrates are used for passenger car applications.

6.14 Air Handling Improvements

Table 84. Reference Data for Line Haul Air Handling Improvements

Class 8 Air Handling Improvements

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$750 to $1,500	28, 47, 54, 55, 7	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2014 introduction	Air Handling Improvements through medium rate cooled EGR

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: VVA (VVT + VVL); engine friction reduction

Class 8 Air Handling Improvements

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000	Pre-2004 base engine technology	Reduced waste heat and improved thermal management
47	Ricardo. "A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies." Prepared for U.S. EPA. Report #EPA420-R-08-004a. June 2008.	?	Gas Handling System	Advanced EGR cooling will likely include increased cooling capacity, EGR DOC for fouling mitigation, and EGR bypass
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$1000 to $2000	11-15 Liter Engine Diesel	Accessory Electrification — Electric Auxiliaries (alternator, air compressor, power steering pump, air cond, fan, fuel pump, water pump); in combination with hybrid or other vehicle electrification.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $750	11-15 Liter Engine Diesel	Advanced low-temperature EGR, lower pressure drop
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$1,500	11-15 Liter Engine Diesel	1400 RPM and 60 percent load, the EGR temperature coming out of the EGR cooler was reduced from 167° C down to 104° C.

6.15 Mechanical Turbocompound

Table 85. Reference Data for Line Haul Mechanical Turbocompound

Class 8 Mechanical Turbocompound

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$2,000 to $3,000	7, 54, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2010 Introduction	Mechanical Turbocompund

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Mechanical Turbocompound

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$2650 to $5300	Turbocompound – Mechanical	Includes VVA
7 research notes	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$2,200	Mechanical turno-compound	with port liners
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$2,000 to $3,000	Turbocompound – Mechanical	No WHR
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$2,000 to $3,000	Turbocompound – Mechanical	No WHR

6.16 Electric Turbocompound

Table 86. Reference Data for Line Haul Electric Turbocompound

Class 8 Electrical Turbocompound

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$3,400 to $5,000	7, 54, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2010 Introduction	Electrical Turbocompund

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Electrical Turbocompound

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$2650 to $5300	Turbocompound – Mechanical	Includes VVA
7 research notes	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$5,000 - $7,000	Electrical turbocompound	including site visit to DD
52	Kruiswyk, R. “Diesel Engine Waste Heat Recovery Utilizing Electric Turbocompound Technology.” Caterpillar, Inc., 2005 Annual Progress Report for Advanced Combustion Engine Technologies, US Department of Energy. Pp 276-281. January 2006.	$2,000 to $3,400	Electrical turbocompound	Power electronics account for 50% of the cost
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$6,000 to $7,000	Electric Turbocompound, including accessory electricification	No WHR ($3,000 to $4,000 inc.to Hybrid)

6.17 Hybrid Electric Vehicle

Table 87. Reference Data for Class 2b&3 Hybrid Electric Vehicle

Class 2b&3 Hybrid Electric Vehicles						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$9,000 to $30,000	7, 28, 45, 54, 55, 58, 59, 79	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$		Parallel hybrid-electric powertrain, integrated starter-alternator technology with idle off, and regenerative braking capability

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Hybrid Electric Vehicles

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$30,000 to $40,000	Class 8 Line Haul	Parallel hybrid-electric powertrain. 50kW motor/generator. 4 kW-hr battery pack.
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$6,000 to $8,000	Class 2b to 6 Truck Technologies	Hybrid electric powertrain
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000 (diesel) $1,000-1,200 (gasoline)	Class 2b to 6 Truck Technologies	Integrated starter-alternator technology with idle off and regenerative braking capability
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$7,100	medium-duty package and beverage delivery trucks	Idle off and regenerative braking capability
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$38,000	Class 3 to Class 6 Straight Box Truck	Parallel hybrid-electric powertrain.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$50,000	Class 3 to 6 Bucket Truck	Parallel hybrid with electric power takeoff.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$8,700	Light Duty Vehicles	Large SUV/pickup (V8)
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/580901-(f21).html. Accessed July 2013.	455	Stop/Start capable battery	used as replacement cost (full cost)
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$35,000 to $40,000 (w PTO $49k to $52k)	Class 3 to 6 box and bucket trucks	Parallel Hybrid Electric Vehicle
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$20,000	Class 3 to Class 6 Straight Box Truck	Parallel hybrid-electric powertrain. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$30,000	Class 3 to 6 Bucket Truck	Parallel hybrid with electric power takeoff. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$9,000	Class 2b pickup and van	Parallel hybrid. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$25,000	Class 8 Line Haul	Parallel electric hybrid with idle reduction (2015-2020)
79	California Air Resources Board, "Implementation Manual for the FY 2011-12 California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, November 1, 2012	$25,000 to $30,000	Class 2b to Class 3	Alternate incremental costs for specific vehicles can be used on a case-by-case basis

Table 88. Reference Data for Vocational Hybrid Electric Vehicle

Class 4-6 Hybrid Electric Vehicles						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$24,000 to $40,000	7, 28, 45, 54, 55, 58, 59, 79, 81	6.7L V8 Turbo Diesel, High Pressure direct inject	2011$		Parallel hybrid-electric powertrain, integrated starter-alternator technology with idle off, and regenerative braking capability with power takeoff.

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Hybrid Electric Vehicles

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$30,000 to $40,000	Class 8 Line Haul	Parallel hybrid-electric powertrain. 50kW motor/generator. 4 kW-hr battery pack.
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$6,000 to $8,000	Class 2b to 6 Truck Technologies	Hybrid electric powertrain
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000 (diesel) $1,000-1,200 (gasoline)	Class 2b to 6 Truck Technologies	Integrated starter-alternator technology with idle off and regenerative braking capability
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$7,100	medium-duty package and beverage delivery trucks	Idle off and regenerative braking capability
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$38,000	Class 3 to Class 6 Straight Box Truck	Parallel hybrid-electric powertrain.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$50,000	Class 3 to 6 Bucket Truck	Parallel hybrid with electric power takeoff.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$8,700	Light Duty Vehicles	Large SUV/pickup (V8)
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/580901-(f21).html. Accessed July 2013.	455	Stop/Start capable battery	used as replacement cost (full cost)
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$35,000 to $40,000 (w PTO $49k to $52k)	Class 3 to 6 box and bucket trucks	Parallel Hybrid Electric Vehicle
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$20,000	Class 3 to Class 6 Straight Box Truck	Parallel hybrid-electric powertrain. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$30,000	Class 3 to 6 Bucket Truck	Parallel hybrid with electric power takeoff. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$9,000	Class 2b pickup and van	Parallel hybrid. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$25,000	Class 8 Line Haul	Parallel electric hybrid with idle reduction (2015-2020)
79	California Air Resources Board, "Implementation Manual for the FY 2011-12 California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, November 1, 2012	$40,000 to $50,000	Class 4 to Class 6	Alternate incremental costs for specific vehicles can be used on a case-by-case basis
81	California Air Resources Board, "HVIP Eligible Vehicles – Hybrid," Updated February 21, 2014	$24,000 to $40,000	Class 4 to Class 7	Hino, Kenworth, Peterbilt, Navistar, & Freightliner Package Delivery Trucks

Table 89. Reference Data for Line Haul Hybrid Electric Vehicle

Class 8 Hybrid Electric Vehicles

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$30,000 to $50,000	7, 28, 45, 54, 55, 58, 59, 79, 81	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$		Parallel hybrid-electric powertrain, integrated starter-alternator technology with idle off, and regenerative braking capability.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Hybrid Electric Vehicles

Reference Number	Reference	Value from Reference	Description	Additional Notes
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$30,000 to $40,000	Class 8 Line Haul	Parallel hybrid-electric powertrain. 50kW motor/generator. 4 kW-hr battery pack.
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$6,000 to $8,000	Class 2b to 6 Truck Technologies	Hybrid electric powertrain
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$2,000 (diesel) $1,000-1,200 (gasoline)	Class 2b to 6 Truck Technologies	Integrated starter-alternator technology with idle off and regenerative braking capability
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$7,100	medium-duty package and beverage delivery trucks	Idle off and regenerative braking capability
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$38,000	Class 3 to Class 6 Straight Box Truck	Parallel hybrid-electric powertrain.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$50,000	Class 3 to 6 Bucket Truck	Parallel hybrid with electric power takeoff.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$8,700	Light Duty Vehicles	Large SUV/pickup (V8)
56	Batteries Direct. "Varta 580901 (F21)." http://www.batteriesdirect.com.au/shop/product/22640/580901-(f21).html. Accessed July 2013.	455	Stop/Start capable battery	used as replacement cost (full cost)
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$35,000 to $40,000 (w PTO $49k to $52k)	Class 3 to 6 box and bucket trucks	Parallel Hybrid Electric Vehicle
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$20,000	Class 3 to Class 6 Straight Box Truck	Parallel hybrid-electric powertrain. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$30,000	Class 3 to 6 Bucket Truck	Parallel hybrid with electric power takeoff. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$9,000	Class 2b pickup and van	Parallel hybrid. (2015-2020)
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012.	$25,000	Class 8 Line Haul	Parallel electric hybrid with idle reduction (2015-2020)
79	California Air Resources Board, "Implementation Manual for the FY 2011-12 California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project, November 1, 2012	$70,000	Class 8 (not only line haul)	Alternate incremental costs for specific vehicles can be used on a case-by-case basis
81	California Air Resources Board, "HVIP Eligible Vehicles – Hybrid," Updated February 21, 2014	$40,000 to $50,000	Class 8: Eligible Hybrid Tractors	Kenworth, Freightliner, Navistar, & Peterbilt Tractors w/Eaton Hybrid System (voucher amounts half of incremental costs)

6.18 Diesel APU

Table 90. Reference Data for Line Haul Diesel APU

Class 8 Diesel APU						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$6,000 to $12,000	54, 59, 60	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Diesel engine, generator, particulate filter, and NOx trap. Diesel fuel consumption of 0.20 to 0.33 gal/hr.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Diesel APU

Reference Number	Reference	Value from Reference	Description	Additional Notes
59	National Research Council. “Review of the 21st Century Truck Partnership, Second Report.” 2012. http://www.nap.edu/catalog.php?record_id=13288	$8,000	Diesel APU: Diesel engine, generator, particulate filter, NOx trap	add $1,000 for DPF. Fuel Consumption of 0.20 to 0.33 gal/hr. Maintenance Cost of $400/yr
59	National Research Council. “Review of the 21st Century Truck Partnership, Second Report.” 2012. http://www.nap.edu/catalog.php?record_id=13288	$6,000 to $8,000	Auxiliary Power Unit	Emissions control needed in California. 0.2 to 0.3 gal/hr fuel use.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$7,499 to $8,100	Black Rock Systems	Heat/Cools Cab, 0.2 or 0.3 gal/hr
		$7,200 to $8,100	Comfort Master	Heat/Cools Cab, 0.25 gal/hr, 110V AC, Auto-on, Shorepower
		$6,500	Diamond Power Systems	Heat/Cools Cab, 0.26 gal/hr, 110V AC, Auto-on, Shorepower
		$7,000 to $9,000	Double Eagle Industries	Heat/Cools Cab, Heat Engine, 0.3 gal/hr, DC
		$6,999	Flying J	Heat/Cools Cab, Heat Engine, 110V AC, Auto-on, Shorepower
		$6,000 to $7,500	Frigette Truck Climate System	Heat/Cools Cab, 110V AC
		$6,900 to $7,750	Idlebuster	Heat/Cools Cab, Heat Engine, 110V AC, Auto-on, Shorepower
		$6,925	Kool-Gen	Heat(optional)/Cools Cab, 110V AC
		$7,500	Pony Pack	Heat/Cools Cab, Heat Engine, 0.2 gal/hr, DC
		$6,300	Rig Master Power	Heat/Cools Cab, Heat Engine, 0.2 gal/hr, 110V AC
		$5,995 to $6,500	Star Class	
		$8000 to $10000 (+$3000 DPF for CA)	Thermo King	Heat/Cools Cab, Heat Engine, 0.04 to 0.14 gal/hr, 110V AC, Auto-on
		$8,499	TRIDAKO Energy Systems	Heat/Cools Cab, Heat Engine, 0.4 gal/hr
		$6,000 to $7,000	Truck Gen	Heat/Cools Cab, 0.2 gal/hr, 110V AC, Shorepower
60	North American Council for Freight Efficiency, "Trucking Efficiency Summit." October 7, 2013 http://nacfe.org/wp-content/uploads/2013/10/Master-TE-Summit-Oct7-100313.pdf	$6,900 to $10,000	Preliminary Anti-Idling Estimate: Diesel APU	Heat/Cools Cab, Heat Engine
78	North American Council for Freight Efficiency, "Confidence Report on Idle-Reduction Solutions," June 25, 2014	$8,000 to $12,000	Preliminary Anti-Idling Estimate: Diesel APU	Heat/Cools Cab, Heat Engine, 0.1 to 0.5 gal/hr. 7 to 18 HP engine. 110V AC to cab
78	North American Council for Freight Efficiency, "Confidence Report on Idle-Reduction Solutions," June 25, 2014	$1,000	Residual value in 4 year old (MY2009)	

6.19 Battery APU

Table 91. Reference Data for Line Haul Battery APU

Class 8 Battery APU						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$4,000 to $8,800	59, 60, 61	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Cools with some electricity availability. Heating system not included.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Battery APU

Reference Number	Reference	Value from Reference	Description	Additional Notes
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012. http://www.nap.edu/catalog.php?record_id=13288	$4,000	Battery-powered air-conditioning system	Battery, motor, vapor compression air conditioning components. 0.15 gal/hr, Maintenance Cost of $200/yr
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012. http://www.nap.edu/catalog.php?record_id=13288	$3,000 to $8,000	Battery that requires recharge infrastructure	Heats and cools with some electricity availability (no diesel fuel consumption) Need recharge infrastructure
60	North American Council for Freight Efficiency, "Trucking Efficiency Summit." October 7, 2013 http://nacfe.org/wp-content/uploads/2013/10/Master-TE-Summit-Oct7-100313.pdf	$5,200 to $6,700	Preliminary Anti-Idling Estimate: Battery APU	Heat/Cools Cab, Heat Engine
61	Shorepower Technologies (formerly Shurepower) website accessed November 2013 http://www.shorepower.com/docs/Shorepower-capable-APUs.pdf	$3,495	Bergstrom Inc. www.nitesystem.com	10 hours of full operational use. It takes 4-6 hours to recharge.
61	Shorepower Technologies (formerly Shurepower) website accessed November 2013 http://www.shorepower.com/docs/Shorepower-capable-APUs.pdf	$6,895	Driver Comfort System www.drivercomfort.com	AC and Heat. 3000 watt inverter/charger, 270 amp alternator.
61	Shorepower Technologies (formerly Shurepower) website accessed November 2013 http://www.shorepower.com/docs/Shorepower-capable-APUs.pdf	$7,995	Idle Free Systems, LLC www.idlefree.net	10,000 BTU Dometic Air conditioner; Espar D-5 Hydronic Heater; Xantrex Prosine 2.0 Inverter/Charger; cab power/shore power kit Reefer Link System w/reefer alternator upgrade
61	Shorepower Technologies (formerly Shurepower) website accessed November 2013 http://www.shorepower.com/docs/Shorepower-capable-APUs.pdf		Kenworth Truck Company www.kenworth.com	Thermal capacity of 21,000 BTUs and requires 4-6 hours of charging to provide up to 10 hours of cooling in 95°, low-solar load environment.
61	Shorepower Technologies (formerly Shurepower) website accessed November 2013 http://www.shorepower.com/docs/Shorepower-capable-APUs.pdf	$1,600	Safer Corporation www.saferco.com	"Viesa," Evaporative Cooling System. does not provide heat or electrical power. Best in hot, dry climates, <60% humidity.
78	North American Council for Freight Efficiency, "Confidence Report on Idle-Reduction Solutions," June 25, 2014	$8,500 to $8,800	Battery APU not including optional diesel fuel heater for heating	Used to power air conditioning and hotel loads. Heating system optional.

6.20 Fuel-Fired Heater

Table 92. Reference Data for Line Haul Fuel-Fired Heater

Class 8 Fuel Fired Heater

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$900 to $1,500	54, 59, 60	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Diesel fuel heater. Heats Cab, 0.04 to 0.06 gal/hr diesel fuel use. Maintenance cost: $110/yr

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Fuel Fired Heater

Reference Number	Reference	Value from Reference	Description	Additional Notes
59	National Research Council. “Review of the 21st Century Truck Partnership, Second Report.” 2012.	$1,000 to $3,000	Idle Reduction Technology: Heater	Heats Cab, 0.2 to 0.3 gal/hr diesel fuel use
59	National Research Council. “Review of the 21st Century Truck Partnership, Second Report.” 2012. http://www.nap.edu/catalog.php?record_id=13288	$1,300	Cab Confort Technology Summary: Cab bunk heater	Heats Cab, 0.04 to 0.06 gal/hr diesel fuel use. Maintenance cost: $110/yr
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$900 to $1,200	Automotive Climate Control	Heats Cab, battery-powered fuel-fired heater, 1 gal/24 hr
		$1,000 to $3,000	Espar Heater System: Cab	Heats Cab, battery-powered fuel-fired heater, 1 gal/20 hr
		$1,000 to $3,000	Espar Heater System: Engine	Heats Engine, battery-powered fuel-fired heater, 1 gal/(4 to 6 hrs)
		$1,000 to $3,000	Webasto Product North America: Cab	Heats Cab, battery-powered fuel-fired heater, 1 gal/20 hr
		$1,000 to $3,000	Webasto Product North America: Engine	Heats Engine, battery-powered fuel-fired heater, (0.03 to 0.24 gal)/hr
60	North American Council for Freight Efficiency, "Trucking Efficiency Summit." October 7, 2013 http://nacfe.org/wp-content/uploads/2013/10/Master-TE-Summit-Oct7-100313.pdf	$500 to $1,600	Preliminary Anti-Idling Estimate: Diesel Fired Heater	Heats Cab, diesel fuel use.
78	North American Council for Freight Efficiency, "Confidence Report on Idle-Reduction Solutions," June 25, 2014	$900 to $1,500	Diesel fuel-operated air heater	Heats Cab, diesel fuel use.

6.21 A/C System Improvements

Table 93. Reference Data for Class 2b&3 (Gasoline, Diesel) A/C System Improvements

Class 2b&3 Air Conditioning Improvements						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$135 to $500	28, 45, 54, 55, 75	6.2 V-8: gasoline PFI, fixed valve	2011$	2014 introduction	Air Conditioning Improvements - Higher efficiency compressor, separate electric condensor fan to avoid use of engine-driven fan.

Baseline Engine:
Prior Technology:

Class 2b&3 Air Conditioning Improvements

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$500	Class 7 & 8 Truck Technologies	Electrical auxiliaries (air compressor, hydraulic pump, radiator fan). Stage 1
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$1,500	Class 7 & 8 Truck Technologies	Fuel-cell (with reformer) - operated auxiliaries (HVAC included). Stage 2
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	Diesel Engine	Electricfy auxiliaries, such as air-conditioning compressor, air compressor, fans, hydraulic pump, and coolant pump, are gear- or belt-driven by truck base engine.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $2000	5-8 L Gasoline Engine	Accessory Electrification — Electric Auxiliaries (alternator, air compressor, power steering pump, air cond, fan, fuel pump, water pump); in combination with hybrid or other vehicle electrification.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$70 to $90	Light Duty Vehicles	HVAC—variable stroke, increased efficiency (A/C system and reducing refrigerant leakage from the system at less than $110 to the consumer)
75	Vyas, A., L. Gaines, and R. Cuenca, "Evaluation of Electric Vehicle Production and Operating Costs", ANL/ESD-41, Nov. 1999	$135	Air-conditioning drive	Subcompact EV Powertrain Characteristics and Purchase Price

Table 94. Reference Data for Vocational (Gasoline, Diesel) A/C System Improvements

Class 4-6 Air Conditioning Improvements

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$135 to $500	28, 45, 54, 55, 75	6.2 V-8: gasoline PFI, fixed valve	2011$	2014 introduction	Air Conditioning Improvements - Higher efficiency compressor, separate electric condensor fan to avoid use of engine-driven fan.

Baseline Engine:

Prior Technology:

Class 4-6 Air Conditioning Improvements

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$500	Class 7 & 8 Truck Technologies	Electrical auxiliaries (air compressor, hydraulic pump, radiator fan). Stage 1
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,500	Class 7 & 8 Truck Technologies	Fuel-cell (with reformer) - operated auxiliaries (HVAC included). Stage 2
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	Diesel Engine	Electricfy auxiliaries, such as air-conditioning compressor, air compressor, fans, hydraulic pump, and coolant pump, are gear- or belt-driven by truck base engine.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $2000	6-9L Diesel Engines	Accessory Electrification — Electric Auxiliaries (alternator, air compressor, power steering pump, air cond, fan, fuel pump, water pump); in combination with hybrid or other vehicle electrification.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$70 to $90	Light Duty Vehicles	HVAC—variable stroke, increased efficiency (A/C system and reducing refrigerant leakage from the system at less than $110 to the consumer)
75	Vyas, A., L. Gaines, and R. Cuenca, "Evaluation of Electric Vehicle Production and Operating Costs", ANL/ESD-41, Nov. 1999	$135	Air-conditioning drive	Subcompact EV Powertrain Characteristics and Purchase Price

Table 95. Reference Data for Line Haul A/C System Improvements

Class 8 Air Conditioning Improvements

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$135 to $500	28, 45, 54, 55, 75	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2014 introduction	Air Conditioning Improvements - Higher efficiency compressor, separate electric condensor fan to avoid use of engine-driven fan.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: Variable Valve Actuation (VVT + VVL), Engine Friction Reduction

Class 8 Air Conditioning Improvements

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$500	Class 7 & 8 Truck Technologies	Electrical auxiliaries (air compressor, hydraulic pump, radiator fan). Stage 1
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,500	Class 7 & 8 Truck Technologies	Fuel-cell (with reformer) - operated auxiliaries (HVAC included). Stage 2
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	Diesel Engine	Electricfy auxiliaries, such as air-conditioning compressor, air compressor, fans, hydraulic pump, and coolant pump, are gear- or belt-driven by truck base engine.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1000 to $2000	11-15 Liter Engine Diesel	Accessory Electrification — Electric Auxiliaries (alternator, air compressor, power steering pump, air cond, fan, fuel pump, water pump); in combination with hybrid or other vehicle electrification.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$70 to $90	Light Duty Vehicles	HVAC—variable stroke, increased efficiency (A/C system and reducing refrigerant leakage from the system at less than $110 to the consumer)
75	Vyas, A., L. Gaines, and R. Cuenca, "Evaluation of Electric Vehicle Production and Operating Costs", ANL/ESD-41, Nov. 1999	$135	Air-conditioning drive	Subcompact EV Powertrain Characteristics and Purchase Price

6.22 Cab Insulation to Reduce A/C

Table 96. Reference Data for Class 2b&3 (Gasoline, Diesel) Cab Insulation to Reduce A/C

Class 2b&3 Cab Insulation to Reduce A/C

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$250 - $500	64,65,66	6.2 V-8: gasoline PFI, fixed valve	2011$	2015 Intro	Cab thermal insulation and improved glass glazing to reject sunload

Baseline Engine:

Prior Technology: None additional required

Class 2b&3 Cab Insulation to Reduce A/C

Reference Number	Reference	Value from Reference	Description	Additional Notes
64	http://shop.hushmat.com/k/search?q=peterbilt, accessed 12/4/2013	$200-$400	HushMat Ultra Sound Deadening and Thermal Insulation material	aftermarket price for truck cab insulation material (no install)
65	"An Evaluation of the Effects of Glass-Plastic Windshield Glazing in Passenger Cars", NHTSA Report Number DOT HS 808 062 November, 1993	$65 - $100	glass-plastic windshield glazing, auto application	initial cost expected to be manageable, but replacement cost significantly higher than convenitional auto glass
66	http://www.greencarcongress.com/2012/12/sabic-20121219.html, accessed 12/2013	n/a	glass-plastic windshield glazing, auto application	The Fiat 500L has already launched in Europe and is set to roll out in the United States in early 2013. The rear fixed side windows of the vehicle will be the first in the United States to use two-shot injection compression molding

Table 97. Reference Data for Vocational (Gasoline, Diesel) Cab Insulation to Reduce A/C

Class 4-6 Cab Insulation to Reduce A/C

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$250 - $500	64,65,66	6.2 V-8: gasoline PFI, fixed valve	2011$	2015 Intro	Cab thermal insulation and improved glass glazing to reject sunload

Baseline Engine:

Prior Technology: None additional required

Class 4-6 Cab Insulation to Reduce A/C

Reference Number	Reference	Value from Reference	Description	Additional Notes
64	http://shop.hushmat.com/k/search?q=peterbilt, accessed 12/4/2013	$200-$400	HushMat Ultra Sound Deadening and Thermal Insulation material	aftermarket price for truck cab insulation material (no install)
65	"An Evaluation of the Effects of Glass-Plastic Windshield Glazing in Passenger Cars", NHTSA Report Number DOT HS 808 062 November, 1993	$65 - $100	glass-plastic windshield glazing, auto application	initial cost expected to be manageable, but replacement cost significantly higher than convenitional auto glass
66	http://www.greencarcongress.com/2012/12/sabic-20121219.html, accessed 12/2013	n/a	glass-plastic windshield glazing, auto application	The Fiat 500L has already launched in Europe and is set to roll out in the United States in early 2013. The rear fixed side windows of the vehicle will be the first in the United States to use two-shot injection compression molding

Table 98. Reference Data for Line Haul Cab Insulation to Reduce A/C

Class 8 Cab Insulation to Reduce A/C

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$250 - $500	64, 65, 66, 78	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2015 Intro	Cab thermal insulation and improved glass glazing to reject sunload

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Cab Insulation to Reduce A/C

Reference Number	Reference	Value from Reference	Description	Additional Notes
64	http://shop.hushmat.com/k/search?q=peterbilt, accessed 12/4/2013	$200-$400	HushMat Ultra Sound Deadening and Thermal Insulation material	aftermarket price for truck cab insulation material (no install)
65	"An Evaluation of the Effects of Glass-Plastic Windshield Glazing in Passenger Cars", NHTSA Report Number DOT HS 808 062 November, 1993	$65 - $100	glass-plastic windshield glazing, auto application	initial cost expected to be manageable, but replacement cost significantly higher than convenitional auto glass
66	http://www.greencarcongress.com/2012/12/sabic-20121219.html, accessed 12/2013	n/a	glass-plastic windshield glazing, auto application	The Fiat 500L has already launched in Europe and is set to roll out in the United States in early 2013. The rear fixed side windows of the vehicle will be the first in the United States to use two-shot injection compression molding
78	North American Council for Freight Efficiency, "Confidence Report on Idle-Reduction Solutions," June 25, 2014	no price provided		wall/window insulation can reduce heat/cool loads 34-36%

6.23 Air Compressor Improvements

Table 99. Reference Data for Line Haul Air Compressor Improvements

Class 8 Air Compressor Improvements

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$200 to $500	54, 55, 57, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2012 introduction	Viscous drive clutch, actuator pin-out on ECM, wiring

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Air Compressor Improvements

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Accessory Electrification -- Electric Auxiliaries (air comp, ps pump, air cond, fan, alt, water pump); in combination with upgrade to 42V electrical system or hybrid.
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$120	Improved Accessories	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$822	Improved Accessories — Level 1 (IACC1) (shown in package cost)	Included in pacakge with Auto 4VDV6 +EFR2 +ASL2 +LDB +IACC1 +EPS +Aero1 +LRRT1 +HEG +DCP +WR5% +6sp.
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$200 to $500	Variable displacement pumps, incremental improvements	Belt-driven mechanical accessories

6.24 Shore Power

Table 100. Reference Data for Line Haul Shore Power

Class 8 Shore Power

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$100 to $2,000	59, 60	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Heats and cools with electricity availability. No diesel fuel consumption. Requires recharge infrastructure.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF

Prior Technology:

Class 8 Shore Power

Reference Number	Reference	Value from Reference	Description	Additional Notes
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012. http://www.nap.edu/catalog.php?record_id=13288	$10 ($9,000 to $16,700 infrastructure cost)	Electrified parking space (single system)	Heating, cooling module on pedestal connected to window-mounted module (includes communications entertainment). Usage cost of $1.00/hr to $2.45/hr
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012. http://www.nap.edu/catalog.php?record_id=13288	($2,500 to $6,000 infrastructure cost)	Electrified parking space (dual system)	Onboard equipment (e.g., inverter/charger, electric heating/cooling device) powered by extension cord. Usage cost of $1/hr
59	National Research Council. "Review of the 21st Century Truck Partnership, Second Report." 2012. http://www.nap.edu/catalog.php?record_id=13288	~$100	Shore power	Heats and cools with electricity availability. No diesel fuel consumption. Requires recharge infrastructure
60	North American Council for Freight Efficiency, "Trucking Efficiency Summit." October 7, 2013 http://nacfe.org/wp-content/uploads/2013/10/Master-TE-Summit-Oct7-100313.pdf	$250 to $2,000	Preliminary Anti-Idling Estimate: Shorepower	Heat/Cools Cab, Heat Engine
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$125	Dual System: Philips and Temro	
		$200 to $2,000	Dual System: Shurepower	Service Fee: $0.50/hr
		$2,500	Dual System: Teleflex (Proheat)	
		$1,500 inverter/charger : $1,500 electric HVAC	Dual System: Xantrex	Service Fee: $2,500/space
			Single System: Craufurd Manufacturing	Service Fee: $8,550/space
		$10 adapter	Single System: IdleAire Technologies	Service Fee: $2.18/hr retail Service Fee: $1.85/hr fleet
78	North American Council for Freight Efficiency, "Confidence Report on Idle-Reduction Solutions," June 25, 2014	no price provided		AC power port (off-board AC power). Many variations in AC wiring systems. Difficult to show a range of prices.

6.25 Aero Bin III

Table 101. Reference Data for Line Haul Aero Bin III

Class 8 Aero Trailer Side Skirt (4 to 6 m)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$450 to $650	42, 45, 54, 58, 76, 80	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Aero Bin III Tractor features will be baseline 2019, partial Side Skirts trailer will be added cost

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Aero Trailer Side Skirt (4 to 6 m)

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$1,500	Trailer aero	Vehicle Profile Improvement II - Closing and Covering of Gap Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$1,500	Trailer aero	front fairing/nose, side skirt, rear flaps
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $4000	Side skirts or belly box- va	Price range varies with length, flexibility, retractability, underside coverings, etc
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,500 to $2,000	Aerodynamic Technology Matrix	partial Skirts (4 to 6 m)
		$3,000 per trailer	Aerodynamic Technology Matrix	Smartway trailer – partial skirts + partial gap fairing or boat tail
76	Sharpe, B., and M. Roeth, "Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector", International Council on Clean Transportation and North American Council for Freight Efficiency report, February 2014	$700 to $1,100	High volume price ($700) including installation to low volume price ($1100)	Full skirts (7-9 m) at low volume price.
80	National Research Council. "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report." The National Academies Press Pre-Publication copy, 2014.	$750 and up	Skirt data for A,B,C,D combined.	Full Skirts on 53+ ft trailers. Installed price for trailer side skirts has decreased from $2,800 to less than $1,000

Class 8 Aero Boat Tail

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$800 to $1600	42, 45, 54, 58, 76, 80	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Aero Bin III Tractor features will be baseline 2019, boat tail trailer will be added cost

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$1,500	Trailer aero	Vehicle Profile Improvement II - Closing and Covering of Gap Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$1,500	Trailer aero	front fairing/nose, side skirt, rear flaps
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	300 to 500	cab Extender	
		$1,500 to $2,000	Boat tail -- structural or inflatable	17, 23 (structural), 26 (inflatable)
		$2,800 (inflatable)	Boat tail -- inflatable	17, 23 (structural), 26 (inflatable)
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,500 to $2,000	Aerodynamic Technology Matrix	Boat tail — structural or inflatable
		$3,000 per trailer	Aerodynamic Technology Matrix	Smartway trailer – partial skirts + partial gap fairing or boat tail
76	Sharpe, B., and M. Roeth, "Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector", International Council on Clean Transportation and North American Council for Freight Efficiency report, February 2014	$1,600	Low volume price including installation (high volume $1,000)	Boat tail — structural or inflatable
80	National Research Council. "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report." The National Academies Press Pre-Publication copy, 2014.	$800 and up	Trailer Tail	Smartway categories “trailer boat tails” and “advanced trailer end fairing."

6.26 Aero Bin IV and V

Table 102. Reference Data for Line Haul Aero Bin IV and V

Class 8 Aero Full Trailer Skirt (7 to 9 m)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$750 to $1100	42, 45, 54, 58, 76, 80	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Aero Bin III Tractor features will be baseline 2019, trailer will be added cost

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Aero Full Trailer Skirt (7 to 9 m)

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$1,500	Trailer aero	Vehicle Profile Improvement II - Closing and Covering of Gap Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$1,500	Trailer aero	front fairing/nose, side skirt, rear flaps
		$2,250	Trailer aero	undercarriage flow treatment device (UFD)
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,600 to $2400	Side skirts or belly box-varying length	Price range varies with length, flexibility, retractability, underside coverings, etc
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$2,000 to $4,000	Aerodynamic Technology Matrix	Full Skirts (7 to 9 m)
		$800 to $1,000	Aerodynamic Technology Matrix	Partial Gap Fairing
		$3,000 per trailer	Aerodynamic Technology Matrix	Smartway trailer – partial skirts + partial gap fairing or boat tail
		$4,000 per trailer	Aerodynamic Technology Matrix	Full next-generation trailer aero – full skirts, boat tail, and full gap fairing
76	Sharpe, B., and M. Roeth, "Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector", International Council on Clean Transportation and North American Council for Freight Efficiency report, February 2014	$700 to $1,100	High volume price ($700) including installation to low volume price ($1100)	Full skirts (7-9 m) at low volume price.
80	National Research Council. "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report." The National Academies Press Pre-Publication copy, 2014.	$750 and up	Skirt data for A,B,C,D combined.	Full Skirts on 53+ ft trailers. Installed price for trailer side skirts has decreased from $2,800 to less than $1,000

Class 8 Aero Full Tractor Skirt

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$1500 to $2000	42, 54, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Aero Bin III Tractor features will be baseline 2019, Full tractor skirts including wheel covering

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$1,500	Trailer aero	Vehicle Profile Improvement II - Closing and Covering of Gap Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$2,750	Tractor Aero	radical cab streamlining
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,500 to $2,000	Chassis Skirts (aka, "chassis fairing", "fuel tank fairing") -- full length	Long Haul, sleeper cabs
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,500 to $2,000	Chassis Skirts (aka, "chassis fairing", "fuel tank fairing") -- full length	Long Haul, sleeper cabs

Class 8 Aero Gap Filler

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$650 to $1,000	42, 45, 54, 58, 76, 80	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Aero Bin III Tractor features will be baseline 2019, add full gap filler device

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$1,500	Trailer aero	Vehicle Profile Improvement II - Closing and Covering of Gap Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$1,500	Trailer aero	front fairing/nose, side skirt, rear flaps
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$300 to $500	Cab Extender	Class 8 in 2012 time frame. 80-90% adoption rate
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$800 to $1,000	Aerodynamic Technology Matrix	Partial Gap Fairing
		$1,000 to $1,500	Aerodynamic Technology Matrix	Full Gap fairing
		$3,000 per trailer	Aerodynamic Technology Matrix	Smartway trailer – partial skirts + partial gap fairing or boat tail
		$4,000 per trailer	Aerodynamic Technology Matrix	Full next-generation trailer aero – full skirts, boat tail, and full gap fairing
76	Sharpe, B., and M. Roeth, "Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector", International Council on Clean Transportation and North American Council for Freight Efficiency report, February 2014	$700 to $1000	High volume price ($700) including installation to low volume price ($1000)	Gap reducers
80	National Research Council. "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report." The National Academies Press Pre-Publication copy, 2014.	$650 and up	Tractor-trailer gap reducer	

6.27 Aero on Regional Haul

Table 103. Reference Data for Aero on Regional Haul

Class 8 Aero on Regional Haul

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$1,000 to $1,300	42, 45, 54, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Aero Bin III Tractor features will be baseline 2019, trailer will be added cost

Baseline Engine:

Prior Technology:

Class 8 Aero on Regional Haul

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$750	Trailer aero	Vehicle Profile Improvement I - Cab Top Deflector, Sloping Hood and Cab Side Flares Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$1,000	Front Fairing for Tractor Trailer	tractor trailer
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $1,300	Roof top deflector, day cab	day cabs only
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,000 to $1,300	Roof top deflector, day cab	day cabs only

6.28 Class 2b&3 Improved Aerodynamics

Table 104. Reference Data for Class 2b&3 (Gasoline, Diesel) Improved Aerodynamics

Class 2b&3 Improved Aerodynamics						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$60 to $500	54, 55, 28, 47	6.2 V-8: gasoline PFI, fixed valve, 6-speed AT	2011$	2014 introduction	Improved 2b & 3 Aerodynamics- Active grill shutters, belly pan under engine, belly pan under complete chassis, wheel well skirts

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Improved Aerodynamics

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$750	Trailer aero	Vehicle Profile Improvement I - Cab Top Deflector, Sloping Hood and Cab Side Flares Between Tractor and Trailer, Aerodynamic Bumper, Underside Air Baffles, and Wheel Well Covers
42	TIAX/UCS	$650-$1,000	Front Fairing/Nosecone	Straight Truck
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$400 to $500	Fuel Tank fairings	Class 3 -6
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $1,000	Box Skirts - (Laydon composites makes a modular design)	Class 3 -6
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $650	Cab side extension or Cab/Box Gap fairing	Class 3 -6
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$750	2010 Aero cab: aero mirrors, aero bumper, fuel tank fairings, streamlined shape	Class 3 -6
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$2,900	2012 Aero: roof deflector, rear-mounted frame extension in addition to 2010 aero cab	Class 3 -6
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$68	Aero Improvements - 10%	LD Truck V8
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$60 - $116	Vehicle Streamlining	Class 2b Van and Pickup—
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$1,000 to $1,300	Roof top deflector, day cab	day cabs only
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,000 to $1,300	Roof top deflector, day cab	day cabs only

6.29 Improved Transmissions

Table 105. Reference Data for Class 2b&3 (Gasoline) Improved Transmissions

Class 2b&3 Improved Transmissions (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$280 to $680	11, 28, 54, 55	6.2 V-8: gasoline PFI, fixed valve, 6-speed AT	2011$	2013 introduction	6-spd AT to 8-speed AT

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Improved Transmissions (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$251	High Efficiency Gearbox	combined w. 6-speed auto with inmproved internals
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$638	8-spd AT	V8

Table 106. Reference Data for Class 2b&3 (Diesel) Improved Transmissions

Class 2b&3 Improved Transmissions (D)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$750 to $1,000	11, 28, 54, 55	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	2013 introduction	6-spd AT to 8-speed AT

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Improved Transmissions (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$251	High Efficiency Gearbox	combined w. 6-speed auto with inmproved internals
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$638	8-spd AT	V8

Table 107. Reference Data for Vocational (Gasoline) Improved Transmissions

Class 4-6 Improved Transmissions (G)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$500 to $1,000	11, 28, 54, 55	6.2 V-8: gasoline PFI, fixed valve, 6-speed AT	2011$	2013 introduction	6-spd AT to 8-speed AT

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission
Prior Technology: None additional required

Class 4-6 Improved Transmissions (G)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$251	High Efficiency Gearbox	combined w. 6-speed auto with inmproved internals
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$638	8-spd AT	V8

Table 108. Reference Data for Vocational (Diesel) Improved Transmissions

Class 4-6 Improved Transmissions (D)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1,000 to $1,650	11, 28, 54, 55	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	2013 introduction	6-spd AT to 8-speed AT

Baseline Engine: 6.7L V8 turbo diesel, high pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 4-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Improved Transmissions (D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$251	High Efficiency Gearbox	combined w. 6-speed auto with inmproved internals
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$638	8-spd AT	V8

Table 109. Reference Data for Line Haul Improved Transmissions

Class 8 Improved Transmissions

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1000 to $2600	11, 28, 54, 55	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF, 10-spd MT	2011$	2014 introduction	10-spd manual to 16-spd manual or automatic

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Improved Transmissions

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. "The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks." Argonne National Laboratory. August 2002.	$750		Advanced transmission with lock-up, electronic controls, and reduced friction.
		$1,000	Advanced transmission	
54	National Research Council. "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles." 2010.	$500 to $1,650	6-speed to 8-speed AT	Class 2b pickup and van technology matrix
		$1,000 to $1,650	6-speed to 8-speed AT	Class 3-6 box and bucket truck technology matrix
11	NHTSA: 49 CFR Parts 523, 531, 533, 534, 536 and 537: Average Fuel Economy Standards: Passanger Cars and Light Trucks MY2011: Final Rule	$140 to $280	4-speed to 6-speed	TABLE 3-3 Fuel Consumption Technology Matrix—Pickup Trucks
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$1,000	Advanced transmission	
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	2,100 to $2,600	Incresed 2 gears (6 to 8 on Refuse)	Increase in 2 gears, Line haul not ideintfied in this category
		$5,800	Tractor trailer	NAS Summary of Technologies for 2015-2020

6.30 Automated Manual Transmission

Table 110. Reference Data for Vocational (Gasoline, Diesel) AMT

Class 4-6 Automated Manual Transmission

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$700 to $1,400	54, 55, 57	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	2014 introduction	Eaton Ultrashift AMT or similar

Baseline Powertrain: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 6-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Automated Manual Transmission

Reference Number	Reference	Value from Reference	Description	Additional Notes
54 research notes	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$4,000 (Freightliner) to $9,500 (Volvo)	AMT/Optimized Shift Strategy	found large variation in price estimates amoung manufacturers
54 research notes	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$600	AMT/Optimized Shift Strategy Class 2b	found large variation in price estimates amoung manufacturers
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	4,500 to $5,700	AMT/Optimized Shift Strategy	+70 lbs
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	4,500 to $5,700	AMT/Optimized Shift Strategy	Tractor Trailer Application+70 lbs
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$700 to $1400	AMT/Optimized Shift Strategy	Class 2b&3 application

Table 111. Reference Data for Line Haul AMT

Class 8 Automated Manual Transmission

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$4,500 to $5,700	54, 55, 57	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF, 10-spd MT	2011$	2014 introduction	Eaton Ultrashift AMT or similar

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Automated Manual Transmission

Reference Number	Reference	Value from Reference	Description	Additional Notes
54 research notes	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$4,000 (Freightliner) to $9,500 (Volvo)	AMT/Optimized Shift Strategy	found large variation in price estimates amoung manufacturers
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	4,500 to $5,700	AMT/Optimized Shift Strategy	+70 lbs
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	4,500 to $5,700	AMT/Optimized Shift Strategy	+70 lbs

6.31 Dual Clutch Automatic

Table 112. Reference Data for Vocational (Gasoline, Diesel) Dual Clutch Automatic

Class 4-6 Dual Clutch Automatic (G,D)

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$1,800 to $3,600	54, 55, 58	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	2014 introduction	Dual Clutch automatic tranmission with 10 gears

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 6-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Dual Clutch Automatic (G,D)

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$15,000	10-spd Automatic	Tractor Trailer Application+200 lbs
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$1,800	8-speed automatic transmission, reduced driveline friction, aggressive shift logic	Class 3 to Class 6 Straight Box Truck
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$15,000	Automatic Transmission	Tractor Trailer Application+200 lbs

Table 113. Reference Data for Line Haul Dual Clutch Automatic

Class 8 Dual Clutch Automatic

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$15,000 to $20,000	54, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF, 10-spd MT	2011$	2014 introduction	Dual Clutch automatic tranmission with 16 gears

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 10-speed MT

Prior Technology: None additional required

Class 8 Dual Clutch Automatic

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$15,000	10-spd Automatic	+200 lbs
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$15,000	Automatic Transmission	+200 lbs

6.32 Low Rolling Resistance Tires

Table 114. Reference Data for Class 2b&3 (Gasoline, Diesel) LRR Tires

Class 2b&3 LRR Tires (G,D)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$6 to $44	28, 55, 57	6.2 V-8: gasoline PFI	2011$	continuous improvement	LRR tires

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology: None additional required

Class 2b&3 Low Rolling Resistance Tires

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$180	V8 Gasoline	LRR Tires 2004 introduction
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$53	LRR	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$6	Level 1 LRR	40,000 Maintenance interval
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$44	Level 2 LRR	40,000 Maintenance interval

Table 115. Reference Data for Vocational (Gasoline, Diesel) LRR Tires

Class 4-6 LRR Tires (G,D)

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$6 to $44	28, 55, 57	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	continuous improvement	LRR tires

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 6-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Low Rolling Resistance Tires

Reference Number	Reference	Value from Reference	Description	Additional Notes
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$180	V8 Gasoline	LRR Tires 2004 introduction
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$53	LRR	
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$6	Level 1 LRR	40,000 Maintenance interval
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$44	Level 2 LRR	40,000 Maintenance interval

Table 116. Reference Data for Line Haul LRR Tires

Class 8 LRR Tires

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$25 to $35	28, 42, 45, 57	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	LRR tires

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Low Rolling Resistance Tires

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$30/tire	per tire price	assumes steel dualies
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$550	total incremental	assumes steel dualies
42	TIAX/UCS	$550	total incremental	assumes steel dualies
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$550		
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$6	Level 1 LRR	40,000 Maintenance interval
		$44	Level 2 LRR	40,000 Maintenance interval

6.33 Single Wide Tires

Table 117. Reference Data for Line Haul Single Wide Tires

Class 8 Single Wide Tires						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$90 to $192	7,28,42, 47, 54, 80	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Single Wide Low Rolling Resistance Tires, including compatible rims

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Single Wide Tires

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$225	per wheel and tire	Wide range of cost estimates: Freightliner has $900 per tractor; Navistar says $2,000/per vehicle; Volvo has $750/tire upcharge; Smartway claims cost-neutral compared to duals. WBS Tires, low rolling resistance
7	NESCCAF, ICCT, Southwest Research Institute, and TIAX. "Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions." Washington, D.C.: International Council on Clean Transportation (ICCT). October 2009.	$1,120	per vehicle	16 tires and wheels become 8 (excluding the front axle).
42	TIAX/UCS	$1070 to $1210	Tractor Trailer Low-Rolling-Resistance Tires or Super Single	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$700	Super Single	Excluding the front axle.
80	National Research Council. "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: First Report." The National Academies Press Pre-Publication copy, 2014.	$360	Wide base single tires with Ferrous Wheel	Tandem Cost
		$768	Wide base single tires with Aluminum Wheel	Tandem Cost

6.34 Automated Tire Inflation

Table 118. Reference Data for Vocational (Gasoline, Diesel) ATI

Class 4-6 Automated Tire Inflation System

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$400 to $1200	54, 55, 57, 58	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	2014 introduction	Automated Tire Inflation systems continually monitor and adjust the level of pressurized air in tires.

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 6-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Automated Tire Inflation System

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$300 to $400	trailer only	
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$4000 to $5000	tractor	
3, 4, 5, 7	TIAX site visits during research for National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$900 to $1,000	Tire monitoring system	steel std duals
42	TIAX/UCS	$900	tractor + trailer	
76	Sharpe, B., and M. Roeth, "Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector", International Council on Clean Transportation and North American Council for Freight Efficiency report, February 2014	$700 to $1,000	Trailer only (700 for high volume and 1000 for low volume)	Automatic tire inflation system ($750-$1000 for tire pressure monitoring system)
77	Brady, S., D. Van Order, and A. Sharp, "Advanced Sensors and Applications: Commercial Motor Vehicle Tire Pressure Monitoring and Maintenance," US DOT Federal Motor Carrier Safety Administration report #FMCSA-RRT-13-021, February 2014	$750	Trailer only	Automatic tire inflation system ($785 for tractor tire pressure monitoring system)

Table 119. Reference Data for Line Haul ATI

Class 8 Automated Tire Inflation System

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$750 to $1535	42, 54, 76, 77	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	2014 introduction	Automated Tire Inflation systems continually monitor and adjust the level of pressurized air in tires.

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Automated Tire Inflation System

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$300 to $400	trailer only	
		$4000 to $5000	tractor	
42	TIAX/UCS	$900	tractor + trailer	
76	Sharpe, B., and M. Roeth, "Costs and Adoption Rates of Fuel-Saving Technologies for Trailers in the North American On-Road Freight Sector", International Council on Clean Transportation and North American Council for Freight Efficiency report, February 2014	$700 to $1,000	Trailer only (700 for high volume and 1000 for low volume)	Automatic tire inflation system ($750-$1000 for tire pressure monitoring system)
77	Brady, S., D. Van Order, and A. Sharp, "Advanced Sensors and Applications: Commercial Motor Vehicle Tire Pressure Monitoring and Maintenance," US DOT Federal Motor Carrier Safety Administration report #FMCSA-RRT-13-021, February 2014	$750	Trailer only	Automatic tire inflation system ($785 for tractor tire pressure monitoring system)

6.35 Weight Reduction

Table 120. Reference Data for Class 2b&3 Weight Reduction

Class 2b&3 Weight Reduction

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$1000 to $3000	28,42, 45, 58, 69	6.2 V-8: gasoline PFI	2011$	continuous improvement	Weight Reducion of 500 lbs. with the use of advanced materials

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology:

Class 2b&3 Weight Reduction

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$4,770	Material substitution—1,000 lb.	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,300	Material substitution—5% improvement	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$2,000	lightweight materials	3000 lbs reduction
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,000 - $2,000	class 2b Materials substitution - Weight Reduction - 5% , $2 to $4/lb	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$2,000 - $4,000	tractor trailer weight reduction 470- 940 lbs: $4-$8/lbs	

Table 121. Reference Data for Vocational Weight Reduction

Class 4-6 Weight Reduction

Item	Cost	Reference Number	Baseline	Cost Basis	Volume Assumptions	Technology Content
System cost	$4000 to $8000	28,42, 45, 58, 69	6.2 V-8: gasoline PFI	2011$	continuous improvement	Weight Reducion of 1000 lbs. with the use of advanced materials

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission

Prior Technology:

Class 4-6 Weight Reduction

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$4,770	Material substitution — 1,000 lb.	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$1,300	Material substitution — 5% improvement	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$2,000	lightweight materials	3000 lbs reduction
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$1,000 - $2,000	Class 2b Materials substitution - Weight Reduction - 5% , $2 to $4/lb	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$4,000 - $8,000	Class 3-6 Box and bucket reduction per 1000 lbs: $4-$8/lbs	

Table 122. Reference Data for Line Haul Weight Reduction

Class 8 Weight Reduction

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$8000 to $16000	54, 45, 58, 69	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Weight Reduction of 2000 lbs. with the use of advanced materials

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 Weight Reduction

Reference Number	Reference	Value from Reference	Description	Additional Notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$13,500	Material substitution — 2,500 lb.	
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$2,000	Lightweight materials	3000 lbs reduction
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$8,000 - $16,000	Tractor trailer weight reduction 1,000- 2,000 lbs: $4-$8/lbs	
69	"Assessment of Fuel Economy Technologies for Medium- and Heavy- Duty Vehicles", TIAX report Report to National Academy of Sciences, November 2009	$8,000 - $16,000	Tractor trailer weight reduction 1,000- 2,000 lbs: $4-$8/lbs	

6.36 6x2 Tractors

Table 123. Reference Data for Line Haul 6x2 Tractors

Class 8 6x2 Axle Configuration

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$300 to $2,000	55, 58, 67, 68	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Single drive axle instead of tandem drive, application to most applications except off-road for traction reasons. 6x2 versus 6x4 axle set-up

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology:

Class 8 6x2 Axle Configuration

Reference Number	Reference	Value from Reference	Description	Additional Notes
55	National Research Council. "Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy." 2011.	$200-$300	Single drive axle	
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$200-$300	Single drive axle	
67	North American Council for Freight Efficiency, "Confidence Report on 6x2 Axles," January 13, 2014	$1,000 - $2,000	"Dead axle" 6x2 compared to 6x4	6x2 may eventually be cost-neutral compared to 6x4 in the future.
67	North American Council for Freight Efficiency, "Confidence Report on 6x2 Axles," January 13, 2014	Late MY ($11,000), MY07-09 ($5,500), MY04-06 $700	Resale value of 6x2 tractors when compared to 6x4 tractors.	6x2 may have lower resale in many cases.
68	http://www.truckinginfo.com/channel/fuel-smarts/article/story/2013/05/rise-of-the-6x2.aspx, accessed 11/2013	($5,500)	residual value of 6x2 tractors when compared to 6x4 tractors in todays market	

6.37 Chassis Friction Reduction and Improved Lube

Table 124. Reference Data for Class 2b&3 (Gasoline, Diesel) Chassis Friction Reduction and Improved Lube

Class 2b&3 Low Friction Axles & Lubricants						
Item	**Incremental Price**	**Reference Number**	**Baseline**	**Price Basis**	**Volume Assumptions**	**Technology Content**
System cost	$100 to $400	45, 28, 42, 54, 57, 58	6.2 V-8: gasoline PFI	2011$	continuous improvement	Synthetic lube vs. standard, most efficient axles vs. standard

Baseline Engine: 6 to 8L gasoline engine, naturally aspirated, port fuel injection; 4-spd automatic transmission
Prior Technology: None additional required

Class 2b&3 Low Friction Axles & Lubricants

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	Transmission Friction Reduction through Low-Viscosity Transmission Lubricants	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$500	Class7 & 8	Internal friction reduction through better lubricants and improved bearings.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	0 to $500	5-8L Gasoline Engine	research notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$110 to $500	Reduced Friction	Tractor Trailer
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$6	Low Friction Lub	Engine oil Only
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$110 to $500	Reduce friction - lubricants, bearings, etc	Continuous Improvement - 5-8L Gasoline Engine

Table 125. Reference Data for Vocational (Gasoline, Diesel) Chassis Friction Reduction and Improved Lube

Class 4-6 Low Friction Axles & Lubricants

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$100 to $400	45, 28, 42, 54, 57, 58	6.7L V8 Turbo Diesel, High Pressure direct inject, 6-speed AT	2011$	Continuous Improvement	Synthetic lube vs. standard, most efficient axles vs. standard

Baseline Engine: 6.7L V8 Turbo Diesel, High pressure common rail fuel injection, direct inject; multi-stage turbocharger; cooled EGR + DPF; 6-spd automatic transmission

Prior Technology: None additional required

Class 4-6 Low Friction Axles & Lubricants

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	Transmission Friction Reduction through Low-Viscosity Transmission Lubricants	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$500	Class7 & 8	Internal friction reduction through better lubricants and improved bearings.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	0 to $500	5-8L Gasoline Engine	research notes
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$110 to $500	Reduced Friction	Tractor Trailer
57	National Highway Traffic Safety Administration. "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards." 49 CFR Parts 523, 531, 533, et al. and 600, final rule.	$6	Low Friction Lub	Engine oil Only
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	$110 to $500	Reduce friction - lubricants, bearings, etc	Continuous Improvement - 5-8L Gasoline Engine

Table 126. Reference Data for Line Haul Chassis Friction Reduction and Improved Lube

Class 8 Low Friction Axles & Lubricants

Item	Incremental Price	Reference Number	Baseline	Price Basis	Volume Assumptions	Technology Content
System cost	$100 to $400	11, 28, 42, 54, 58	11 to 15L diesel engine, DI; turbo; cooled EGR + SCR, DPF	2011$	continuous improvement	Synthetic lube vs. standard, most efficient axles vs. standard

Baseline Engine: 11 to 15L diesel engine, direct inject; multi-stage turbocharger; cooled EGR + SCR, DPF; 20 to 23 Bar BMEP

Prior Technology: None additional required

Class 8 Low Friction Axles & Lubricants

Reference Number	Reference	Value from Reference	Description	Additional Notes
45	Frey, Kuo, "Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation," NC State University prepared for U.S. DOT, October 2007 and references within	$500	Transmission Friction Reduction through Low-Viscosity Transmission Lubricants	
28	Vyas, A., C. Saricks, and F. Stodolsky. “The Potential Effect of Future Energy-Efficiency and Emissions-Improving Technologies on Fuel Consumption of Heavy Trucks.” Argonne National Laboratory. August 2002.	$500	Class 7 & 8	Internal friction reduction through better lubricants and improved bearings.
54	National Research Council. “Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.” 2010.	$100 to $400	5-8L Gasoline Engine	Packaged with all Engine Friction Reduction
		$0 to $1,000	Reduced Friction	Tractor Trailer
58	National Highway Traffic Safety Administration. "Factors and Considerations for Establishing a Fuel Efficiency Regulatory Program for Commercial Medium- and Heavy-Duty Vehicles." October 2010.	0 to $500	Reduce friction - lubricants, bearings, etc	Continuous Improvement - Same cost for 6-9 L Diesel and 11-15 L Diesel

DOT HS 812 177
June 2015

U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

11687-062215-v1a