Evolution of HDV GHG / Fuel Economy Standards: The Importance of US HDV Rule

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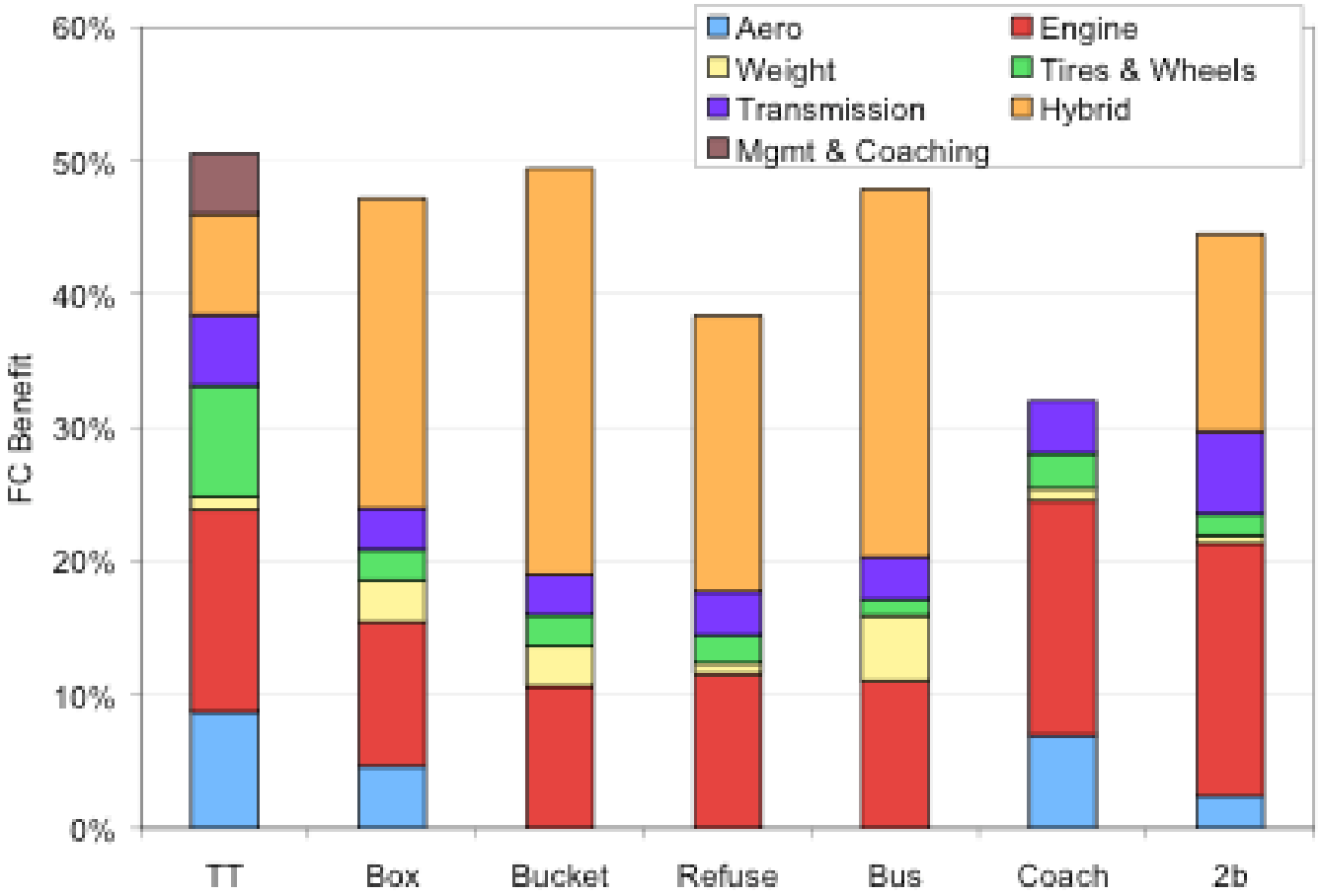
Global Regulatory Landscape

Country/Region	Regulation Type	2010	2011	2012	2013	2014	2015	2016	2017	2018
Japan	Fuel economy						Regulation implemented starting MY 2015			
United States	GHG/Fuel efficiency	Standard proposal	Final rule			Regulation implemented starting MY 2014 (mandatory DOT program starts MY 2016)				
Canada	GHG/Fuel efficiency		Standard proposal	Final rule		Regulation implemented starting MY 2014				
China	Fuel consumption	Test procedure finalized	Industry standard proposal	Standard proposal	Final rule		Regulation implemented starting MY 2015			
European Union	GHG	Technical studies			Test procedure finalized	Mandatory efficiency reporting and regulatory development				
California	End-user purchase requirements	Requirements for tractors and trailers (MY 2011+)			Additional reqs. for existing tractors and trailers (<MY 2010)				Additional reqs. for existing trailers and reefers (<MY 2010)	

US Technology Assessment

- National Academy of Sciences Report (March 2010) found 35 – 50% improvement could be achieved in the 2015 to 2020 timeframe



National Academy of Sciences (2010) FIGURE S-1 Comparison of 2015-2020 New Vehicle Potential Fuel Savings Technology for Seven Vehicle Types: Tractor Trailer (TT), Class 3-6 Box (Box), Class 3-6 Bucket (Bucket), Class 8 Refuse (Refuse), Transit Bus (Bus), Motor Coach (Coach), and Class 2b Pickups and Vans (2b). Also, for each vehicle class, the fuel consumption benefit of the combined technology packages is calculated as follows: % FCpackage = 1 – (1 - %FCtech 1)(1 - %FCtech2)(1 - %FCtech N) where %FCtech x is the percent benefit of an individual technology. SOURCE: TIAX (2009) ES-4.

Elements of US Rule: Three Vehicle Categories

Class 7/8 Tractors

Class 2B/3 Pickup Trucks and Vans

Everything Else!

US HDV GHG / Fuel Economy Rule

US program is 4 rules bundled together: Engine, Tractor, Vocational, Pickups and Vans.

Vehicle Type	Subclass		Engine	Vehicle only	Vehicle + Engine
Tractors	Day Cabs	Class 7 Low/mid Roof	6%	4%	10.3%
		Class 7 High Roof	6%	7%	13.0%
		Class 8 Low/mid Roof	6%	3%	9.1%
		Class 8 High Roof	6%	8%	13.6%
	Sleeper	Class 8 Low Roof	6%	12%	17.5%
		Class 8 Mid Roof	6%	12%	18.0%
		Class 8 High Roof	6%	17%	23.4%
Vocational	Light HD	Class 2b - 5	9%	0%	8.6%
	Medium HD	Class 6 - 7	9%	0%	8.9%
	Heavy HD	Class 8	5%	1%	5.9%
Pickups & Vans	Gasoline				12.0%
	Diesel				17.0%

Largest reductions – and regulatory attention – focus on the vehicle categories that use the most fuel. In HD sector, combination tractors and pickup trucks use about ¾ of the fuel.

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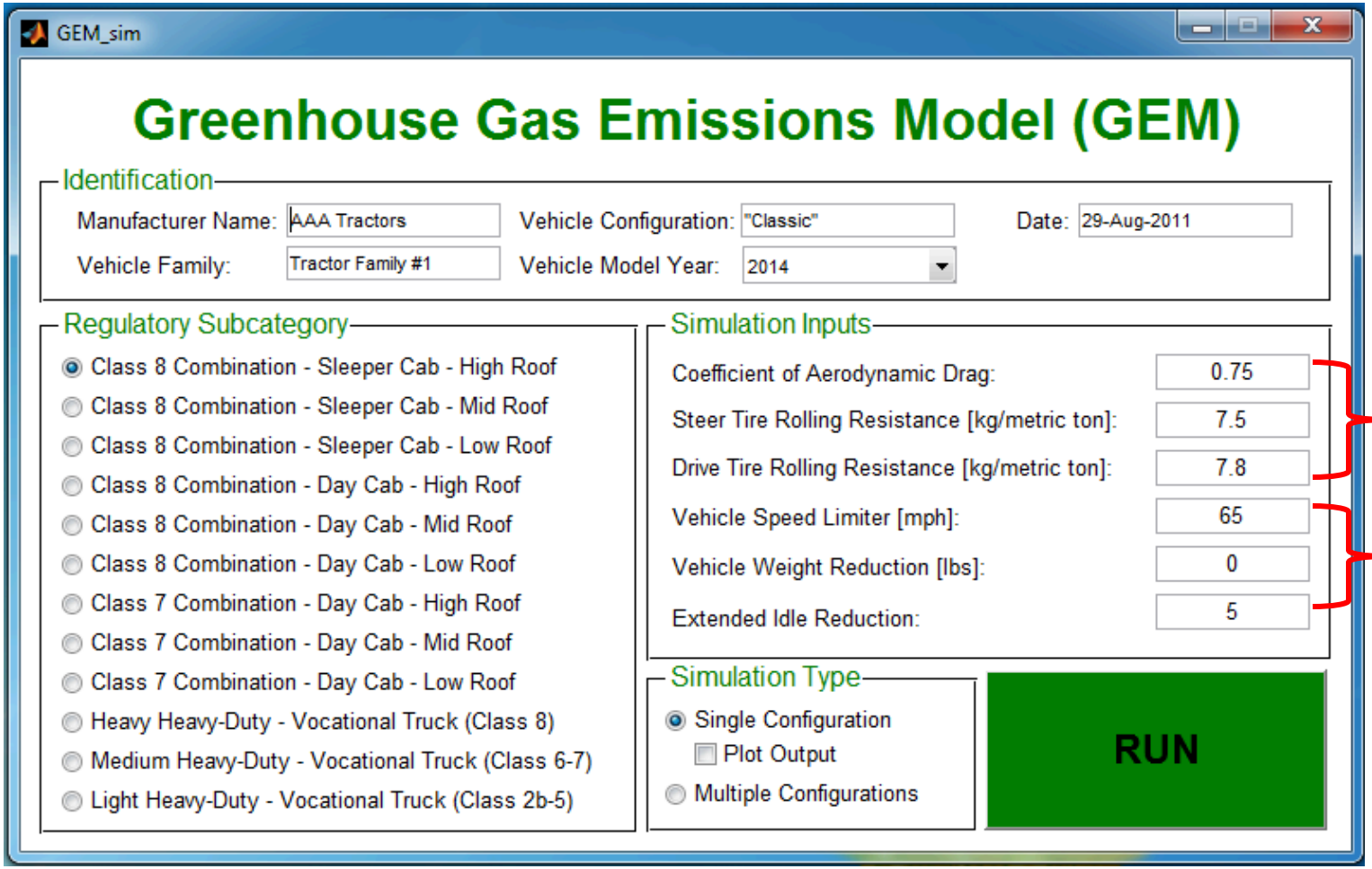
Baseline Engine + Vehicle (MY2010)

REGULATORY CATEGORY	BASELINE CONFIGURATION
Heavy-Duty Diesel Engine	• Electronic control • SCR/EGR/DPF exhaust aftertreatment system which achieves 2010MY criteria emissions standards • Turbocharged with variable geometry turbocharger • 2200 bar injection pressure • Single fixed overhead valve • Belt driven accessories
Combination Tractor	• Aerodynamics: tractor fleet consists of 25% Bin I, 70% Bin II, and 5% Bin III • Tires: Dual tires with steel wheels, CRR=7.8 (steer) and 8.2 (drive) • Body and Chassis: steel components • Idle Reduction: Currently 30% of sleeper cabs contain an idle reduction technology, but not necessarily an automatic engine shutoff • Vehicle Speed Limiter: 0% of tractors contain a non-override VSL set at below 65 mph

Compliance Example: Working with the GEM



Determined by testing

"yes/no" parameters

Compliance Example: Tractor #1

"Classic" style

Drag inducing features: flat grill and bumper, protruding elements

Frontal area

Drag coefficient

Step 1: coastdown testing to determine $C_d * A$

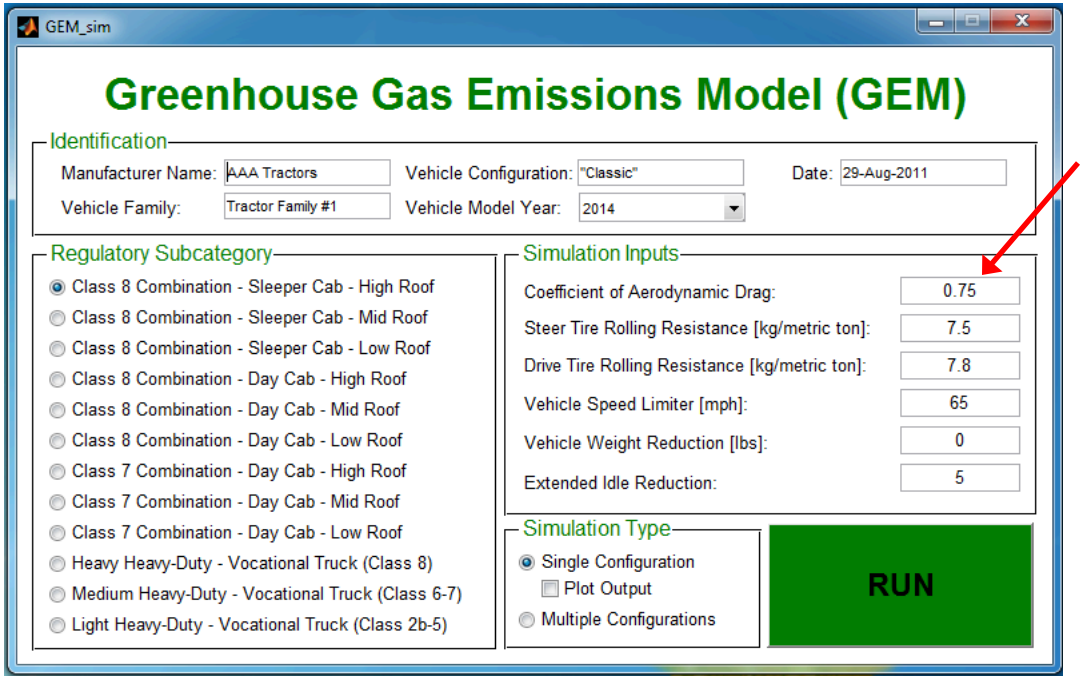
$C_d * A = 7.7$ → this tractor belongs to "Bin I"

	Class 7	Class 8	
	Day Cab	Day Cab	Sleeper Cab
	High Roof	High Roof	High Roof
Aerodynamic Test Results (C_dA in m^2)			
Bin I	≥ 8.0	≥ 8.0	≥ 7.6
Bin II	7.1 – 7.9	7.1 – 7.9	6.7 – 7.5
Bin III	6.2 – 7.0	6.2 – 7.0	5.8 – 6.6
Bin IV	5.6 – 6.1	5.6 – 6.1	5.2 – 5.7
Bin V	≤ 5.5	≤ 5.5	≤ 5.1

Compliance Example: Tractor #1

Step 2: select C_d values in table below based on Bin #, as determined by coastdown testing

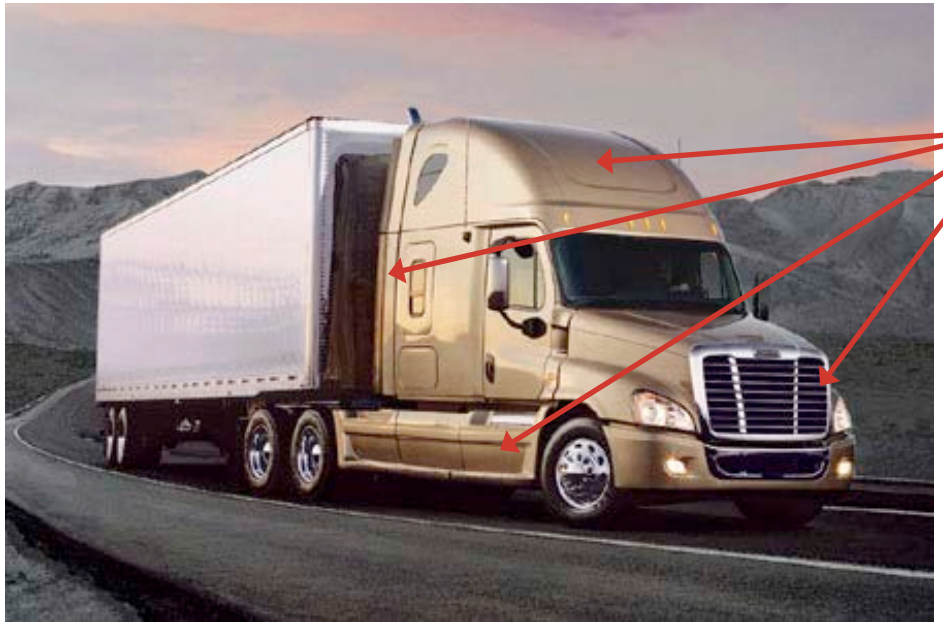
	Class 7	Class 8	
	Day Cab	Day Cab	Sleeper Cab
	High Roof	High Roof	High Roof
Aerodynamic Input to GEM (C_d)			
Bin I	0.79	0.79	0.75
Bin II	0.72	0.72	0.68
Bin III	0.63	0.63	0.60
Bin IV	0.56	0.56	0.52
Bin V	0.51	0.51	0.47



Enter "0.75" into aerodynamic coefficient field in GEM simulation model

Compliance Example: Tractor #2

"SmartWay" style



Drag reducing features: smoothed front grill and bumper, roof fairing, chassis fairings, side extenders, etc.

In the coastdown test, Tractor #2 will have a lower drag result than Tractor #1 because of all of these aerodynamic enhancements

$C_d * A = 6.1$ → this tractor belongs to "Bin III"

	Class 7	Class 8	
	Day Cab	Day Cab	Sleeper Cab
	High Roof	High Roof	High Roof
Aerodynamic Test Results (C_dA in m^2)			
Bin I	≥ 8.0	≥ 8.0	≥ 7.6
Bin II	7.1 – 7.9	7.1 – 7.9	6.7 – 7.5
Bin III	6.2 – 7.0	6.2 – 7.0	5.8 – 6.6
Bin IV	5.6 – 6.1	5.6 – 6.1	5.2 – 5.7
Bin V	≤ 5.5	≤ 5.5	≤ 5.1

Compliance Example: Tractor #2

Step 2: select C_d values in table below based on Bin #, as determined by coastdown testing

	Class 7	Class 8	
	Day Cab	Day Cab	Sleeper Cab
	High Roof	High Roof	High Roof
Aerodynamic Input to GEM (C_d)			
Bin I	0.79	0.79	0.75
Bin II	0.72	0.72	0.68
Bin III	0.63	0.63	0.60
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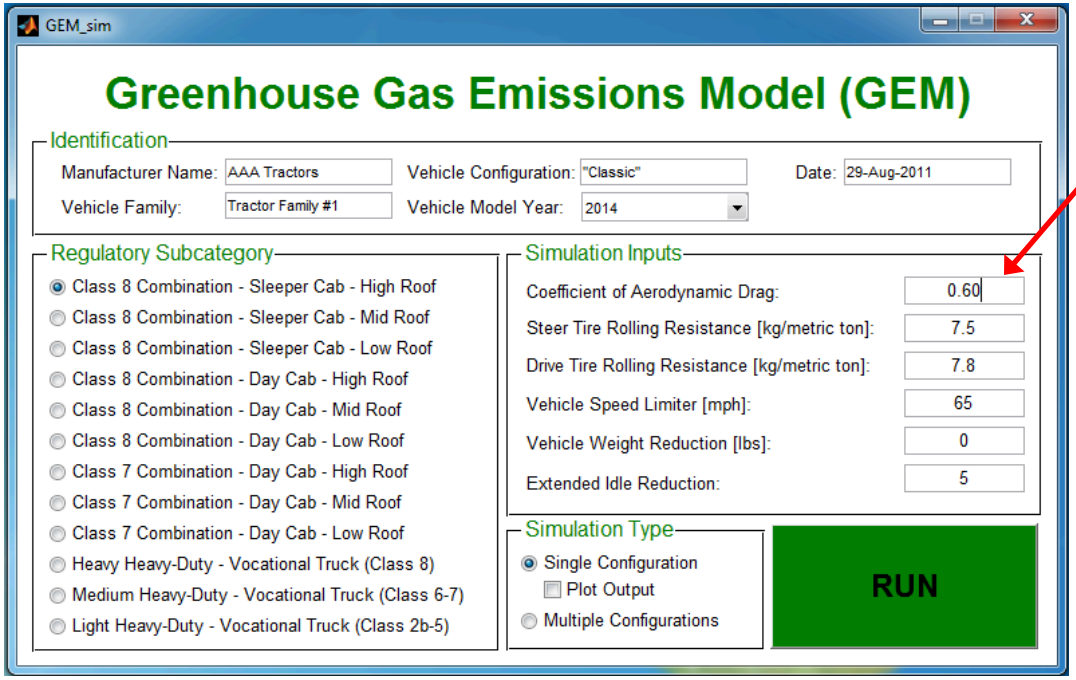


Enter "0.60" into aerodynamic coefficient field in GEM simulation model

Compliance Example: Tractor #1

Step 3: fill in rolling resistance coefficients (C_{RR}) for steer and drive tires. C_{RR} values are determined using the ISO 28580:2009 test procedure.

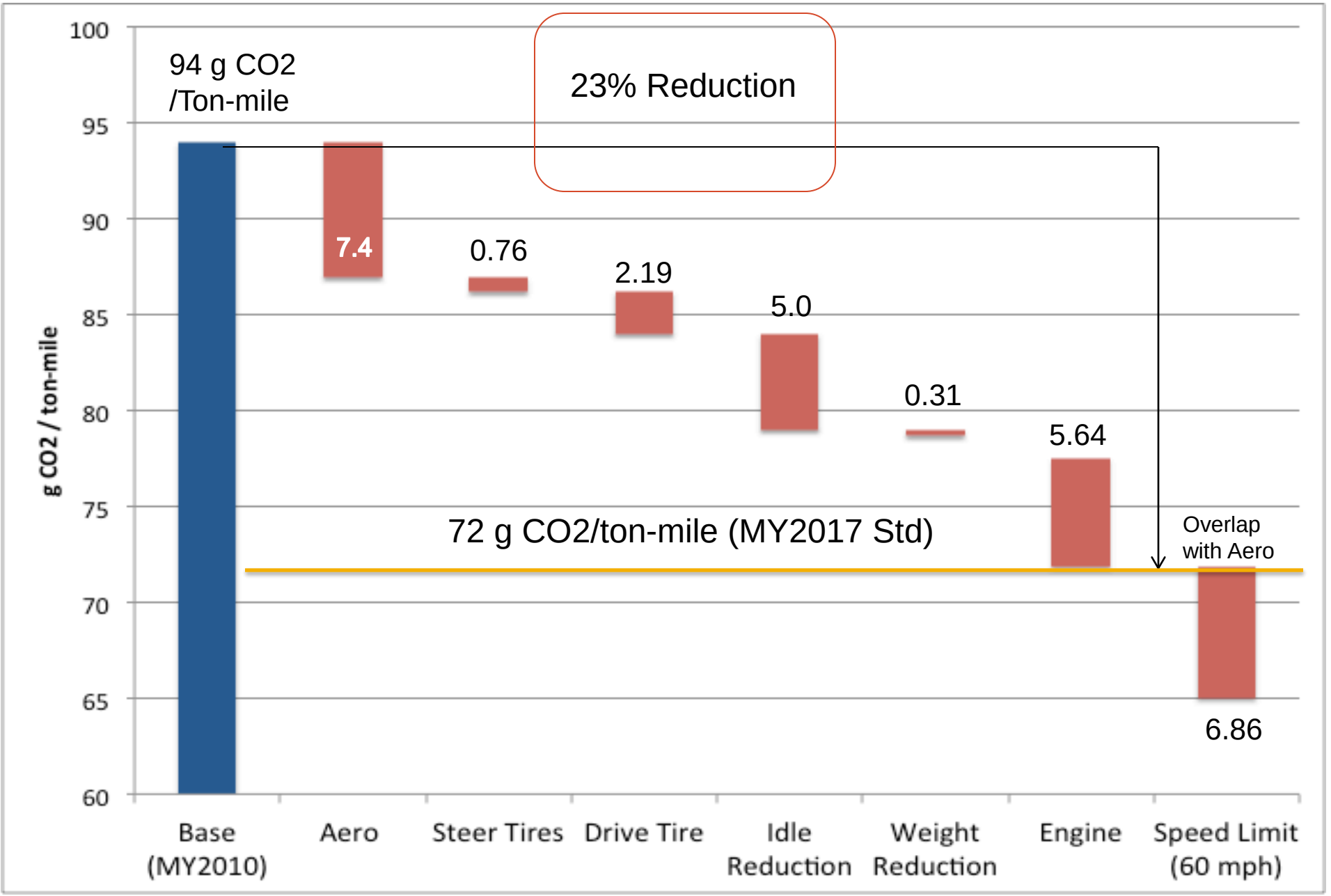
Compliance Example: Tractor #1

Step 4: manufacturers will get weight reduction credit for using aluminum and high strength steel. For places where these materials are used on the vehicle, weight reduction credits will be given based on the default values in the tables below.

Weight Reduction Technology		Weight Reduction (lb per tire/wheel)
Single Wide Drive Tire with…	Steel Sheel	84
	Aluminum Wheel	139
	Light Weight Aluminum Wheel	147
Steer Tire or Dual Wide Drive Tire with…	High Strength Steel Wheel	8
	Aluminum Wheel	21
	Light Weight Aluminum Wheel	30

Weight Reduction Technologies	Aluminum Weight Reduction (lb.)	High Strength Steel Weight Reduction (lb.)
Door	20	6
Roof	60	18
Cab Rear Wall	49	16
Cab Floor	56	18
Head Support Structure	15	3
Fairing Support Structure	35	6
Instrument Panel Support Structure	5	1
Brake Drums - Drive (4)	140	11
Brake Drums - Non Drive (2)	60	8
Frame Rails	440	87
Crossmember - Cab	15	5
Crossmember - Suspension	25	6

Class 8 Tractor Sleeper Cab High Roof Compliance Pathway



Class 8 Sleeper Cab High Roof Standards Predicated on:

Aero - Aggressive aerodynamic technology penetration (10% Bin II, 70% Bin III, 20% Bin IV).

Steer and Drive Tires RR - Does not require 100% penetration of low rolling resistance tires, predicated penetration rates vary by application.

Weight Reduction – 400 lbs weight reduction.

Extended idle reduction – Credit is 5 g CO2 for extended idle reduction + 5 minute automatic engine shut off. Only for tractor sleeper cabs.

Engine Standards – 6% improvement in 2017.

Vehicle Speed Limiter – Not predicated in final standards. Only available for combinations tractors (not vocational).

Closing Thoughts

- HDV GHG / fuel economy standards are a critically important area of regulatory development for the US and globally.
- The search for continually improving upon regulatory design (metric, cycle, test method, etc) will continue for the next 5 to ten years at least.
- Important questions remain:
  - Simulation Modeling v. Chassis Dyno
  - Performance v. Technology Standards
  - Test method accuracy and repeatability
  - Incorporating trailers
  - Hybrid technology development and incorporation
  - Opportunities for global alignment of programs