

Diesel Technology Report
for the
California Energy Commission
Integrated Energy Policy Report

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Agenda

- * Overview
- * Observations on diesel fuel and technology
- * New Research – Current and Future Benefits of Diesel Technology For California
- * Conclusions

About the Diesel Technology Forum

www.dieselforum.org

- *AGCO
- *BP
- *BorgWarner
- *BOSCH
- *Caterpillar Inc.
- *Chrysler
- *Cummins Inc
- *Daimler
- *Delphi Automotive
- *Deere & Company
- *Ford Motor Company
- *General Motors
- *Honeywell
- *Johnson Matthey
- *Mazda North American Operations
- *Navistar
- *Terra Environmental
- *Volvo Group
- *Volkswagen Group of America
- *Yanmar

Allied Members

- *Association of Diesel Specialists
- *National Biodiesel Board
- *Western States Petroleum Association

Definitions Used Today

* Light Duty



Cars, SUVs, and Heavy-duty pick up trucks (Class 1-2)



* Heavy Duty



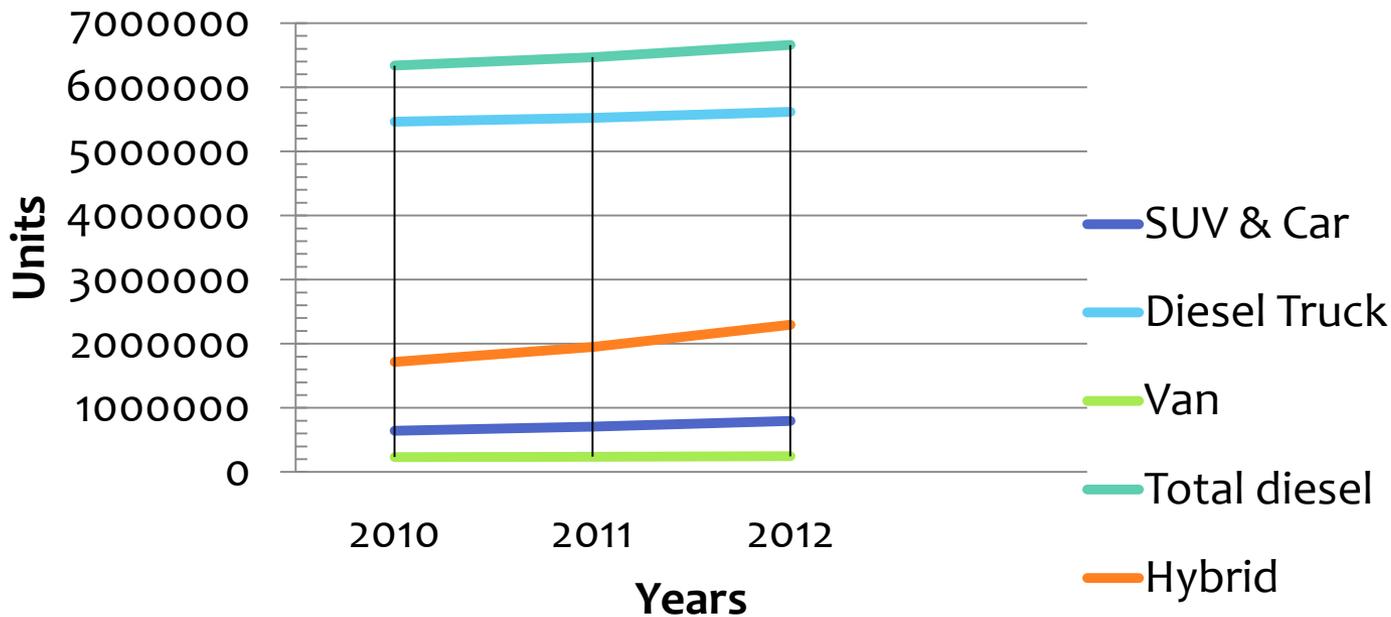
Medium, Heavy-duty and Vocational Commercial Trucks Weight Class 3-8



Consumer acceptance of new clean diesel technology in light-duty vehicles is growing

Registrations of Diesel Cars and Trucks

>3.5 that of hybrids



* Diesel car registrations up 24%;
Hybrids up 33%

2010-2012

Source R.L. Polk and Company, March 2013

California: #1 in Diesel Vehicle Registrations & Fastest Growing Car & SUV (2012)

Top 10 states by numbers of diesel vehicles **registered** 2012

- * CALIFORNIA (84,000)
- * TEXAS
- * FLORIDA
- * NEW YORK
- * ILLINOIS
- * PENNSYLVANIA
- * OHIO
- * MICHIGAN
- * NEW JERSEY
- * NORTH CAROLINA

Fastest growing states for diesel cars and SUV registrations (2010-2012)

- * CALIFORNIA
- * MASSACHUSETTS,
- * NEW YORK



Source: 2012 Data from R.L. Polk and Company

New Research on Current and Projected Future Fuel Savings and GHG reduction Benefits of Light & Heavy Duty Diesel Vehicles



Final

***U.S. Light & Heavy Duty Diesel
Engine Benefits***



June 25, 2013

DETROIT • CHICAGO • FRANKFURT • SHANGHAI • BEIJING

Light Duty Objectives

Analyze historic fuel savings and CO2 reductions for 2005-2012 light duty diesel vehicles

- Aggregated by cars, trucks, and HD pickups
- National and state specific fuel savings
 - *Targeted states to include CA, NY, TX, VA*

Project potential future fuel savings and CO2 reductions for 2013-2020 for the same scenario of vehicles and markets as above

- This projection will be based on available 3rd party forecasting information, CAFÉ regulation estimates for diesel technology adoption, and projected future diesel powertrain announcements

Biodiesel benefit analysis

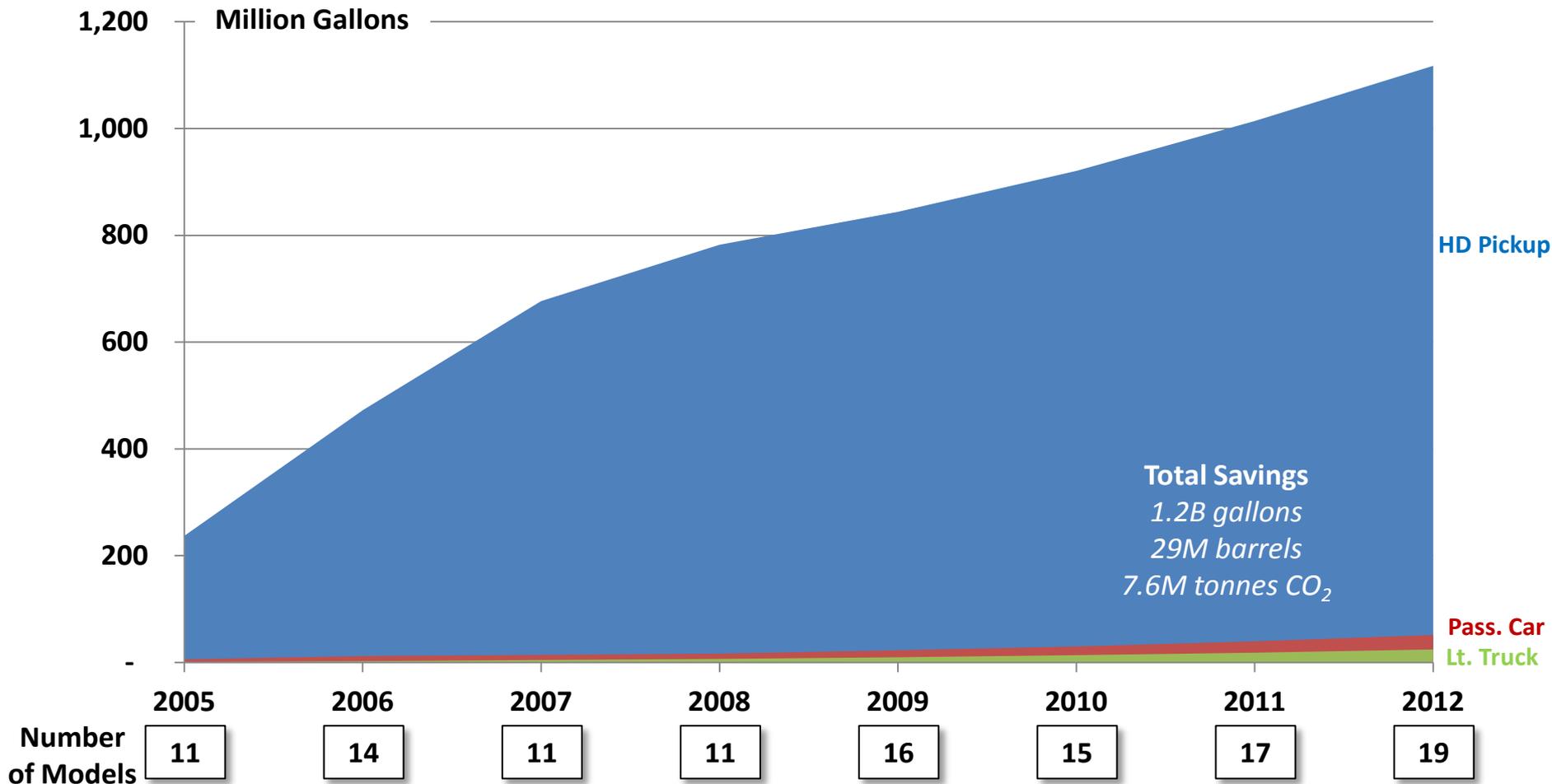
- The above forecasting scenario will then be run with various levels of biodiesel in place of B0 reference fuel and the benefits will be recalculated for B5.

Analyze the potential fuel and CO2 savings and generate an appropriate comparisons

Diesel engines sold between 2005 and 2012 have saved ~1.2B gallons of fuel.

U.S. Market

Cumulative Diesel Savings – U.S. Market



Total savings for cars, light trucks, and HD pickups
 Assumes average VMT of 15,000 miles/year

Gasoline = 8,887gCO₂ /gal.
 Diesel = 10,180gCO₂ /gal.



Putting the numbers into perspective...

U.S. Market ■

The 2.9M light-duty new clean diesels introduced from 2005 through 2012 have saved the American consumer:

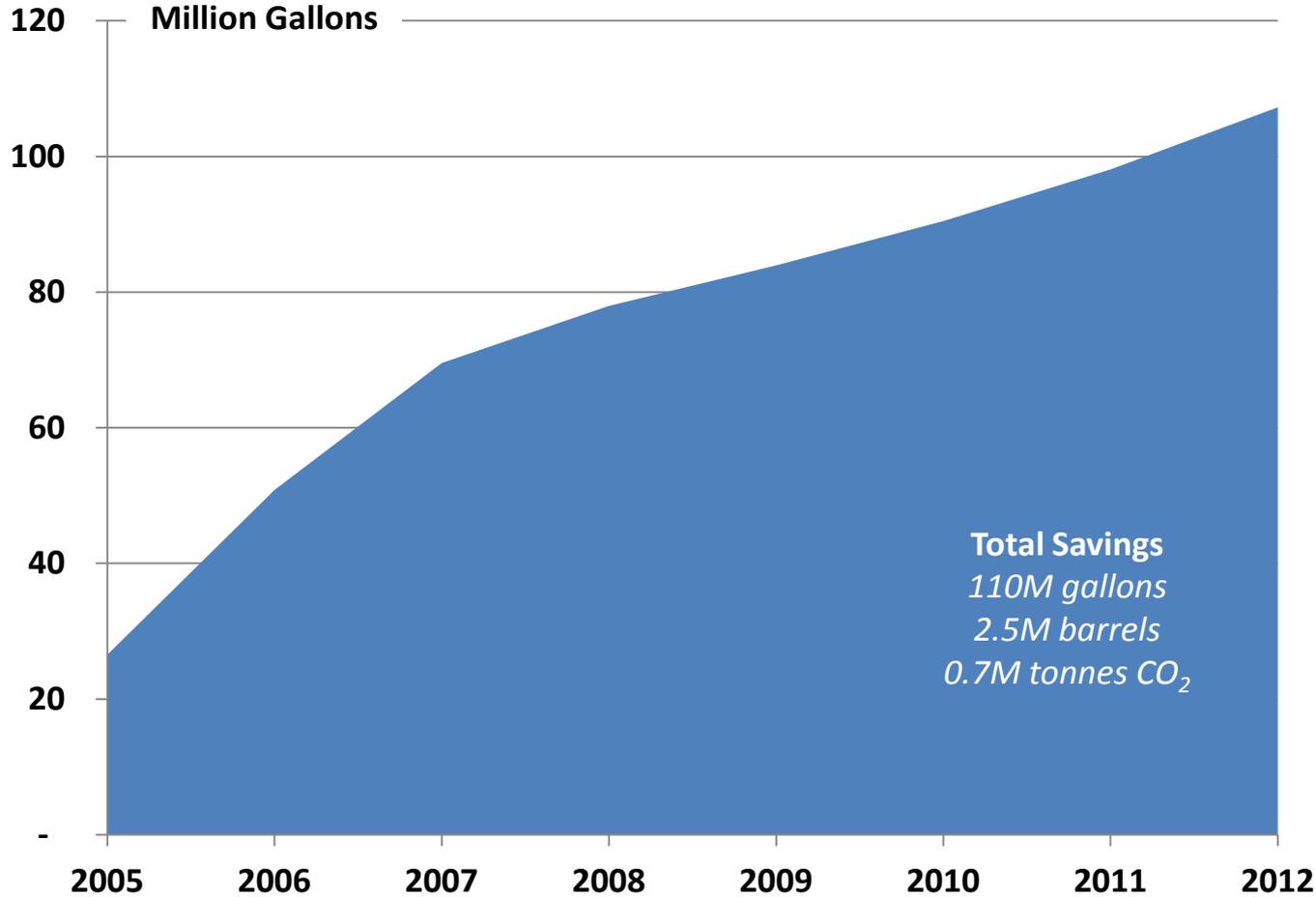
- 7.6M tonnes of CO₂
- 1.2B gallons of gasoline
- 29M barrels of crude oil

These reductions are equivalent to:

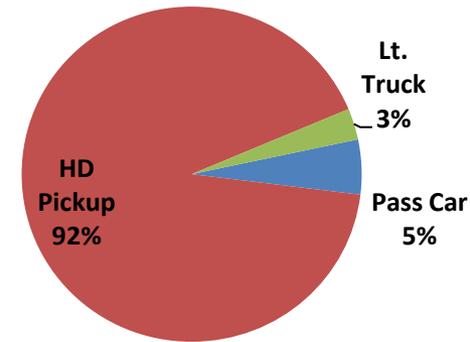
- Removing 1.6M vehicles from the road for a year
- Carbon sequestration from 6.2M acres of forests
 - *This is an equivalent forest the size of Vermont*
- Removing the annual emissions from 2.2 coal fired power plants
 - *32,000 railcars of coal stretching continuously from Boston to Philadelphia*
- Roughly 11% of the Strategic Petroleum Reserve for sweet crude.

Since 2005, new diesel vehicles in the state of California have saved the environment nearly 700,000 tonnes of CO₂.

Cumulative Diesel Savings – California



Benefits by Vehicle Type



Total savings for cars, light trucks, and HD pickups
 Assumes average VMT of 15,000 miles/year

Gasoline = 8,887gCO₂ /gal.
 Diesel = 10,180gCO₂ /gal.



Passenger car diesel owners will stop to refuel 9 less times per year.

Passenger Car

| Savings to the clean diesel buyer | Per Year | 54 Month Ownership |
|--|----------|--------------------|
| Fuel savings - gallons | 128 | 578 |
| Fuel savings - bbl | 3 | 14 |
| Fuel cost savings | \$340 | \$1,530 |
| CO ₂ savings – metric tones | 0.6 | 2.5 |
| Refueling trips saved | 9 | 40 |

Assumptions:

- Fuel savings based on Polk sales weighted average of diesel vehicles for 2012.
- DOE Average gasoline and diesel prices for the U.S. as of 4/29/13. Gasoline = \$3.59 Diesel = \$3.85
- CO₂ conversion based on EPA's content per gallon.
- While not specifically evaluated in this study, other reports and data from used car sales indicate that diesel powered vehicles retain a higher residual value compared to gasoline counterparts.

Customers that choose the light duty diesel in a SUV will reduce their carbon footprint by 3.5 metric tons.

Light Duty Truck

| Savings to the clean diesel buyer | Per Year | 54 Month Ownership |
|---------------------------------------|----------|--------------------|
| Fuel savings - gallons | 192 | 860 |
| Fuel savings - bbl | 4.6 | 21 |
| Fuel cost savings | \$502 | \$2,300 |
| CO ₂ savings – metric tons | 0.8 | 3.5 |
| Refueling trips saved | 8 | 35 |

Assumptions:

- Fuel savings based on Polk sales weighted average of diesel vehicles for 2012.
- DOE Average gasoline and diesel prices for the U.S. as of 4/29/13. Gasoline = \$3.59 Diesel = \$3.85
- CO₂ conversion based on EPA's content per gallon.
- While not specifically evaluated in this study, other reports and data from used car sales indicate that diesel powered vehicles retain a higher residual value compared to gasoline counterparts.

The average diesel engine in a heavy duty pickup saves the customer ~\$5,600 in fuel over the typical ownership cycle.

Heavy Duty Pickup Truck

| Savings to the clean diesel buyer | Per Year | 54 Month Ownership |
|--|----------|--------------------|
| Fuel savings - gallons | 425 | 1,900 |
| Fuel savings - bbl | 10 | 45 |
| Fuel cost savings | \$1,307 | \$5,600 |
| CO ₂ savings – metric tones | 2.7 | 12.2 |
| Refueling trips saved | 15 | 66 |

Assumptions:

- Fuel savings based on Polk sales weighted average of diesel vehicles for 2012.
- DOE Average gasoline and diesel prices for the U.S. as of 4/29/13. Gasoline = \$3.59 Diesel = \$3.85
- CO₂ conversion based on EPA's content per gallon.
- While not specifically evaluated in this study, other reports and data from used car sales indicate that diesel powered vehicles retain a higher residual value compared to gasoline counterparts.

National – Light Duty

Selected States – Light Duty

Savings to Diesel Buyer – Light Duty

National – Forecast

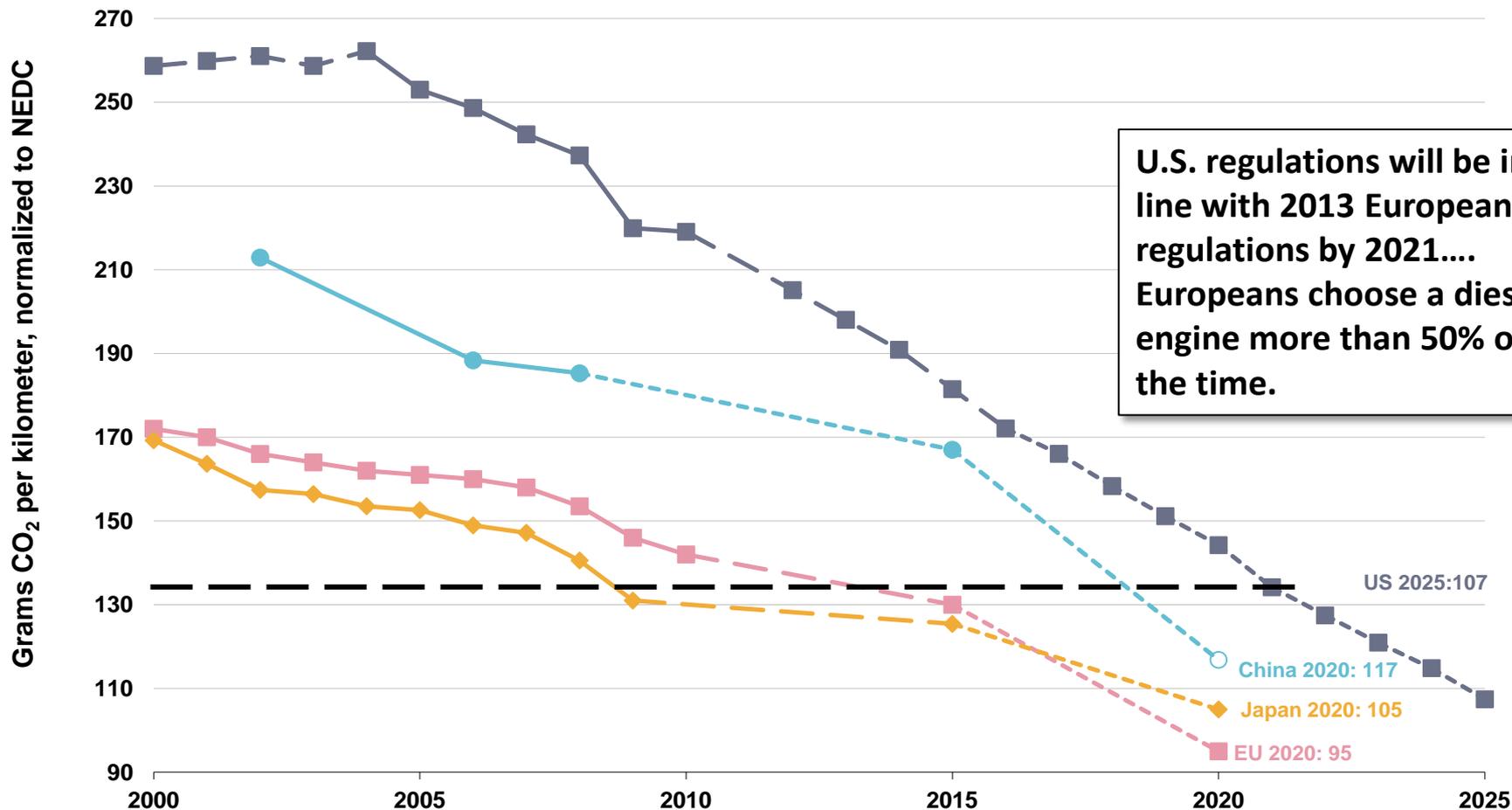
National – Heavy Duty

Savings to Diesel Buyer – Heavy Duty

Future CO₂ legislation will continue to require greater advances in technology.

Regulations ▀

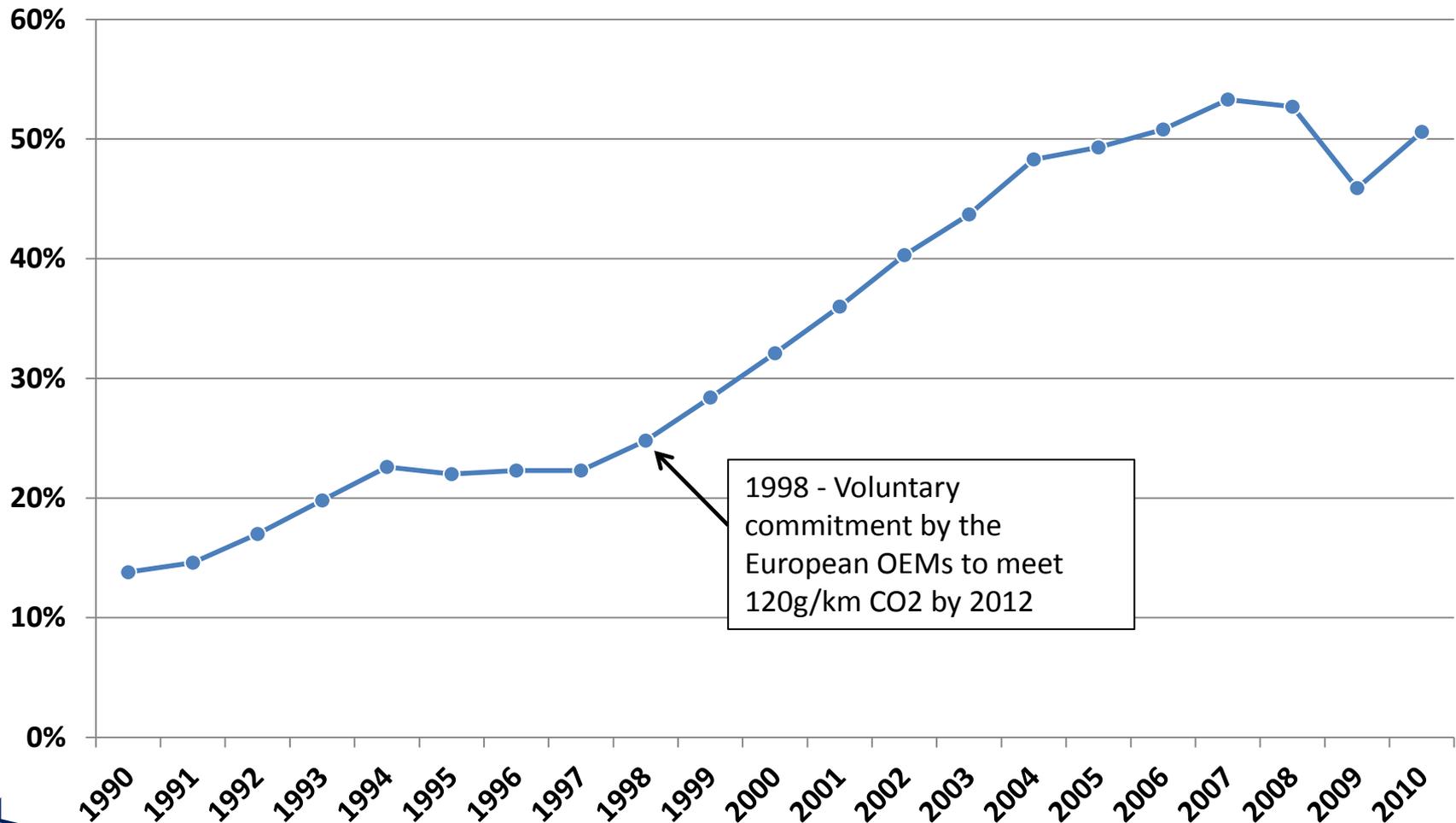
Global Light Duty CO₂ Standards



U.S. regulations will be in line with 2013 European regulations by 2021.... Europeans choose a diesel engine more than 50% of the time.

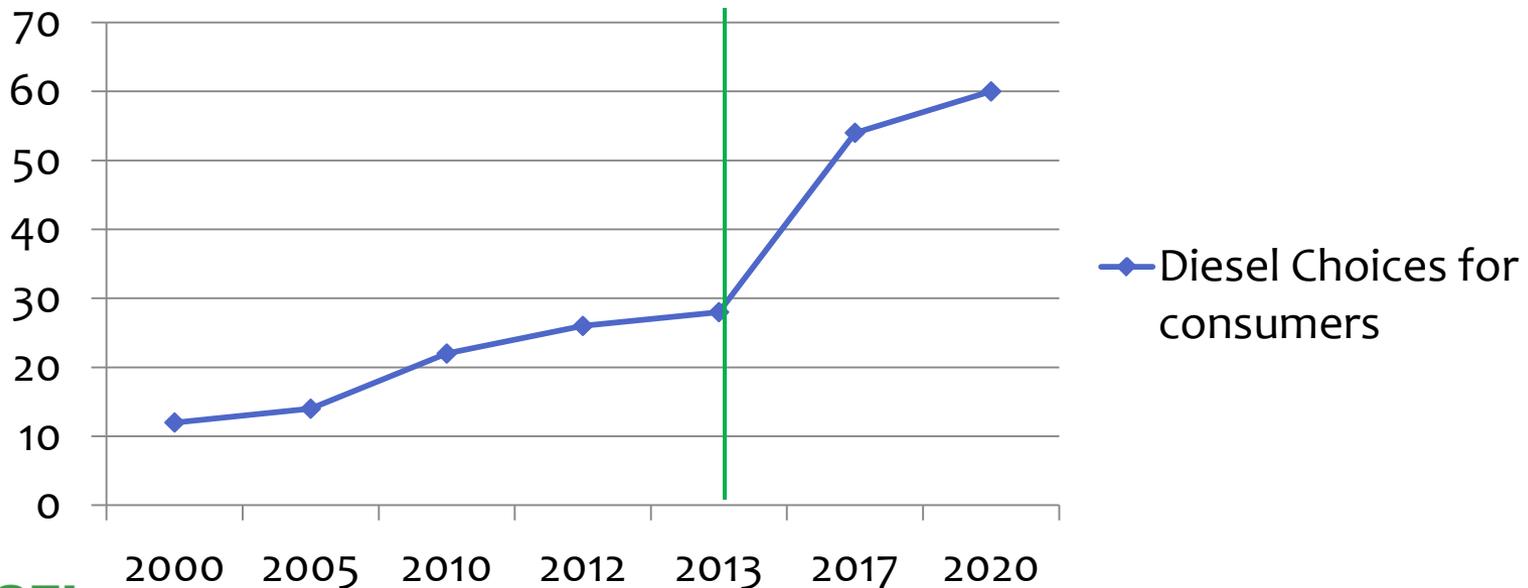
Diesel acceptance in Europe exploded with the introduction of direct injection and turbocharging to meet CO₂ objectives.

Historic Diesel Engine Market Share - Europe



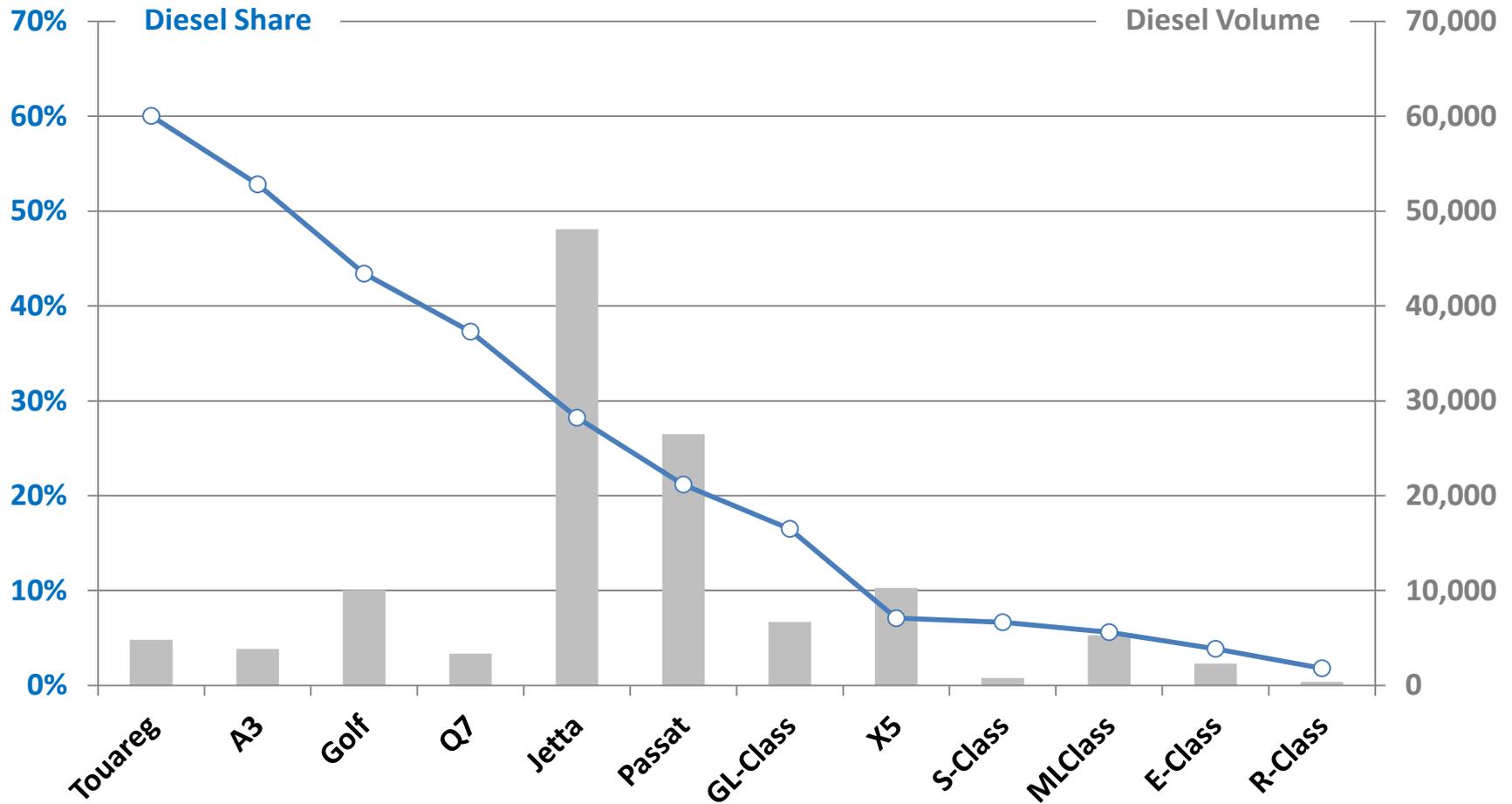
Twice as many clean diesel choices today.. More on the way

Diesel Choices for Consumers (Cars, SUVs, Vans and HD Diesel Pick Ups)



New clean diesel engine sales show strong customer acceptance.

New Clean Diesel Engine Sales – 2012 U.S. Market



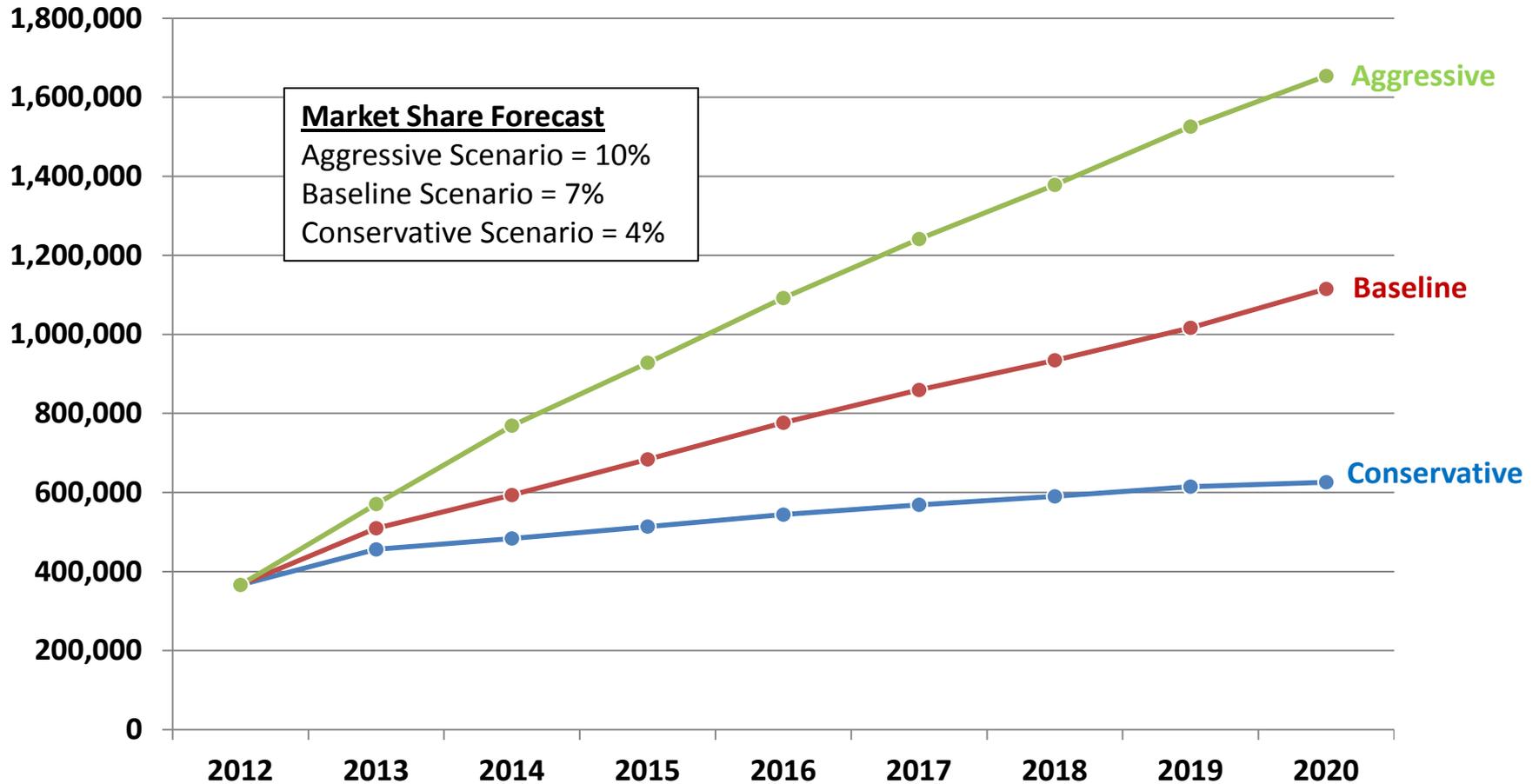
Sales based on <http://www.hybridcars.com/december-2012-dashboard>



Baseline assumptions for diesel engine growth yield a 7% market share and over 1M new diesel sales per year by 2020.

Forecast ■

New Clean Diesel Engine Sales Forecast – U.S. Market

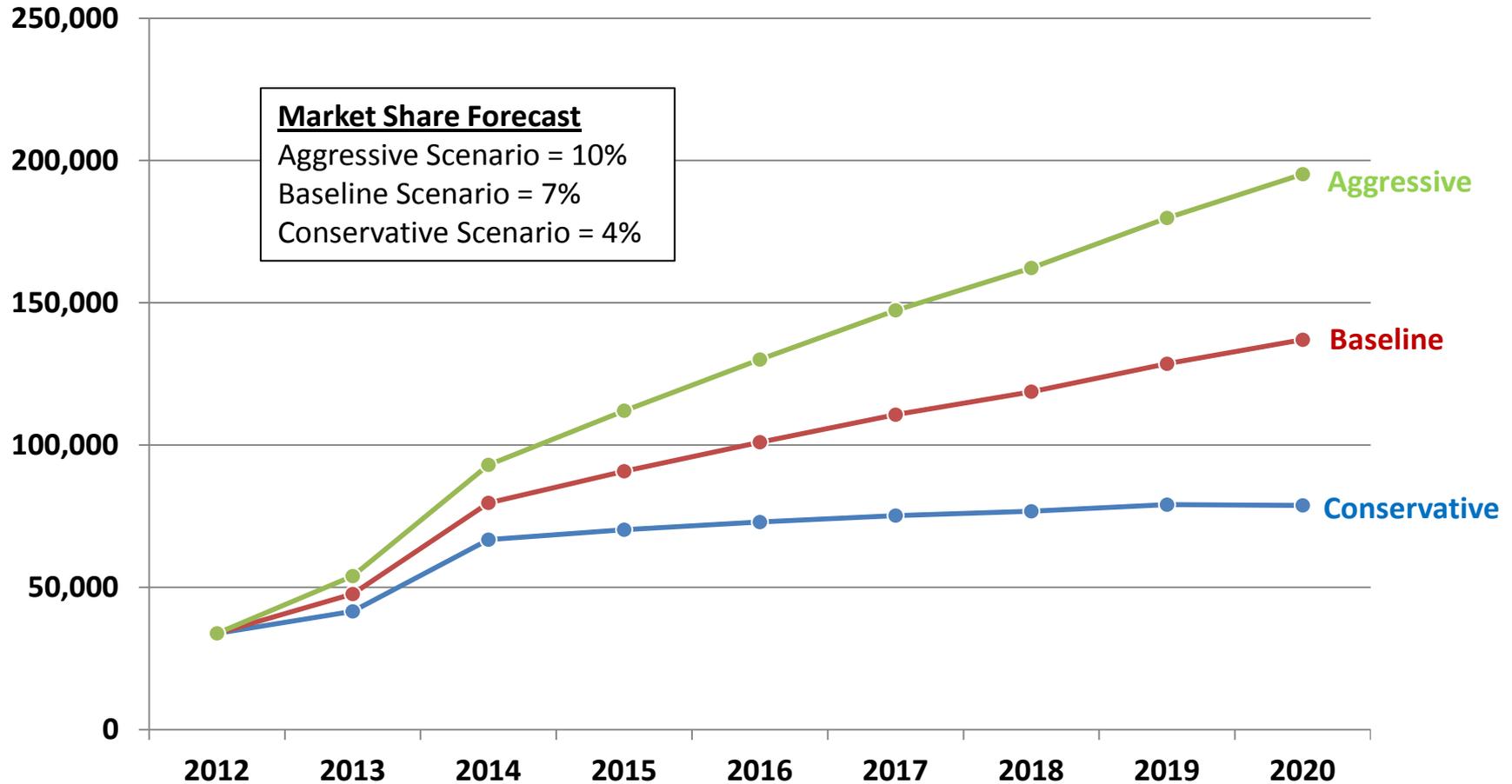


Total sales for cars, light trucks, and HD pickups based on future EPA compliance paths, fuel requirement changes under RFS2 and ARB LCFS and announced OEM diesel vehicle introductions.

Baseline assumptions for diesel engine growth yield a 7% market share and over **130,000** new diesel sales per year by 2020.

Forecast ■

New Clean Diesel Engine Sales Forecast – California

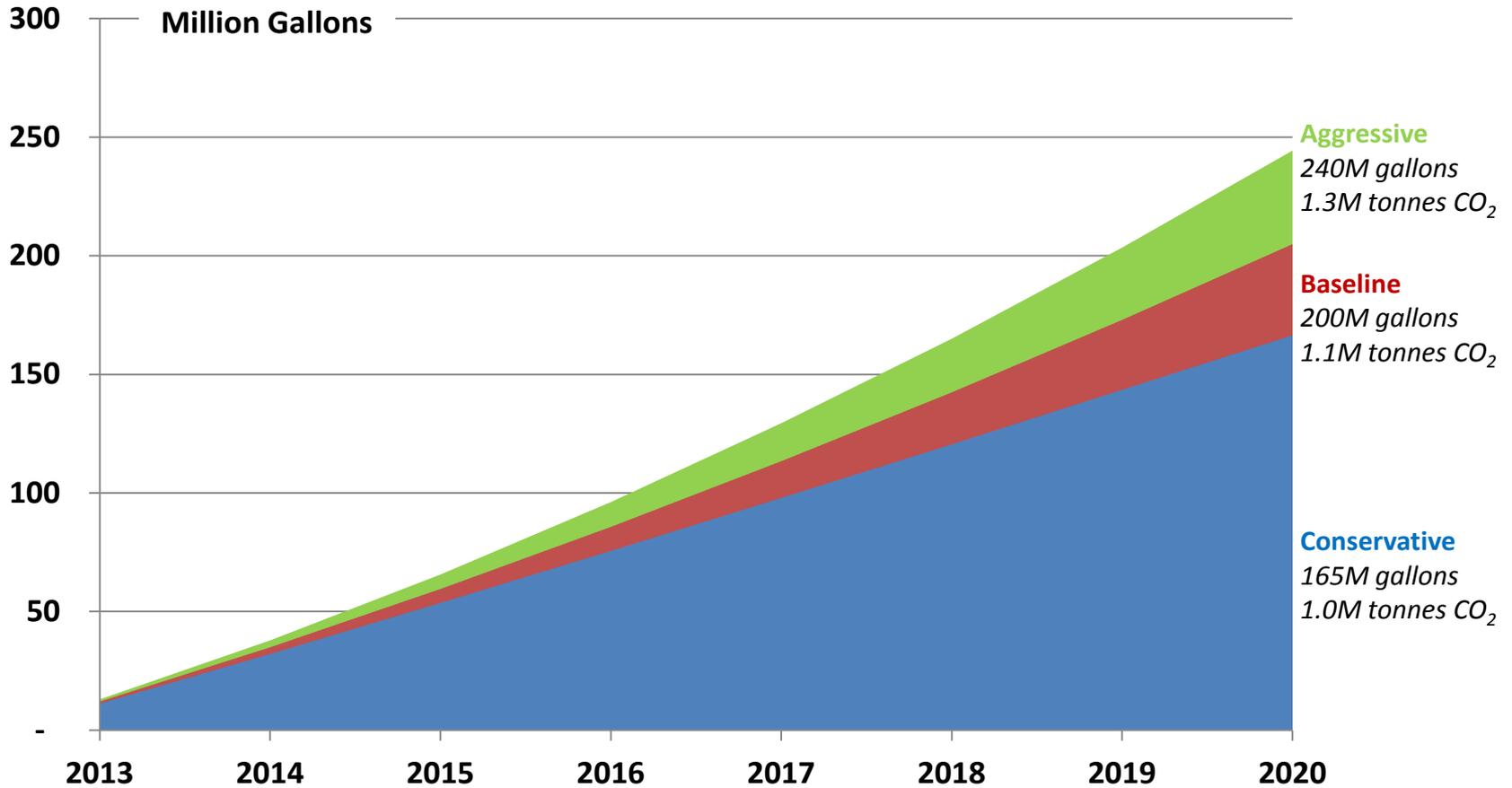


Total sales for cars, light trucks, and HD pickups based on future EPA compliance paths, fuel requirement changes under RFS2 and ARB LCFS and announced OEM diesel vehicle introductions.

Forecasted diesel savings for new diesel sales are expected to save 165-240M gallons of gasoline.

Forecast

Cumulative Diesel Engine Savings – California



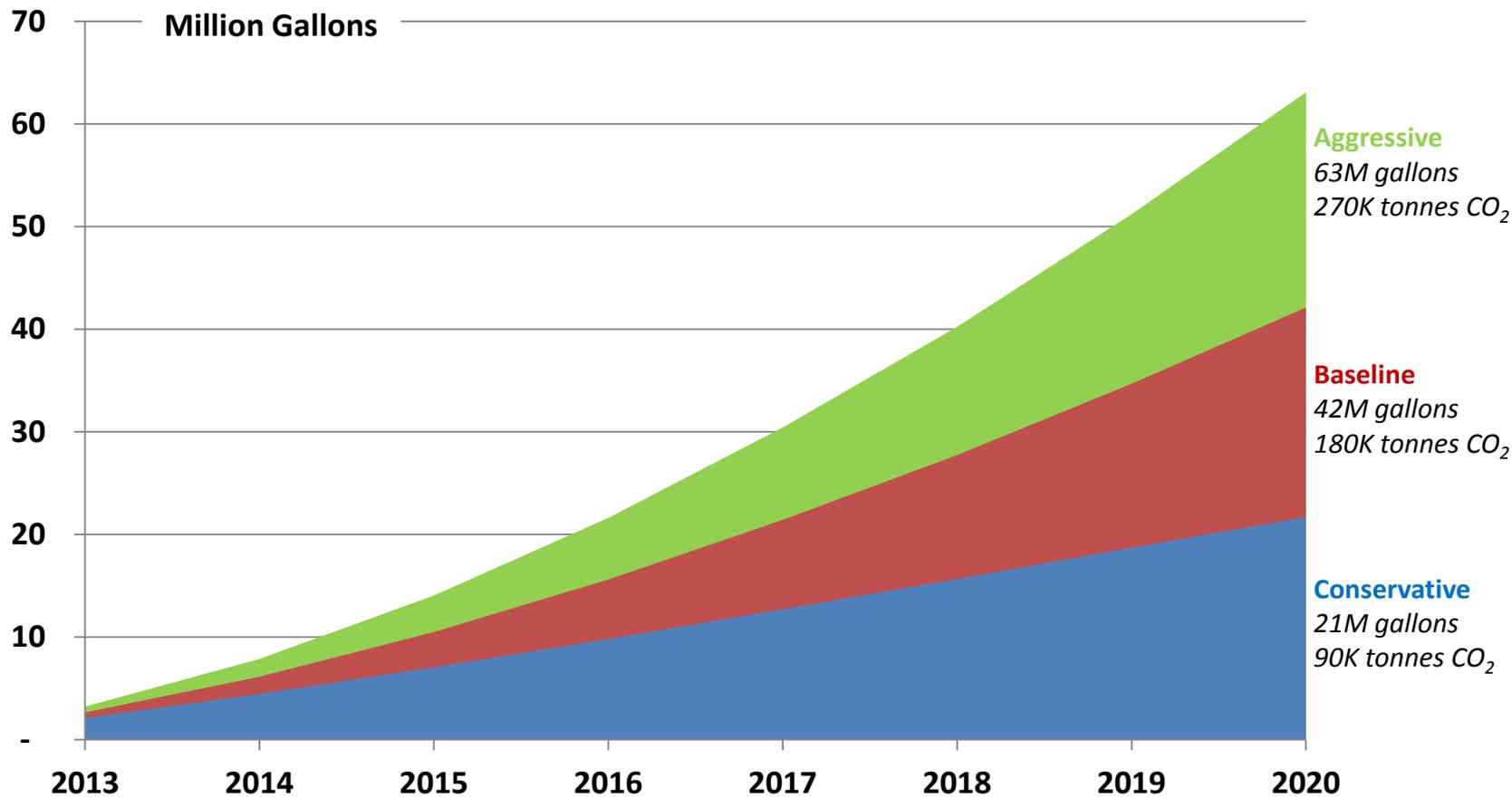
Total savings for cars, light trucks, and HD pickups
 Assumes average VMT of 15,000 miles/year
 Gasoline = 8,887gCO₂ /gal.
 Diesel = 10,180gCO₂ /gal.



Forecasted diesel savings for new passenger car diesel sales are expected to save 21-63M gallons of gasoline.

Forecast

Cumulative Diesel Engine Savings – California Passenger Cars



Total savings for passenger cars
Assumes average VMT of 15,000 miles/year

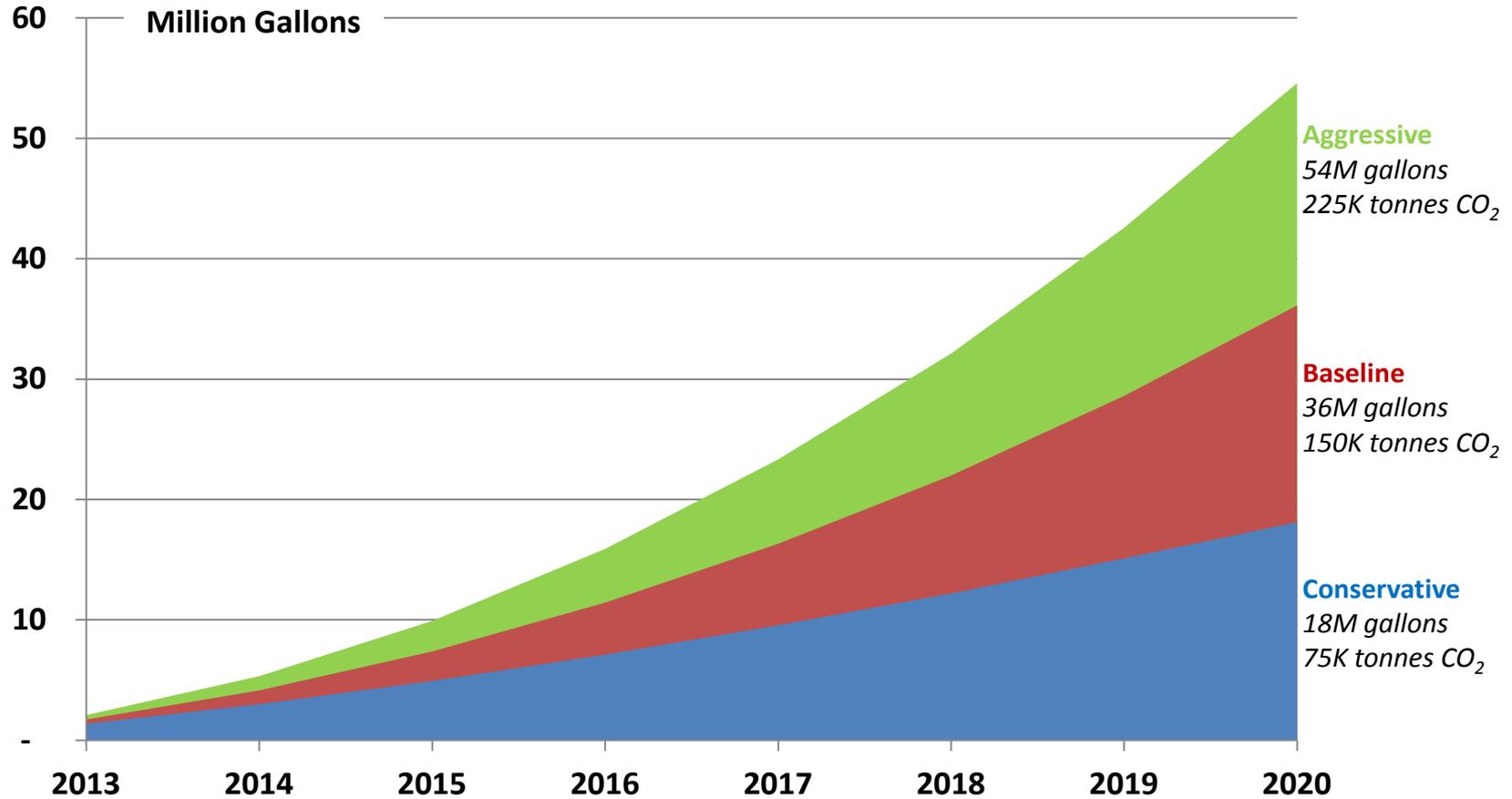
Gasoline = 8,887gCO₂ /gal.
Diesel = 10,180gCO₂ /gal.



Forecasted diesel savings for new light truck diesel sales are expected to save 18-54M gallons of gasoline.

Forecast

Cumulative Diesel Engine Savings – California Light Trucks



Total savings for light trucks
Assumes average VMT of 15,000 miles/year

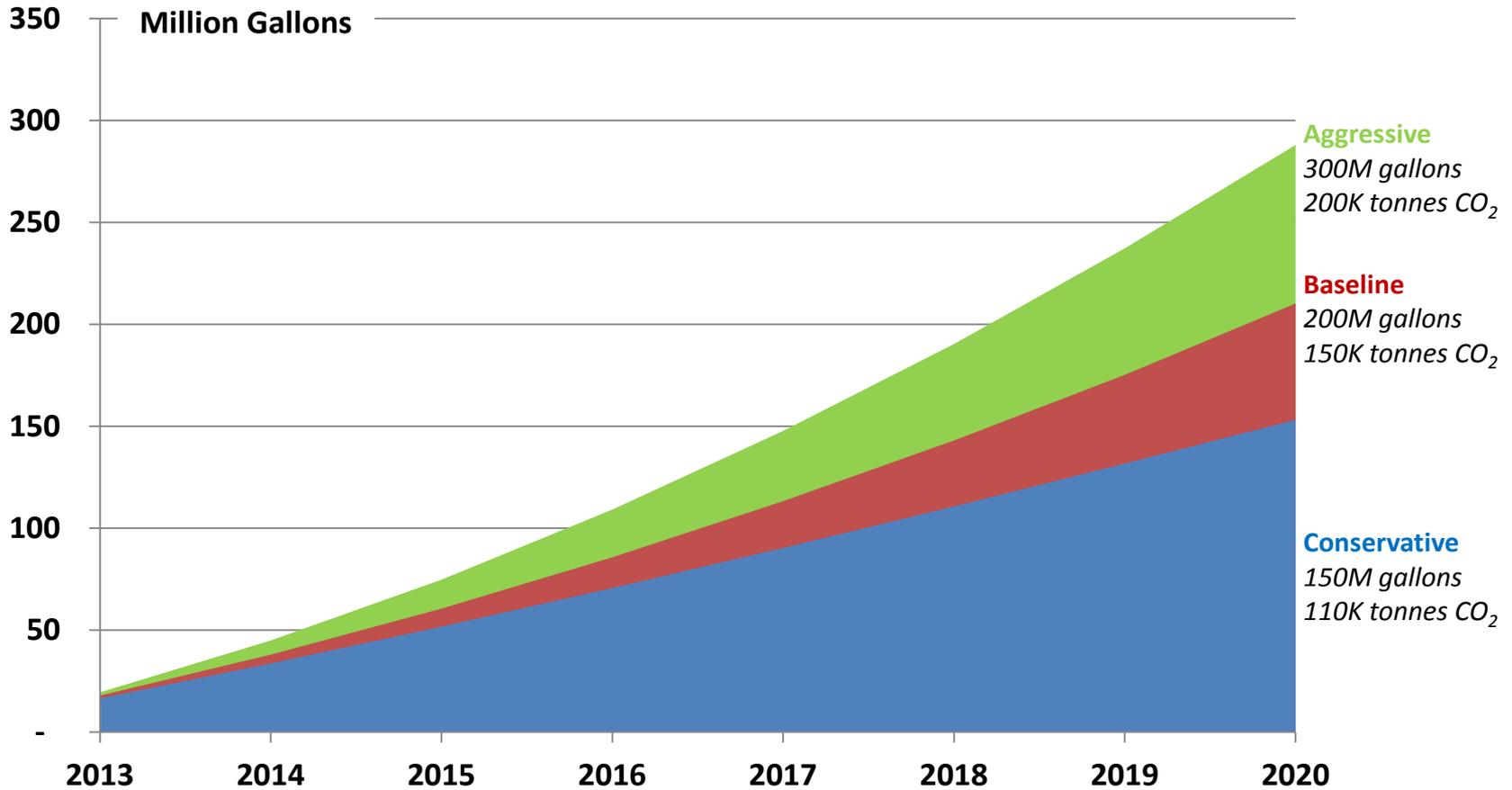
Gasoline = 8,887gCO₂ /gal.
Diesel = 10,180gCO₂ /gal.



If all new light-duty diesel vehicles are fueled with B5 biodiesel, the US will save an additional 150-300M gallons as compared to diesel fuel alone.

Biodiesel ■

Cumulative B5 Biodiesel Fuel Savings – U.S. Market



Total savings for cars, light trucks, and HD pickups
Assumes average VMT of 15,000 miles/year

Gasoline = 8,887gCO₂ /gal.
Diesel = 10,180gCO₂ /gal.
Biodiesel = 9,460gCO₂ /gal.



Light-duty Diesel Engine Summary

2005-2012 light duty diesel engines have saved the American consumer:

- 7.6M tonnes of CO₂
- 1.2B gallons of gasoline
- 29M barrels of crude oil

Conservative estimates of fuel savings and CO2 reductions for new light duty diesel engines introduced between 2013-2020 will save American consumers an additional:

- 7.7M tonnes of CO₂
- 1.3B gallons of gasoline
- 31M barrels of crude oil

Increased usage of biodiesel will have an additional positive savings for America.

- Up to a conservatively estimated 260M gallons of gasoline

National – Light Duty

Selected States – Light Duty

Savings to Diesel Buyer – Light Duty

National – Forecast

National – Heavy Duty

Savings to Diesel Buyer – Heavy Duty

Heavy Duty Objectives

Goal is to understand the market adoption and benefits of Clean Diesel Engines (2007 and later MY) three key categories of trucks

- Line-haul trucks Class 8
- Medium duty pick up and delivery (classes 3-7)
- Vocational vehicles

For new clean diesel engines/trucks (produced after 2007):

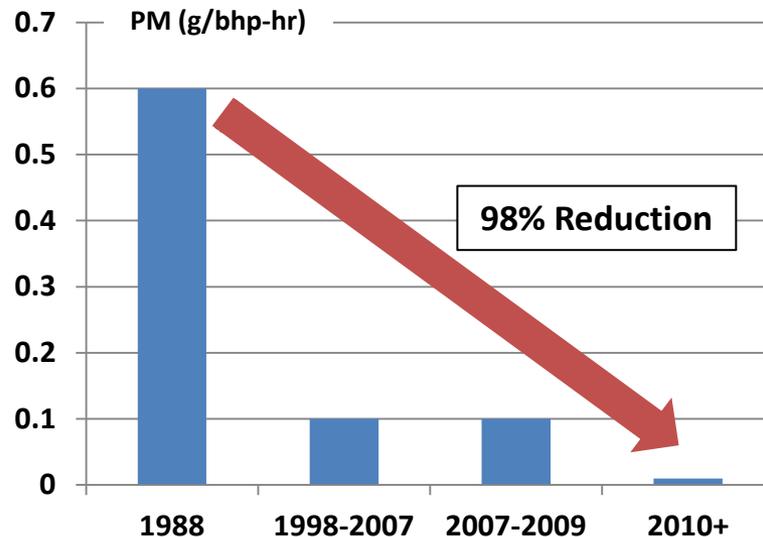
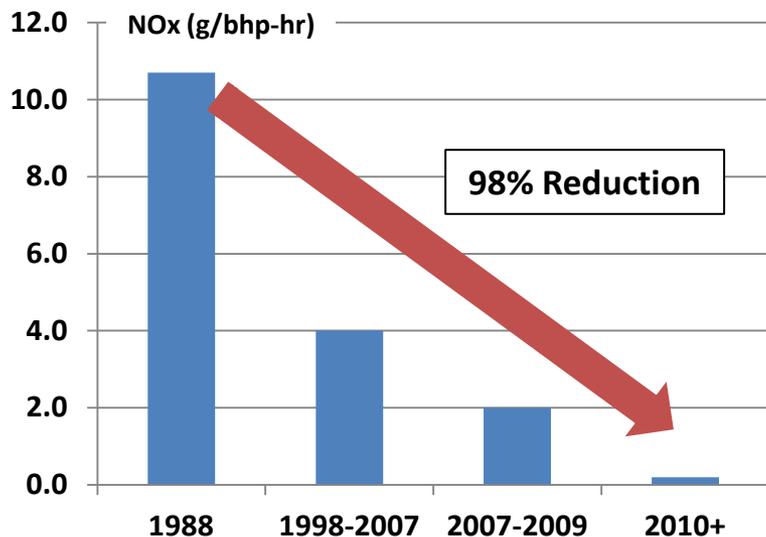
- What is the penetration of Clean Diesel trucks in the total population of commercial vehicles in operation, both on a 2007 and later model year basis and a 2010 and later model year basis, on a National basis and on a state by state basis ?
- What are the benefits - emissions reductions (NOx and PM and CO2) and fuel savings achieved from the adoption of the clean diesel trucks since 2007 on a nationwide and state by state basis?

Based on available information on pre-2010 vehicles, generate an example for each key category of trucks listed above.

- A new (Class 8, pick up and delivery, or vocational) is getting on average 8.5 mpg; an X percent improvement over a pre-2010 similarly equipped vehicle.
- At an annual average mileage for this type of truck (125,000 miles per year), this translates into XXXX gallons of annual fuel savings, and a savings of \$\$ at 3.50 a gallon diesel and YY at \$4.00 gallon diesel and ZZ at \$4.25 gallon diesel.
- This annual fuel savings translates into XXXX fewer tons of CO2 emitted, on average for each class of truck.

New clean diesel engines have reduced NOx and PM emissions by more than 95% over the last 25 years.

U.S. Emission Standards – Heavy Duty Trucks

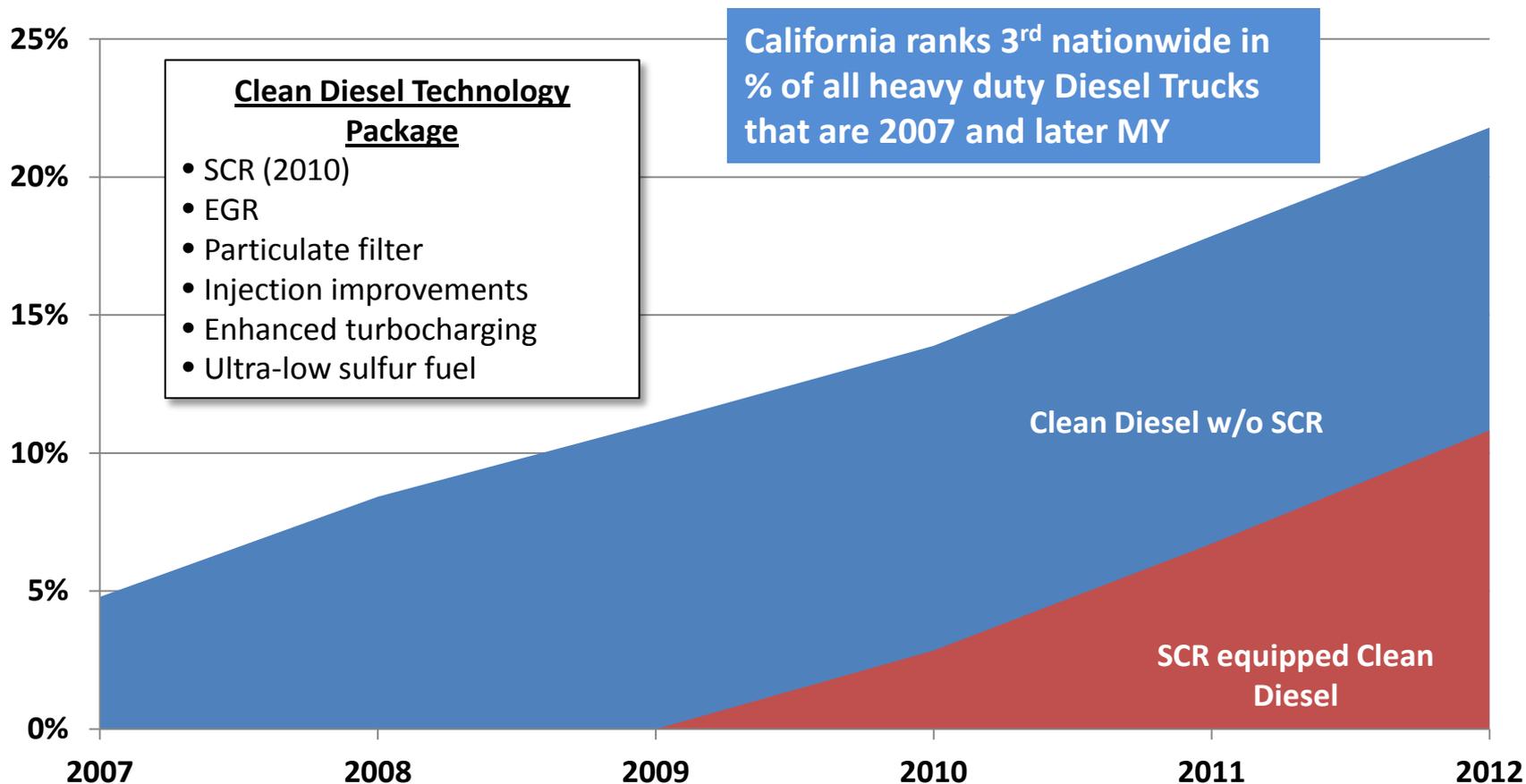


| HD Emission Standard | NOx (g/bhp-hr) | PM (g/bhp-hr) |
|----------------------|----------------|---------------|
| 1988 | 10.7 | 0.6 |
| 1998-2007 | 4.0 | 0.1 |
| 2007-2009 | 2.0* | 0.1 |
| 2010+ | 0.2 | 0.01 |

*Actual standard is NMHC*NOx with a 0.5g/bhp*hr maximum on NMHC

Over 20% of the 2012 heavy duty fleet are powered with new clean diesel engines built after 2006.

U.S. New Clean Diesel Engines in Operation – Heavy Duty



- Clean Diesel Technology Package**
- SCR (2010)
 - EGR
 - Particulate filter
 - Injection improvements
 - Enhanced turbocharging
 - Ultra-low sulfur fuel

California ranks 3rd nationwide in % of all heavy duty Diesel Trucks that are 2007 and later MY



Based on Polk HD class 4-8 registrations and vehicles in operation for the U.S.



In-use emission rates for 2010MY and beyond class 4-8 trucks has dropped by over 90% since 2007.

U.S. In-use Emissions by Vehicle Class – Heavy Duty Trucks

| Class | Example Production Vehicle | VMT Range | In-use NOx Emissions (g/mi) | In-use PM Emissions (g/mi) |
|-------|----------------------------|-------------|--|--|
| 4 | Ford F-450 | 30-35,000 | Pre-2007: 4.35 2007-2009: 1.66 2010+: 0.26 | Pre-2007: 0.096 2007-2009: 0.0133 2010+: 0.013 |
| 5 | Kenworth T170 | 30-40,000 | Pre-2007: 4.55 2007-2009: 1.79 2010+: 0.28 | Pre-2007: 0.085 2007-2009: 0.014 2010+: 0.014 |
| 6 | Peterbilt Model 330 | 40-50,000 | Pre-2007: 5.99 2007-2009: 2.20 2010+: 0.35 | Pre-2007: 0.186 2007-2009: 0.017 2010+: 0.017 |
| 7 | Kenworth T370 | 40-50,000 | Pre-2007: 7.47 2007-2009: 2.73 2010+: 0.43 | Pre-2007: 0.192 2007-2009: 0.022 2010+: 0.022 |
| 8 | Freightliner Cascadia | 110-140,000 | Pre-2007: 9.19 2007-2009: 2.94 2010+: 0.50 | Pre-2007: 0.233 2007-2009: 0.025 2010+: 0.025 |

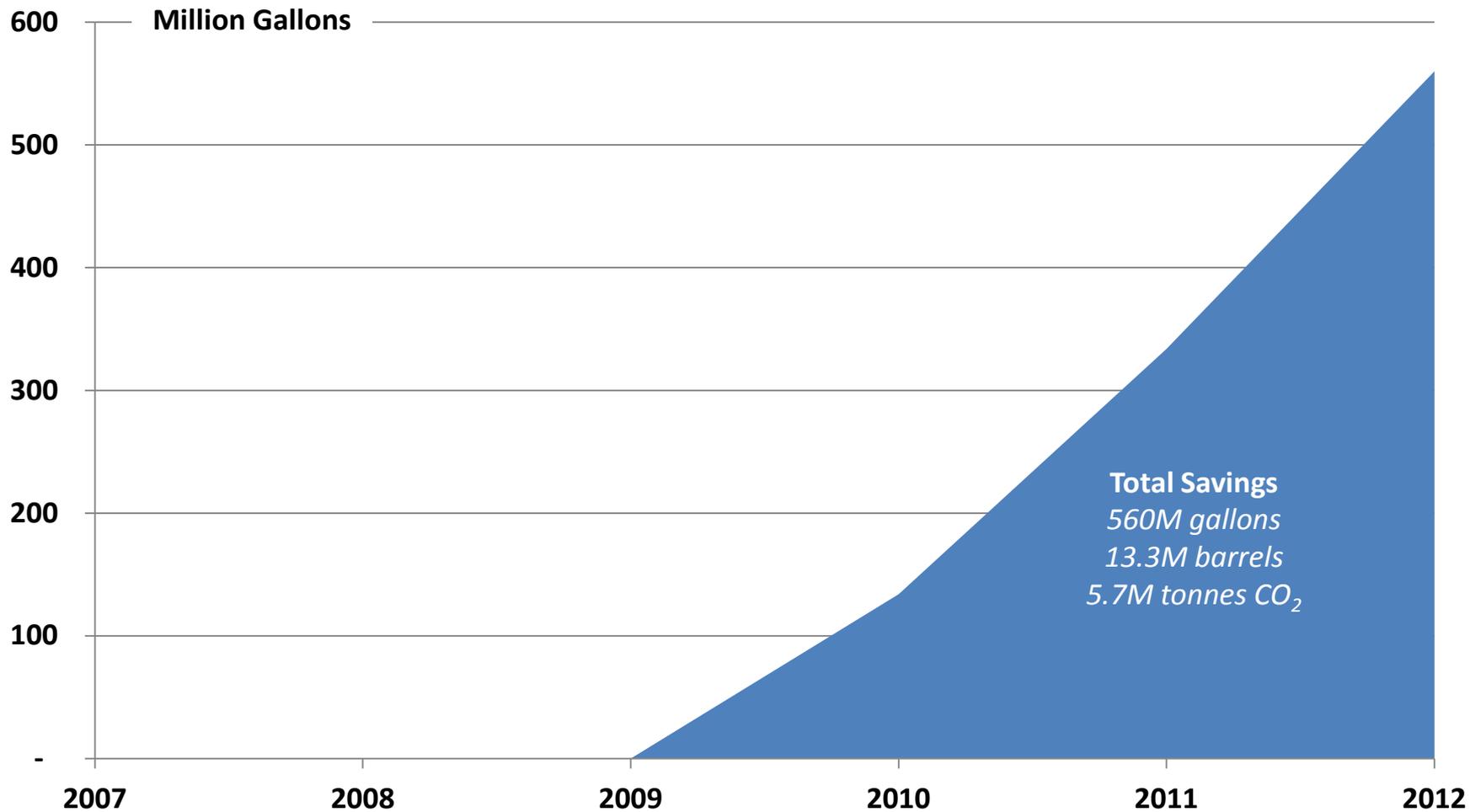
Methodology Details

Due to the various different engines used by heavy truck manufactures, the EPA made the heavy duty certification standards engine based. These engine based standards, rated in g/bhp-hr, are converted by EPA for use in modeling emissions of the fleet through the MOBILE6 emission modeling software. The emission rates shown above (in g/mi) are based on the EPA's modeling of the heavy duty fleet output necessary for the MOBILE6 model. These factors combined with the average emission rates used by EPA to model the heavy duty fleet are used on the following pages to generate a fleet wide savings for new technology diesel engines operating in the U.S. today.

2010-2012 new clean diesel engines in heavy duty trucks have saved 5 million tonnes of CO₂.

U.S. Market ■

Cumulative Diesel Savings – Heavy Duty Trucks



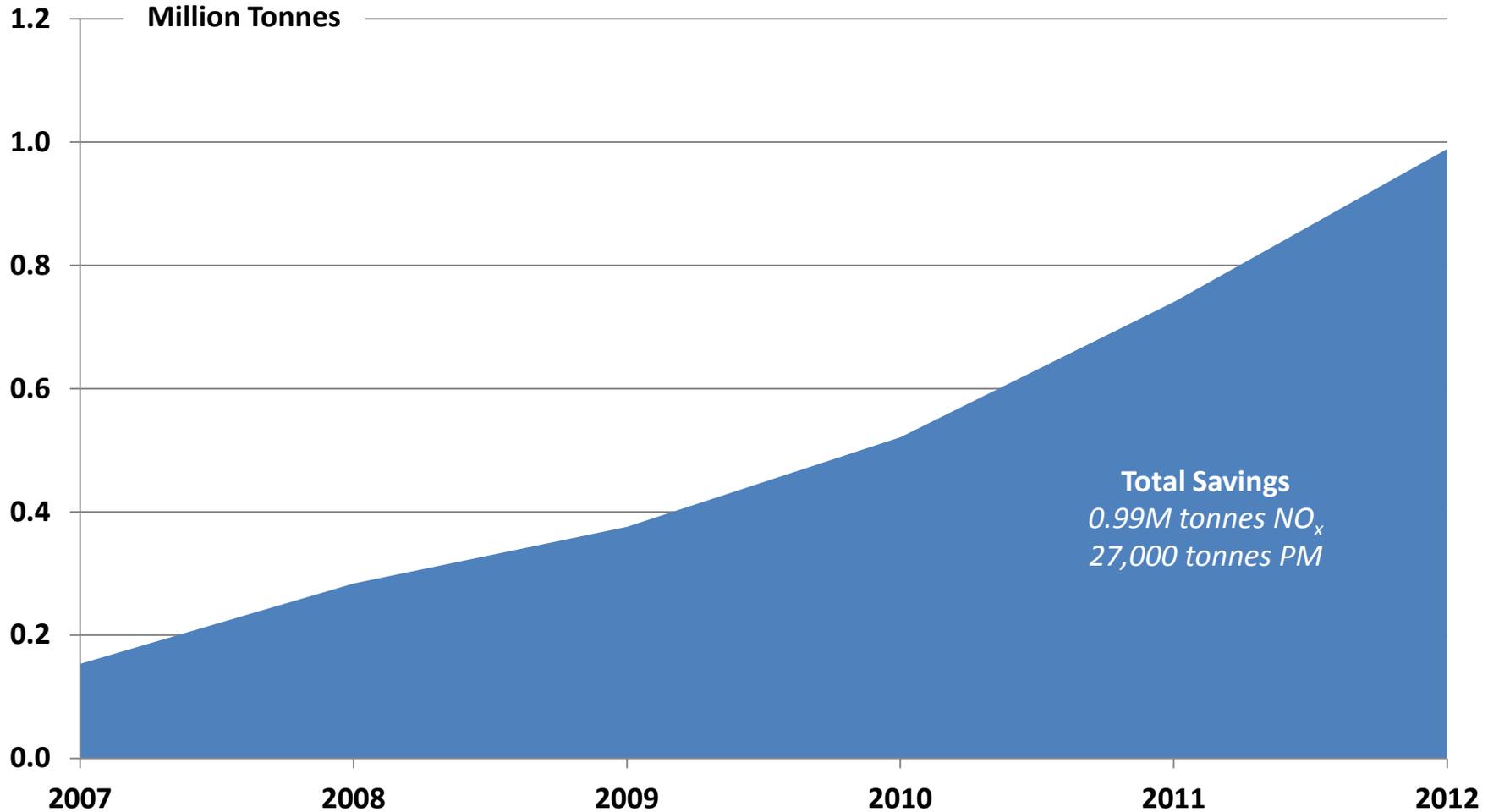
Total Savings
560M gallons
13.3M barrels
5.7M tonnes CO₂



2007-2012 new clean diesel engines have removed 1 million tonnes of NOx from the atmosphere.

U.S. Market

Cumulative Diesel Savings – Heavy Duty Trucks



Putting the numbers into perspective...

The 1.9M heavy-duty diesels introduced from 2007 through 2012 have saved the American consumer:

- 5.7M tonnes of CO₂
- 560M gallons of diesel
- 13.3M barrels of crude oil
- 1M tonnes of NO_x
- 27,000 tonnes of PM

These reductions are equivalent to:

- Removing the CO₂ emissions from 1.2M light-duty vehicles from the road for one year
 - *NO_x emissions from 87M and PM from 225M light-duty vehicles for one year*
- The CO₂ emissions from 235M home barbeque cylinders
- Carbon sequestration from 4.6M acres of forests
 - *This is an equivalent forest half the size of Maryland*
- Removing the annual CO₂ emissions from 1.6 coal fired power plants
 - *24,000 railcars of coal stretching continuously from New York City to Washington, DC*
 - *NO_x emissions from 105 coal power plants*
- Roughly 5% of the Strategic Petroleum Reserve for sweet crude.

National – Light Duty

Selected States – Light Duty

Savings to Diesel Buyer – Light Duty

National – Forecast

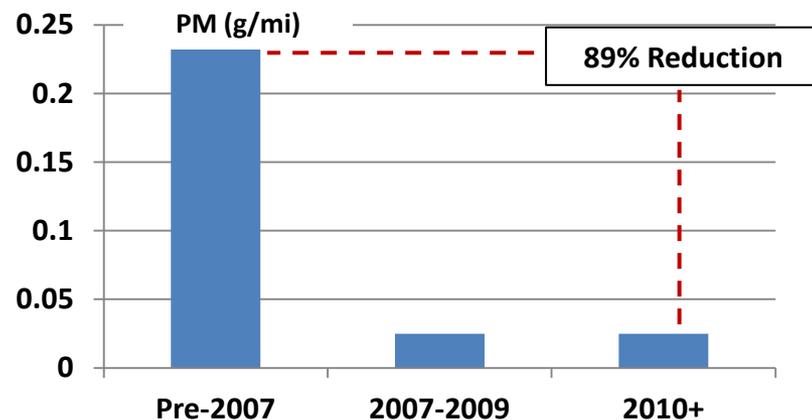
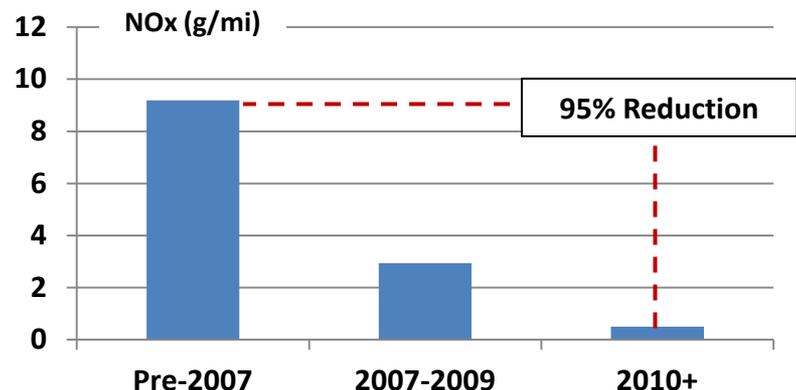
National – Heavy Duty

Savings to Diesel Buyer– Heavy Duty

New clean diesel engines in class 8 trucks save ~\$3,500/year in fuel costs.

Class 8 Line Haul Savings from clean diesel

| Savings to the new clean diesel buyer | Per Year |
|---|----------|
| Average vehicle miles traveled | 125,000 |
| Fuel savings - gallons | 875 |
| Fuel savings - bbl | 21 |
| Fuel cost savings @ \$4.00/gal | \$3,500 |
| CO ₂ savings – metric tonnes | 8.9 |
| NO _x savings – metric tonnes | 1.1 |
| Particulate matter savings – kg | 26 |

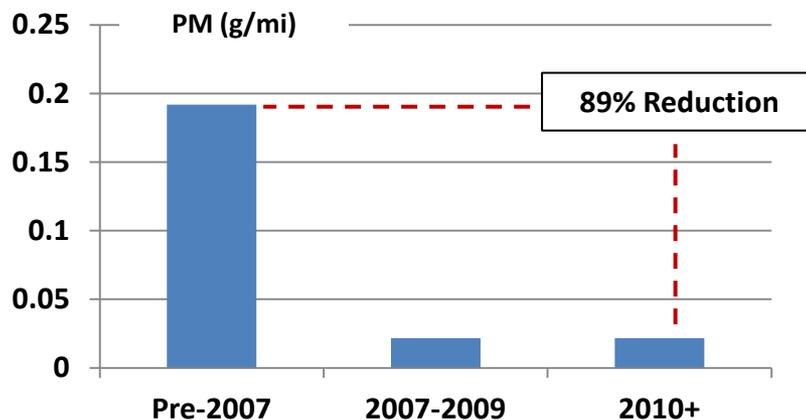
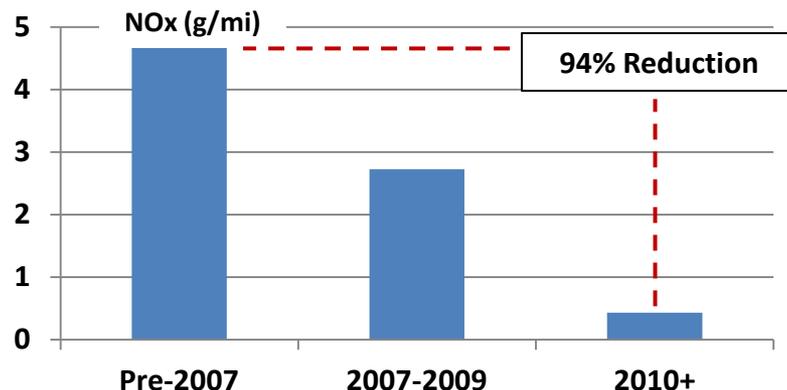


EPA estimates for in-use distance based output. Phase-in for 2004 and 2007 rulemaking is averaged across 2007-2009 and 2010 and beyond respectively. Pre-2007 estimates are based on an estimate of all vehicles in operation before 2007.

Class 7 vocational trucks with new clean diesel engines save 3.1 tonnes of CO2 per year.

Class 7 Vocational Savings from clean diesel

| Savings to the new clean diesel buyer | Per Year |
|---|----------|
| Average vehicle miles traveled | 45,000 |
| Fuel savings - gallons | 310 |
| Fuel savings - bbl | 7 |
| Fuel cost savings @ \$4.00/gal | \$1,240 |
| CO ₂ savings – metric tonnes | 3.1 |
| NO _x savings – metric tonnes | 0.32 |
| Particulate matter savings – kg | 8 |



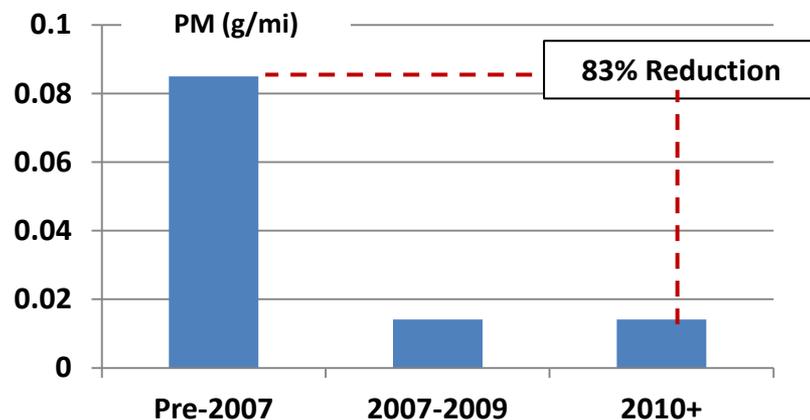
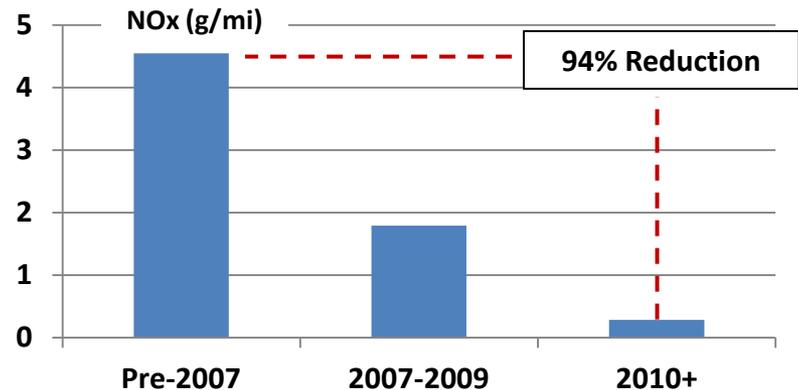
EPA estimates for in-use distance based output. Phase-in for 2004 and 2007 rulemaking is averaged across 2007-2009 and 2010 and beyond respectively. Pre-2007 estimates are based on an estimate of all vehicles in operation before 2007.



Pick up and delivery vehicles have achieved a 20X reduction in real world NOx emissions with new clean diesel engines.

Class 5 Pick Up & Delivery Savings from Clean Diesel

| Savings to the new clean diesel buyer | Per Year |
|---|----------|
| Average vehicle miles traveled | 35,000 |
| Fuel savings - gallons | 160 |
| Fuel savings - bbl | 4 |
| Fuel cost savings @ \$4.00/gal | \$640 |
| CO ₂ savings – metric tonnes | 1.6 |
| NO _x savings – metric tonnes | 0.15 |
| Particulate matter savings – kg | 2 |



EPA estimates for in-use distance based output. Phase-in for 2004 and 2007 rulemaking is averaged across 2007-2009 and 2010 and beyond respectively. Pre-2007 estimates are based on an estimate of all vehicles in operation before 2007.

Future Heavy-Duty Trucks: Balancing New Fuel Efficiency Standards & Near Zero Emissions

- * **New commercial diesel trucks (2014-2018) will be getting more fuel efficient**
 - * EPA/NHTSA GHG rules for HD trucks require anywhere from 6 % to 23 % reductions in fuel consumption by 2018 (3 classes of vehicles, - pickup trucks/vans, vocational and tractors)
 - * Combinations of engine and vehicle technologies deployed phase 1
- * **Phase 2 – 2014-2018 Significant challenges to achieve future fuel economy gains**
 - * Meeting near-zero emissions of NOx with lower CO2 Reductions gets harder– future standards
 - * Further changes in NOx emissions challenge ability to meet future fuel economy requirements.

Conclusions

Summary

- * Transformation to clean diesel fuel and engine technology, the significant penetration of diesel in key sectors of California's economy, and the inherent energy efficiency, positions diesel to play a key role in meeting future GHG and clean air objectives in California.
- * Significant fuel savings and clean air benefits are accruing from existing new clean diesel engines, and have already saved California 2.5M barrels of oil and 0.7 million tonnes of CO₂.
- * Increasing use of diesel in passenger cars, light trucks and SUVs will deliver significant future national savings, in the range of displacing 31 Million bbl of crude oil (1.3 Billion gallons gasoline).

Summary – National



2005-2012 light duty diesel engines have saved the American consumer:

- 7.6M tonnes of CO₂
- 1.2B gallons of gasoline
- 29M barrels of crude oil

Conservative estimates of fuel savings and CO₂ reductions for new light duty diesel engines introduced between 2013-2020 will save American consumers an additional:

- 7.7M tonnes of CO₂
- 1.3B gallons of gasoline
- 31M barrels of crude oil

Increased usage of biodiesel will have an additional positive savings for America.

- Up to a conservatively estimated 260M gallons of gasoline.



Over 20% of the 2012 heavy duty fleet are powered with new clean diesel engines built after 2006.

- Over 95 % reductions in NO_x and PM over the last 25 years.
- Savings from 2006-2012:
 - ~1M tonnes NO_x, or emissions from 105 coal power plants over one year.
 - 27,000 tonnes of particulate matter, or emissions from 225 light duty vehicles

~ 11% of all on-highway diesel engines in operation are built after 2010 and equipped with SCR emission control technology saving GHG and fuel. This fuel savings equates to:

- 560M gallons of diesel, average class 8 truck savings of ~\$3,500/year
- 13.3M barrels of crude, roughly 5% of the SPR for sweet crude
- 5.7M tonnes of CO₂, the carbon sequestration from a forest half the size of Maryland

Summary – California

CURRENT : 2005-2012 light duty diesel engines have saved California:

- 7.6M tonnes of CO₂
- 1.2B gallons of gasoline
- 29M barrels of crude oil

FUTURE: Conservative estimates of fuel savings and CO₂ reductions for new light duty diesel engines introduced between **2013-2020** will save California consumers an additional:

- 165 M to 240 M gallons of Gasoline
- 1.0M to 1.3M tonnes CO₂

New generation clean diesel Heavy-duty vehicles now account for 21.1 % of all HD vehicles registered in CA (805,542)

Diesel to be # 1 Transport Fuel by 2020

ExxonMobil: Diesel will surpass gasoline as the number one global transportation fuel by 2020. Diesel demand will account for 70% of the growth in demand for all transportation fuels through the forecast period to 2040. Although natural gas will play a greater role as a transportation fuel by 2040, it will remain only a small share of the global transportation fuel mix, at 4 percent by 2040, up from today's 1 percent, according to ExxonMobil's forecast.

The World Energy Outlook: Diesel fuel will remain the “dominant” growth fuel between now and 2035, according to the International Energy Agency. Globally, the report suggests the possibility of only a two percent share of natural gas in the heavy-duty transport market by 2035.

The National Petroleum Council in its 2012 report “Advancing Technology for America's Transportation Future” for the U.S. Department of Energy stated: “Diesel engines will remain the powertrain of choice for HD (heavy-duty) vehicles for decades to come because of their power and efficiency.”



Thank You

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