Tier 3 Vehicle and Fuel Standards

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Overview

- Background on Passenger Car Standards
- Overview of the Tier 3 Systems Based Approach
  - Vehicle Standards
  - Fuel Sulfur Control
- How Manufacturers & Refiners Will Comply
  - Vehicle Technology
  - Refinery Processes / Low-Sulfur Crudes
- Compliance Costs
- Emissions Impacts
- Ambient Air Quality Benefits
## Previous Federal & California Vehicle Standards – Since Passage of the 1990 Clean Air Act

### Federal Rules

<table>
<thead>
<tr>
<th>Tier 1</th>
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<tbody>
<tr>
<td>• Specified by 1990 CAA, and adopted by rule in 1991</td>
</tr>
<tr>
<td>• Standards phased-in for MY 1994-1996 cars and light trucks</td>
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<tr>
<td>• Reduced VOCs from cars by 30% and NOx by 60% from then current levels</td>
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<table>
<thead>
<tr>
<th>Tier 2</th>
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<tbody>
<tr>
<td>• Adopted in 2000, with standards phased-in for 2004-2006 MYs</td>
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<td>• Further reduced emissions another 77% (cars) and 98% (trucks)</td>
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<tr>
<td>• Limited gasoline sulfur for the first time, to 30 ppm (a 90% reduction)</td>
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### California Rules

<table>
<thead>
<tr>
<th>Low Emission Vehicle (LEV I)</th>
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<tbody>
<tr>
<td>• Originally adopted by CA in 1990</td>
</tr>
<tr>
<td>• Standards for model years 1994 to 2003 cars</td>
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<tr>
<td>• Reduced smog-forming pollutants from new cars by 75%</td>
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<tr>
<th>LEV II</th>
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<tr>
<td>• Phased-in between 1994-2010</td>
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<tr>
<td>• Further reduced smog-forming pollutants another 57%</td>
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<table>
<thead>
<tr>
<th>LEV III</th>
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<tr>
<td>• Further controls smog-forming pollutants, and adds greenhouse gas limits</td>
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Why A Third Tier of Federal Standards?

- Presidential memo of May 2010 requested a comprehensive approach to regulating motor vehicles
  - GHGs and non-GHGs
  - Review adequacy of non-GHG standards and fuel standards, specifically sulfur

- 2008 ozone NAAQS RIA assumed tighter vehicle certification standards as a control measure in the baseline

- Clean Air Act mandate added by Energy Independence and Security Act (EISA) of 2007. Requires study by 2009 of adverse air quality impacts from renewable fuels standards. Based on study, EPA was to issue fuel standards to mitigate adverse air quality impacts of the RFS.

- Based on EPA’s assessment, there were clearly opportunities to further reduce NOx, VOC, PM, and toxics with currently available technology at reasonable cost
What is Tier 3?

- Tier 3 program will result in “near-zero” vehicle emissions from new light-duty vehicles and pick-up trucks—something not thought possible 10 years ago.

- Approach is systems-based (fuel + standards): more stringent vehicle standards are enabled by stricter gasoline sulfur control.
  - follows the model of the Highway Diesel Rule (finalized in 2001) and the Non-road Diesel Rule (finalized in 2004).

- Further reductions in sulfur are necessary to allow vehicles to reach the Tier 3 standards; sulfur interferes with catalyst function.

- Sulfur control provides large, immediate emission reductions from the existing fleet by improving efficiency of every vehicle catalyst already in use.

- Tier 3 harmonizes federal and California fuel and vehicle standards, and enacts fuel sulfur levels in line with those in numerous other countries.
Vehicle Standards: Overview

- Developed through extensive consultation with the auto industry and state of California
- Tier 3 standards were developed with broad auto industry support, if combined with lower sulfur gasoline
- Oil industry expressed concerns about capital costs and timeframes and diminishing returns for further sulfur control
- Creates a 50-state vehicle program
  - Harmonized with California’s upcoming LEV III standards, (which Section 177 CA LEV States have also adopted)
- Phase-in coordinated with GHG standards (2017-2025)
  - Manufacturers can coordinate their compliance with both standards
  - Allows a single redesign optimized for both standards
- Updated certification test fuel to contain 15% ethanol instead of current E0 (0% ethanol)
Vehicle Standards: Overview

- Vehicles addressed by Tier 3 proposal:
  - Light-Duty Vehicles (LDVs)
    - passenger cars and very small trucks)
  - Light-Duty Trucks (LDTs)
    - larger pickups and minivans)
  - Medium-Duty Passenger Vehicles (MDPVs)
    - Heavy-duty vehicles 8,500 to 10,000 lbs gross vehicle weight (GVW), designed for passenger transport
    - Large pickups and vans (“Class 2b and 3” trucks)
      - Heavy-duty vehicles 8,500 to 14,000 lbs GVW

- Proposed Certification Standards Under Tier 3
  - Tailpipe standards
    - Combined Non-methane Organic Gases + nitrogen oxides (NMOG + NOx)
    - Particulate Matter
  - Evaporative emissions standards
    - New bleed test, leak test and CARB OBD evap

- Vehicle costs estimated by EPA at $2 billion in 2030, with monetized benefits of $6.7 to $19 billion.
Tailpipe Standards: NMOG+NOx

• A combined NMOG+NOx format (instead of separate NMOG & NOx standards) provides flexibility without compromising environmental benefits.

• Standards for NMOG+NOx are fleet-averaged, meaning the manufacturer weights the average emissions of all the vehicles it produces in a class in a model year to determine compliance. Standards differ by vehicle class and certification test cycle.

• Declining fleet average starting in MY 2017 through MY 2025
  • California’s LEVIII program starts earlier (MY 2015)
  • Manufacturers can earn credits for early compliance

• Useful life (for regulatory standard purposes) is being extended from 120,000 miles to 150,000 miles
Tailpipe Standards: NMOG+NOx (continued)

For Light-Duty Vehicle and Light-Duty Trucks (<8,500 lbs GVWR) and Medium-Duty Passenger Vehicles (8,500-10,000 lbs GVWR): (Represents an 80% reduction from today’s vehicles)

- Proposed/Finalized a standard of **30 mg/mi** by MY 2025 on the Federal Test Procedure (FTP)
  - an 80% reduction from current fleet average of 160 mg/mi
- Supplemental Test Procedure (SFTP) standard of **50 mg/mi** by 2025
  - a 75% reduction from current fleet average of ~200 mg/mi

Heavy-duty Pick-Ups and Vans; Class 2b (8,500-10,000 lbs GVWR) & Class 3 (10,001-14,000 lbs GVWR):
(Represents a 60% reduction from today’s vehicles)

- Class 2b - **178 mg/mi** (down from 395 mg/mi) on the FTP
- Class 3   - **247 mg/mi** (down from 630 mg/mi) on the FTP
- Additional standards for the SFTP
A Quick Look at the FTP & US06 Drive Cycles

The FTP Driving Trace

The US06 (or “High-Speed” portion of the STTP) Driving Trace

Note: Not shown are Urban & Speed Driving Cycles (UDDS & SC03)
Lookback at Past VOC & NOx Tailpipe Stds

Tier 3 further lowers passenger car averages for combined NMOG+NOx to levels of less than 0.03 g/mi (by model year 2025)
PM standards are expressed on a per-vehicle basis, and are applied on each specific vehicle (instead of a fleet average). The standards vary by vehicle class and for different certification test cycle.

For Light-Duty Vehicles, Light-Duty Trucks, & Medium-Duty Passenger Vehicles: (Represents ~70% reduction in PM from today’s vehicles)
- Proposed/Finalized a 3 mg/mi certification standard (from current 10 mg/mi standard) on the current FTP
- Proposed/Finalized a 10 mg/mi standard on the US06 cycle (current is 70 mg/mi) through MY 2018 and 6 mg/mi afterwards
  - Addresses PM emission concerns due to high oil consumption, high speed operation, and new gasoline DI technology
  - Decided to lower this standard from proposal, based on more recent data supporting a lower certification level for the US06 test cycle.

For Heavy-Duty Pickups and Class 2b and 3 Vans: (Represents a 60% reduction from today’s vehicles)
- Proposed/Finalized a 8 mg/mi certification standard for Class 2b and 10 mg/mi for Class 3 on the FTP
- EPA is also setting PM standards for these vehicle classes over the Supplemental FTP, with standards and duty-cycles varying by class and power-to-weight ratio.
Lookback at Past PM & CO Standards

Particulate Matter (PM$_{10}$)

Carbon Monoxide (CO)

With Tier 2, EPA established direct PM$_{2.5}$ tailpipe standards [i.e., $<2.5$ micrometers ($\mu$m)]. Tier 3 lowers direct PM$_{2.5}$ from 0.07 to 0.01 g/mi by 2018 (and finally 0.006 g/mi).
Evaporative Standards for Vehicles

- Program designed to push fuel vapor emissions to “zero levels” (range from \textbf{0.300-0.005 g/test} for LDVs/MDVs to \textbf{0.600 g/test} for HDVs)
  - Nominally a \textit{50\% reduction over current standards}; 98\% from uncontrolled levels
- Apply during the same extended 150,000 mile useful life
- Holistic approach to vehicle evap controls including vehicle technology, fuels, and in-use performance
  - Bring nationwide the evap control technology used in California
  - Improved in-use system durability through extended useful life and new “bleed test” and “leak test” requirements, & new CARB OBD
Certification Fuel Changes

• Updated vehicle certification test fuel specifications to better match in-use fuel and be forward-looking with respect to ethanol and sulfur content
• Ensures vehicles are designed for future real world fuels future
• Key highlights for certification gasoline
  • Proposed E15 (15 vol% ethanol), but finalized E10 (CARB is at E10)
    Ø E15 is not proliferating as quickly as EPA expected, & CARB harmonization
    Ø RVP of 9 psi
  • Specify certification lab test fuel for E85 vehicle certification testing
Vehicle Technology Feasibility

• Technological focus will be on:
  • Reducing NMOG at cold start
    ➢ almost all emissions will be within the first 20 seconds
  • Reducing NOx during “running” operation
    ➢ And essentially eliminate cold-start NOx
Vehicle manufacturers have confirmed that technologies are already in use today that will enable them to comply—in conjunction with lower sulfur gasoline, e.g.:

- Additional catalyst improvements
- Improved Thermal management, including close coupled catalysts
- Secondary air injection
- Hydrocarbon adsorbers
- Hybridization and Electric Drive
- For some vehicles, alternative “credit technologies” that may marginally help with compliance at less cost
  - Direct Ozone Reduction (DOR) credit and 150K mi warranty credit
  - Transmission Efficiency Improvements / CVTs / etc.

Total vehicle cost is expected to increase by ~$72 per vehicle.
Technologies Already Being Used in Today’s Cars

- Gasoline direct injection
- Turbocharging and engine downsizing
- Advanced thermal management
- Lower rolling resistance tires
- Advanced mass reduction
- High speed automatic transmissions
- Dual-clutch automatic transmissions
- Cooled exhaust gas recirculation
- Cam switching
- Cylinder deactivation
- Low-friction engine design and advanced lubricants

- Electric motor
- Regenerative braking
- Battery
- Hybrid

- Electric motor
- Charge port
- Battery charger
- 100% Electric

- Electric motor
- Fuel cell
- H₂ tank and filler
- Fuel Cell
The Need for Lower Gasoline Sulfur

- Gasoline sulfur control is critical for Tier 3
  - Enables more stringent vehicle standards (through better catalysts)
  - Achieves large, immediate emission benefits from the existing fleet
- Studies consistently show that sulfur at current average levels (30 ppm) degrades catalytic converter performance
  - Most significant problem is for NOx
- The 80%+ reduction in vehicle standards would not be possible without sulfur control
  - Vehicles must achieve essentially zero warmed-up NOx to comply, and maintain this performance for 150,000 miles
  - Especially problematic for SUVs and pickups
  - An increase of emissions of only a few mg/mi due to sulfur may make compliance impossible for some vehicles
- Sulfur effect alone will increase NOx emissions on the compliance test by ~25%
A Look Back at Average Gasoline Sulfur Levels
Fuel Sulfur Standard

- Lower the average sulfur standard by 60%
- (from 30 ppm to 10 ppm)
  - Greater emission benefits the lower you go, but 10 ppm avg is about the limit of what can be reliably delivered given the range of US refinery situations
  - Averaging format allows flexibility and reduces costs
    - A refinery may remain above 10 ppm if others are below 10 ppm
    - Some batches can be higher during maintenance and disruption periods, while still complying and maintaining production
  - California gasoline is already at slightly under 10 ppm sulfur

Start Date

- Proposed/Finalized - January 1, 2017
- 2017 to allow for necessary lead time and to tie in with the start of the vehicle phase-in
In addition to the 10 ppm average sulfur limit, EPA proposed two alternatives for a sulfur cap at the refinery gate/downstream retail:

A) To retain the current 80 ppm refinery gate, 95 ppm downstream retail per gallon caps
   - Industry is already complying
   - Emission impacts driven by the average, not the cap
   - Provides maximum ABT flexibility
   - 10 ppm avg will automatically limit amount of higher sulfur fuel

B) Or to lower these caps to 50 ppm at the refinery gate, 65 ppm downstream retail
   - To limit the sulfur level in potential “hot spots”
   - Not expected to significantly impact costs
   - Not expected to significantly raise downstream issues

An analysis performed since the proposal found that a lower refinery cap would likely result in higher costs to the industry and a decreased ability to could potentially impact gasoline supply and pricing, without any significant increase in nationwide emissions reductions from Tier 3.
Many Industrialized Nations Have Already Moved Limit Gasoline Sulfur Content

- By 2011, 36 countries (excluding the US) had 10 ppm sulfur limits, including the EU, Scandinavia, Japan, South Korea, etc.
- Taiwan, Brazil, UAE, Saudi Arabia, and Belarus adopted 10 ppm limits in 2013

Modeling Refinery Impacts/Costs

- Of the 111 U.S. refineries impacted by the sulfur limits, EPA estimated that only 16 would need to install new equipment to comply.
  - 29 of the remaining either already produce fuel that meets the Tier 3 limits, or could do so by making operational changes only.
  - The remaining 66 could meet Tier 3 by modifying existing equipment.

- EPA projects the gasoline sulfur standard will cost less than a 1 cent per gallon (API estimates 6-8 cents per gallon). The overall cost of the entire Tier 3 program (including vehicles) cost $1.5 billion in 2030.
How Does A Refinery Remove Sulfur From Gasoline?

Sulfur is a naturally occurring in crudes, with varying levels based on the geology of the region they are found.

Sulfur damages not only vehicle catalysts, but also those in refinery processes.

When sulfur-contaminated products are combusted, airborne SOx is produced.

Refineries use hydrotreating processes, like hydrodesulphurization, to remove sulfur from products. Processes like mercaptin oxidation, or Merox, can also be used.

End products are S2 or H2SO4, which are sold to chemical and phosphorus fertilizer producers. Refineries have become the world’s largest supplier of elemental sulfur.
How Does That Fit Into Refinery Operations?
Fuel Refining Flexibilities

- Early credit program to phase in the sulfur standard from January 1, 2014 through December 31, 2019

- Relief for Small Refineries
  - Delay of 3 years through December 31, 2019, consistent with the end of the early credit phase-in for large refiners
  - Propose small business refiner relief consistent with past fuel rules
    - 10 refiners representing ~1% of gasoline production
  - Also propose small refinery relief for those <75,000 BPD consistent with what congress established for RFS2
    - Total of 35 refineries representing a total of 10% of gasoline production

- Economic and Technical Hardship provisions available to all refiners as in other rules
## Tier 3 Averaging/Banking/Trading Program

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<tbody>
<tr>
<td><strong>Refiners and importers</strong></td>
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<td></td>
<td>&lt; Early credit generation &gt;</td>
<td>&lt; Standard credit generation &gt;&gt; &gt;</td>
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<td>&lt; Early credit use &gt;</td>
<td>&lt; Standard credit use &gt;&gt; &gt;</td>
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<tr>
<td><strong>Small refiners &amp; small volume refineries</strong></td>
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<td>&lt; Early credit generation &gt;</td>
<td>&lt; “Early standard credit” generation &gt;</td>
<td>&lt; Standard credit generation &gt;&gt; &gt;</td>
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<td>&lt; Standard credit use &gt;&gt; &gt;</td>
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All gasoline at 10 ppm on average
# Emissions Benefits of Tier 3 (2018 & 2030)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>2018 Nationwide Benefits</th>
<th>2030 Nationwide Benefits</th>
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<tbody>
<tr>
<td></td>
<td>(Annual Short Tons / % of Onroad Inventory)</td>
<td>(Annual Short Tons / % of Onroad Inventory)</td>
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<tr>
<td>NOx</td>
<td>264,369 10%</td>
<td>328,509 25%</td>
</tr>
<tr>
<td>VOCs</td>
<td>47,504 3%</td>
<td>167,591 16%</td>
</tr>
<tr>
<td>Direct PM$_{2.5}$</td>
<td>130 0.1%</td>
<td>7,892 10%</td>
</tr>
<tr>
<td>Benzene</td>
<td>1,916 6%</td>
<td>4,762 26%</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>14,813 56%</td>
<td>12,399 56%</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>257 5%</td>
<td>677 29%</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>513 2%</td>
<td>1,277 10%</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>600 3%</td>
<td>2,067 21%</td>
</tr>
<tr>
<td>Acrolein</td>
<td>40 3%</td>
<td>127 15%</td>
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<tr>
<td>Ethanol</td>
<td>2,704 2%</td>
<td>19,950 16%</td>
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Health Benefits of Tier 3

- By 2030, the Tier 3 Standards would annually prevent:
  - Between 770 and 2,000 premature deaths
  - 2,200 hospital admissions and asthma ER visits
  - 19,000 asthma exacerbations
  - 30,000 upper and lower respiratory symptom events in children
  - 1.4 million lost school days, work days, and minor-restricted activities
<table>
<thead>
<tr>
<th>Description</th>
<th>2030</th>
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<tbody>
<tr>
<td>Vehicle Program Costs</td>
<td>$0.76</td>
</tr>
<tr>
<td>Fuels Program Costs</td>
<td>$0.70</td>
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<tr>
<td>Total Estimated Costs</td>
<td>$1.5</td>
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<tr>
<td>Total Estimated Health Benefits</td>
<td></td>
</tr>
<tr>
<td>3 percent discount rate</td>
<td>$7.4 - $19</td>
</tr>
<tr>
<td>7 percent discount rate</td>
<td>$6.7 - $18</td>
</tr>
<tr>
<td>Annual Net Benefits (Total Benefits – Total Costs)</td>
<td></td>
</tr>
<tr>
<td>3 percent discount rate</td>
<td>$5.9 - $18</td>
</tr>
<tr>
<td>7 percent discount rate</td>
<td>$5.2 - $17</td>
</tr>
</tbody>
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Note: Total includes ozone and PM2.5 estimated benefits. Annual benefits analysis results reflect the use of a 3 percent and 7 percent discount rate in the valuation of premature mortality and nonfatal myocardial infarctions, consistent with EPA and OMB guidelines for preparing economic analyses.
Projected Change in 8-hr Ozone Design Values

2018

2008 Ozone NAAQS = 75 ppb

2030
Projected Changes in PM$_{2.5}$ Design Values

2012 PM$_{2.5}$ annual NAAQS = 12.0 µg/m$^3$
Projected Changes in 24-Hr PM$_{2.5}$ Design Values

2006 24-hour PM$_{2.5}$ NAAQS = 35 μg/m$^3$