Overview

- How the EPA GHG Standards Work
- Industry Progress-to-Date and Contribution of Powertrain Improvements
- How EPA Considers Transmission Technologies for 2025 Time-Frame
- What might 2025 look like?
  - EPA technical assessment (thus far)
- What Comes Next?
How the EPA GHG Standards Work
Footprint-based CO₂ Target Curves for Trucks – “The Standards”

As Sales Shift, OEMs Standards automatically adjust

With a shift from cars to SUVs & trucks, the OEM’s standard becomes less stringent
### So What is the 2025 EPA Standard?

Projections for Model Year 2025 Fleet CO2 Compliance Target
Fuel Prices/Fleet Mix Affect EPA’s PROJECTION of 2025 Standard

<table>
<thead>
<tr>
<th></th>
<th>2012 Projection</th>
<th>Summer 2016 Projection</th>
<th>Fall 2016 Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Price ($/gallon)</td>
<td>$3.87</td>
<td>$2.95</td>
<td>$2.97</td>
</tr>
<tr>
<td>Car/truck mix</td>
<td>67/33%</td>
<td>52/48%</td>
<td>53/47%</td>
</tr>
<tr>
<td>2025 Fleet CO₂ Compliance Level (g/mi, 2-cycle)</td>
<td>163</td>
<td>175</td>
<td>173</td>
</tr>
<tr>
<td>MPG-e (2-cycle)</td>
<td>54.5</td>
<td>50.8</td>
<td>51.4</td>
</tr>
</tbody>
</table>

These are industry compliance values. For consumers, the 2025 average real-world value is ~ 36 MPG.
Industry Progress-to-Date and Contribution of Powertrain Improvements
Vehicle CO₂ Emissions at Record Low –
every major vehicle category improving

- MY2015: 358 g/mi CO₂ (24.8 mpg)
- MY 2016 Projected: 25.6 mpg

Truck SUVs highest % improvement since 2004, up 33%
Pickups improved most in past year, up 0.8 mpg to 18.8 mpg
Automakers Adopting a Wide Array of Technologies at Rapid Rates

- **GDI** use on nearly half of all vehicles (up from 3% in MY2008), with Mazda at 100%, 6 more OEMs above 75%

- ~20% fleet use **7+ speed transmissions**, led by Mercedes, BMW, and Fiat-Chrysler

- >20% fleet use **CVTs**, led by Subaru, Nissan, and Honda
Early Years of Program Producing Positive Results

Industry Outperforming Standards

Large Industry-wide Bank of Credits

Enough credits for MY2015 fleet to comply thru MY2019 standards*

* Assuming all firms participate fully in credit-trading
How EPA Considers Transmission Technologies for 2025 Time-Frame
Overview of Technology Assessment

- **Midterm Evaluation**
  - Review of Final Rulemaking assessment of MY2022-2025 standards
  - Technology assessment has been ongoing since 2012

- **EPA made significant investment in new tools and studies**
  - Laboratory benchmarking of 30 of the most efficient vehicles in the world, allowing us to generate engine and transmission maps
  - In-house ALPHA vehicle simulation model allowing physics-based projections of effectiveness of various technology packages
  - Cost teardown studies of key powertrain components by contractor used by automakers

- **Supplemented by more intensive information collection and sharing**
  - Hundreds of meetings with automakers and suppliers
  - Review of hundreds of technical papers and reports
  - EPA authorship of 30 peer-reviewed papers and technical reports
**EPA Vehicle level benchmarking**
- Analyzed solenoid control signals during driving maneuvers on road
- Determined main line pressures as basis for bench testing
- Characterized transmission shift schedules, torque converter lock-up, and overall transmission effectiveness
- Vehicles: 2013 GM Malibu – 6-speed, (2) 2014 Dodge Chargers – one equipped with a 5-speed, the other with an 8-speed, 2015 Volvo S60, Ford F150, GM Silverado, Ram 1500 HFE, 2016 Honda CVT, 2016 ILX 8 speed DCT with TC, and more than a dozen other late model vehicles

**EPA Component benchmarking**
- Implemented transmission controls observed in vehicle to control transmission on test bench
- Eliminated TCM in the controls
- Vehicles: GM 6T40 6-speed AT from 2013 Malibu, GM 6L80 6-speed AT from 2014 Silverado, FCA 845RE 8-speed AT from 2014 Ram 1500, Jatco CVT7 from 2013 Nissan Altima
- Assessed transmission efficiency at various loads, speeds, and temperatures

**Transmission Maps provided by outside sources**
- DCT 6-speed (from supplier), DCT 7-speed (from supplier), CVT (from OEM), Jatco CVT8 (from supplier), Toyota CVT (from supplier)

**Transmission Data Sources for Latest EPA Technology Assessment**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque</td>
<td>0 Nm to 250 Nm</td>
</tr>
<tr>
<td>Speed</td>
<td>500 rpm to 5000 rpm</td>
</tr>
<tr>
<td>Temp.</td>
<td>35°C, 60°C, 100°C</td>
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Resultant Torque/Speed/Efficiency Curve
EPA Modeling of Transmissions: ALPHA simulation

- AT, DCT, and CVT architectures
- Built from modular sub-models, with control algorithms unique to each architecture
- Allows incorporating benchmarking data and future improvements

**Launch Clutch Model**
- Captures effects of accelerating upstream inertias
- Manage clutch slip where appropriate

**Torque Converter Model**
- Simulation of lockup
- Torque multiplication and resulting engine load

**Gearbox Model**
- Torque and rotational inertia scale through ratio change
- Torque loss and efficiency in each gear from dynamic lookup tables

**Gear Selection (ALPHAshift)**
- Rule based, considering engine torque curve, fuel map
- Minimize fuel consumption with constraints for engine speed and torque reserve

[Graphs showing Efficiency, Torque Loss, and Temperature Effect]
EPA Modeling of Transmissions: Performance Neutrality

Key justification for EPA’s performance neutral approach:

“Estimating the cost of decreasing fuel consumption requires one to carefully specify a basis for comparison. The committee considers that to the extent possible, fuel consumption cost comparisons should be made at equivalent acceleration performance and equivalent vehicle size” (National Academy of Sciences, 2011)*

Various efficiency technologies tend to improve performance

• Transmission improvements (efficiency, gear count, ratio spread)
• Load reduction (mass, aero, tire improvements)

Two possible “tuning” methods

1. Alter rear end ratio
2. Resize engine  **EPA Approach**
   • Maintain performance of baseline vehicle by resizing engine
   • Overall performance is calculated from the sum of the 0-60 time, ¼ mile time and passing times (30-50MPH and 50-70MPH)

What might 2025 look like: EPA technical assessment (thus far)
EPA Most Recent Assessment – Standards can be Met Mostly with Advanced Gasoline Technologies

Cost estimate of $875/vehicle

- Advanced engines and transmissions
- Vehicle light-weighting
- Improved aerodynamics
- More efficient accessories
- Low rolling resistance tires
- Stop-start technology
- Mild hybrid (e.g., 48 volt systems)
- Small levels of strong HEV, EV, PHEV

Fuel Savings Offsets Cost increase

- Net lifetime savings of $1,650

One possible powertrain pathway
Distribution of Fleet Powertrain Efficiencies

MY2012

Fleet Average, Gasoline
Conventional Powertrains
(non-electrified)
Distribution of Fleet Powertrain Efficiencies
MY2013

Fleet Average, Gasoline Conventional Powertrains (non-electrified)
Distribution of Fleet Powertrain Efficiencies
MY2014

Conventional Gas Powertrains (non-electrified)

Hybrids

Fleet Average, Gasoline Conventional Powertrains (non-electrified)
Distribution of Fleet Powertrain Efficiencies
MY2015

- Conventional Gas Powertrains (non-electrified)
- Hybrids

Fleet Average, Gasoline Conventional Powertrains (non-electrified)
Distribution of Fleet Powertrain Efficiencies
MY2016

Fleet Average, Gasoline Conventional Powertrains (non-electrified)
Fleet average efficiency has been steadily increasing, and appears on-pace for EPA’s MY2025 compliance pathway
- Efficient frontier has shifted upward with introduction of new engines and transmissions
- Vehicles on efficient frontier have opportunities for additional powertrain improvements
What comes next?
March 15, 2017 - EPA Administrator Pruitt issued a Notice announcing he will reconsider the EPA Final Determination published in January 2017:

“… EPA has concluded that it is appropriate to reconsider its Final Determination in order to allow additional consultation and coordination with NHTSA in support of a national harmonized program.”

“In accord with the schedule set forth in EPA’s regulations, the EPA intends to make a new Final Determination regarding the appropriateness of the MY 2022-2025 GHG standards no later than April 1, 2018.”
EPA Continues its In-depth Evaluation of Advanced Powertrains

Component benchmarking efficiency maps:
• MY2016 Mazda CX-9 2.5 liter GDI-turbo-charged w/ 6-speed AT
• MY2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 w/ CVT

Vehicle level benchmarking:
• MY2016 Acura ILX w/dual-clutch transmission with torque converter
• MY2017 Ford F150 w/10 speed AT
• MY2016 Chevy Malibu w/1.5 liter GDI-turbo-charged w/ 6-speed AT

Demonstration and Modeling:
• Demonstration of cooled EGR on a modified European Mazda 2.0 liter GDI-naturally-aspirated 14:1 CR engine
• GTPower modeling of a MY2012 PSA 1.6 liter GDI-turbo-charged engine with cooled EGR and an advanced turbo
• GTPower modeling of a MY2016 Honda Civic 1.5 liter GDI-turbo-charged 10.6:1 CR engine
• ALPHA model comparison of several CVTs
• ALPHA modeling of all vehicles included in above component and vehicle benchmarking
Example technologies EPA has not yet considered in our on-going technical assessment.

Potential to Consider New Technologies:

- Variable Compression Ratio – Nissan
- Electric supercharging – Valeo, Eaton, Audi
- 48 volt P2 hybrids – near strong HEV effectiveness at lower cost
- Lean-burn operation – several manufacturers are investigating
- Increased thermal management (e.g., waste heat recovery)
- Additional friction reduction:
  - Cam and crank roller bearings
  - Plasma Vapor Deposition (PVD) cylinder coating – already in production
- Water injection for knock mitigation – BMW
- Ball-based Continuously Variable Transmissions (Dana)
Additional EPA Work Underway in Many Areas

- **Technology cost teardowns with FEV**: modern GDI turbo-downsized engine, advanced diesel engine, CVT
- Updates to OMEGA **cost-effectiveness optimization model** and ALPHA **full vehicle simulation model**
- Ongoing work to evaluate the **willingness to pay (WTP) for vehicle attributes** (e.g., power, fuel economy, size, etc).
  - Our review of 50+ papers from the last 20 years found very wide variation in these WTP values.
  - Ongoing work evaluates what factors may contribute to this variation.
- **Ongoing evaluation of automotive reviews of MY2015 vehicle fuel efficient technologies**
  - Building upon EPA’s study of MY2014 vehicles, we continue to find that positive evaluations for all technologies (70%) exceed negative evaluations of the technologies (18%)
- **Ongoing work to evaluate the vehicle miles traveled (VMT) rebound effect**
- Collaboration with Transport and Environment/Climate Change Canada on **mass reduction** and **aerodynamics**
- Continued evaluation of the vehicle fleet each year to assess technologies, emissions, and compliance – supporting EPA’s forthcoming **MY2016 Manufacturer GHG Performance Report** and **2017 CO2/Fuel Economy Trends Report**