EPA'S ASSESSMENT FOR THE MIDTERM EVALUATION

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U.S. Environmental Protection Agency
Overview

- Climate Change
- Greenhouse Gas Regulations
- MTE Results
  - Powertrain
  - Load reduction
  - Consistency in Findings
  - Electrification
- Conclusion
Climate Indicators: CO2 Concentration & Average U.S. Temperatures

Concentrations of Carbon Dioxide in the Atmosphere from 800,000 Years Ago to Present Day

Rate of Temperature Change in the United States, 1901–2015

Data source: Compilation of 10 underlying datasets.

Data source: NOAA, 2016
Climate Indicators: CO2 Concentration (58 years) & Global Temperatures (166 years)

Atmospheric CO₂ concentration (1958–2016)

Global temperature change (1850–2016)

Light-duty Vehicle Greenhouse Gas Emission Reductions
Multiple Analyses and Rulemakings Conducted Over the Last 9 years

EPA/NHTSA NPRM
September, 2009

EPA/NHTSA NPRM
December, 2011

EPA/NHTSA/CARB DTAR
July, 2016

EPA FD
January, 2017

2012~2016 MY

2017~2025 MY

2022~2025 MY MTE

EPA Staff Report
March, 2008

EPA/NHTSA FRM
May, 2010

EPA/NHTSA FRM
October, 2012

EPA PD
December, 2016

Draft Technical Assessment Report:

EPA’s MTE assessments informed by a wide range of information

- **Technical research initiated by EPA**
  - Benchmarking testing of 30 vehicles across wide range of powertrains & segments
  - Published more than 30 peer-reviewed papers and technical reports
  - Vehicle simulation modeling, cost teardown studies, mass reduction feasibility/cost studies, manufacturer “learning by doing” costs, research on consumer issues, economic inputs, others

- **Extensive reviews of the literature**
  - 100’s of reports/papers from the literature published since 2012, including major studies such as the 2015 National Academy of Sciences report

- **Stakeholder outreach & collaboration**
  - Hundreds of meetings with automakers, suppliers, NGOs, consumer groups, labor, states/local governments, others
  - Collaboration with NHTSA, CARB, DOE, Transport & Environment Canada
EPA has shared technical information publicly throughout MTE Process

Wide range of peer-reviewed publications and presentations:
- Technical papers, including SAE papers and EPA reports
- Conference presentations
- Modeling workshop

+ more …
Compliance can be achieved through a number of different technology pathways reflecting predominantly the application of technologies already in commercial production.

EPA projects that the MY 2022~2025 standards can be met through advances in gasoline vehicle technologies, such as engines, transmissions, light-weighting, aerodynamics, and accessories.

Very low levels of strong hybrids and electric vehicles will be needed to meet the standards.

Standards provide significant benefits to consumers and public
Standards can be met mostly with advanced gasoline technologies

- 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)

One possible pathway EPA modeled:

- Advanced gasoline: 75%
- Mild Hybrid: 18%
- Strong Hybrid: 2%
- Plug-In Hybrid Vehicles: 2%
- Electric Vehicles: 3%
Fuel prices have dropped and people are buying more trucks than cars.

- Achieved CO2 is projected to be 173 g/mi in 2025 MY vs 163 g/mi projected in the FRM

Manufacturers have complied with the first 4 years of the 2012~2016 MY program.

- (2016 MY results have not yet been tabulated.)
- And, for the first time in automotive history, experienced 6 consecutive years of increasing sales

Manufacturers have introduced technologies that we did not anticipate in the 2012 FRM

- Atkinson Cycle engines in non-hybrid applications
- Turbo-downsized engines already performing at levels projected for 2020 MY.
- Continuously Variable Transmissions (CVT) that feel like conventional automatics
- 48 volt Mild Hybrids

<table>
<thead>
<tr>
<th>Attribute</th>
<th>2012 Final Rule</th>
<th>Draft TAR</th>
<th>Proposed Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car/Truck Mix</td>
<td>67/33%</td>
<td>52/48%</td>
<td>53/47%</td>
</tr>
<tr>
<td>CO₂ (g/mi)</td>
<td>163</td>
<td>175</td>
<td>173</td>
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If the conclusions are the same, what has changed?
## MTE Results: MY 2025 Fleet Projections

### Selected Technology Penetrations (Absolute) and Per-Vehicle Average Costs*

to Meet MY2025 Standards

<table>
<thead>
<tr>
<th>Technology</th>
<th>Draft TAR</th>
<th>Proposed Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Primary Analysis</td>
</tr>
<tr>
<td>Turbocharged and downsized engines</td>
<td>33%</td>
<td>34%</td>
</tr>
<tr>
<td>Higher compression ratio, naturally aspirated gasoline engines</td>
<td>44%</td>
<td>27%</td>
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<tr>
<td>8-speed and other advanced transmissions</td>
<td>90%</td>
<td>93%</td>
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<tr>
<td>Mass reduction</td>
<td>7%</td>
<td>9%</td>
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<tr>
<td>Off-cycle technology</td>
<td>Not modeled</td>
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<tr>
<td>Stop-start</td>
<td>20%</td>
<td>15%</td>
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<tr>
<td>Mild Hybrid</td>
<td>18%</td>
<td>18%</td>
</tr>
<tr>
<td>Strong Hybrid</td>
<td>&lt;3%</td>
<td>2%</td>
</tr>
<tr>
<td>Plug-in Hybrid electric vehicle</td>
<td>&lt;2%</td>
<td>2%</td>
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<tr>
<td>Electric vehicle</td>
<td>&lt;3%</td>
<td>3%</td>
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<tr>
<td>Per vehicle cost (2015$)</td>
<td>$920</td>
<td>$875</td>
</tr>
</tbody>
</table>

* Incremental to the Costs to Meet the MY2021 Standards
Manufacturers have multiple cost-effective options for compliance

Engine Example:
• Different engine technologies compete for the frontier of cost-effective options
  • Turbocharging and downsizing
  • Atkinson Cycle/ Deac

• Small changes in package cost and/or effectiveness can result in one or the other technology being applied
  • However, overall costs remain very stable

• Manufacturers will choose which technology best fits their product applications
Similar alternatives exist for vehicle manufacturers regarding the selection of transmission technologies.

Manufacturers are predominantly applying three current primary transmission architectures:

- Conventional automatic transmissions
- Continuously variable transmissions
- Dual clutch transmission

All three transmission types are driving towards the same goal of providing maximum flexibility to operate the engine and maximum transmission efficiency.

Once again, vehicle manufacturers will select the transmission architecture that best fits its product portfolio.
Powertrain Efficiency: Current Levels and Projected Improvement Needed

26.8% Fleet Average to Meet MY2025 GHG Standards (EPA Proposed Determination TSD)

<table>
<thead>
<tr>
<th>MY2017 Gasoline Vehicles</th>
<th>Powertrain Efficiency (%)</th>
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</thead>
<tbody>
<tr>
<td>MY2017 Honda Civic</td>
<td>25.3%</td>
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<tr>
<td>MY2017 Honda Fit</td>
<td>25.4%</td>
</tr>
<tr>
<td>MY2017 Hyundai Tucson</td>
<td>25.6%</td>
</tr>
<tr>
<td>MY2017 Nissan Juke AWD</td>
<td>26.4%</td>
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<tr>
<td>MY2017 Audi A4</td>
<td>25.7%</td>
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<tr>
<td>MY2017 BMW 440i xDrive</td>
<td>23.6%</td>
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<tr>
<td>MY2017 F150 (2.7L, 6sp)</td>
<td>23.5%</td>
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<tr>
<td>MY2017 Porsche 911 Carrera 4S</td>
<td>21.0%</td>
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</table>

Best Powertrain Efficiencies
Progress in Engine Efficiency

MY2008 Actual PFI Engine
• Peak thermal efficiency 34%
• Narrow efficiency region

MY2014 Actual GDI Engine
• Peak thermal efficiency 36%
• Broader efficiency region

MY2016 Actual Turbo downsized Engine
• Peak thermal efficiency 38%
• Very broad efficiency region
• Large overlap with 2-cycle test operation

MY2025 EPA projected turbo downsized engine
• Peak thermal efficiency 38%
• Similar efficiency region as MY2016 actual engine
• Hardware improvements provide some improved low-load efficiency
Improving powertrain efficiency is one half of the solution to improve overall vehicle efficiency.

Managing road loads (the amount of energy required to move a vehicle down the road) is also important.

Road load reductions
- Lower vehicle mass
- Aerodynamic improvements
- Lower rolling resistance tires
Sensitivities

EPA conducted a range of sensitivity analyses to evaluate the effects of individual program elements on the overall results.

Despite the application of unlikely assumptions (i.e. no additional mass reduction) the overall average cost of compliance remained stable.

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Table C.34 MY2025 Absolute Technology Penetrations & Incremental Costs for the Fleet in Each OMEGA Run (2015S)

<table>
<thead>
<tr>
<th>Tech</th>
<th>AEO Ref (Central Case)</th>
<th>AEO High</th>
<th>AEO Low</th>
<th>Perfect Trading</th>
<th>No C/T Transfers</th>
<th>No additional MR</th>
<th>Non-ATK2 Path</th>
<th>Non-TRK22</th>
<th>RPE</th>
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<td>Deca</td>
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<td>1%</td>
<td>8%</td>
<td>7%</td>
<td>7%</td>
</tr>
</tbody>
</table>

$/veh: $875 $882 $886 $843 $880 $797 $920 $1,115 $1,038

$/veh: $0 $7 $11 -$32 $5 -$78 $45 $240 $163
The MTE analysis projects very little electrification will be required to meet the 2025 MY standards, however, for those manufacturers that choose to sell electrified vehicles they can make a major contribution.

2025 MY standards were set largely on improvements in gasoline vehicle performance, and only small levels of electrification

Had the standards been set based on high penetrations of electrification technology, they would need to be much more stringent

What about vehicle electrification?

This table does not include EV's which perform even better with respect to future standards
PHEVs set new sales records in 2016, with EV sales up 25% over last year, and PHEVs up around 70%.

The fourth quarter was a record quarter for PHEVs, and the second best quarter ever for EVs (second only to last quarter).

December, 2016 was a record sales month for both EVs and PHEVs

EVs have now outsold PHEVs for 10 straight quarters
  For the first time in over 2 years PHEVs did outsell EVs in an individual month.
EPA has projected that the future fleet will look and operate much the same as it does today .... But with more technology that improves vehicle efficiency:

- Gasoline engine with smaller displacement and possibly turbocharged
  - Operating in Atkinson or Miller Cycle
- Higher number of gears in a more efficient transmission
  - or be equipped with an advanced CVT or DCT
- Lower weight
- Better Aerodynamics
- Lower rolling resistance tires
- Mild electrification
Thank you!
References

1. 2008 EPA Staff Report: https://nepis.epa.gov/Exe/ZyPDF.cgi/P10025VN.PDF?Dockey=P10025VN.PDF
6. 2016 EPA/NHTSA/CARB DTAR: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100OXEO.PDF?Dockey=P100OXEO.PDF