REGULATORY ANALYSIS OF POWERTRAIN TECHNOLOGIES: ONE PATHWAY FOR COMPLIANCE WITH CAFE AND GHG EMISSIONS STANDARDS

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National Highway Traffic Safety Administration
US Transportation Sector Energy Use in 2012

Source: U.S. Energy Information Administration, Annual Energy Outlook 2014
US Transportation Sector CO₂ Emissions in 2012

Source: U.S. Energy Information Administration, Annual Energy Outlook 2014
Cafe: Required Fleet Fuel Economy and Actual Fuel Economy

*Standards beyond MY2021 subject to de novo rulemaking by DOT*
Key Gasoline Engine Technologies

- Spray Guided Gasoline Direct Injection (GDI)
- Variable Valve Timing, Variable Valve Lift
- Turbocharging with Engine Downsizing
- High BMEP: 24 bar BMEP available beginning in 2012, 27 bar BMEP in 2017
- Cooled EGR (option for 24 bar engines, assumed required for 27 bar engines)
- Relative to fixed-valve naturally aspirated gasoline engine:
  - Projected Effectiveness: 20 - 27% for 24 bar BMEP
  - 24 - 28% for 27 bar BMEP (low usage in 2025)
- Projected Cost in 2025: $650 - $2300

![Image of Turbocharger with labels: Turbocharger, EGR Cooler, Gasoline Direct Injection]
Advanced Diesel Engine

- Common Rail Fuel Injection
- Selective Catalytic Reduction (SCR) Aftertreatment
- Higher Injection Pressures
- Advanced Controls
- Reduced Friction
- Relative to fixed valve naturally aspirated gasoline engine:
  
  Projected Effectiveness: 28 - 31%
  
  Projected Cost in 2025: $2300 - $3400
Key Transmission Technologies

- Greater than 6 speeds
- Dual Clutch Transmission
- High Efficiency Gear Box
- Optimized Shift Control

Relative to a 5-speed automatic transmission:

- Projected Effectiveness: 16% - 19%
- Projected Cost in 2025: $285 - $360
### P2 Hybrid Electric Vehicles

**Stop/Start**  
**Regenerative Braking**  
**Electric Assist and Short EV Range**  
**Effectiveness**: 45 – 49%

![Hyundai Sonata Hybrid](image)

<table>
<thead>
<tr>
<th>MY 2025 P2 Hybrid</th>
<th>Vehicle Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compact</td>
</tr>
<tr>
<td>Motor/battery power (kW)</td>
<td>19</td>
</tr>
<tr>
<td>Battery Cost</td>
<td>$ 822</td>
</tr>
<tr>
<td>Non-Battery System Cost</td>
<td>$ 1,809</td>
</tr>
<tr>
<td>Total Cost (2009 $)</td>
<td>$ 2,631</td>
</tr>
<tr>
<td>Battery Unit Cost ($/kW)</td>
<td>$ 43</td>
</tr>
</tbody>
</table>

*(All table values assuming 2010 baseline fleet)*

* Relative to a fixed valve naturally aspirated gasoline engine with a 5-speed automatic transmission
Plug-In Hybrid Electric Vehicle

- High capacity Li-ion battery
- All electric accessories
- Regenerative braking
- Effectiveness*: 68 – 70%

Not used for CAFE standard setting
Electricity use accounted for by Petroleum Equivalency Factor

<table>
<thead>
<tr>
<th>MY 2025 PHEV 30</th>
<th>Vehicle Class</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Compact</td>
</tr>
<tr>
<td>Motor size (kW)</td>
<td>95</td>
</tr>
<tr>
<td>Battery Energy (kWh)</td>
<td>10.4</td>
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<tr>
<td>Battery Cost</td>
<td>$ 4,710</td>
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<tr>
<td>Non-Battery System Cost</td>
<td>$ 3,173</td>
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<tr>
<td>Total Cost (2009 $)</td>
<td>$ 7,883</td>
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<tr>
<td>Battery Unit Cost ($/kWh)</td>
<td>$ 453</td>
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</tbody>
</table>

* Relative to a fixed valve naturally aspirated gasoline engine with a 5-speed automatic transmission
Electric Vehicle

- High capacity lithium ion battery
- Significant electric range (~ 70-120 miles all electric range)
- Effectiveness: 90 – 91%

Not used for CAFE standard setting
Electricity use accounted for by
Petroleum Equivalency Factor

<table>
<thead>
<tr>
<th>MY 2025 EV100</th>
<th>Vehicle Class</th>
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<tbody>
<tr>
<td></td>
<td>Compact</td>
</tr>
<tr>
<td>Motor size (kW)</td>
<td>95</td>
</tr>
<tr>
<td>Battery Energy (kWh)</td>
<td>30.4</td>
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<tr>
<td>Battery Cost</td>
<td>$9,363</td>
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<tr>
<td>Non-Battery System Cost</td>
<td>$526</td>
</tr>
<tr>
<td>Total Cost (2009 $)</td>
<td>$9,889</td>
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<tr>
<td>Battery Unit Cost ($/kWh)</td>
<td>$308</td>
</tr>
</tbody>
</table>

* Relative to a fixed valve naturally aspirated gasoline engine with a 5-speed automatic transmission
The agencies assessed more than 50 technologies can be used to improve fuel economy

- Advanced gasoline and diesel engine technologies
- Transmissions with more than 6 speeds and dual-clutch technology
- Hybrids, plug-in hybrid electrics, and all electric vehicles
- Mass reduction
- Improved vehicle aerodynamics
- Reduced rolling resistance tires
- Improved electric accessories
- Improved air conditioning systems
Use a computer model (the CAFE model) to analyze how the industry and each manufacturer could meet more stringent standards

- Optimization program for cost and effectiveness
- Models each manufacture and every vehicle model
- Accounts for redesign cycles
- Accounts for regulatory constraints
- Provides economic and some environmental effects results
NHTSA analysis projects that most manufacturers could comply in 2025 by producing an overall fleet with:

- 91% Advanced gasoline and diesel vehicles
- 66% Advanced transmissions
- 20% Idle stop-start
- 12% Hybrid Electric Vehicles
- 1% Plug-in Hybrid Electric Vehicles or Electric Vehicles
- 4% Average passenger car mass reduction
- 8% Average light truck mass reduction relative to 2011

**NOTE**: the standards are performance standards, not technology mandates. Manufacturers can choose any technologies to meet the standards. The agency analysis projects one pathway for compliance.
Consumer Impacts

- Footprint based standards reduce incentives to change vehicle size and help maintain consumer choice.
- The agency model assumed no change in vehicle utility, except for EV driving range.
- Average vehicle cost increase in 2025 relative to 2016: $1800
- 2025 vehicle lifetime fuel savings: $5,700 to $7,400
- Net lifetime savings: $3,400 to $5,000

Note: all ranges of $ values based on use of a 3% and 7% discount rate.
Impact on Fuel Consumed by U.S. Passenger Cars and Light Trucks

Each billion gallons of fuel consumption corresponds to approximately 11 million metric tons of carbon dioxide emissions.
Mid Term Evaluation

2017  2021  2022  2025

EPA Final unless changed by rulemaking

2017-2021 Final

2022-2025 Conditional

Joint Technical Assessment Report
1. CAFE standards are challenging, but there is lead time and the agencies’ analyses show a pathway to develop and implement technologies to meet the standards.

2. There is a wide range of technologies that manufacturers can use to improve fuel economy.

3. There is significant potential for fuel efficiency improvement in gasoline and diesel engines and in transmissions.

4. The 2025 fleet could be dominated by advanced gasoline and diesel vehicles, with a modest number of HEVs and a small number of PHEV and EVs.

5. The agencies’ pathway does not compromise vehicle functionality.

6. The standards will provide fuel savings that are estimated to significantly exceed consumer costs.

7. NHTSA, EPA and CARB will conduct a mid-term review of the 2022 – 2025 standards. NHTSA will conduct new rulemaking for those years.