On-Going Development of Heavy-Duty Vehicle GHG / Fuel Economy Standards

Rachel Muncrief
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Resources for the Future
1616 P Street NW, Washington DC
Geographic Scope: Top Vehicle Markets

- Top eleven major global vehicle markets
  - Most have auto efficiency standards – Some working on truck standards
Technology Potential in US Trucks

- National Academy of Sciences Report (March 2010)
  - Found 35 – 50% improvement achievable in 2015-2020 timeframe

National Academy of Sciences (2010) FIGURE S-1 Comparison of 2015-2020 New Vehicle Potential Fuel Savings Technology for Seven Vehicle Types: Tractor Trailer (TT), Class 3-6 Box (Box), Class 3-6 Bucket (Bucket), Class 8 Refuse (Refuse), Transit Bus (Bus), Motor Coach (Coach), and Class 2b Pickups and Vans (2b). Also, for each vehicle class, the fuel consumption benefit of the combined technology packages is calculated as follows: \( \% \text{FCpackage} = 1 - (1 - \%\text{FCtech 1})(1 - \%\text{FCtech 2})(1 - \%\text{FCtech N}) \) where \( \%\text{FCtech x} \) is the percent benefit of an individual technology. SOURCE: TIAX (2009) ES-4.
Compliance Example: Class 8 Tractor

- Technologies to go from baseline to compliance tractor
  - Example high-roof sleeper cab: 94 $\rightarrow$ 72 gCO$_2$/ton-mile from 2010 to 2017

Based on US EPA / NHTSA 2014-2018 heavy duty vehicle regulatory assessment
Different technologies have different value in different conditions

- Approximate differences, compared to value in US context

<table>
<thead>
<tr>
<th>Technology</th>
<th>US*</th>
<th>Basis for Reduction</th>
<th>Japan</th>
<th>China</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>20%</td>
<td>Advanced 11-15L diesel with bottoming cycle</td>
<td>More</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerodynamics</td>
<td>11.5%</td>
<td>Improved SmartWay tractor + three aerodynamic trailers</td>
<td>Less</td>
<td>Less</td>
<td>Less</td>
</tr>
<tr>
<td>Tires and Wheels</td>
<td>11%</td>
<td>Improved WBS on tractor + three trailers</td>
<td>More</td>
<td></td>
<td>Less</td>
</tr>
<tr>
<td>Hybrid/Idle Reduction</td>
<td>10%</td>
<td>Mild parallel hybrid with idle reduction</td>
<td>More</td>
<td></td>
<td>Less</td>
</tr>
<tr>
<td>Transmission</td>
<td>7%</td>
<td>AMT, reduced driveline friction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management and Coaching/Speed limits</td>
<td>6%</td>
<td>60 mph speed limit; predictive cruise control with telematics; driver training</td>
<td>Less</td>
<td>Less</td>
<td>Less</td>
</tr>
<tr>
<td>Weight</td>
<td>1.25%</td>
<td>Material substitution—2,500 lb.</td>
<td>More</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These are based on NAS tractor-trailer Class 8 for US context; reductions are approximate, and are not additive.
Early heavy-duty standards (Japan, US, China, etc) slow the emissions rise

- Far greater potential exists to increase truck efficiency over the long-term

Based on ICCT Roadmap project
Big Issues for 2020+ Regulation

- Test procedures:
  - Simulation vs testing? Separate engine standards?
  - Do we need full vehicle testing?
- How to incorporate all major technologies in regulations
  - Transmission technologies
  - Hybrid technology
  - Incorporate tires, aerodynamics
  - Inclusion of trailers
- Global alignment:
  - Merge different counties’ test procedures over time?
### Efficiencies Captured in Standard

- Efficiencies captured different in standards
  - Governments, industry interested in possible alignment

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>U.S.</th>
<th>China</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>Yes</td>
<td>Through separate engine standards</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Transmission</td>
<td>Somewhat</td>
<td>Optional; by demonstration outside of standard protocol</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hybridization</td>
<td>-</td>
<td>By demonstration outside of standard protocol</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Aerodynamic drag, rolling resistance</td>
<td>No</td>
<td>Yes</td>
<td>Aerodynamic drag, but not rolling resistance</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Full vehicle testing?

- Full chassis dynamometer testing –
  - Allows ability test any vehicle configuration
  - Would allow for incorporation of advanced transmission, hybrids

- Disadvantages:
  - Capital and operating expense
  - Coastdown testing requirement

Source: research.psu.edu

* From recent ICCT SAE paper #2012-01-1986
Testing of standard vs. optimized trailer *

- Aerodynamic drag differs with speed
  - 40% of on-road resistance at 50 km/hr
  - 70% of on-road resistance at 88 km/hr

- Optimized trailer benefits:
  - Constant speed: 4% aero improvement
    - 1% fuel consumption/CO₂ decrease (highway)
  - Coastdown test: 9% aero improvement

- ICCT work ongoing on trailers
  - How to best incorporate aerodynamic improvement?
  - Include trailers?

* Based on work by TU Graz
Heavy Duty Regulation Alignment

Motivation:
- Facilitate compliance, reduce costs for global industry
- Expedite emissions reductions by increasing the market size

Elements
- Metrics
- Segmentation of vehicles
- Test cycles
- Test protocol
- Stringency
- Data and research
Many efficiency technologies are highly cost-effective
- Have net societal benefit (energy savings > up-front cost)
- Less than zero cost per ton CO\textsubscript{2} reduced

Why are these technologies not being deployed?

Barriers include (*):
- More focused on operational driver training
- Low technology awareness by fleets
- OEMs not offering technologies fully
- High costs or high perceived costs of technology
- Low and/or uncertain expected technology benefits (e.g., trailer technology)
- Does not fit with operation

Related ICCT Work
- China industry survey (ongoing)
- Workshop in Europe (Oct 2012)
- US market barriers study (Jan 2013)

* Based on CE-Delft “Market Barriers to Increased Efficiency in the European On-road Freight Sector”
HDV GHG / fuel economy standards are a critically important area of regulatory development for the US and globally.

The search for continually improving upon regulatory design (metric, cycle, test method, etc) will continue for the next 5 to ten years at least.

Important questions remain:

- Expand compliance options to full vehicle and trailer
- Simulation Modeling v. Chassis Dyno
- Hybrid technology development and incorporation
- Opportunities for global alignment of programs
Extra Slides
Cost Effectiveness of Technologies
For Long Haul Segment

*Results from 2012 EU Market Barriers Survey
**Marginal abatement cost range using MACH model, 12 different scenarios
Variables = Discount Rate, Vehicle Lifetime, Fuel Cost
## Test Procedure Summary

**key differences from US**

<table>
<thead>
<tr>
<th>Feature</th>
<th>U.S.</th>
<th>Japan</th>
<th>China</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test Cycles</strong></td>
<td>CARB Transient Cycle and 55-mph and 65-mph cruise cycles.</td>
<td>Road grade</td>
<td>WTVC (China adjusted)</td>
<td>Mission-based cycles (may include road grade, altitude, stops)</td>
</tr>
<tr>
<td><strong>Cycle Weighting</strong></td>
<td>Transient 5%, 55-mph cruise 9% and 65-mph cruise 86% for sleeper cab tractor trucks.</td>
<td>Transient 90% Highway10%</td>
<td>Road (rural) 10% Highways 90%</td>
<td>No weighting necessary for mission-based cycles.</td>
</tr>
<tr>
<td><strong>Test Payload</strong></td>
<td>19 tons</td>
<td>Similar</td>
<td>Double</td>
<td>Similar</td>
</tr>
<tr>
<td><strong>Test Method</strong></td>
<td>Simulation</td>
<td>Engine fuel consumption map generated from engine dynamometer testing, enter into simulation</td>
<td>Chassis test required for baseline. Simulation or chassis for improved model</td>
<td>Simulation based on actual vehicle values</td>
</tr>
<tr>
<td><strong>Engine vs Full Vehicle</strong></td>
<td>Engine certification for fuel consumption separately</td>
<td>No separate engine certification for fuel consumption</td>
<td>No separate engine certification for fuel consumption</td>
<td>No separate engine certification for fuel consumption</td>
</tr>
<tr>
<td><strong>Aerodynamic drag (C_d)</strong></td>
<td>Manufacturer testing to determine C_d (coastdown preferred)</td>
<td>Standard value</td>
<td>Manufacturer testing to determine C_d (coastdown preferred) or standard value</td>
<td>Manufacturer testing to determine C_d (constant speed test preferred)</td>
</tr>
<tr>
<td><strong>Rolling Resistance (C_r)</strong></td>
<td>Manufacturer testing to determine C_r for the steer and drive tire</td>
<td>Standard value</td>
<td>None</td>
<td>Standard values from tire labels</td>
</tr>
</tbody>
</table>
# Test Procedures – Comparison

<table>
<thead>
<tr>
<th>Pro</th>
<th>Con</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle testing</strong></td>
<td>Represents “actual” vehicle performance over a given drive cycle; technology advances automatically captured in results; allows for compliance/enforcement testing.</td>
<td>Expensive; test cycle(s) may not reflect full range of operation</td>
</tr>
<tr>
<td><strong>Chassis</strong></td>
<td>Limited space requirements</td>
<td>Does not capture aerodynamics or rolling resistance.</td>
</tr>
<tr>
<td><strong>Truck/Road</strong></td>
<td>Captures aerodynamics and rolling resistance</td>
<td>Limited repeatability</td>
</tr>
<tr>
<td><strong>Vehicle simulation</strong></td>
<td>Less expensive; testing over multiple cycles as easy as testing over a single cycle; results are replicable</td>
<td>Need extensive and continual updating to capture technology advances and ensure consistency with real-world performance</td>
</tr>
<tr>
<td><strong>Component-based</strong></td>
<td>Least expensive; most direct incentive to improve component efficiency</td>
<td>Interactions of components not reflected; variations in performance over different cycles may not be accounted for</td>
</tr>
</tbody>
</table>