Outline

- Relevance of HDVs and status of regulations
- ICCT research on US technology potential
- Global technology potential project
Relevance of heavy-duty vehicles

- Growth in HDV energy consumption and CO₂ emissions predicted to outpace growth in other modes.
- Forecasted 72% increase from 2010-2030.

- HDV represents 8% of total energy consumption and CO₂ emissions.
HDV Global Regulatory Landscape

- Major markets shown cover over 75% of freight ton-km and energy use
- Only four countries in the world currently have HDV CO₂/efficiency standards

<table>
<thead>
<tr>
<th>Country</th>
<th>HDV efficiency regulation in place</th>
<th>Regulations under consideration</th>
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</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>✓</td>
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<tr>
<td>China</td>
<td>✓</td>
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<tr>
<td>EU-27</td>
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<td>✓</td>
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<tr>
<td>India</td>
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<td>Japan</td>
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<tr>
<td>Brazil</td>
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<td>Canada</td>
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<td>Russia</td>
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<td>Mexico</td>
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<td>S. Korea</td>
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- HHDV (14k+ kg)
- MHDV (6.4-14k kg)
- LHDV (3.5-6.4k kg)
HDV Global Regulatory Landscape

- Four countries in the world currently have HDV CO2/efficiency standards
- Others are working towards standards

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<td>Phase 3</td>
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<tr>
<td>EU</td>
<td>Certification, Monitoring, Reporting</td>
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<td>Phase 1</td>
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Hashed areas represent unconfirmed projections of the ICCT
Impact of heavy-duty efficiency standards on global CO$_2$ emissions
Objective:

- Assess US heavy-duty tractor-trailer efficiency potential in the 2020-2030 timeframe.
- Develop state-of-the-art model that models the system interactions between engine, transmission, aerodynamics, rolling resistance, lightweighting efficiency technologies.
- Develop flexible modeling capabilities for vehicle vehicle types, different vehicle test cycles, different baseline markets.

Project steps:

- Engine laboratory data collection and energy audit.

- Stakeholder workshop to solicit input from key industry players.

- Full-vehicle system technology modeling using vehicle simulation software (Autonomie) + development of Advanced Truck Technology Efficiency Simulation Tool (ATTEST).

- Cost assessment.
Engine analysis

- In collaboration with West Virginia University
- Data collection for engine compliant with US EPA 2010 regulations
  - Engine fuel consumption map (fuel use, vs torque, rpm)
  - Energy audit: breakdown of engine loss characteristics
  - Advanced improved energy efficiency potential in energy loss areas

Engine Maps

Engine audit, and projections

Tractor-trailer vehicle simulation

- Full-vehicle systems modeling of engine, transmission, and road load efficiency technologies on tractor trailers
  - Utilize the widely-used Autonomie modeling framework to handle system interactions
  - Augment the Autonomie model for new engine map; improved engine, transmission technologies; improved road load technologies (aero, tires, weight)
  - Vehicle propulsion architecture shown:

ATTEST Tool Structure
Results: Fuel consumption from selected efficiency technology packages

Mid-term, technology tracking

Long-term technology forcing

Fuel consumption (gal/1000 ton-mi)
Next step: Global assessment

- **Objective:**
  - Conduct technical analysis to incorporate HDVs into the GFEI.

- **Methodology:**
  - Select representative vehicles.
    - Five markets: Brazil, China, EU, India, and US.
    - Two segments: tractor-trailer and rigid trucks.
  - Gather **engine and vehicle data** to create a baseline.
    - Engine maps
    - Vehicle parameters (tires, aerodynamics, mass, etc.)
    - Duty cycle (speeds, grade, payload)
  - Simulate **technology potential to 2030**
    - Equivalent to US SuperTruck technology level for US and EU
    - Equivalent to US Phase 2 technology level for Brazil, China, India
  - Map remaining world markets
    - To the market which they are most similar
    - Use ICCT roadmap model to estimate sales-weighted reductions that are possible.
## Comparison of HDVs in different markets (preliminary)

<table>
<thead>
<tr>
<th></th>
<th>Brazil</th>
<th>China</th>
<th>EU</th>
<th>India</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: axle configuration</td>
<td>6x2</td>
<td>6x4</td>
<td>4x2</td>
<td>4x2</td>
<td>6x4</td>
</tr>
<tr>
<td>B: tractor curb weight</td>
<td>9.7t</td>
<td>10t</td>
<td>7t</td>
<td>6t</td>
<td>8t</td>
</tr>
<tr>
<td>C: GVW</td>
<td>35t</td>
<td>33t</td>
<td>40t</td>
<td>40t</td>
<td>36t</td>
</tr>
<tr>
<td>D: Transmission type</td>
<td>MT</td>
<td>MT</td>
<td>AMT, 12 spd.</td>
<td>MT, 6 spd.</td>
<td>MT, 10 spd.</td>
</tr>
<tr>
<td>E: engine displacement</td>
<td>13L</td>
<td>&lt; 11L</td>
<td>13L</td>
<td>&lt; 6L</td>
<td>15L</td>
</tr>
<tr>
<td>F: engine power</td>
<td>~325kW</td>
<td>~260kW</td>
<td>~325kW</td>
<td>~135kW</td>
<td>~340kW</td>
</tr>
<tr>
<td>G: emission standard</td>
<td>Proconve 7</td>
<td>China IV</td>
<td>Euro VI</td>
<td>Bharat III</td>
<td>US EPA 2010</td>
</tr>
</tbody>
</table>

A: axle configuration, B: tractor curb weight, C: GVW, D: Transmission type, E: engine displacement, F: engine power, G: emission standard
Comparison of HDVs in different markets (preliminary)

Energy audit for representative tractor-trailers in India and US.
Observations and conclusions

- Regulatory action needed to address CO$_2$ emissions and fuel use from heavy-duty vehicles.
  - Japan, US, China and Canada currently have programs while India, Mexico, Korea and Europe are actively developing programs.

- Country-specific analysis required to evaluate technology potential.
  - Complexity added by differences in market structure, baseline fleet, and duty cycles.
  - However, shared use of simulation models holds promise.

- Strong compliance programs required
  - Conformity of production and in-use verification requirements are needed to ensure that regulatory requirements translate to real-world.
Thank you!

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