Heavy-duty vehicle technology potential around the world

IEA-PCRA workshop on heavy-duty vehicle fuel efficiency regulations
New Delhi, India
April 29, 2015

Ben Sharpe
Outline

- Big picture: regulatory development globally
- Heavy-duty vehicle (HDV) energy balance examples
- Technology potential studies for North America and Europe
- Comparing technology potential in different regions around the world and preliminary observations for India
- Conclusions
The International Council on Clean Transportation

- Non-profit research organization incorporated in 2005
- Roughly 35 full-time staff with offices in San Francisco, Washington DC, Berlin, London, and Beijing
- Mission: improve the environmental performance and energy efficiency of all modes of motorized transportation – passenger cars, heavy-duty trucks and buses, ocean-going ships, and commercial aviation – and the fuels they burn to address air pollution and climate change
Industry survey project

- Primary objectives
  - Interview a diverse cross-section of stakeholders in the trucking industry in India to build a deeper understanding on a number of topics related to fuel-saving technologies and practices
  - Gain insights into the key factors in decision-making processes for manufacturers and fleets
- Targeted stakeholder groups
  - Truck and bus original equipment manufacturers
  - Tier 1 suppliers (e.g., engines, transmissions, tires/wheels)
  - Truck and bus fleets
  - Testing facilities
  - Industry associations
- **All responses will be kept anonymous!**
- Key contacts
  - Ben Sharpe, ICCT – [ben@theicct.org](mailto:ben@theicct.org)
  - Jai Malik, TERI – [jai.kishanmalik@teri.res.in](mailto:jai.kishanmalik@teri.res.in)
Efficiency regulations in major markets

- Efficiency regulations under consideration in major freight markets
  - Markets include over 75% of HDV freight ton-km, HDV freight energy use

<table>
<thead>
<tr>
<th>Country</th>
<th>HDV efficiency regulation in place</th>
<th>Regulations under consideration</th>
<th>Heavy-duty freight vehicle fuel use (million BOE/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>✓</td>
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<td>[Graph showing fuel use]</td>
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<td>[Graph showing fuel use]</td>
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<td>S Korea</td>
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<td>[Graph showing fuel use]</td>
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</tbody>
</table>

Source: ICCT Roadmap, 2013; BOE = barrel of oil equivalent energy

Legend:
- HHDV (14k+ kg)
- MHDV (6.4-14k kg)
- LHDV (3.5-6.4k kg)
Areas for on-vehicle efficiency improvements

Truck and trailer aerodynamics

- Engine efficiency
- Driver behavior and telematics
- Drivetrain
- Auxiliary loads
- Reducing vehicle empty weight
- Rolling resistance
Example energy balance: tractor truck and trailer

Tractor-trailer, HHDDT65 drive cycle (80 kph average), half loaded, level road

Major loss areas

- Aerodynamic losses: 17%
- Engine losses: 60%
- Drivetrain: 1.5%
- Auxiliary loads: 1.5%
- Rolling resistance: 15%
- Braking: 5%

Source: ICCT simulation analysis
Example energy balance: urban delivery truck

Urban delivery, HTUF Class 6 drive cycle (15 kph average), half loaded, level road

Major loss areas

- Aerodynamic losses: 3%
- Rolling resistance: 6%
- Drivetrain: 5%
- Braking: 15%
- Engine losses: 70%
- Auxiliary loads: 1.5%

Source: ICCT simulation analysis
Impact of aerodynamics and rolling resistance as a function of speed

Aerodynamic drag contributes to an increasing portion of overall resistance as vehicle speed increases.

Studies on HDV technology potential

- **North American studies**
  - NESCAUM Tractor-trailer study (Oct 2009)
  - National Research Council report (March 2010)
  - National Research Council report (April 2014)
  - Analysis of SuperTruck technologies (June 2014)
  - Tractor-trailer simulation modeling of technology potential (April 2015)
  - Tractor-trailer technology cost and payback period assessment (April 2015)

- **European studies**
  - LOT 1 report (Feb 2011)
  - TIAX report (Jan 2012)
Substantial opportunity for HDV efficiency improvements

Studies from N. America and Europe show per-vehicle fuel consumption reduction potential of ~ 30-50% in the 2015 to 2020 timeframe compared to a 2010 baseline.


Tractor-trailer efficiency

- Combinations tractor-trailers are largest fuel consumer in most regions
  - For example, in the U.S., tractor-trailers are ~2% of all on-road vehicles, but consume 20% of vehicles’ energy use and greenhouse gas emissions
  - According to the ICCT Roadmap model, tractor-trailers represent nearly 80% of total heavy-duty vehicle fuel use and carbon emissions in India
  - There are many available and emerging efficiency technologies

**Tractor**
- Tires
- Aerodynamics
- Engine idle-off
- Lightweighting

**Engine**
- Friction, load reduction
- Aftertreatment
- Advanced control, injection
- Turbo, air handling improvements
- Turbocompounding, clutch
- Waste heat recovery

**Transmission**
- Optimal gearing
- Direct, single drive
- Friction reduction
- Automated manual
- Dual clutch
- Hybridization

**Trailer**
- Tires/wheels
- Aero skirt
- Aero gap
- Aero tail
Fuel consumption reduction potential for tractor-trailers

Results from an informal technology efficacy survey done at an ICCT workshop in July 2014
Engine contribution to advanced efficiency packages

- ICCT’s latest technology potential report for tractor-trailers in North America: engine efficiency amounts to about 1/3 to almost 1/2 of all potential fuel consumption benefits from 2020-2030 technology packages

Fuel consumption reduction from 2010 baseline

- Advanced integrated powertrain (2020+ engine (48% BTE), dual-clutch)
- Advanced tractor-trailer road load technology (-30% Cd aerodynamics, -30% Crr tires, -14% mass)
- Engine downsizing (10%)
- Engine waste heat recovery (52%BTE)
- Long-term tractor-trailer road load technology (-50% Cd aerodynamics, -35% Crr tires, -17% mass)
- Long-term engine technology (55% BTE)
- Hybrid system (60% braking regeneration efficiency)

Preliminary technology potential observations for India

- Typical characteristics of HDVs in India
  - Freight hauling: lower speeds than trucks in Europe or North America; likely comparable to speeds in China
  - Overloading quite common
  - Trucks have lower power-to-weight ratios compared to other major markets

- Impacts for fuel efficiency
  - Lower speeds, high percentage of heavily-loaded trucks → engine and rolling resistance improvements much more important than aerodynamics
Relative contribution to overall technology potential for tractor-trailers

<table>
<thead>
<tr>
<th>Country/region</th>
<th>Powertrain</th>
<th>Aerodynamics</th>
<th>Rolling resistance</th>
<th>Idle reduction</th>
<th>Hybridization</th>
<th>Weight reduction</th>
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Conclusions

- Development of HDV fuel efficiency and GHG regulations is happening in a number of countries and regions around the world
- Assessing the technology potential across the various categories of HDVs is an essential step in the regulatory development process
- Numerous studies evidence significant opportunities for the development and deployment of fuel-saving technologies
- Technology efficacy varies from region to region based on drive cycles, payloads, geography, and infrastructure conditions
- For India, engine and tire rolling resistance improvements are the technology areas that likely present the biggest opportunities for fuel savings in the near-term
Thank you!

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Anup Bandivadekar  anup@theicct.org
Overview of heavy-duty vehicle regulations globally

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# Regulatory development timelines

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<td>Phase 2 implementation</td>
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<tr>
<td>United States</td>
<td>GHG/Fuel efficiency</td>
<td>Standard proposal</td>
<td>Final rule</td>
<td>Phase 2 regulatory development</td>
<td>Regulation implemented starting MY 2014 (mandatory DOT program starts MY 2016)</td>
<td>Phase 2 proposal</td>
<td>Phase 2 final rule</td>
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<tr>
<td>Canada</td>
<td>GHG</td>
<td>Standard proposal</td>
<td>Final rule</td>
<td>Regulation implemented starting MY 2014 (optional until MY 2016)</td>
<td>Phase 2 regulatory development</td>
<td>Phase 2 proposal</td>
<td>Phase 2 final rule</td>
<td>Phase 2 implementation</td>
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<td>China</td>
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<td>Test procedure finalized</td>
<td>Industry standard proposal</td>
<td>Industry standard implemented</td>
<td>National standard adopted</td>
<td>Final regulation of National standard effective on July 1, 2014 for newly certified vehicles and July 1, 2015 for existing vehicles</td>
<td>Next phase implementation</td>
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<td>Technical studies</td>
<td>Impact assessment</td>
<td>Test protocol and simulation model finalization</td>
<td>Policy implementation</td>
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<td>California</td>
<td>End-user purchase requirements</td>
<td>Requirements for new tractors, trailers (2011+)</td>
<td>Additional requirements for existing tractors and trailers (&lt; MY 2010)</td>
<td>Additional requirements for existing trailers and reefers (&lt; MY 2010)</td>
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*Items in blue are ICCT expectations (not public announcements)*
Continuum of test procedure options

1. ‘Full vehicle’ simulation
   - Road load
   - Engine
   - Transmission

2. Vehicle simulation + separate engine standard
   - Engine dyno
   - Hardware

3. Vehicle simulation + separate engine standard/powertrain testing
   - Powertrain dyno
   - Hardware

4. Chassis dynamometer testing
   - Hardware

China: “Variant” vehicle models

Phase 1 rule

Option for Phase 2 rule

Model fidelity and validation challenges increase
### Qualitative assessment of test procedure options for India

<table>
<thead>
<tr>
<th>Certification option</th>
<th>Ability to leverage existing testing facilities</th>
<th>Complexity of certification process</th>
<th>Timeframe for regulatory implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full vehicle simulation – adapted version of VECTO, GEM, Japan or China model</td>
<td>Moderate</td>
<td>Moderate</td>
<td>5-7 years</td>
</tr>
<tr>
<td>Full vehicle simulation – new India model</td>
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<td>?</td>
<td>5-7 years</td>
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<tr>
<td>Chassis dynamometer</td>
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<tr>
<td>Engine dynamometer</td>
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<td>Moderate</td>
<td>3-5 years</td>
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</tbody>
</table>

**Notes:**
- **Green** indicates Favorable
- **Yellow** indicates Moderate
- **Red** indicates Unfavorable