Heavy-Duty Vehicle GHG Regulatory Developments Around the World

Opportunities and Challenges of Moving Towards Global Alignment

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Topics

- Key policy drivers
- Current heavy-duty vehicle policy landscape
- Regulatory design summary for Japan, N. America, the EU, and China
- What does alignment mean?
- Benefits of challenges of moving towards ‘global’ alignment
- Maximizing the GHG benefits of N. American alignment
- Evolution of heavy-duty hybrid test procedures creates the opportunity for stronger links between criteria pollutant and GHG programs as well as greater alignment globally
- Summary remarks
In 2001, a group of 18 leading air quality and transportation regulators and experts from around the world met in Bellagio, Italy to develop policy guidelines for the future regulation of motor vehicles and transportation fuels.

The ICCT has over 30 full time staff with offices in San Francisco, Washington DC, Berlin, and Beijing.

The mission of the ICCT is to dramatically improve the environmental performance and efficiency of onroad vehicles, aircraft, and marine vessels in order to protect public health, the environment, and quality of life.
Key Policy Drivers

- HDVs are a significant and steadily growing portion of transport fuel use
  - HDVs dominate in many developing countries (e.g. China, India)

[Text with images and charts showing transport CO2 equivalent emissions by mode in 2010 and 2030 for various countries.]

ICCT Roadmap model v34 (Expect for Canada percentages, which come from Environment Canada)
Despite clear link between fuel efficiency and operational cost savings, there remains significant market barriers to efficiency technology uptake and penetration:

- Return on investment vs. payback time
- Split incentives (e.g. trailers)
- Lack of standardized information (e.g. tires)
- Other priorities (e.g. driver retention)
Policy Landscape: Timelines Across Regions

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<td>Phase 2</td>
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<td>GHG/Fuel efficiency</td>
<td>Standard proposal</td>
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<td>Canada</td>
<td>GHG</td>
<td>Standard proposal and final</td>
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<td>China</td>
<td>Fuel consumption</td>
<td>Test procedure finalized</td>
<td>Industry standard proposal</td>
<td>Standard proposal</td>
<td>Final rule</td>
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<td>European Union</td>
<td>GHG</td>
<td>Technical studies</td>
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<td>California</td>
<td>End-user purchase requirements</td>
<td>Requirements for new tractors and trailers (MY 2011+)</td>
<td>Additional reqs. for existing tractors and trailers (&lt;MY 2010)</td>
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In addition, we expect that countries such as Brazil and India with significant HDV populations will be considering policies to improve fuel efficiency in the coming years.
<table>
<thead>
<tr>
<th></th>
<th>Regulatory Categories</th>
<th>Certification Test Procedures</th>
<th>Metric</th>
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</thead>
<tbody>
<tr>
<td><strong>Japan</strong></td>
<td>Other Truck (11 subcategories)</td>
<td>Simulation modeling + engine dynamometer testing</td>
<td>Fuel economy (km/L)</td>
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<td></td>
<td>Tractor (2 subcategories)</td>
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<td>Route Bus (5 subcategories)</td>
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<td></td>
<td>Other Bus (8 subcategories)</td>
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<td><strong>N. America</strong></td>
<td>Tractors</td>
<td>Vehicles $\rightarrow$ simulation model</td>
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<td></td>
<td>Vocational vehicles</td>
<td>Engines $\rightarrow$ dynamometer testing</td>
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<td></td>
<td>HD pickup trucks and vans</td>
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<td></td>
<td>Engines (tractors, voc. vehicles)</td>
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<tr>
<td>*<em>China</em></td>
<td>Tractors, dump trucks, rigid trucks, city buses, other buses</td>
<td>“Base” vehicles $\rightarrow$ chassis dynamometer</td>
<td>Fuel consumption (L/100 km)</td>
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<tr>
<td></td>
<td></td>
<td>“Variant” vehicles $\rightarrow$ simulation modeling</td>
<td></td>
</tr>
<tr>
<td>*<em>European Union</em></td>
<td>Truck and bus categories based on GVWR, chassis configuration, and axle configuration</td>
<td>Simulation modeling</td>
<td>GHG (g/ton-mi)</td>
</tr>
</tbody>
</table>

*Regulatory design is currently under development in China and the EU. This represents the ICCT’s best estimate of the structure of these future programs. For the EU, this information represents an upcoming certification program, not necessarily a standard.
What “Alignment” Can Mean

Alignment can occur across one of more of the following regulatory design areas:

- Regulatory subcategories
  - Regulated entities
  - Vehicle groups

- Certification procedures
  - Component testing protocols (e.g. engines, tires)
  - Simulation models
  - Test cycles
  - Evaluation metric(s)

- Timing

- Stringency
Two primary benefits of increased global alignment:

1. Facilitates compliance, thereby reducing costs, for companies selling across multiple regions.

2. Expedites emission reductions by increasing the size of the market for fuel efficiency technologies → research and development costs can be spread out over a larger market.

“…heavy-duty vehicles are global products and each category is produced in relative low volumes. Manufacturers are, therefore, highly dependent on economy of scale.”

- European Automobile Manufacturers Assoc. (2010)
Challenges of Moving Towards Global Alignment

- Varying vehicle characteristics and market dynamics from region to region
  - Configurations: e.g. cab-over-engine vs. extended cab tractors
  - Differences in the way similarly configured vehicles are used
  - Differing technology ‘baselines’ and emission control levels
  - Power-to-weight ratios
  - Degree of vehicle customization
  - Capacity for physical testing

- Industry and government unfamiliarity with new test cycles
  - Long history with engine-based cycles (e.g. FTP)

- Desire for autonomy
Is the US rule and Canadian proposal aligned in the following categories?

<table>
<thead>
<tr>
<th>Regulatory Categories</th>
<th>Test Procedures for Certification</th>
<th>Stringency and Timing</th>
<th>Averaging, Banking, and Trading</th>
</tr>
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<tbody>
<tr>
<td>Alignment Option A</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<td></td>
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<td></td>
<td>Country-specific ABT programs</td>
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<tr>
<td>Alignment Option B</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td></td>
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<td>Canada accepts US certificates</td>
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</table>

- Option A allows for quantifiable benefits in Canada
- Option B: no way to ensure certain levels of GHG reductions
A Canada-specific Averaging, Banking, and Trading (ABT) program ensures that fuel-saving technologies enter the Canadian HDV fleet.

Take tractors as an example:

- Without a Canada-specific ABT program, a disproportionate amount of less fuel-efficient tractors could be sold in Canada.
- With a Canada-specific program, manufacturers or importers would have to sell a mix of tractors that, on average, meets the standard in that category (e.g. Class 8 high-roof sleeper).
The case for developing sound test procedures for HD hybrid systems and vehicles is very strong
- More equitable testing of hybrid vehicles/systems
- Opportunities for better alignment between criteria pollutant and fuel efficiency/GHG programs
- Pathways to ‘global’ harmonization of test procedures

Criteria pollutant certification for HDVs has always been based on engine dynamometer testing
- Not suitable for hybrids, which use two energy sources

Working Party on Pollution and Energy (GRPE)
- Informal Group on HD Hybrids is charged with establishing an amendment to Global Technical Regulation No. 4, which will be a test procedure for HD hybrid powertrains
- Member countries (e.g. Japan, the US, European nations, etc.) may choose to use this test procedure for HD hybrids in their criteria pollutant and, if applicable, GHG programs

This test procedure for HD hybrids can be the first step towards harmonization of both criteria pollutant and GHG programs worldwide
# HD Hybrid Test Method Comparison

<table>
<thead>
<tr>
<th></th>
<th>Consistency w/ existing engine test procedures</th>
<th>Applicable powertrain configurations</th>
<th>Robustness</th>
<th>Resource requirements</th>
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<tr>
<td>Chassis dynamometer</td>
<td><img src="Favorable" alt="Yellow Icon" /></td>
<td><img src="Moderate" alt="Green Icon" /></td>
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<td><img src="Unfavorable" alt="Red Icon" /></td>
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<tr>
<td>Engine dynamometer</td>
<td><img src="Moderate" alt="Green Icon" /></td>
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<td><img src="Moderate" alt="Green Icon" /></td>
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<tr>
<td>Powertrain dynamometer</td>
<td><img src="Favorable" alt="Yellow Icon" /></td>
<td><img src="Moderate" alt="Green Icon" /></td>
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<tr>
<td>HIL simulation and testing</td>
<td><img src="Favorable" alt="Yellow Icon" /></td>
<td><img src="Moderate" alt="Green Icon" /></td>
<td><img src="Favorable" alt="Yellow Icon" /></td>
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No one method is clearly superior across all relevant parameters!
Japan: HD Hybrid Certification

**Criteria Pollutants**
- Engine
  - Test cycle
    - Engine test bed
      - Regulated emissions (g/kWh)

**HDH HILS Test Procedure**
- Vehicle data
  - Veh. test cycle based on class, segment
    - HILS simulation
      - Unique engine speed/load cycle

**Fuel Efficiency**
- Component testing
- Vehicle data
  - Simulation program to convert vehicle speed vs. time to engine speed/load
    - ECU's in the loop
      - Calculate fuel consumption based on engine map
        - grams CO₂/t-km

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Strong link between criteria pollutant and FE programs
E.U. Proposed Option for HD Hybrid Certification

### Criteria Pollutants
- Engine
- Test cycle
- Engine test bed
  - Regulated emissions (g/kWh)

### GRPE HDH HILS TU Graz Proposal
- Power pack
- Full load curve
- Post-transmission test cycle
- HILS simulator (or PP test bed)
  - Unique engine speed/load cycle
  - ECU's in the loop

### LOT 2 Final Test Procedure for FE/GHGs
- Engine map
- Vehicle data
- Veh. test cycle based on class, segment
- HDV simulator
  - Hybrid
  - Conv.
  - grams CO₂/t-km

### Strong link between criteria pollutant and FE programs

Criteria Pollutants

- Hybrid engine only
- Engine dyno testing using FTP and SET cycles
- Regulated emissions (g/bhp-hr)

Fuel Efficiency/GHG: 3 Options

- Chassis dyno testing vs. a conventional vehicle “A to B testing”

- Engine dyno based testing vs. a conventional engine
  For pre-transmission systems only

- Powertrain dyno based testing vs. a conventional vehicle “A to B testing”

Poor alignment between the two programs

- Criteria pollutant program: emission levels may be misrepresented because hybrid engine may not be operating as it would in the complete hybrid system
- FE/GHG program: testing a hybrid system using two (or three) of the certification options would likely provide different results for the benefit of the hybrid system
Key issue #1: Establishing consistency for hybrid certification in Phase 2 of the FE/GHG program

<table>
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<th>Pathway</th>
<th>Key Considerations</th>
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<tr>
<td>• Adopt GTR test procedure as sole option for hybrid certification</td>
<td>• Strengthens opportunities for global alignment for conventional vehicles as well</td>
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</table>
| • Choose either chassis testing or powertrain testing as the sole option for hybrid certification | • Resource constraints  
|                                                                         |   • Test setup complexity                                 |
| • If all of the current options will be allowed in the Phase 2 program, establish functional equivalency between the options | • Developing a vehicle cycle based on the FTP and/or engine cycles based on the vehicle test cycles |

Key issue #2: Allowing hybrid systems to be certified in the criteria pollutant program rather than separate testing for hybrid engines
Considerations for GRPE HD Hybrid Test Procedure

- **Harmonization of criteria pollutant and fuel efficiency/GHG test procedures**
  - Decreases testing burden and the opportunities for gaming
  - WHTC (engine cycle) was developed to be functional equivalent to the WTVC (vehicle cycle)
    - Leveraging these cycles allows for consistency for both conventional and hybrid vehicles

- **Accommodating a variety of advanced technologies**
  - Finalized amendments to GTR No. 4 will have a lasting influence
  - Test methods should be able to accommodate a wide range of current and future driveline configurations

- **Ensuring compliance over vehicle lifetime**
  - Especially salient issue for criteria pollutant emissions
  - Thought should be given to whether the test procedure can be used for both certification and in-use compliance testing
There are HD GHG regulatory developments in many countries/regions around the world.

Various aspects of regulatory design are different from country-to-country but there is opportunity for increased global alignment.

Countries/regions must balance the desire to design the most ‘accurate’ program and moving towards increased alignment.

“Full” N. American alignment is an important step:
- Canada-specific ABT program ensures GHG reductions for Canada.
- Agencies in Mexico working on a suite of standards that will allow for alignment with the US FE/GHG program:
  - Ultra-low sulfur diesel
  - US2010 criteria pollutant standards

GRPE test procedure for HD hybrids is scheduled to be finalized and adopted by the end of 2014:
- Opportunity for better harmony between criteria pollutant and GHG programs.
- Member countries can integrate this HD hybrid test procedure into their GHG programs → opportunity for increased alignment of test procedures for conventional vehicles as well.
thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます Спасибо danke ขอบคุณ thank you gracias merci obrigado 谢谢 감사합니다 ありがとうございます
China: Fuel Consumption Program Summary

Agencies currently working to develop a standard based on rigorous technology potential analysis.

2011: Industry standard proposal
2012: Industry standard finalized
2013: Industry standard enforced

Finalized Test Procedure:

Fuel consumption test methods for HD commercial vehicles

“Base” vehicle → Chassis dyno

“Variant” vehicle → Simulation modeling

Coastdown test data

Run C-WTVC cycle

Measurement and calculation of fuel consumption
Trio of Standards Under Development in Mexico

- Ultra low sulfur diesel
- US2010 emission standards
- Fuel efficiency regulation

Typical US2010 aftertreatment configuration (www.cumminsengines.com)