Policy Measures for Reducing Greenhouse Gas Emissions from Heavy-Duty Vehicles: California, the US, and the World

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Sustainable Transportation Seminar
The Precourt Energy Efficiency Center
Stanford University
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Topics

- Background and overview of policy measures in increase heavy-duty vehicle (HDV) efficiency
- Regulatory timelines across countries/regions
- Voluntary ‘green freight’ programs
- Regulatory design summaries and considerations for next phases of fuel efficiency and GHG regulations
  - California
  - US and Canada
  - Japan
  - China
  - European Union
- Summary remarks
The International Council on Clean Transportation

- 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.
- Full-time staff of roughly 40
- Staff are natives of 10 countries and speak more than a dozen languages
- Offices in San Francisco, Washington DC, Berlin
Background: HDV CO₂ Emissions

- Heavy-duty vehicles are a major, growing energy demand and CO₂ source
- Policies for light-duty are well underway, but policies for HDVs are in early phases

Global Transport Emissions

Source: ICCT Roadmap Model, 2013
## Integrated Vehicle Efficiency Policy Portfolio

<table>
<thead>
<tr>
<th>Category</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VEHICLE FUEL EFFICIENCY STANDARDS</strong></td>
<td>• Introduce and regularly strengthen mandatory standards</td>
</tr>
<tr>
<td></td>
<td>• Establish and harmonize testing procedures for fuel efficiency measurement.</td>
</tr>
<tr>
<td><strong>FISCAL MEASURES</strong></td>
<td>• Fuel taxes and vehicle taxes to encourage the purchase of more fuel-efficient vehicles.</td>
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<td></td>
<td>• Infrastructure support and incentive schemes for very fuel-efficient vehicles.</td>
</tr>
<tr>
<td><strong>MARKET-BASED APPROACHES</strong></td>
<td>• Voluntary programs such as U.S. SmartWay and other green freight programs</td>
</tr>
<tr>
<td><strong>INFORMATION MEASURES</strong></td>
<td>• Vehicle fuel economy labels</td>
</tr>
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<td></td>
<td>• Improving vehicle operational efficiency through eco-driving and other measures.</td>
</tr>
</tbody>
</table>

Today's presentation
Heavy-Duty GHG Regulation Status

- HDV efficiency standards being considered at some minimal level – represents over 80% of global HDV population

Source: ACEEE
<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>Fuel economy</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>Phase 1 regulation implemented starting MY 2015</td>
</tr>
<tr>
<td>United States</td>
<td>GHG/Fuel efficiency</td>
<td>Standard proposal</td>
<td>Final rule</td>
<td></td>
<td></td>
<td>Regulation implemented starting MY 2014 (mandatory DOT program starts MY 2016)</td>
<td></td>
<td>Phase 2 implementation</td>
<td></td>
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<tr>
<td>China</td>
<td>Fuel consumption</td>
<td>Test procedure finalized</td>
<td>Industry standard proposal</td>
<td>Industry standard implemented</td>
<td>National standard adopted</td>
<td></td>
<td></td>
<td>Regulation implemented starting MY 2015</td>
<td></td>
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<tr>
<td>European Union</td>
<td>CO₂ test procedure</td>
<td>Technical studies</td>
<td>Impact assessment/Test procedure finalized</td>
<td></td>
<td></td>
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<td>Policy implementation</td>
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<tr>
<td>Canada</td>
<td>GHG/Fuel efficiency</td>
<td>Standard proposal</td>
<td>Final rule</td>
<td></td>
<td>Regulation implemented starting MY 2014</td>
<td></td>
<td>Phase 2</td>
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<tr>
<td>Korea</td>
<td>Fuel efficiency</td>
<td>Technical studies</td>
<td>Impact assessment/Test procedure finalized</td>
<td></td>
<td>Policy implementation (second half of 2015)</td>
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<tr>
<td>Mexico</td>
<td>Fuel efficiency</td>
<td>Proposal</td>
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<td>Regulation implemented starting MY 2016</td>
<td>Phase 2 implementation</td>
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<tr>
<td>California</td>
<td>End-user purchase requirements</td>
<td>Requirements for new tractors, trailers (2011+)</td>
<td>Additional reqs. for existing tractors and trailers (&lt;MY 2010)</td>
<td></td>
<td>Additional reqts. for existing trailers and reefers (&lt;MY 2010)</td>
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*Items in blue are ICCT expectations (not public announcements)*
Voluntary, Public-Private Partnership Programs

- Over the past decade a number of voluntary programs have been implemented to improve the environmental performance and efficiency of the goods movement sector.
- First program: US EPA’s SmartWay Transport Partnership began in 2004 (http://www.epa.gov/smartway/)
- SmartWay has grown from roughly a dozen charter companies to over 3,000 partner companies and affiliates
  - Roughly 1/3rd of all trucking miles in the US are done by SmartWay members.
- SmartWay as a model for other countries/regions
  - SmartWay in Canada
    http://oee.nrcan.gc.ca/transportation/business/smartway/18053
  - China Green Freight Initiative
    http://www.greenfreightandlogistics.org/programs/green-freight-china-program-2/
  - Green Freight Europe
    http://www.greenfreighteuurope.eu/
  - Transporte Limpio (Mexico)
    http://www.transportelimpio.gob.mx/
How SmartWay Works

“If you cannot measure it, you cannot improve it.”
- Lord Kelvin, U. of Glasgow (1824 – 1907)

Measure Supply Chain Footprint

Improve Efficiency

Benchmark Performance

Innovate Operations

Report Results

Source: US Environmental Protection Agency
SmartWay Trucking Company Performance Data

Empowering shippers with information about trucking company performance

15 Carrier Categories
- (TL, LTL, Refrigerated, Tanker, etc.)
8 Emission Metrics

SmartWay Carrier Rating Pollutant Specific Performance Levels

Quintile Rankings (ex: Truckload CO₂ g/mile)

- Top 20% TL Dry Vans: 1550 g/mile
- Second 20% TL Dry Vans: 1650 g/mile
- Middle 20% TL Dry Vans: 1750 g/mile
- Fourth 20% TL Dry Vans: 1850 g/mile
- Bottom 20% TL Dry Vans: 1950 g/mile

Source: US Environmental Protection Agency
Policies Affecting Heavy-Duty Vehicles in California

**Voluntary, Incentive-based**
- Grants for vehicle or technology purchase
- R&D funding
- Tax credits
- Demonstration project funding

**Regulations**
- Fleet renewal and purchase requirements
- PM and NOx control requirements
- Engine emission standards
- Low Carbon Fuel Standard
- Tractor-trailer GHG Rule

**Criteria Pollutant-focused Measures**
- National Clean Diesel Campaign
- Grants for vehicle or technology purchase
- R&D funding

**Greenhouse Gas-focused Measures**
- Grants for vehicle purchase (e.g. HVIP)
- SmartWay Program
- R&D funding

**Incentive-based policy in California**

**Policy administered at the federal level**

**Regulatory program in California**

**CA and US policy harmonized**
California’s Tractor-Trailer GHG Rule: Context

Energy balance for a fully loaded tractor-trailer traveling at 65 mph on level road

- Aerodynamic losses: 85 kWh (21%)
- Engine losses: 240 kWh (60%)
- Rolling resistance losses: 51 kWh (13%)
- Auxiliary loads: 15 kWh (4%)
- Drivetrain losses: 9 kWh (2%)

Source: 21st Century Truck Partnership
Goal: Reduce Greenhouse Gas (GHG) emissions from long-haul tractors by improving tractor and trailer aerodynamics and tire rolling resistance

Based on elements of US EPA SmartWay Program

Applies to: 53-foot box-type trailers and heavy-duty (HD) tractors that pull them on California highways

Implementation began 2010

Responsible for compliance: owners, drivers, motor carriers, California-based brokers, California-based shippers
Tractor-Trailer GHG Rule: Tractor Requirements

- 2011+ model year sleeper cabs:
  - *SmartWay* certified beginning January 1, 2010
- 2011+ model year day cabs:
  - *SmartWay* verified low rolling resistance (LRR) tires (1.5% fuel efficiency improvement) certified beginning January 1, 2010
- Pre-2011 model year sleeper & day cabs:
  - *SmartWay* verified LRR tires beginning January 1, 2013
Tractor-Trailer GHG Rule: Trailer Requirements

- 53-foot box type trailers → *SmartWay* certified or retrofitted with *SmartWay* verified technologies, including:
  - LRR tires (1.5% fuel efficiency improvement), and
  - Aerodynamic technologies that provide,
    - 5% fuel efficiency improvement for dry vans
    - 4% fuel efficiency improvement for refrigerated vans

- Compliance deadlines:
  - 2011+ model year (new) trailers: January 1, 2010 for aero and tires
  - Pre-2011 model year trailers
    - Aerodynamic technologies by January 1, 2013 or choose a delayed compliance option 2012-2016
    - LRR tires by January 1, 2017
Tractor-Trailer GHG Rule: Fleets Going Beyond!

Some fleets seeing fuel savings > 10%
Achieving 80% reduction in GHGs from the on-road transportation sector by 2050 requires wide-scale adoption of zero-emission vehicles → BOTH in light- and heavy-duty vehicles.

Zero emission solutions are in their infancy for HDVs. Significant technological progress and cost reductions are required! → Especially for long-haul trucking.
US FE/GHG Phase 1 Program: Background

- Rule finalized in August 2011 → Implementation starts in model year 2014
- Two distinct but nearly identical programs:
  - EPA has authority to regulate GHGs under the Clean Air Act
  - National Highway Traffic Safety Admin. (NHTSA) has authority to regulate fuel efficiency under the Energy Independence and Security Act
- EPA program will regulate CO$_2$, CH$_4$, N$_2$O, and HFCs (refrigerant)
- EPA and NHTSA programs are identical in terms of fuel use/CO$_2$
  - Only real difference between the two programs is that the EPA’s includes CH$_4$, N$_2$O, and HFCs
- EPA program starts in model year (MY) 2014, NHTSA: MY2016
  - In reality, manufacturers will only have to “worry” about meeting the EPA regulation
US FE/GHG Phase 1 Program: Stringency

- Largely relies on promoting “off-the-shelf” technologies
- Regulation can be thought of as 3 distinct programs

Class 7/8 Tractors

10-23%

Class 2B/3 Pickup Trucks and Vans

12-17%

Everything Else = “Vocational Vehicles”

6-9%

Required avg. reduction in fuel consumption in MY 2017 vs. MY 2010 baseline
Class 7 and 8 Tractor Program

Engines subject to their own standard

Unique vehicle characteristics: aerodynamics, rolling resistance, weight reduction, idle reduction, speed limiter

Full vehicle is certified using the GEM vehicle simulation tool

Fuel
- CO₂
- CH₄
- N₂O
Class 2B – 8 “Vocational” Vehicle Program

Engines subject to their own standard

Unique chassis characteristic: rolling resistance

Full vehicle is certified using the GEM vehicle simulation tool

Fuel
- CO₂
- CH₄
- N₂O

Unique chassis characteristic:

Greenhouse gas Emissions Model (GEM) v1.0

Regulatory Class
- Class 8 Combination - Steeper Cab - High Roof
- Class 8 Combination - Steeper Cab - Mid Roof
- Class 8 Combination - Steeper Cab - Low Roof
- Class 8 Combination - Day Cab - High Roof
- Class 8 Combination - Day Cab - Mid Roof
- Class 8 Combination - Day Cab - Low Roof
- Class 7 Combination - Day Cab - High Roof
- Class 7 Combination - Day Cab - Mid Roof
- Class 7 Combination - Day Cab - Low Roof
- Heavy Heavy-Duty - Vocational Truck (Class 8)
- Medium Heavy-Duty - Vocational Truck (Class 6-7)
- Light Heavy-Duty - Vocational Truck (Class 3b-5)

Simulation Inputs
- Coefficient of Aerodynamic Drag: 0.69
- Snow Tire Rolling Resistance (dynamic ton): 7.6
- Drive Tire Rolling Resistance (dynamic ton): 8.2
- Vehicle Speed Limiter (mph): N/A
- Vehicle Weight Reduction (lbs): N/A
- Extended Idle Reduction (ECU units): N/A

RUN
Class 2B and 3 Pickup Trucks and Vans Program

- Meant to mirror the light-duty testing program
- Main difference from LD program: vehicles are certified based on their “work factor” (WF)

\[
WF = [0.75 \times (\text{Payload Capacity} + \text{xwd})] + [0.25 \times \text{Towing Capacity}]
\]
where
Payload Capacity = GVWR (lbs) – Curb Weight (lbs)
xwd = 500 if the vehicle is equipped with 4-wheel drive and 0 otherwise
Key Opportunities for Improvement in US Phase 2

Integrating transmissions into the testing protocols

- Recognizing interactions btw engine and transmission
- Properly evaluating HD hybrid systems

Source: Oak Ridge National Lab

Including trailers

- 5-10% fuel savings available from trailer aero and RR improvements
- Opportunity to build on success of SmartWay program
Trailer Regulatory Challenges

- Trailer market diversity
- Approximately 2 or 2.5 trailers for every tractors
- Split incentive: owner of trailer often does not operate trailer, thus has little incentive to invest in fuel-saving technologies
- Large number of small businesses in trailer manufacturing
Japan: Fuel Economy Program Summary

2006: Japan introduced the world’s first fuel economy standard for HDVs

- Vehicles included
  - Commercial vehicles with gross vehicle weight rating (GVWR) > 3.5 metric tons, buses with carrying capacity > 11 people
- Targets (km/l) disaggregated by vehicle type, class, and weight
- Most efficient vehicle (“top runner”) in MY 2002 set as baseline
  - Hybrid vehicles were excluded when determining the top runner
- Manufacturers must meet targets starting in MY 2015
- Roughly 10-13% FE improvement required vs. 2002 Top Runner baseline → improvements primarily from engines

- Phase 2 developments currently under way → target year 2025
- Expected completion timeframe: 2014/2015
China: Fuel Consumption Program Summary

Finalized Test Procedure

- Fuel consumption test methods for HD commercial vehicles
  - "Base" vehicle
    - Chassis dyno
  - Coastdown test data
  - Run C-WTVC cycle: record FC on urban, rural, and motorway segments of cycle
  - Measurement and calculation of fuel consumption
  - Weighting factors to each vehicle type (e.g., bus, long-haul tractor)
- "Variant" vehicle
  - Simulation modeling

Industry standard proposal
Industry standard finalized
Industry standard enforced
National standard proposed
National standard finalized in 2013
China: Industry vs. National Standard

- **Industry Standard (Stage 1)**
  - Proposed in 2011 and adopted in Dec 31, 2011
  - New models must meet standard starting July 1, 2012; existing models July 1, 2014
  - Standard is set at the 90th percentile of the baseline
  - Goal: Phasing out most inefficient and chance to collect further data
  - Based on 300+ vehicles tested

- **National Standard (Stage 2)**
  - Proposed September 2012
  - New models must meet standards starting from July 1, 2014; existing models by July 1, 2015
  - Tightens Industry standard ~10-15%, almost 50% of vehicles tested did not meet limits. (based on further testing)
Developments in the European Union

New Developments in the EU

- **Truck shape – cab over engine**
  - Due to length restrictions of total truck (not just trailer as in US)
  - New proposal to allow for more aerodynamic tractor/trailers

- For new trucks ~2018-2020
  - Previous weight/length limit – 40 metric tons/61.5 feet
  - New limits allow for increased weight to accommodate hybrid powertrain and increased length to accommodate aerodynamic design
  - Estimate 7-10% reduction in GHG emissions from long haul trucks

![Diagram of HDVs with current and proposed regulations]
Conclusions

- It is an important period for heavy-duty vehicle GHG / fuel economy policy – worldwide
- Both voluntary and mandatory policy measures have an important role to play
- Incorporation of major technologies is important for standards
  - Transmission technologies
  - Hybrid technology
  - Tires, aerodynamics, lightweighting
  - Trailers
- More Information
  - www.theicct.org/heavy-duty-vehicles
  - www.transportpolicy.net
Questions?

Thank you!
ben@theicct.org
National Academy of Sciences Report (March 2010) found 35 – 50% improvement could be achieved in the 2015 to 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.
## Regulatory Design Summary

<table>
<thead>
<tr>
<th>Region</th>
<th>Regulatory Categories</th>
<th>Certification Test Procedures</th>
<th>Metric</th>
</tr>
</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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<tr>
<td></td>
<td>Tractor (2 subcategories)</td>
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<td></td>
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<tr>
<td></td>
<td>Route Bus (5 subcategories)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other Bus (8 subcategories)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>N. America</strong></td>
<td>Tractors</td>
<td>Vehicles $\rightarrow$ simulation model</td>
<td>Tractors, Vocational</td>
</tr>
<tr>
<td></td>
<td>Vocational vehicles</td>
<td>Engines $\rightarrow$ dynamometer testing</td>
<td>HD Pickups</td>
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<tr>
<td></td>
<td>HD pickup trucks and vans</td>
<td></td>
<td>Engines</td>
</tr>
<tr>
<td></td>
<td>Engines (tractors, voc. vehicles)</td>
<td></td>
<td></td>
</tr>
<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>
</tr>
<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/tonne-km)</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.*
Test Procedure Comparison

Payload
- ~1/2 payload
- Full Payload

Rolling Resistance/Aerodynamic Drag
- From Testing
- Standard Value

Separate Engine Standard

Simulation Model

Engine Map
- From Testing
- Standard Value

Chassis Dyno Test (base vehicles tested, variants simulated)

Test Cycles
- 3 cycles (weighted)
- 2 cycles (weighted, incl grade)
- 1 cycle (weighted)
- Mission based (may incl grade)

**Compliance and Enforcement program is key**
Technical Potential Globally

- 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></td>
<td>More</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>Less</td>
<td></td>
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<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>
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<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>
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<tr>
<td>Weight</td>
<td>1.25%</td>
<td>Material substitution—2,500 lb.</td>
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<td>More</td>
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</tr>
</tbody>
</table>

* These are based on NAS tractor-trailer Class 8 for US context; reductions are approximate, and are not additive
### Efficiency Improvements Promoted by Regulation

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>U.S. and Canada*</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>Unclear</td>
<td>By demonstration outside of standard protocol</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Aerodynamic drag, rolling resistance</td>
<td>No</td>
<td>Yes</td>
<td>Yes**</td>
<td>Yes</td>
</tr>
<tr>
<td>Trailer</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

* Potentially Mexico as well  
** Option to use default values  
# Refers to ongoing government research and testing protocols; No standards in place