HEAVY-DUTY VEHICLE EFFICIENCY: ALIGNING STANDARDS INTERNATIONALLY

INTEGRATION OF ENGINES AND POWERTRACTS
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop Background</td>
<td>3</td>
</tr>
<tr>
<td>Project Context and Rationale</td>
<td>4</td>
</tr>
<tr>
<td>Summary of Presentations and Discussions</td>
<td>6</td>
</tr>
<tr>
<td>Session 1— Technology Potential</td>
<td>6</td>
</tr>
<tr>
<td>Session 2— Testing</td>
<td>8</td>
</tr>
<tr>
<td>Session 3— Simulation</td>
<td>12</td>
</tr>
<tr>
<td>Session 4— CO\textsubscript{2}/NO\textsubscript{x} Emissions Tradeoff and International Alignment</td>
<td>15</td>
</tr>
<tr>
<td>Future Workshops and Tentative Topic Areas</td>
<td>17</td>
</tr>
<tr>
<td>Attendees</td>
<td>18</td>
</tr>
<tr>
<td>Additional Information</td>
<td>19</td>
</tr>
</tbody>
</table>
WORKSHOP BACKGROUND

On October 22, 2013, the ICCT held a workshop entitled “Heavy-Duty Vehicle Efficiency: Aligning Standards Internationally, Integration of Engines and Powertrains” in San Francisco, CA. The primary objective of the workshop was to bring together stakeholders from government, industry, and the research community to provide a forum for an exchange of ideas about heavy-duty vehicle engine and powertrain efficiency advancements and strategies for best capturing these improvements in a regulatory context.

This event was made possible by a generous grant from the Japan Foundation’s Center for Global Partnership and is the first in a series of four workshops. The aim of the project, which centers around these four technical meetings, is to help foster stronger relationships between technical experts and their colleagues in Japan, the US, Canada, China and Europe. In effect, creating more durable ties and lasting international understanding related to how to address the twin goals of reducing energy consumption and greenhouse gas emissions from heavy-duty vehicles in order to help mitigate climate change.

This summary document first provides some background on the importance of efforts to curb fuel consumption and greenhouse gas (GHG) emissions from heavy-duty vehicles and the context for this particular project. Second, we provide a summary of the day’s presentations and discussions. In the final section, we preview some of the potential topics and key issues for future workshops along with a tentative timeline for those events.
PROJECT CONTEXT AND RATIONALE

Worldwide, heavy-duty vehicles (HDVs) are a major and growing contributor to fuel consumption and climate change emissions in the on-road transportation sector. As shown in Figure 1 from the ICCT’s Global Transportation Energy and Climate report (http://www.theicct.org/global-transportation-energy-and-climate-roadmap), in the 2020 to 2030 time frame, HDV emissions will become approximately equivalent to those of automobiles, currently the largest overall contributor to climate change within the transport sector.

Efforts to reduce energy consumption from transportation are generally focused on more fuel-efficient vehicles, renewable fuels, and promoting advanced technologies such as electric vehicles. Regulatory standards for vehicles have been and continue to be, the main driver for many of these emission reductions and increased efficiency. To date, worldwide efforts to reduce energy consumption through improved vehicle efficiency have been focused primarily on light duty vehicles (passenger vehicles), though there has been increasing regulatory activity in the HDV space in recent years in certain countries and regions around the world. A number of countries are at various stages in the process of developing and implementing HDV policies and regulations. Japan adopted the world’s first HDV efficiency standard and test procedure in 2005, with standards to be fully implemented from April 1, 2015.

Japan’s pioneering efforts established important design features for subsequent regulatory efforts. In 2011 the US followed with its own HDV standard for model years 2014 through 2018, and in early 2013 Canada adopted standards that harmonized with the US regulation in virtually every element of regulatory design, including test procedures and stringency.

![FIGURE 1: CO₂ equivalent emissions from global transportation](image-url)
China recently finalized its national HDV efficiency program, while the European Union is in the process of finalizing a testing and certification procedure and labeling program for HDV efficiency, with future standards anticipated. Furthermore, the US, Canada, Japan and China have all begun preliminary work on “Phase II” efficiency requirements for model year 2020+ vehicles.

One of the most promising ways to take advantage of the full potential for efficiency improvements is to ensure that the policies in each of the major policy-making regions are aligned – that is, measure vehicle efficiency in similar ways as to promote promising efficiency technologies on a consistent basis across markets. “Alignment” is a process and involves exploring prospects for introducing common elements into multiple programs that will then allow for the development of global product platforms for the heavy-duty market. Because aligned standards and certification methods can deliver cost benefits to manufacturers and consumers and promote a faster global adoption of CO₂ reducing technologies, they are seen as highly beneficial for industry, consumers, and policy-makers. Some progress has been already made, particularly in North America. As aforementioned, Canada has harmonized its standards with the US, and Mexico is currently developing similarly aligned standards, but the greatest benefits would come from aligning all major markets – Japan, North America, China, and Europe.

Fortunately, an opportune policy window exists, as authorities in Japan, the US, China and Europe are all currently working to develop or implement HDV efficiency programs. There is great potential for the countries to coordinate and share best practices and technical expertise in order to align standards, which will benefit both manufacturers and consumers while reducing greenhouse emissions and energy consumption. This project creates a new forum for expanded dialogues between technical researchers and regulators in Japan, North America, China, and Europe working on HDV efficiency to scope out areas of mutual interest, identify complementary approaches that can be quickly adopted, and begin initial dialogues about areas of contention before they encounter the political winds of high-level national approaches or in other international forums such as the United Nations Economic Commission for Europe’s (UNECE) World Forum for Harmonization of Vehicle Regulations (WP.29).
The day’s proceedings were organized into four sessions: 1) technology potential, 2) testing methods, 3) simulation approaches and 4) NOx/CO2 emissions tradeoffs and opportunities for international alignment. The primary theme of the workshop was engines and transmissions, but, as all vehicle systems are intimately interconnected, many of the presentations and discussions touched on important issues related to other areas such as aerodynamics, tire rolling resistance, and use of lightweight materials.

The following sections summarize the presentations and discussion periods of each of the day’s four sessions.

SESSION 1— TECHNOLOGY POTENTIAL

The workshop commenced with three excellent presentations from US-based manufacturers. Dr. Morgan Andreae of Cummins Inc. began the day with an overview of improvement opportunities for engines over the next decade as well as a description of Cummins’ vision for the Phase II regulation in the US and Canada. Looking out to 2020, Dr. Andreae outlined the Cummins technology roadmap, which pushes towards nearly 55% peak brake thermal efficiency (up from a 2010 baseline of roughly 45%). The roadmap incorporates a number of technology advancements, including engine downspeeding, aftertreatment improvements and reduced backpressure, waste heat recovery, improved turbomachinery efficiency, reduced friction, increased compression ratios, and reduced heat transfer. Cummins is actively working on these technology improvements as part of the US Department of Energy’s SuperTruck Program. Dr. Andreae also described the significant opportunities for efficiency gains that are possible with deeper integration of engines and transmissions. He went on to highlight the joint product venture with Eaton, the Eaton-Cummins Alliance (see Figure 2), in which the co-design of the Cummins ISX15 engine and the Eaton Fuller Advantage automated manual transmission (AMT) have been shown to provide fuel consumption benefits of 3-6% in typical long haul drive cycles. In the final segment of the presentation, Dr. Andreae explained the Cummins position for regulatory design for the US Phase II GHG standard. In their vision, the Phase II rule would retain the separate engine standard, but would allow manufacturers the option of testing and certifying physical engine-transmission combinations, or complete powertrains, to better capture the improvements that are possible through better integration of engines and transmissions.

FIGURE 2: The Eaton-Alliance product is an example of the efficiency improvements that are possible from deep integration of engine and transmission design.
During the question-and-answer period, key issues were raised. During his presentation, Dr. Andreae asserted that CO\textsubscript{2} reductions are going to be the primary focus going forward, implying that Cummins does not anticipate any tightening of federal criteria pollutant emissions standards in the foreseeable future. Representatives from the California Air Resources Board (ARB) spoke about California’s unique air quality needs in two of its at-risk air basins and articulated that the federal ozone standards coming into effect over the next two decades will require HDV NO\textsubscript{x} emissions reductions on the order of 90%. Dr. Andreae acknowledged the research currently underway that will explore pathways for achieving these significant NO\textsubscript{x} reductions and commented that if we continue to see improvements in SCR conversion efficiency, it may be possible to achieve deep cuts in NO\textsubscript{x} emissions without compromising efficiency improvements.

The second presentation was given by Matt Busdiecker of the Eaton Corporation and focused on the technology potential of commercial vehicle transmissions. He described the current state of transmission technology in both the linehaul and vocational markets and then went on to outline what Eaton sees as near-term (2014-2017) and longer-term improvement opportunities. In showing a typical energy loss profile for a linehaul drive cycle, Mr. Busdiecker illustrated that because transmissions are already very efficient (roughly 98% efficient) when cruising at highway speeds, most of the future fuel consumption reduction potential that transmission can provide is related to better integration with the engine and the rest of the vehicle. Better engine-transmission integration can enable more efficient use of the engine. Examples include engine downspeeding at cruise and reducing engine operation in low efficiency areas by minimizing shift transients and making more intelligent shift decisions. He also discussed the technical advances and cost reductions that Eaton is currently pursuing in the area of hybridization, which can provide substantial fuel savings in certain vocational applications. Finally, Mr. Busdiecker described Eaton’s fairly extensive experience in the area of powertrain dynamometer testing as well as some of the difficulties of simulating the complex interactions of the engine and transmission. The rationale for allowing this test method as an option in the US Phase II regulation builds upon Dr. Andreae’s comments in the previous presentation.

The final talk of the first session was given by Mike Christianson of Daimler Trucks North America (DTNA). This presentation offered a distinct proposal for testing and certification procedures for the US Phase II regulation that diverges from the approach that was taken in Phase I. In contrast to the suggested test procedure framework for Phase II that was outlined in the two previous presentations, Mr. Christianson made the case that eliminating the separate engine standard and complete vehicle simulation—including vehicle-specific engines and transmissions—allows for the maximum flexibility of efficient, repeatable, and accurate assessment of multiple vehicle configurations and also minimizes the physical testing burden for manufacturers. He went on to illustrate the updates that would be required to the Greenhouse gas Emission Model (GEM), which manufacturers are using in the Phase I program for certification of all of the vehicle-specific (i.e. non-engine) parameters such as aerodynamics, tire rolling resistance, and weight reduction. In the DTNA proposal, the key updates to GEM include the ability of manufacturers to input unique engine maps, transmission characteristics, and driveline information for the specific vehicle as opposed to the Phase I simulation strategy, which uses generic engines and transmissions. He also acknowledged the need for the Phase II rule to include trailers to better promote the deployment of cost-effective technologies, as well as to ensure that tractors are being designed and certified with efficient trailers.
During the discussion period, two relevant points were raised about the merits of a full vehicle simulation approach for the Phase II regulation. First, though a full vehicle simulation framework could potentially decrease testing costs and capital investments, as GEM becomes increasingly sophisticated, model fidelity and validation challenges increase. Second, there were concerns raised about the ability of a model to accurately represent the complexities posed by engines, transmissions, and manufacturer-specific control strategies.

Over the course of this session, as well as the entire workshop, one of the primary themes that was revisited on multiple occasions is the fact that it is quite challenging to identify a test procedure framework that is clearly superior to other options across all relevant parameters, including testing costs, capital investment, accuracy, complexity, repeatability, and validation requirements. Certification procedure options that include a physical testing component have their advantages and disadvantages, depending on a specific stakeholder’s perspective, as does the full vehicle simulation approach. As HDV regulatory programs are being developed and continuing to evolve in diverse markets around the world, policy makers will increasingly have to balance the desire for added functionality and complexity of the simulation models that are used for certification. More specifically, the need for standards that promote the appropriate technologies in a clear way and provide a level playing field for all manufacturers.

SESSION 2— TESTING

Across the four major markets that are featured in this workshop series, there is tremendous heterogeneity in the sizes, configurations, and operating patterns of HDVs. One of the key themes highlighted during this workshop was the current diversity in approaches for capturing engines, transmissions, other vehicle systems in regulatory programs. The diversity of testing approaches utilized in the four major markets for HDV fuel efficiency and GHG certification are summarized in Figure 3 below, which is taken from Mike Christianson’s presentation. As shown in the figure, all four the certification approaches require a mix of physical testing and computer simulation. Even Europe’s certification pathway, which is ultimately going to be based on a full vehicle simulation, requires extensive data and measurements that must be derived from physical testing (e.g. constant speed aerodynamic testing, laboratory tire testing to determine rolling resistance values, engine mapping on an engine dynamometer).

![FIGURE 3](image)

**FIGURE 3**: Testing and certification approaches for heavy-duty vehicle fuel efficiency and GHG emissions utilized in major markets (from Mike Christianson’s presentation).
In Session 2, the testing approaches that are in place and currently under development in China, Japan, and Canada were discussed.

Hui He of the ICCT started the session by speaking on behalf of Tianlei Zheng of the China Automotive Technology and Research Center (CATARC), who was unable to be in San Francisco due to visa delays that were caused by the shutdown of the US federal government. The talk covered not only the extensive HDV testing campaign that CATARC has led in support of the development of fuel consumption standards in China, but also the framework of the regulation in terms of regulation design, stringency, and the status of implementation.

CATARC was commissioned by the Ministry of Industry and Information Technology (MIIT) to develop a fuel consumption test procedure that combined chassis dynamometer testing and simulation modeling. In brief, the test procedure requires that fuel consumption of base models be measured using chassis dynamometer testing, whereas fuel consumption of variants may be measured using a computer simulation model developed by CATARC. In order to determine the stringency of the HDV fuel consumption standards, CATRAC and two other testing laboratories conducted a study to estimate the fuel consumption level of the newest vehicles from the existing fleet. This study was performed in 2010 and 2011 by following the previously mentioned test procedure on a number of vehicles. The resulting data, collected from a combination of chassis and simulation tests of over 300 HDVs, were then used as the basis for setting an Industry Standard for HDV fuel consumption (known as the Stage I standard), which was adopted by MIIT in January 2012. Due to a relatively limited understanding of the HDV market and fuel consumption level at the time, the Industry Standard was intentionally set at a level that manufacturers could meet relatively easily, and it focused on the three vehicle types (tractors, straight trucks, and coach buses) with highest sales and highest expected overall fuel consumption.

Over the course of 2012, MIIT collected more fuel consumption data through additional testing and simulation, but with a special focus on city buses and dump trucks. The agency also obtained additional fuel consumption data from new models through the new fuel consumption type approval process for the Industry Standard. Based on a broader set of fuel consumption data, MIIT proposed the next stage of HDV fuel consumption standards in September 2012. Similar to the Industry Standard, the National Standard (Stage II standard) sets fuel consumption limits following a step function, using gross vehicle weight as the utility parameter (see Figure 4). As shown in the figure, the Stage II standard tightens vehicle consumption limits for tractors, trucks, and coaches by an average of 10.5% to 14.5% compared to the limits under the Stage I standard. The proposed National Standard is to be implemented for new HDV models applying for type approval starting on July 1, 2014. By July 1, 2015, all new commercial HDVs manufactured in China (except for specialized vocational vehicles) are required to comply with the National Standard.
In addition to these fuel consumption reduction efforts and preliminary work in support of Stage III fuel consumption standard development, regulatory agencies in China are starting to research the feasibility of merging the test procedures for fuel consumption and criteria pollutants. In this approach, fuel consumption and criteria pollutants would be measured simultaneously during the chassis dynamometer test cycle.

Dr. Hisakazu Suzuki of Japan’s National Traffic Safety Environmental Laboratory (NTSEL) followed the CATRAC presentation with a talk that described criteria pollutant standards, emission control strategies, testing protocols, and the fuel economy regulation for HDVs in Japan. Focusing in on Dr. Suzuki’s remarks on Japan’s HDV fuel efficiency program, in 2006 the Japanese government introduced the world’s first fuel economy standards for new heavy-duty diesel vehicles, which becomes fully enforceable in 2015. These standards affect commercial trucks with a gross vehicle weight (GVW) in excess of 3.5 metric tons and buses with a carrying capacity above 11 people. This HDV fuel economy regulation was incorporated into Japan’s “Top Runner” system for energy efficiency, which applies to both passenger vehicles and heavy-duty vehicles. Between 2013 and 2014, MLIT is expected to develop its Phase II fuel efficiency program. For certification methods, the regulation relies on a combination of simulation modeling and engine dynamometer testing, which is described in greater detail in the following section.

Stephane Couroux of Environment Canada gave Session 2’s final presentation, which summarized a collaborative project on powertrain testing undertaken by Environment Canada and the US EPA in support of the development of the Phase 2 GHG regulation for HDVs.
As described in the previous section, a key feature of the Phase 1 regulation is the separate standard for engines, which are tested and certified on an engine dynamometer. Existing engine certification test cycles are designed to offer a reasonable approximation of how an engine installed in a conventional vehicle would operate during in-use driving. Conceptually, engine speed-torque cycles are shown in Figure 5, where the engine is exercised as hardware, and all of the other elements of the vehicle are generic and captured inherently in the test cycle.

As detailed in Session 1, there are significant efficiency gains that can be realized in the area of transmission technology as well as in higher levels of integration between engines and transmissions. In order to better capture these powertrain efficiency improvements in the framework of the regulatory test procedures, Environment Canada, in conjunction with the EPA, has been engaged in a powertrain testing project for much of 2012 and 2013. The joint venture between the two agencies has pursued testing of both conventional and hybrid-electric powertrains and has also investigated lab-to-lab variations in results that are partially due to the different power and torque capabilities of the respective powertrain dynamometers.

A powertrain test cell differs from a traditional engine test cell in that it requires a dynamometer that can accommodate the additional rotational inertia and speeds associated with the inclusion of the transmission in the test setup (see Figure 6). In practical terms, a powertrain test cell has the power absorption capabilities of a traditional heavy-duty chassis dynamometer, but with the power absorbers connected directly to the transmission output shaft, rather than to rollers that support the drive wheels of the test vehicle.
Vehicle simulation is at the heart of each of the certification procedures in all four regulatory programs, and, building on the presentations from Session 2, the presenters of Session 3 provided details on the current characteristics as well as potential future evolutions of the HDV simulation models in their respective countries/regions.

Dr. Giorgos Fontaras, consultant to the Joint Research Centre (JRC) of the European Commission, began the session by providing an overview of the test procedure for fuel consumption and CO$_2$ emissions from HDVs in the European Union. Dr. Fontaras began his talk by providing context for the portfolio of research projects that have supported the development of a certification framework for the type-approval of HDVs that is centered around full vehicle simulation modeling. He described the proposed vehicle classification structure, which is based on weight, chassis and axle configurations, and mission profile. The total fuel consumption for HDVs is simulated in the Vehicle Energy Consumption calculation tool, or “VECTO,” based on vehicle longitudinal dynamics from the input data on the vehicle and engine characteristics. Compared to the simulation models of the other three countries/regions, VECTO is, at present, arguably the most sophisticated in terms of the breadth of component testing data that are required as inputs. He explained the 100-point engine mapping testing protocols as well as the process for correcting the map for transient behavior. VECTO also
has a number of input modules for transmissions, but, in many cases, default data is available for use by the manufacturers if they so choose. In addition to other input modules for aerodynamics and tire rolling resistance, VECTO has a fairly detailed treatment of auxiliaries such as the alternator, compressor, steering pump, and air conditioning system. In the final part of the presentation, Dr. Fontaras discussed the model validation efforts that are currently in progress, and he shared some of the results from the on-road tests.

Looking at the European test procedure in the broader policy context, the European Commission is still analyzing its options for reducing HDV fuel consumption and GHGs. This effort will culminate next year in a formal regulatory impact assessment, and it’s expected that sometime following the release of this report, the Commission will announce an indication of their policy direction.

The session’s second presenter was James Sanchez of the US EPA, who spoke about the Phase 1 regulation and options currently under consideration for Phase 2 testing and simulation methods. Although the EPA has acknowledged that all of the certification options shown in Figure 7 are still under consideration, Mr. Sanchez emphasized that it’s virtually certain that simulation will remain a principal element of whatever certification pathway is ultimately chosen. He went on to discuss the efforts that are underway to explore added functionality in GEM in terms of potentially allowing for the option of inputting vehicle-specific data on engines and transmissions. He also described the extensive model validation project that is happening concurrently and in conjunction with the Southwest Research Institute. In addition to exploring the possibility of providing functionality for inputting unique powertrain information, other planned enhancements to GEM include an improved driver model, a frictional clutch model, and updates to the graphical user interface.

![FIGURE 7: The range of testing and certification options under consideration for the Phase 2 regulation (from James Sanchez’s presentation)](image)
Dr. Suzuki of NTSEL presented for a second time, this time focusing on the simulation methods and test procedure approach that is used to certify the fuel efficiency performance of HDVs in Japan. After considering several testing options based upon multiple criteria—equipment and labor costs, accuracy, the ability to account for non-engine efficiency improvements, and overlaps with emissions test cycles—the Japanese government chose to measure fuel economy under its heavy-duty standards through a combination of engine-only fuel consumption testing and simulation modeling of gear shifting and vehicle resistance loads. The test method, as designed, essentially constrains compliance options for manufacturers to engine efficiency improvements only. Since the simulation model assigns standard values by fuel efficiency category for driving resistance and chassis size, efficiency improvements due to changes in these variables are not counted toward compliance.

Figure 8 illustrates the linkage between physical engine testing and vehicle simulation in Japan’s certification procedure. In Step 1, an engine map is created for each engine type, relating fuel consumption to engine speed and torque. That map is generated on an engine dynamometer using instantaneous fuel consumption readings at a minimum of 30 points spanning the range of normal vehicle operating conditions. In Step 2, full vehicle technical specifications (actual values for engines and transmissions, and fuel efficiency category standard values for rolling resistance and vehicle size) are input into a simulation model that determines gear shift points throughout the test cycle. Those shift positions, combined with vehicle speed, are used to calculate engine speed and torque (Step 3). In Step 4, engine revolutions and torque are paired with the previously generated fuel economy map to produce fuel consumption throughout the drive cycle. This, in turn, is then converted to fuel economy (Step 5).
The relevant government regulators and technical experts from testing and research facilities are currently in the process of scoping out what the second phase of their fuel economy regulation will encompass in terms of the evolution of testing and simulation approaches as well as the opportunity to promote a wider range of technology advancements (e.g., aerodynamics, reduced tire rolling resistance, light-weighting, etc.). Dr. Suzuki commented that Japan is still very early in their regulatory development process, and much analytical work is still needed to determine the technology potential for HDVs in their market along with the appropriate test methods that can most effectively capture these improvements in the regulation.

SESSION 4— \( \text{CO}_2/\text{NO}_x \) EMISSIONS TRADEOFF AND INTERNATIONAL ALIGNMENT

The final session of the workshop was a catch-all session that brought together three topics that are not immediately related, but each presentation was of great importance in the overall context of the workshop.

First up, Dr. Nigel Clark of West Virginia University gave a compelling talk on the complex relationship between \( \text{NO}_x \) and \( \text{CO}_2 \) emissions in modern heavy-duty engines. Far from being a simple tradeoff (i.e. as engines are calibrated for high efficiency, \( \text{NO}_x \) emissions increase and vice versa), sophisticated aftertreatment systems and elaborate engine control strategies create a complex dynamic in which the relationship between \( \text{NO}_x \) and \( \text{CO}_2 \) emissions is tied heavily to the specific parameter that is being evaluated (e.g. injection timing, exhaust gas recirculation (EGR), diesel particulate filter regeneration, etc.). With the full implementation of the EPA's latest emission standard, all of the manufacturers are utilizing selective catalytic reduction (SCR) to achieve the required \( \text{NO}_x \) levels. SCR systems have the distinct advantage of allowing engines to be tuned for high-\( \text{NO}_x \) and high efficiency, and an aqueous urea solution must be injected into the exhaust stream to reduce \( \text{NO}_x \) emissions. Therefore, total fluid consumption—that is, the combination of diesel and urea—must be considered when analyzing the total cost of operation. Present SCR-based emission control strategies suggest that significant further reductions in \( \text{NO}_x \) levels would require higher urea usage and engine efficiency loss. Given this current technological constraint and the need for vastly lower \( \text{NO}_x \) emissions in two key air basins in California, the Air Resources Board is funding research to investigate pathways that can achieve deep engine \( \text{NO}_x \) reductions without compromising on fuel efficiency and \( \text{CO}_2 \).

The second talk was given by Bernardo Martinez of the European Commission (DG Enterprise). In an effort to move towards a systems certification approach and a better integration of heavy-duty hybrid vehicles into emissions testing programs, the United Nations Economic Commission for Europe (UNECE) WP.29 group has an Informal Group on Heavy-Duty Hybrids that is in the process of developing an amendment to Global Technical Regulation No. 4, which established a harmonized type-approval procedure for heavy-duty engine exhaust emissions. As discussed by Mr. Martinez, the charter of this Working Party on Pollution and Energy (GRPE) informal working group is to develop a certification procedure for HD hybrids based on the Japanese hardware-in-the-loop simulation (HILS) method. Under the current timeline, the test procedure will be finalized and formally adopted by WP. 29 in 2014. This world harmonized test procedure for HD hybrids represents a concrete area where Japan, the U.S., Europe, and China can potentially align their certification approaches.
The final presentation of the workshop provided an excellent culmination of one of the key themes of the workshop: opportunities for higher levels of alignment between HDV regulations in four key markets: Japan, North America, China, and Europe. Tony Greszler of Volvo Group Truck Technology began the talk by reviewing the reasons why alignment is attractive from both an industry and government perspective. After providing an overview of the certification procedures in each country/region, he then spent the remainder of the talk presenting Volvo’s ideas about specific areas where harmonization might be advantageous and the reasons why. Returning to one of the key discussion points of Session 1, Mr. Greszler made the case for why a full vehicle simulation certification including laboratory-derived inputs for the engine and transmission is the superior method for promoting real-world fuel consumption reductions. Secondly, he argued that allowing manufacturers to pursue these reductions is the most cost-effective manner as possible. Moreover, he contended that a move to eliminate the engine standard from the US regulation gives the four markets the best opportunity to align their simulation models, since the US is currently the only of the four countries/regions that requires separate engine certification. From the Volvo perspective, the globally harmonized simulation model should have aligned input formats, component characterization (e.g., engine maps, accessories, etc.), metrics, and processes for determining default values. However, he held that certain elements of a simulation model and overall regulation should not be harmonized, including stringency, duty cycles, and simulation model default values.
## Future Workshops and Tentative Topic Areas

<table>
<thead>
<tr>
<th>Location</th>
<th>Major Topic &amp; Value of Exchange</th>
<th>Approximate Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>China Automotive Technology and Research Center (CATARC) Tianjin, China</td>
<td>Technical dialogue on benefits and challenges of full-vehicle certification of heavy-duty vehicles to promote efficiency technology. Examples of discussion topics include chassis testing protocols, on-road testing protocols, and how to combine chassis testing with simulation.</td>
<td>February 25-26, 2014</td>
</tr>
<tr>
<td>European Commission Joint Research Centre (JRC) Ispra, Italy</td>
<td>Technical dialogue on the approaches for determining aerodynamic and powertrain-related vehicle simulation inputs using physical testing. Examples of discussion topics include comparison of major simulation models, model validation, and methodology for inclusion of various components into simulation models.</td>
<td>TBD during the week of June 23, 2014</td>
</tr>
<tr>
<td>Waseda University Tokyo, Japan</td>
<td>Final convening of high-level US, Canada, EU, and Japan regulatory participants presenting findings from the overall workshop series.</td>
<td>October/November 2014</td>
</tr>
</tbody>
</table>
ATTENDEES

- Morgan Andreae, Cummins
- Henrik Berg, Scania
- Tim Blubaugh, Engine Manufacturers Association (EMA)
- Dr. Rasto Brezny, Manufacturers of Emission Controls Association (MECA)
- Matthew Busdiecker, Eaton
- Mike Carter, Air Resources Board (ARB)
- Patrick Chen, Air Resources Board (ARB)
- Mike Christianson, Daimler - North America
- Nigel Clark, West Virginia University
- Stéphane Couroux, Environment Canada
- Erik Dykes, Eaton
- Georgios Fontaras, European Commission’s Joint Research Centre (DG JRC)
- Debbie Gordon, Allison Transmission
- Tony Greszler, Volvo Group Truck Technology
- Jamie Hall, Calstart
- Hui He, The International Council on Clean Transportation (ICCT)
- Fumiyoshi Kai, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
- Drew Kodjak, The International Council on Clean Transportation (ICCT)
- Wakao Koike, Japan Foundation’s Center for Global Partnership
- Stephan Lemieux, Air Resources Board (ARB)
- Mitzi Magtoto, Air Resources Board (ARB)
- Bernardo Martinez, DG Enterprise
- Bob Nyugen, Air Resources Board (ARB)
- Dan Rutherford, The International Council on Clean Transportation (ICCT)
- James Sanchez, Environmental Protection Agency (EPA)
- Ben Sharpe, The International Council on Clean Transportation (ICCT)
- Matt Spears, Environmental Protection Agency (EPA)
- Hisakazu Suzuki, National Traffic Safety and Environment Laboratory (NTSEL)
- Tomoya Tohnai, DENSO International America, Inc.
- John Whitefoot, National Highway Traffic Safety Administration (NHTSA)
- Jackie Yeager, Cummins
- Chris Zach, Mission Motors
Funding for this four workshop series over the course of 2013-2014 was made possible by a generous grant from the Japan Foundation’s Center for Global Partnership. The project centers around these four technical meetings and aims to help foster stronger relationships between technical experts and their colleagues in Japan, the US, Canada, China and Europe. Attendees are able to exchange lasting international understanding related to addressing the dual goals of reducing energy consumption and greenhouse gas emissions from heavy-duty vehicles in order to help mitigate climate change.

This series has been organized by the ICCT’s HDV team. If you would like to follow up about any of the information presented above please contact:

Ben Sharpe, ben@theicct.org, (415)202-5746
Rachel Muncrief, rachel@theicct.org, (202)407-8343

Full presentations from the SF workshop are available on our website:
http://theicct.org/events/hdv-efficiency-aligning-standards-internationally-part-i