Use of biodiesel/diesel blends reduced exhaust emissions from locomotives in North Carolina.

Photo credit: Brandon Graver, North Carolina State University.

by Garry Gunter, Dominic DiCicco, Ed Nam, Thomas Long, Matthew Thornton, Tao Huai, Jorn Herner, Shirish Shimpi, Susan Collet, Henry Hogo, and Kevin Black

Highlights from the Coordinating Research Council's 25th Real-World Emissions Workshop

The Coordinating Research Council (CRC) held its 25th annual Real-World Emissions Workshop on March 22–25, 2015, in Long Beach, CA. The workshop is an international forum for researchers in the field of vehicle and engine emissions to discuss recent findings in emissions measurement and monitoring, inspection and maintenance (I/M), modeling, and fuel efficiency. The 2015 workshop featured presentations, posters, and equipment demonstrations. It also included keynote presentations by Dr. Alberto Ayala, Deputy Executive Officer for the California Air Resources Board (CARB), detailing the challenges of reducing greenhouse gas (GHG) and nitrogen oxides (NO_x) emissions to meet future regulatory standards, and Rueben Sarkar, Deputy Assistant Secretary for Transportation for the U.S. Department of Energy, describing the department's Optima program designed to optimize fuels and vehicles for improved fuel efficiency and lower GHG emissions; as well as an expert panel discussing trends in NO_x and particulate matter (PM) emissions control, energy sources, and fuel efficiency. Highlights from the workshop sessions are summarized in the following article.

Emissions Modeling

This session described studies examining the new version of the Motor Vehicle Emissions Simulator (MOVES2014) model from the U.S. Environmental Protection Agency (EPA), which includes a new dynamic age distribution model to forecast vehicle populations, sales, and scrappage. Results from a three-city analysis using MOVES2014 showed that, compared to MOVES2010, 2011 inventories were slightly lower, while projected 2030 inventories were much lower mostly due to new regulations. Similarly, a North Central Texas study showed MOVES2014 estimating slightly higher NO_x emissions in 2006, but significantly lower NO_x emissions in 2018.

A variety of MOVES inputs were evaluated and updated for the National Emissions Inventory, including age distributions, long-haul truck vehicle miles traveled (VMT), and truck idle locations. The MOVES model was run millions of times to generate a MOVES-Matrix model that will run quickly, with equivalent results. A simplified "MOVES Lite" model was created and integrated with a traffic simulator (DTALite) to demonstrate the emissions impact of traffic management strategies, as shown in Figure 1.

Air quality source apportionment methods were compared. The Comprehensive Air Quality Model with Extensions–Ozone Source Apportionment Tool (CAMx–OSAT) is used to study source contributions, while the Community Multi-scale Air Quality Model (CMAQ) and CAMx-zero-out quantify response to emission changes. Another CMAQ study projected that a NO_x-focused control strategy may maintain or increase ozone in the South Coast Air Basin.

Vehicle Emissions Measurements

This session included presentations on emissions measurement methods and accuracy. Sample line losses of PM-phase hydrocarbons may lead to under-reporting of unregulated emissions. A study evaluating measurement of semi-volatile organic compounds (SVOC) showed that since SVOC occur at very low concentrations in diesel exhaust, methods for sampling, handling, and analyzing SVOC are critical to obtaining quality results.

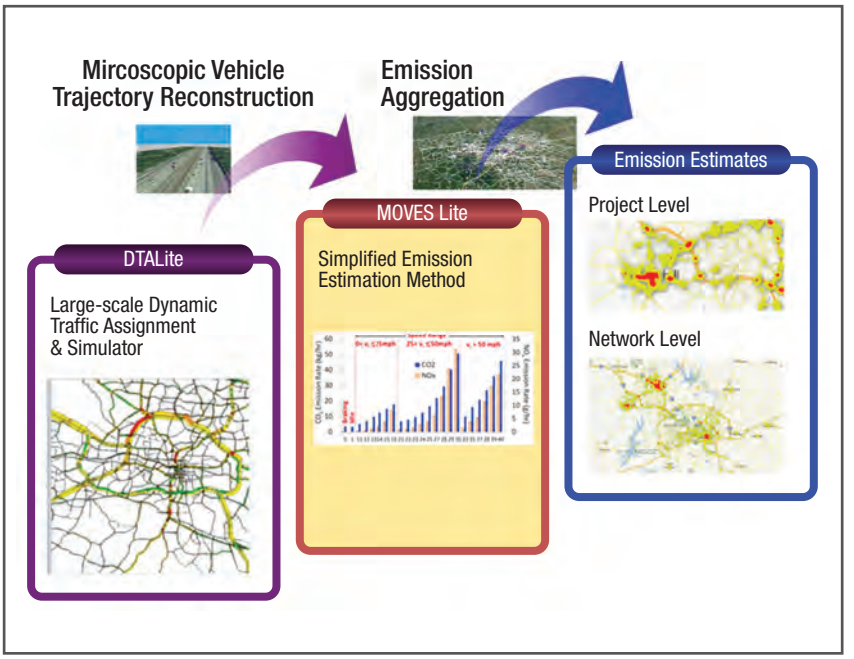

Figure 1. The integrated MOVESLite and DTALite models generate fast emissions estimates.

A new prep cycle was developed and evaluated for fuel effects of gaseous and PM emission on spark ignition direct injection (SIDI) vehicles. The cycle was designed to ensure that when changing test fuels, a vehicle determined that the fuel has changed and properly adjusted for fuel trims. To improve current sampling and measurement procedures for low-level PM emissions, another presentation looked at alternative PM sampling options to those prescribed in the Code of Federal Regulations (CFR). In this study, a single filter sample method was compared with the conventional three-filter method.

An evaluation of PM mass measurement uncertainty revealed that there is a noticeable difference between robotically weighed and manually weighted filters. CARB evaluated PM emissions measurements using three alternative methods. Of the three methods, integrated particle size distribution offered a marginal improvement in coefficient of variation (COV) relative to the gravimetric method.

High-temperature aerosol measurements were evaluated as an alternative to dilute measurements. To avoid water and sulfur compound issues, a new version of the Electric Low Pressure Impactor (ELPI+) was developed for high-temperature, low-concentration PM measurements.

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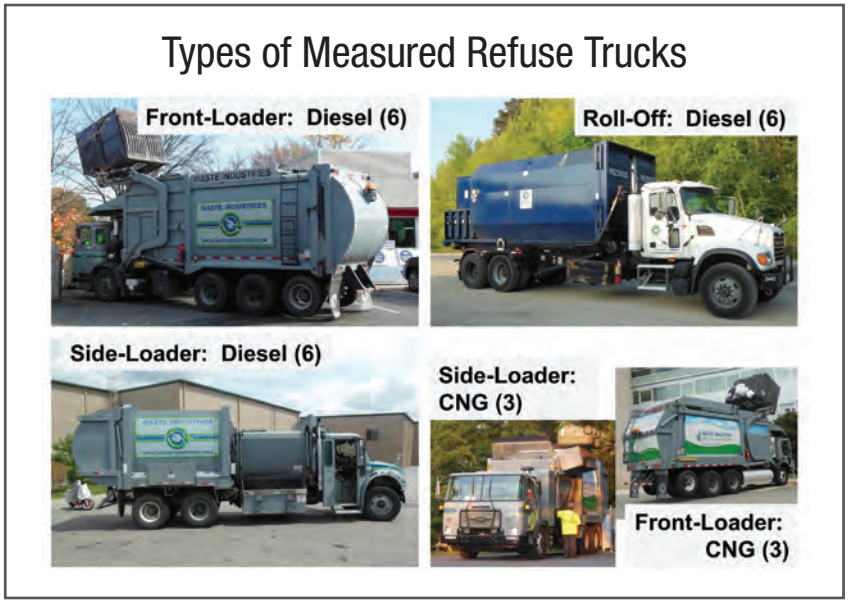

Figure 2. Various types of refuse trucks were evaluated for NO_x emissions, DPF/SCR effectiveness, fuel economy, and GHG emissions.

Off-Road Emissions

This session included the results of a study that used a portable emissions monitoring system (PEMS) to investigate emissions from a ferry boat, hydro-fracking truck, push-boat, and mining truck in order to respond to future regulations implementing in-use testing for emission measurement. The use of a 20% biodiesel/diesel blend (B20) was found to be an effective method to reduce emissions of locomotives (see photo on page 30) to meet air quality requirements for federal transportation improvement funding in North Carolina.

Swiss authorities used the Verification of Emissions Reduction Technologies (VERT) to recognize best available technology for retrofitting diesel engines used for digging and extracting debris in tunnel construction projects. A study of emissions from a marine vessel operated on Lake Michigan found the use of sugarcane renewable fuel produced emissions reduction benefi s.

Fuel Effects: Light-Duty Vehicles

This session described a follow-up study to the EPAct/V2/E-89 program focusing on gasoline PM that confirmed the presence of a reinforcing interaction between Particulate Matter Index (PMI) and ethanol content. The study also found a clear difference between port fuel injection (PFI) and gasoline direct injection (GDI) vehicles in the relationship between PM emission rates and coolant temperature.

A study at University of California, Riverside examining fuel effects of ethanol and iso-butanol found that for non-flex fuel vehicles (non-FFV), total hydrocarbons (THC) and non-methane hydrocarbons (NMHC) increased with oxygenate level in the first couple of hundred seconds after cold start, but there was little effect on weighted emissions. For non-FFVs, emissions of carbon monoxide (CO), PM mass, and number (PN) all decreased with higher oxygen levels. FFVs produced higher carbonyl emissions (acetaldehyde or butyraldehyde) with higher oxygen levels. Benzene, toluene, ethylbenzene, and xylene (BTEX) emissions decreased in FFVs with higher fuel alcohol content. Non-FFVs suffered greater fuel economy penalty for oxygenates than did FFVs.

A study of the effect of natural gas fuel composition found emissions correlated to fuel methane number and Wobbe Index. Testing of two-passenger vehicles and a RAM 2500 compressed natural gas (CNG)-fueled truck showed THC and methane emissions increased with lower Wobbe Index fuels. Some vehicles showed greater sensitivity of NO_x and CO emissions with respect to Wobbe Index. Low methane number did not produce engine knock.

Biodiesel and renewable diesel effects were compared to federal ultra-low-sulfur diesel (ULSD) and CARB ULSD in a study of eight light-duty vehicles. NO_x, PM mass, and PN were not affected by biodiesel blends, while carbon dioxide (CO_2) emissions increased for blends. Formaldehyde and acetaldehyde emissions increased for some biodiesel blends relative to CARB ULSD.

Fuel Effects: Heavy-Duty Vehicles

This session addressed emissions from vehicles with engines fueled with diesel, natural gas, and dual fuel. Vehicles ranged from conventionally powered to hybrid powertrains, including all-electric vehicles.

Real-world refuse truck operation showed diesel particulate filter (DPF) and selective catalytic reduction (SCR) after-treatment was effective despite stop-and-go driving cycles. Average fuel use rates differ between types of refuse trucks

and for compressed natural gas (CNG) versus diesel, as shown in Figure 2. Newer diesel trucks with DPF and SCR in some cases had better fuel economy than older trucks without. Dual fuel engines with diesel/natural gas generated lower CO_2 emissions, but methane slip can produce higher equivalent GHG emissions. Approximate GHG reduction is between 5% and 10%. NO_x emissions are reduced by 40–70%.

Hybrid vehicles in "hybrid-on" mode produced better fuel economy and NO_x emissions than in "hybrid-off" mode. All-electric vehicles in heavy-duty applications may produce up to 80% fuel economy improvement and lower NO_x emissions as well.

Emission Control Measures

This session described an assessment of emerging technologies and fuels for their potential to reduce emissions of NO_x, diesel PM, and GHG from trucks and buses, locomotives, marine, cargo handling equipment, airport sources, and fuels. The information will be used to inform policy decisions that support technology and market development.

As light-duty vehicles age, the on-board diagnostic systems monitors become less ready and the number of diagnostic trouble codes increase. Evidence from repair shops shows evaporative canister degradation. These occurrences are being investigated to determine consistent trends using existing apparatus.

Performing heavy-duty vehicle in-use compliance testing is not feasible. There is a possibility heavy-duty vehicle in-use programs will mimic those in the light-duty fleet. In California, more than 50,000 heavy-duty diesel engine retrofits are in operation on various engine types and duty cycles.

Emission Rates and Inventory

This session described how portable emissions monitoring systems (PEMS) measurements are used to develop the emissions factor model for Hong Kong. Analysis of PEMS data and remote sensing data of diesel and gasoline European and U.S. cars from two separate studies showed that diesel cars have higher NO_x emissions compared to gasoline cars. Inspection and maintenance analysis showed emissions deterioration is characterized by multiplicative patterns from Tier1 through Tier2 vehicles and confirms that reductions over 20 years are proportional to the standards.

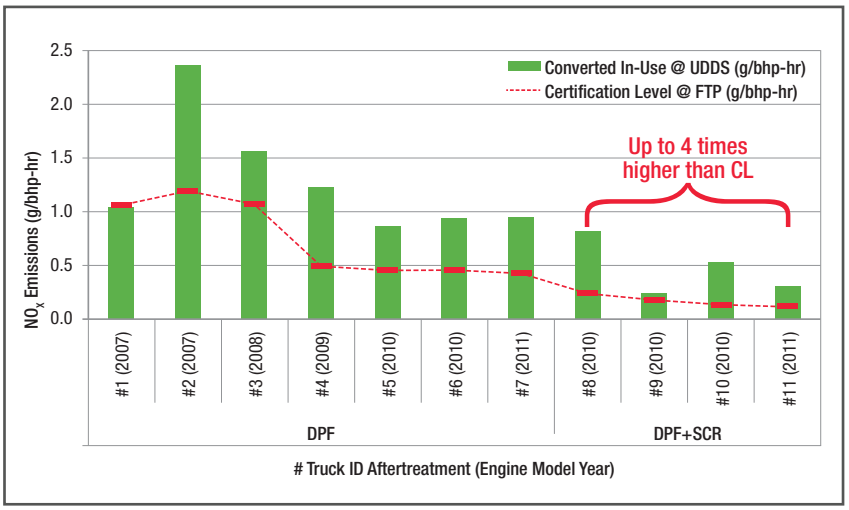

Figure 3. Comparison of in-use NO_x emissions with certification levels.

A study comparing PM mass emissions with PM number count emissions from modern heavy-duty trucks found particle size distribution and number concentration measurements to be dependent on engine technology (i.e., diesel compared to natural gas). In-use NO_x emissions measurements from heavy-duty trucks were up to four times higher than engine certification standards, as shown in Figure 3.

A third study examining impacts of California's regulations on heavy-duty diesel vehicle emissions found reduction of NO_x and black carbon emissions were consistent with the compliance schedule required in the regulation. Specific driving cycles being developed for Texas using new technologies such as Global Positioning System (GPS) to track vehicles in five urban areas found the specific cycles were different from driving cycles in the EPA MOVES model, as shown in Figure 4.

An update was provided on development of the latest version of California's Emission Factors model (EMFAC). Key changes include updated vehicle population data, updated diesel emission factors, and recognition of most current state and federal regulations on criteria pollutant emissions and GHG emissions.

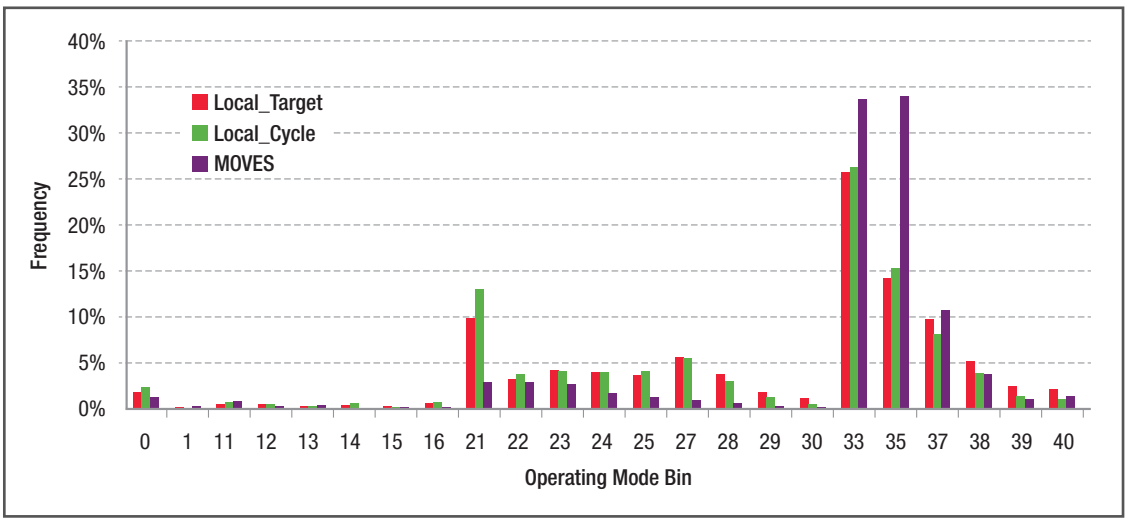

Figure 4. Comparison of Texas-specific driving cycles with default driving cycles in MOVES.

Poster papers were presented on volatile organic compound emissions from light-duty vehicles, nitrous oxide emissions from mobile sources, nighttime particulate formation from evaporative fuel vapors, and comparing real-world fuel economy and emissions with EPA and Euro ratings.

Fuel Efficiency

This session included presentations on technologies, approaches, and policies for reducing fuel and energy consumption. National Research Council reports discussed use of the greenhouse Gas Emission Model (GEM) for certification of vehicles for meeting fuel efficiency regulations. Factors addressed in the reports included engine efficiency, tire rolling resistance, technology advances, and operational considerations. Engine efficiency could be determined using fuel maps for assessing magnitudes and distribution of fuel and energy. Using this approach, a simple energy balance method evaluates reductions in fuel consumption through reductions in loss mechanisms.

Another presentation showed how reductions in fuel consumption of transit buses could be realized using accessory electrification. Typical urban bus accessories for heating, cooling, lights, and everything not required for propulsion may consume nearly as much power as propulsion itself.

Increasing vehicle size trends and traffic congestion can offset energy-saving benefits. To counter this, policies that promote fuel consumption limits, effective traffic management and control measures, and alternative fuel technologies are essential to reduce fuel consumption and emissions.

In-Field Measurements

This final session focused on new measurement methods and results suggesting possible improvements to certain emissions standards. For example, the not-to-exceed regulation for NO_x emissions from heavy-duty vehicles has too many exclusions to be fully effective, and alternatives such as work windows or moving averages should be considered. The Euro VI standard for light-duty requires PEMS measurements to ensure real-world emissions reductions, and guidelines are being explored to control for altitude, road grade, payload, and so forth.

Tests using a small compact PEMS unit showed a Euro VI diesel light-duty vehicle emitting more NO_x than a Euro V diesel vehicle in the city, but less on the highway, consistent with previous work on temperature requirements in new NO_x control devices. Another study suggested less than 3% difference in CO_2 measurements between laboratory and PEMS data, but a more than 7% difference for NO_x. Several studies focused on new and innovative ways to measure on-road emissions with novel remote sensing or PEMS systems. One study used the OBD broadcast to predict CO_2 and NO_x emissions.

As emissions control technologies and measurement methods continue to develop, demand continues for research collaboration to improve emissions data, measurement methods, and models. **em**

Proceedings are available upon request from CRC. The 26th CRC Real-World Emissions Workshop is scheduled for March 13–16, 2016, in Newport Beach, CA.