Data Collection, Testing, and Analysis of Hybrid Electric Trucks and Buses Operating in California Fleets

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Technical Report
NREL/TP-5400-62009
June 2015

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NATIONAL RENEWABLE ENERGY LABORATORY

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List of Acronyms

ASTM	ASTM International
CAN	controller area network
CARB	California Air Resources Board
CE-CERT	Center for Environmental Research and Technology
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
DPF	diesel particulate filter
EPA	U.S. Environmental Protection Agency
FTIR	Fourier transform infrared
GC-ECD	gas chromatography-electronic capture detection
GHG	greenhouse gas
GVW	gross vehicle weight
GVWR	gross vehicle weight rating
HEV	hybrid electric vehicle
HHDDT	Heavy Heavy-Duty Diesel Truck
HTUF4	Hybrid Truck Users Forum Class 4 Parcel Delivery Driving Schedule
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
LA	Los Angeles
MY	model year
N_2O	nitrous oxide
NEC	net energy change
NH_3	ammonia
NMHC	non-methane hydrocarbons
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NREL	National Renewable Energy Laboratory
NYCC	New York City Composite
OCTA	Orange County Transit Authority Cycle
OEM	original equipment manufacturer
PEMS	portable emissions measurement system
PM	particulate matter
RESS	rechargeable energy storage system
TCE	total cycle energy
THC	total hydrocarbons
UDDS	Urban Dynamometer Driving Schedule
WVU CITY	West Virginia University City

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Executive Summary

The objective of this project was to evaluate and quantify the emission impacts of commercially available hybrid medium- and heavy-duty vehicles relative to their non-hybrid counterparts. This effort will allow the California Air Resources Board (CARB) and other agencies to more effectively encourage development and commercial deployment of the most efficient, lowest emitting hybrid technologies needed to meet air quality and climate goals.

Hybrid technology has the potential to provide significant greenhouse gas and criteria pollutant emission reductions, particularly in urban, stop-and-go duty cycles. California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) has provided $38 million since its launch in 2010 to help California fleets purchase about 1,700 hybrid trucks and buses. These early hybrid truck deployments, mostly in the Classes 4 through 7 delivery vehicle vocations, provide a critical role in enabling consumer acceptance and technology transfer needed for the advanced hybrid and zero-emission heavy-duty vehicles California will need to meet its long-term air quality and climate challenges. This study provides a unique opportunity to evaluate the emission impacts of the nation's first commercially available hybrid trucks, and is intended to help inform effective policies to accelerate advanced hybrid truck and bus deployment.

This project was executed by the National Renewable Energy Laboratory (NREL) under an agreement with CARB (#11-600). It examined the in-use performance of more than 120 vehicles across four vocations: beverage delivery, parcel delivery, uniform and linen delivery, and food distribution. More than 80 of these vehicles were hybrid electric vehicles (HEVs) that had received vouchers through HVIP. The remaining vehicles were selected as conventional comparisons to benchmark performance. A sub-set of these vehicles was also selected for chassis dynamometer testing and on-road emissions testing. It is important to note that despite efforts to include baseline conventional vehicles equivalent to hybrids in this study, this was not possible in all cases and, as such, some data may not provide an accurate comparison between hybrid and conventional vehicles due to potentially important differences in vehicle build and engine model year. However, the in-use, chassis testing data from the Class 5 parcel delivery vehicles offered solid opportunities for isolating the effects of the hybrid system compared with a conventional vehicle, as both vehicles had the same 2011 Cummins ISB engine with a 200 HP rating and calibration CPL#3070. Both the conventional and hybrid vehicles were built on a Freightliner MT45 chassis with a 4.10 final rear-axle ratio. Results from vocational analysis, chassis testing, and on-road testing for the complete data set showed a 10%–27% increase in average fuel economy from the HEVs, but actual gains from individual driving days varied widely depending on the route and drive cycle characteristics. This reinforced the importance of proper route selection when deploying an HEV in order to maximize fuel economy benefits.

Almost all of the HEVs in this study exhibited a decrease in carbon-dioxide (CO_2), carbon-monoxide (CO), and hydrocarbon (HC) emission, but an increase in oxides of nitrogen (NO_x) emissions, relative to their conventional counterparts. It should be noted that all of the hybrids in this study were parallel HEVs. This NO_x emissions issue requires further investigation to pinpoint the exact cause of this increase, but preliminary results have indicated that this is a complex interaction involving the integration of engine, transmission, and final driveline. Factors affecting tailpipe emissions include catalyst temperature, space velocity, and engine operating point. Decisions on transmission gearing and final drive axle ratio can heavily influence engine operation and, in turn, tailpipe emissions. A comparison of aftermarket hybrid and vertically integrated solutions is required to better understand how these two design pathways will ultimately affect emissions across California fleets that use hybrid technology. That is, the conclusion is not that all medium- and heavy-duty HEVs lead to higher NO_x emissions, but that this was observed for specific hybrid configurations included in this study and as such, when future hybrids are designed and integrated for the vocational market segment, close consideration and accounting for both fuel economy and emissions benefits need to be taken into account. This balancing of fuel consumption and emission reduction trade-offs in planning the design and deployment of future medium- and heavy-duty hybrids, which includes engine downsizing, emission control system calibration/conversion optimization, and optimized integration and control of the electric drive system, will lead to vehicles that are able to reduce fuel use and criteria pollutant emissions simultaneously. Therefore this technology for medium-duty and heavy-duty vehicles is still considered an important pathway that will provide fuel consumption and greenhouse gas reductions and will also act as a bridging technology to battery electric and fuel cell vehicle deployment.

In addition, it is also important to view these results in the context of the goals for this project and not extrapolate the results beyond the vehicles that were included in the study. As such, this should be considered a limited dataset—vehicles were selected based on availability and are not necessarily representative of the in-use vehicle population. Also, the focus was to include HEVs participating in HVIP that are not representative of all vehicles—or even all hybrids—operating in California. Because the study focused on HEVs, comparison data on conventional vehicles were available on only a small sample size, and data on 2010 certification conventional vehicles were difficult to acquire because of limited vehicle availability. In addition, some vocations and vehicle classes were excluded by design—the focus was on vocations with the highest representation in HVIP, so this should not be considered a comprehensive dataset. That said, the observations from this study indicate a need for improved electric drive integration and optimization for the medium-duty and heavy-duty vehicle markets. In addition, the observations show that deployment of these vehicles should be approached with an open mind with regard to their potential for fuel reduction and the potential for unintended adverse impacts from the criteria emission perspective if they are not properly designed and certified. Additional analysis is needed to fully understand all of the data and observations gathered during this study in order to fully understand the potential of these vehicles.

The initial impression is that the observed issue related to the increase of NO_x emissions associated with the hybrid vehicles has the potential to be easily solved. CARB is currently working with NREL on a second phase of this work to identify the root cause of this issue and recommend solutions for both current and future hybrid vehicles. To better understand the issue, this future project will monitor emissions-control systems for differences in urea dosing and changes in engine operation (e.g., injection timing and exhaust gas recirculation rates), examine the composition of the selective catalytic reduction (SCR) feed gas (NO_2 to NO_x ratio), and look at tailpipe constituents (NH_3, N_2O, HNCO) to better understand SCR operation, among other things. This will be done by using a well-paired conventional and hybrid vehicle (same MY engine calibration/certification, etc.) on NREL's chassis dynamometer (including the Hino hybrid/conventional vehicle vertically integrated platform) and using representative cycles that are known to show fuel economy benefits and NO_x increase. In addition, the future project will explore the potential to tune for fuel economy and low emissions simultaneously by working with industry partners (e.g., engine, transmission, and hybrid-system developers) to adjust/optimize control strategies and provide recommendations for the next generation of hybrids to ensure that fuel economy benefits continue to be realized without sacrificing emissions.

Introduction

The objective of this project was to evaluate and quantify the emission impacts of commercially available hybrid medium- and heavy-duty vehicles relative to their non-hybrid counterparts. This effort will allow the California Air Resources Board (CARB) and other agencies to more effectively encourage development and commercial deployment of the most efficient, lowest emitting hybrid technologies needed to meet air quality and climate goals.

Project Background and Objective

Hybrid technology has the potential to provide significant greenhouse gas and criteria pollutant emission reductions, particularly in urban, stop-and-go duty cycles. California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) has provided $38 million since its launch in 2010 to help California fleets purchase about 1,700 hybrid trucks and buses. These early hybrid truck deployments, mostly in the Classes 4 through 7 delivery vehicle vocations, fill a critical role in enabling consumer acceptance and technology transfer needed for the advanced hybrid and zero-emission heavy-duty vehicles California will need to meet its long-term air quality and climate challenges. This study provides a unique opportunity to evaluate the emission impacts of the nation's first commercially available hybrid trucks, and is intended to help inform effective policies to accelerate advanced hybrid truck and bus deployment.

Previous efforts to intelligently deploy or place vehicles into fleets, including testing and analysis conducted by the National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE), have illustrated the relationship between duty cycle, fuel economy, and emissions. This initial work has shown that knowledge of real-world vocational drive cycles and vehicle operation is the key to selecting the right technology for a given application. Gathering these data is critical in understanding the performance of various technologies under different operating conditions. Without these fundamental data, chassis dynamometer-derived emissions and fuel economy results may not be representative of real-world performance, and vehicle and deployment models cannot be optimized for real-world vocational conditions. NREL and the DOE have initiated a project called "Fleet DNA" to capture and characterize data from various vocations for further vehicle design and strategic deployment.

This project used the Fleet DNA framework and dataset to supplement this "California-specific" study and effectively provide CARB, original equipment manufacturers (OEMs) producing HEVs, and the various fleets that are purchasing vehicles in California information about the effectiveness of the technology under real-world conditions. Specifically, the objectives of this project were to:

1. Obtain the necessary data from HVIP-eligible vehicles (and their diesel equivalents, when available) on relevant vehicle uses and vocations in California
2. Provide testing and analysis showing the performance of technology on the measured uses and vocations
3. Provide a framework, dataset, and methodology to estimate fuel consumption and emissions of current and future deployments of HVIP vehicles and other advanced technology vehicles in California.

Project Summary

The specific objective of this study was to better understand the use of medium- and heavy-duty vehicles in California by estimating the real-world benefits of implementing advanced technologies. This effort will enable CARB and other California agencies to strategically match advanced propulsion systems and duty cycles to optimize for fuel economy, emissions reductions, and return on grant funding or capital investment.

This project used:

- Chassis dynamometer-based testing of vehicles over a focused set of duty cycles that yielded relevant data and helped with the estimation of vocational emissions inventories and fuel consumption metrics.
- A methodology that will output simulated fuel economy values based on specific vocational duty cycles. This will provide additional estimation capabilities for future deployments.
- Data collection activities to further define a database to capture known and specific characteristics of vocational duty cycles that will allow for improved assessment of powertrain tradeoffs, such as energy storage capacity and component sizing.

This project provided CARB data to:

- Characterize the relative emissions contribution of various medium- and heavy-duty vocations operating in California
- Develop a methodology to create a "strategic roadmap" to initiate research, development, demonstration, and deployment programs that will deploy the highest impact low-emissions vehicle technology within the most appropriate fleet vocations and duty cycles or routes
- Strategically achieve the largest criteria and greenhouse gas (GHG) emissions reductions when using deployment funding
- Provide data to more accurately forecast vocational emissions inventories in California.

This project was executed by NREL under an agreement with CARB (#11-600). It examined the in-use performance of 129 vehicles across four vocations: beverage delivery, parcel delivery, uniform and linen delivery, and food distribution. Eighty-nine of these vehicles were HEVs that had received vouchers through HVIP. The remaining 40 vehicles were selected as conventional comparisons to benchmark performance. Daily drive cycle information was analyzed using NREL's Drive-cycle Rapid Investigation, Visualization and Evaluation (DRIVE) Tool and results were incorporated into Fleet DNA, where they could be compared against hundreds of other vehicles. This analysis also allowed the most representative standard test cycles to be selected for chassis dynamometer testing, which was performed at the University of California Riverside Center for Environmental Research and Technology (CE-CERT). Results from vocational analysis have shown a 10%–27% increase in overall fuel economy from the HEVs, but actual gains from individual driving days varied widely depending on the route and drive cycle characteristics. This reinforced the importance of proper route selection when deploying an HEV.

Most HEVs also exhibited an increase in tailpipe oxides of nitrogen (NO_x) emissions, but it should be noted that all of the hybrids in this study were parallel HEVs. This issue requires further investigation to pinpoint the exact cause, but preliminary results have indicated that this is a complex interaction involving the integration of engine, transmission, and final driveline. Factors affecting tailpipe emissions include catalyst temperature, space velocity, and engine operating point. Decisions on transmission gearing and final drive axle ratio can heavily influence engine operation and tailpipe emissions. A comparison of aftermarket hybrid and vertically integrated solutions is required to better understand how these two design pathways will ultimately affect emissions across California fleets that use hybrid technology.

This project was divided into six primary tasks:

1. Coordination and implementation of fleet partner agreements
2. Drive cycle data collection
3. Fleet drive cycle analysis and characterization
4. Chassis dynamometer emissions and fuel economy measurement
5. Portable emissions and fuel economy measurements
6. Vocational analysis and methodology development.

The following sections will detail the six key project tasks, the execution of these tasks, and the resulting data.

Project Descriptions and Results by Task

Task 1: Coordination and Implementation of Fleet Partner Agreements

Under this task, NREL recruited private fleets for participation in this project for access to vehicles for the execution of Tasks 2, 3, and 4. This effort also included the coordinated third-party fleet agreements as appropriate. Target fleets were operating in California; the project focused on fleets that have participated or are currently participating in the HVIP or in DOE's National Clean Fleet Partners Program. The fleets and vocations that were recruited for partnering in this project have implemented—or are interested in implementing—advanced technology in their fleets. Key vocations that were initially targeted for this project were:

- Class 4–6 parcel delivery fleets
- Class 4–6 service vans
- Class 7–8 tractor/trailer beverage delivery fleets
- Class 7–8 intercity tractor/trailer fleets
- School bus fleets
- Class 8 refuse vehicle fleets
- Class 8 transit bus fleets
- Class 6–7 intercity box truck fleets
- Class 8 intercity delivery tractor/trailer
- Class 6–7 shuttle bus fleets
- Class 3 delivery vans.

CARB planned that three to four of these vocations would be selected for the data collection efforts and that a subset would be used for the two emissions and fuel economy measurement tasks. Once the project was initiated, CARB decided to focus the fleet recruitment on the vocation that had the highest participation level in the HVIP.

Table 1 includes details related to HVIP participation by vocation to date. These data (provided by CARB) show that four of the five largest vocations that are participating in the HVIP are parcel delivery, beverage delivery, uniform and linen delivery, and food distribution. As such, this task concentrated on recruiting fleets in these four vocations; the primary focus was on parcel delivery, beverage delivery, and uniform and linen delivery. Priority was also given to data collection on vehicles with model year 2010 or newer engines.

Table 1. HVIP Participation Statistics

Vehicle Type	Voucher s Issued	Total Voucher Funds	Average Voucher Amount	% of Total Vouchers	% of Total Voucher Funds
Parcel Delivery	621	$15,968,000	$25,713	37%	34%
Beverage Delivery	410	$13,502,000	$32,932	24%	29%
Other Truck	333	$8,092,000	$24,300	20%	17%
Food Distribution	56	$1,593,000	$28,446	3%	3%
Uniform & Linen Delivery	112	$2,800,000	$25,000	7%	6%
Tow Truck	73	$2,327,000	$31,877	4%	5%
Pick-up & Delivery	27	$690,000	$25,556	2%	1%
Refuse Hauler	23	$934,000	$40,609	1%	2%
School Bus	13	$390,000	$30,000	1%	1%
Shuttle Bus	13	$276,776	$21,290	1%	1%
Utility Truck	5	$181,000	$36,200	0.3%	0.4%
Urban Bus	7	$285,000	$40,714	0.4%	0.6%
Dump Truck	4	$103,000	$25,750	0.2%	0.2%
Total	1,697	$47,141,776	$27,779	100.0%	100.0%

In fulfillment of this task, NREL secured agreements from eight companies across all four vocations (two per vocation) to participate in drive cycle data collection activity. These third-party agreements provided access to 89 hybrid trucks (2010 certification, Classes 4 through 8) and 40 conventional trucks (2010 or 2007 certification, classes 4 through 8), across a wide geographic distribution (San Francisco Bay area, Sacramento, Los Angeles [LA] area, and the central valley) (see Figure 1). A subset of fleets from two companies (one beverage delivery and one parcel delivery) also agreed to participate in the chassis dynamometer and portable emissions measurement system (PEMS) testing portion of the project and provide access to HEVs and conventional trucks for emissions testing.

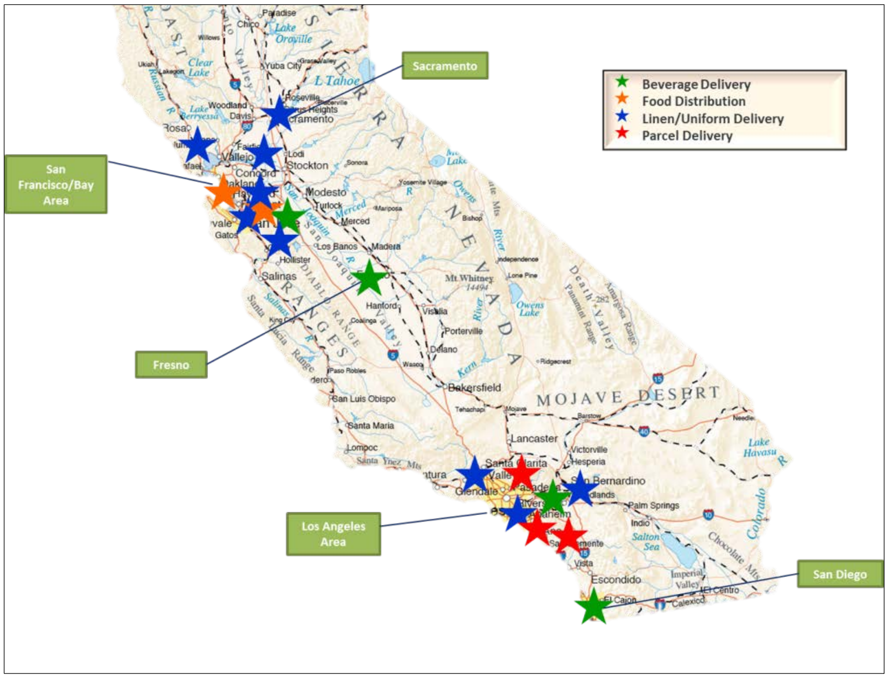


Figure 1. Fleet locations by vocation

For the beverage delivery vocation (Class 7 day cabs), 46 vehicles were recruited (39 HEVs and 7 conventional vehicles), from two beverage delivery companies across four locations (Bay area, LA area, Fresno, and San Diego). For the parcel delivery vocation (Classes 3–5 step vans), 40 vehicles (27 HEVs and 13 conventional vehicles) across three locations and two companies (all in the LA area) were recruited. This was the only vocation in which comparable 2010 certification conventional diesels were included. For the uniform and linen delivery (Class 5 and 6 step vans), 31 vehicles (14 HEVs and 17 conventional vehicles) were recruited across ten locations (five in the Bay area, four in the LA area, and one in Sacramento) across two companies. For the food distribution vocation (Class 7 day cabs and Class 5 delivery), which was the lowest priority of the four target vocations, 12 vehicles (9 HEVs (including 2 Hino 195h's), and 3 conventional vehicles) were recruited across three locations (all Bay area) from two companies. Appendix A provides a complete list of all 129 vehicles recruited under this task for this project.

Task 2: Drive Cycle Data Collection

Data collection hardware supplied by NREL was used to collect data from the fleets and vocational vehicles recruited in Task 1. The following is a list of the specific data targeted (from SAE J1939 broadcast data, analog instrumentation, field records, or manufacturer information/ specification sheets) for collection on each vehicle:

- Vehicle speed (1 hz)
- Engine speed (1 hz)
- Actual engine—percent torque
- Nominal friction—percent torque
- Actual maximum available engine—percent torque
- Reference torque
- Hybrid battery system current measurement
- Motor speed and torque
- Wheel-based vehicle speed
- Engine intake manifold #1 pressure
- Engine intake manifold #1 temperature
- Engine coolant temperature
- Engine exhaust gas temperature
- Engine oil temperature #1
- Engine fuel rate
- Diesel particulate filter (DPF) status
- DPF regeneration
- Emission control system exhaust temperatures (optional, based on availability of proprietary data)
- Average cargo load
- Vehicle description including, at a minimum, laden and unladen gross vehicle weight (GVW), engine make, engine model year (MY), engine displacement, engine horsepower rating, transmission type and number of forward speeds, tire size, and rear axle ratio
- Hybrid system description including, at a minimum, manufacturer, MY, model, motor, motor controller, transmission, energy storage information, and system voltage.

Instrumentation of the vehicles for this task lasted for approximately 3 weeks per vehicle. The project plan was to instrument at least 30 vehicles from three separate locations or depots for three vocations, for a total of 90 vehicles. In the end, this exact deployment strategy was not possible for all vocations because vehicles were not available, but the plan was implemented for two vocations. In several cases, more vehicles were instrumented than were originally planned and 129 vehicles were instrumented across all vocations, leading to more activity data collected under this task than anticipated (see the Appendix for a complete list of all vehicles instrumented and vehicle data). This resulted in approximately 2,000 days, 5,500 driving hours, and 150,000 vehicle miles of operating data from a breadth of operations that were used to characterize each vocation.

The goal was to collect the key engine and emissions control system data for all 129 vehicles in this task. Unfortunately, many vehicle vintages and manufacturers were involved, so not all targeted data were available for all vehicles. After reviewing the data from the first deployment, NREL noticed a few channels that were not recording or were not accurate. Some of the important parameter channels that had issues included DPF status, exhaust temperature, and reference torque. There are several reasons why data from some channels were not received; these are usually related to either how the OEMs set up their sensors and referenced them to particular J1939 code or parameter group numbers (which can vary by engine MY or family for the same OEM) or the channel was being restricted by the OEM. Because the setup of the controller area network (CAN) files was for 2010 or newer vehicles, we did not receive all the expected channels when we had vehicles with 2009 MY engines installed. As such, we did not receive all the requested data for every vehicle instrumented under Task 2. We were able to resolve most of the issues identified in the first round of data collection and were able to obtain most of the priority data CARB had requested during all later deployments. One key change was that we were able to identify the correct parameter group numbers for the data channels with which we had issues in the first deployment—this included several of the temperature channels and the reference torque. Table 2 provides details related to which key data channels were collected in each vocational vehicle group. It shows that the vocation with the most comprehensive dataset was the parcel delivery vocation.

Table 2. Data Channels Collected by Vocational Vehicle Group

	Beverage			Food		Linen				Parcel			All
	H		C	H	C	H		C		H	C		
	F	L	L	L	L	F	L	F	L	F	F	L	
Vehicle Count	22	17	7	9	2	10	4	1	15	26	3	9	125
Total Hours	1,052	840	371	1,133	227	748	156	70	1,103	1,435	90	441	7,667
Driving Hours	809	605	279	901	200	380	128	39	597	1,111	62	339	5,450
Idle Ratio	23.1%	27.9%	24.6%	20.5%	12.1%	49.2%	18.0%	44.7%	45.9%	22.6%	31.4%	23.2%	28.9%
Total Distance (mi)	25,348	16,652	8,825	31,548	8,575	10,241	3,891	1,218	18,575	21,859	1,011	7,109	154,852
Total Fuel (gal)	3,167	2,547	1,430	1,825	1,328	1,058	349	179	1,912	2,398	173	238	16,604
Average (mpg)	8.0	6.5	6.2	17.3	6.5	9.7	11.2	6.8	9.7	9.1	5.8	29.8	9.3
Stops	30,534	31,196	11,847	20,780	2,619	21,070	6,524	2,132	27,068	86,745	5,154	25,824	271,493
Stops / mi	1.2	1.9	1.3	0.7	0.3	2.1	1.7	1.7	1.5	4.0	5.1	3.6	1.8
Stops / hr	29.0	37.1	32.0	18.3	11.5	28.2	41.7	30.6	24.5	60.4	57.1	58.6	35.4
avg KI (1/mi)	0.39	0.74	0.56	0.39	0.22	0.66	0.50	0.42	0.48	1.73	3.65	1.88	0.94
avg DPF Out Temp [C]	253					216		251		215	243		231
avg SCR Out Temp [C]	219					185		224		173	196		193
avg Nox SCR In [g/kWh]	4.60					6.80		4.57		7.92	5.11		6.37
avg Nox SCR Out [g/kWh]	0.88					3.15		0.67		3.56	1.93		2.42
avg Nox SCR In [g/mi]	7.32					6.39		8.43		8.28	8.23		7.40
avg Nox SCR Out [g/mi]	1.39					2.96		1.24		3.59	3.11		2.56
Total Work [kWh]	40,017					9,569		2,247		23,863	1,666		
Driving Work [kWh]	39,896					9,538		2,163		23,640	1,537		
avg Driving Power [kW]	49.3					25.1		56.1		21.3	24.8		

”H” = hybrid, “C” = conventional, “F” = full data set, “L” = limited data set

The result of this task was a large dataset of vocationally based drive cycles (speed and load) and engine information, collected at 1 hz on each vehicle. All the detailed second-by-second (1 hz) data in engineering units from this task have been provided to CARB. Some data have been aggregated to protect the anonymity of the participating fleets. A CAN channel dictionary was also developed for each specific setup and is included with the raw data that was provided to CARB as part of this project.

Task 3: Fleet Drive Cycle Analysis and Characterization

NREL used its in-house software and data analysis capabilities to analyze the real-world drive characteristics and vehicle operation data collected in Task 2 to produce vehicle performance metrics and representative drive cycles. These metrics generated for each set of vocational data were provided to CARB. NREL also used these data to select three to four representative drive cycles (standard cycles) for use in tasks 4 and 5 and to develop custom duty cycles. The drive cycles were selected to "bracket" the range or operation expected from each vocation and enable testing to explore the range of performance of the new technology. NREL's Drive-Cycle Rapid Investigation, Visualization and Evaluation (DRIVE) Tool was used for this exercise. A discussion of the development and selection of these cycles for each vocation follows.

The duty cycle selection for the beverage vocation was based on data logging from 46 vehicles from four locations (Bay Area, LA area, San Diego, and the central valley) (Figure 2). This figure shows the relationship between driving speed and cycle aggressiveness for this vocation. The relative aggressiveness of a drive cycle for this and all vocations can be represented by kinetic intensity, which represents the ratio of energy consumed from acceleration and deceleration to the energy consumed via aerodynamics. High values of kinetic intensity correlate to cycles with high ratios of stop-and-go energy consumption to aerodynamic energy consumption. Consequently, it is cycles with high kinetic intensity that tend to correspond with the highest benefits of technologies that can recapture vehicle kinetic energy such as regenerative braking and flywheel storage systems found in modern hybrid vehicles. The standard duty cycles that matched the observed activity for this vocation and were chosen for use for the chassis testing were the West Virginia University City (WVU CITY) (Figure 3); the Heavy-Duty Urban Dynamometer Driving Schedule (UDDS) (also referred to as UDDS Schedule D) (Figure 4); and the CARB Heavy Heavy-Duty Diesel Truck (HHDDT) with 65 mph variant and U.S. Environmental Protection Agency (EPA) GHG rule weightings (Figure 5). These cycles plotted against the observed activity data for this vocation are shown in Figure 2.

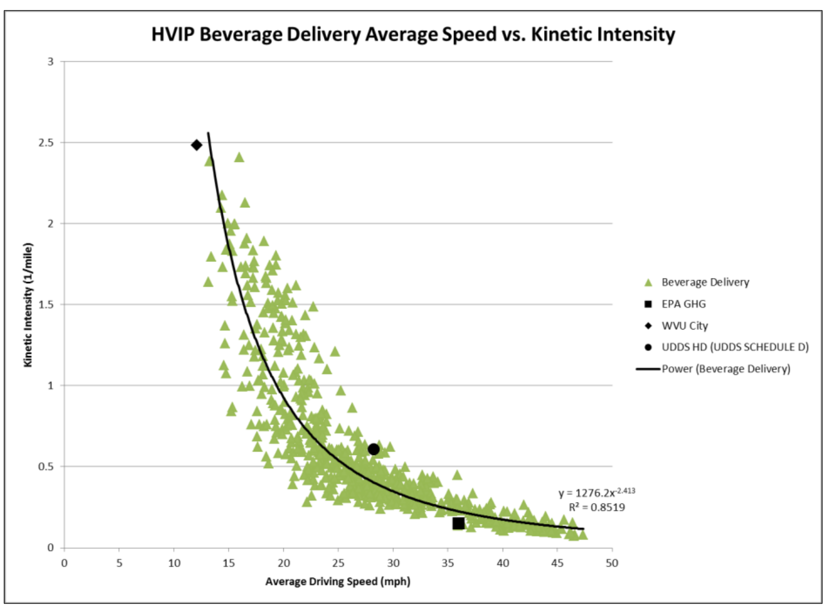


Figure 2. Beverage delivery vocation cycle selection

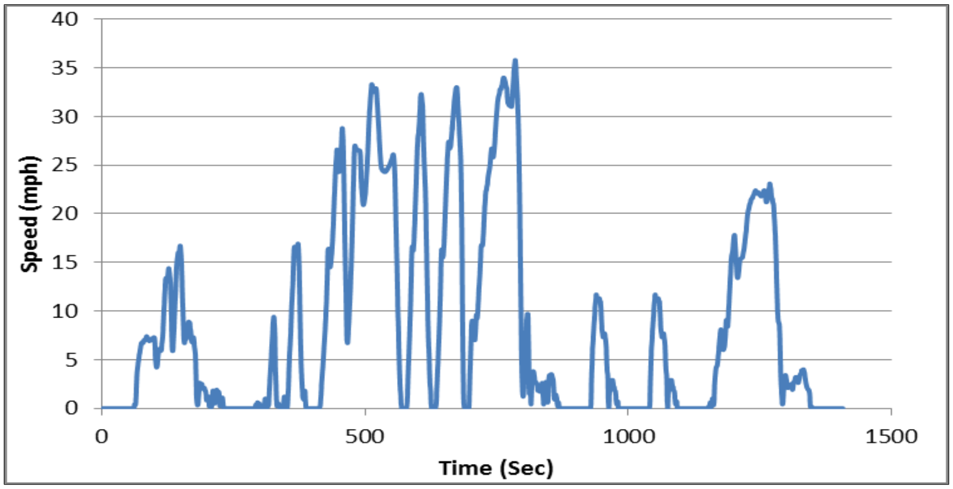


Figure 3. West Virginia University City cycle (WVU CITY)

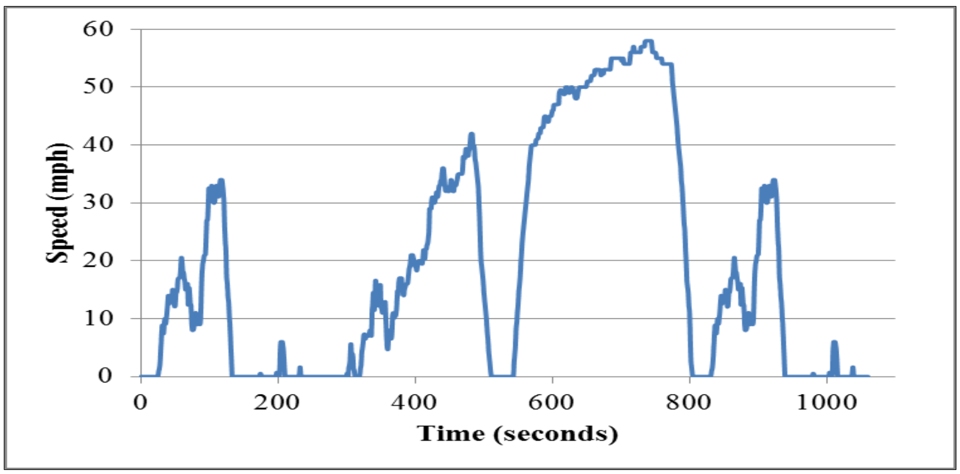
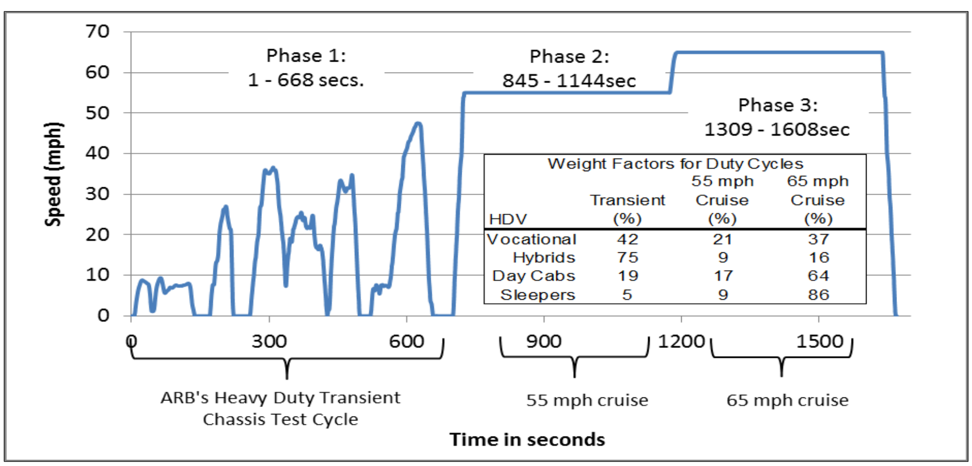


Figure 4. Urban Dynamometer Driving Schedule (UDDS)



Weight Factors for Duty Cycles

HDV	Transient (%)	55 mph Cruise (%)	65 mph Cruise (%)
Vocational	42	21	37
Hybrids	75	9	16
Day Cabs	19	17	64
Sleepers	5	9	86

Figure 5. Revised EPA GHG (HHDDT) cycle for all chassis tests

The duty cycle selection for the parcel delivery vocation was based on data logging from 40 vehicles from three locations in the LA area (Figure 6). For this vocation, the standard duty cycles that matched the observed activity and were chosen for chassis testing for this vocation and vehicle set were the CARB HHDDT with 65 mph variant and EPA GHG rule weightings (Figure 5); the New York City Composite (NYCC) (Figure 7); the UDDS (Figure 4); and the Hybrid Truck Users Forum Class 4 Parcel Delivery Driving Schedule (HTUF4) (Figure 8). These cycles plotted against the observed activity data for this vocation are shown in Figure 6.

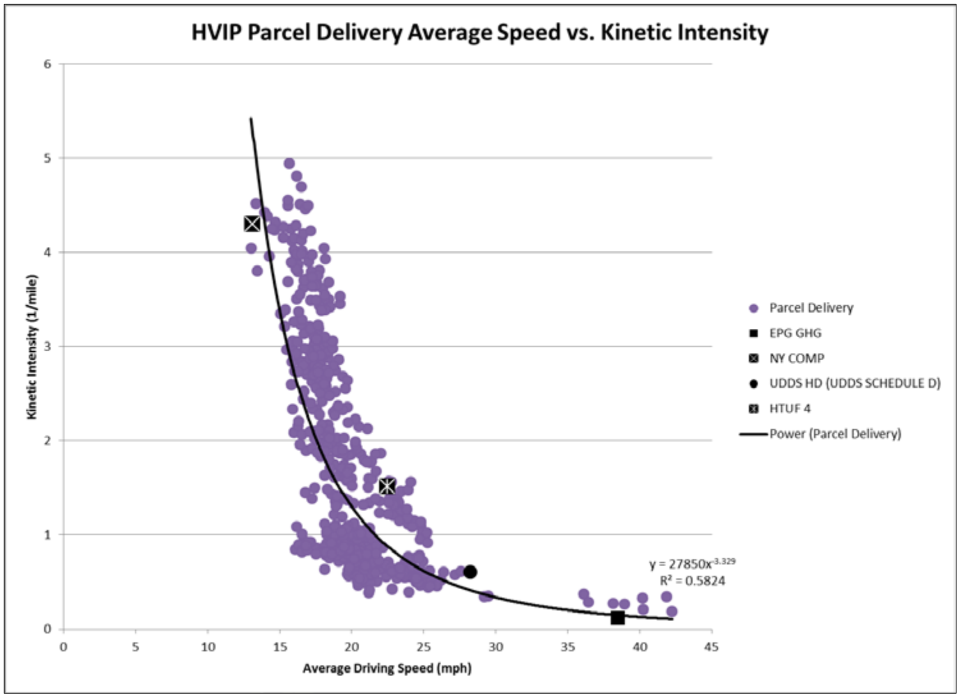


Figure 6. Parcel delivery vocation cycle selection

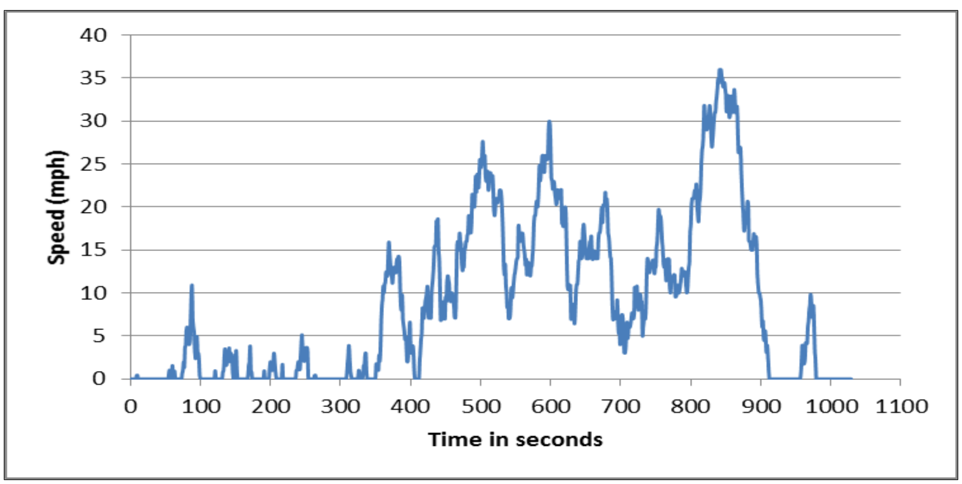


Figure 7. New York City composite cycle (NYCC)

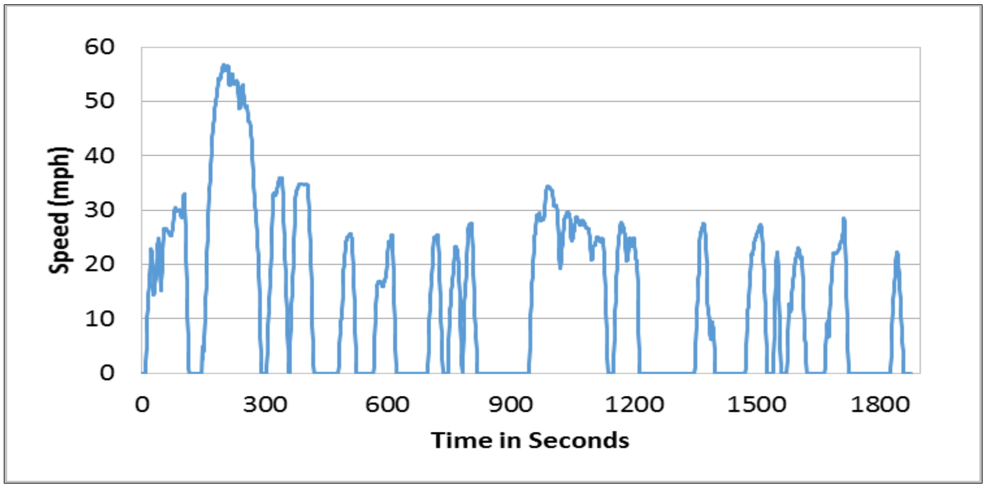


Figure 8. Hybrid users truck forum Class 4 driving schedule (HTUF4)

The duty cycle selection for the uniform and linen delivery vocation was based on data logging from 31 vehicles from ten locations in the Bay area, Sacramento and LA area (Figure 9). The standard duty cycles that matched the observed activity and were chosen for chassis testing for this vocation and vehicle set were the CARB HHDDT with 65 mph variant and EPA GHG rule weightings (Figure 5), the NYCC, (Figure 7) and the UDDS (Figure 4). These cycles plotted against the observed activity data for this vocation are shown in Figure 9.

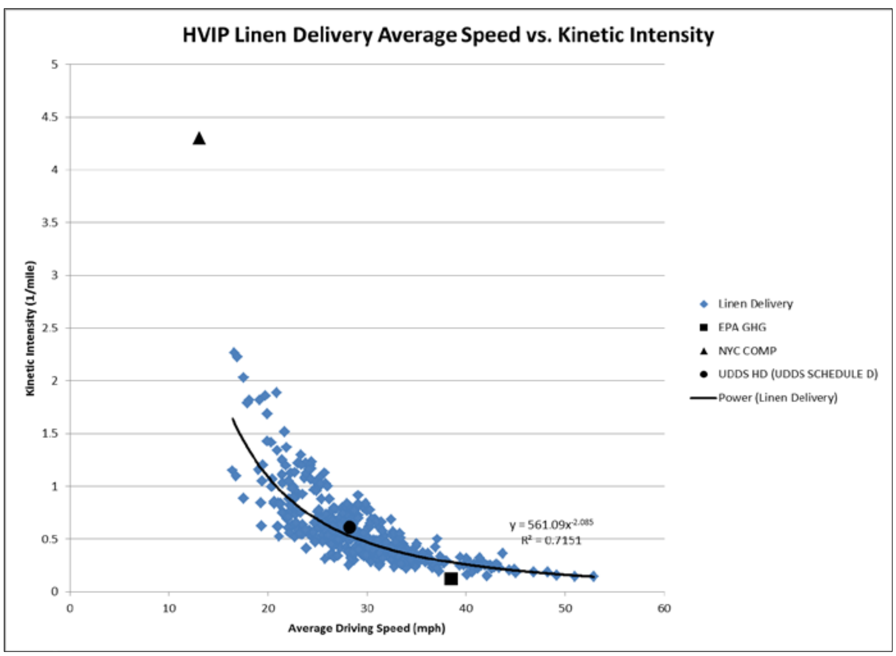


Figure 9. Uniform and linen delivery vocation cycle selection

For the Hino 195h (vertically-integrated HEV) testing, three standard duty cycles were chosen to replicate the use of the Hino HEV in the parcel delivery application. The duty cycle selection for the Hino trucks was based on the data collected for this project on parcel delivery vehicles in the LA area, past studies performed by NREL in Phoenix and Minneapolis, and other factors. The cycles used were the Orange County Transit Authority (OCTA) Cycle (Figure 10), the UDDS (Figure 4), and the HHDDT run as the EPA GHG Cycle (HHDDT, Figure 5).

Figure 11 through Figure 13 show plots of the Hino daily truck activity with Figures 11 and Figure 12 showing activity compared to the HHDDT, UDDS, and OCTA standard drive cycles. These activity data were taken from the two trucks that were included in Task 2 operating in the food distribution vocation in Newark (northern California, East Bay).

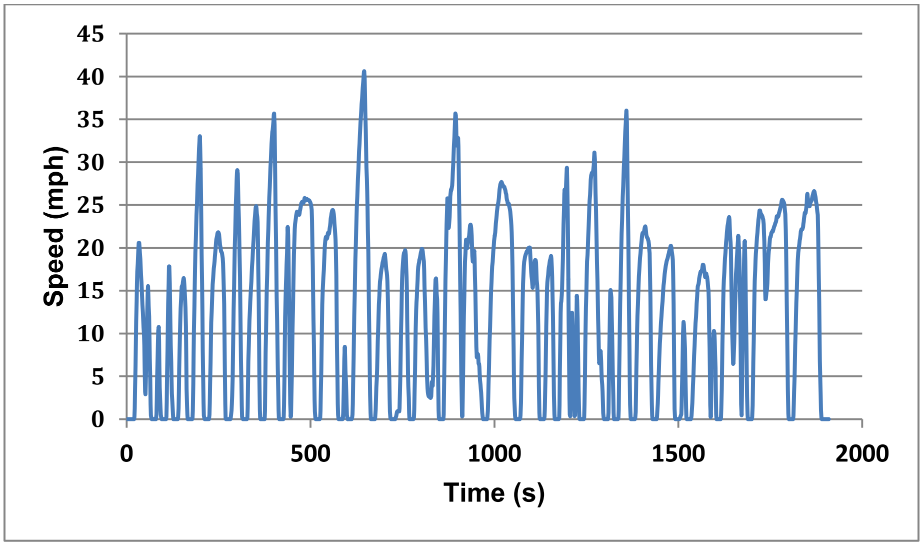


Figure 10. Orange County Transit Authority cycle (OCTA)

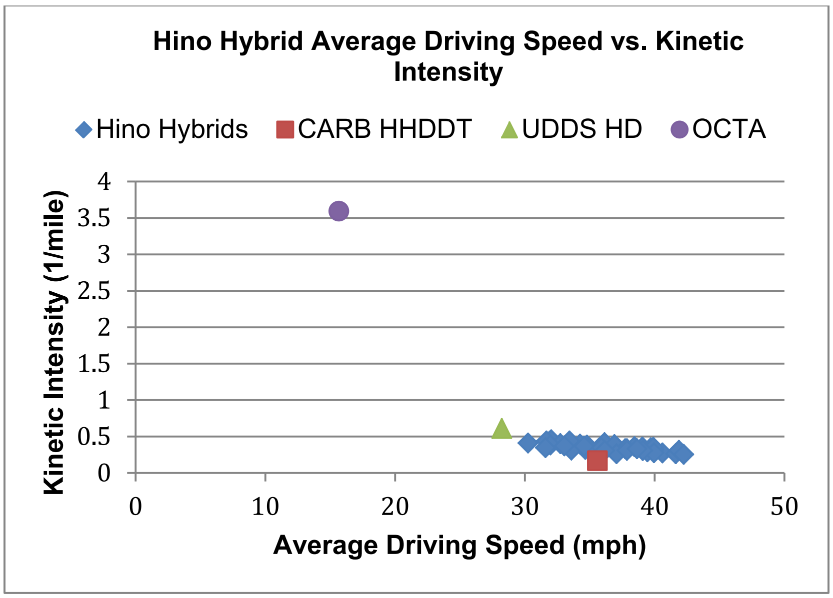


Figure 11. Hino 195h hybrid Class 5 truck in-use operations—average driving speed versus kinetic intensity

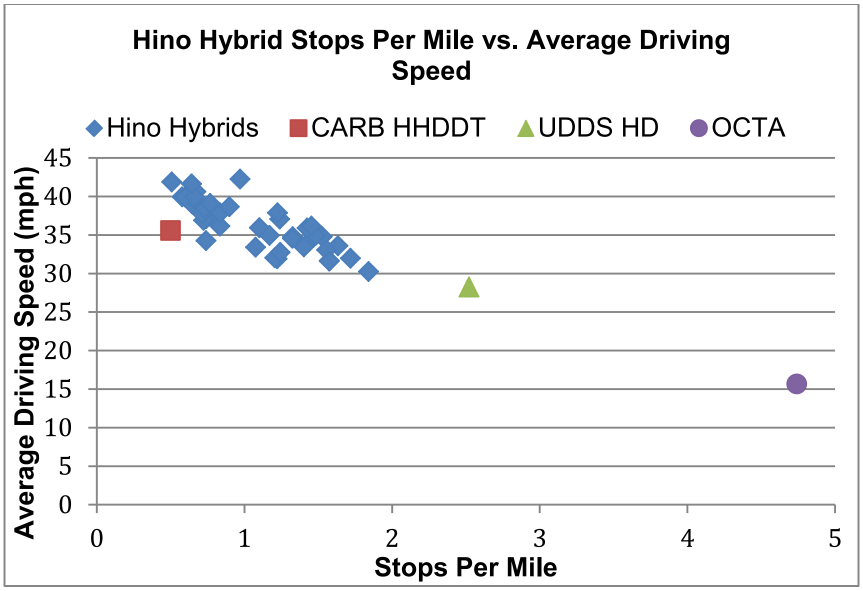


Figure 12. Hino 195h hybrid Class 5 truck in-use operations—stops per mile versus average driving speed

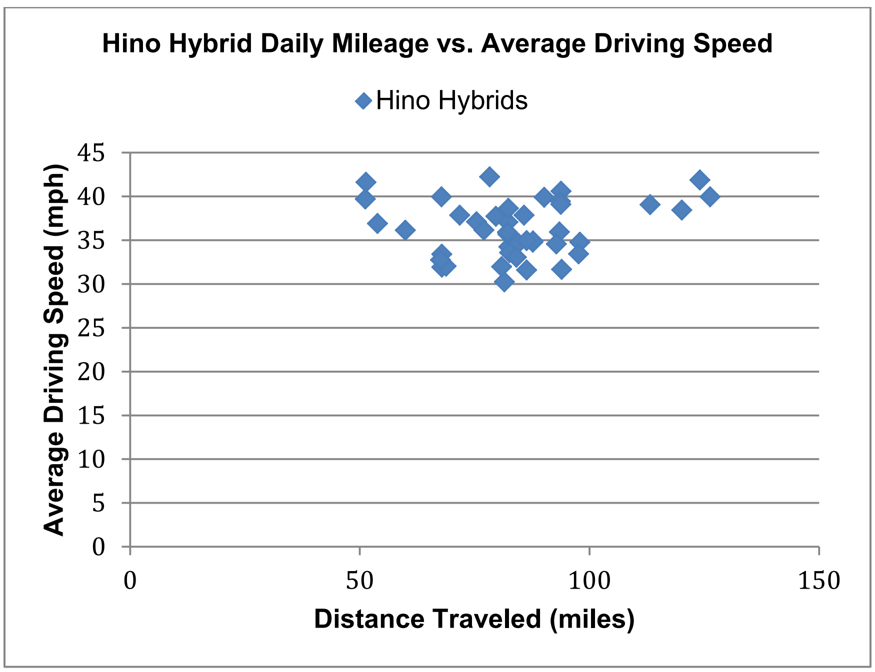


Figure 13. Hino 195h hybrid Class 5 truck in-use operations—daily mileage versus average driving speed

Table 3 through Table 11 show summary vehicle activity statistics (average speed, kinetic intensity, stops per mile, etc.) by vocation for all vehicle data collected in Task 2. The results, by vocation, indicate that the parcel delivery vocation drive cycles reflect significantly more aggressiveness than do those of the other vocations. This fact is highlighted by the parcel delivery vocation possessing the lowest average driving speed of all vocations logged (Table 3), coupled with the highest average accelerations (Table 5 and Table 6).

In contrast, the beverage delivery vocation displays a low aggressiveness as defined by kinetic intensity. Table 11 shows that the parcel delivery vocation possesses a kinetic intensity of 1.74 versus values of 0.61 for the beverage delivery vocation. The relatively low values for kinetic intensity are reflective of the high average driving speed and low acceleration rates over average beverage delivery cycles.

Table 3 shows the average driving speed by vocation in greater detail. The variation in the distribution of average driving speeds across all vocations is significant. This large spread (minimum, median, maximum) is caused by the impact of cycle duration and operating conditions. A short highway type drive cycle with few stops will display a significantly higher average driving speed than that of a long urban drive cycle with many stops. The close proximity of the mean and median values for average driving speed indicates that the minimum and maximum average driving speed values observed in each vocational dataset are closer to statistical outliers than true operating data.

Table 3. Average Driving Speed by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Average Driving Speed (mph)	13.02	19.93	42.26	19.45
Beverage Delivery	Average Driving Speed (mph)	13.13	27.58	47.37	26.51
Food Delivery	Average Driving Speed (mph)	8.25	30.37	49.07	33.23
Linen Delivery	Average Driving Speed (mph)	16.42	29.59	52.86	29.36

Table 4 shows the vocational breakdown of zero-speed cycle time. A significant amount of daily drive cycle operational time is spent at "idle." Independent of vocation, on average, roughly 50% of vehicle operating time is occurring while the vehicle is not in motion or performing its vocational duty. Such high zero-speed time suggests an opportunity to reduce fuel use and emissions by implementing engine off at idle technology.

Table 4. Percentage of Time at Zero Speed by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	% Zero Speed Time	25.46	42.33	64.76	42.63
Beverage Delivery	% Zero Speed Time	10.71	55.91	98.67	61.85
Food Delivery	% Zero Speed Time	14.28	43.58	72.17	43.42
Linen Delivery	% Zero Speed Time	11.64	51.58	93.21	51.38

Table 5 shows the vocational distribution of maximum driving speeds. Outside of outliers, the average maximum driving speeds observed independently of vocation all correlate with operating at highway speed limits. The significant vehicle size difference between the beverage delivery and other vocations may limit the larger beverage delivery vehicles in their average maximum speeds because of engine power and aerodynamic limitations.

Table 5. Maximum Driving Speed by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Maximum Driving Speed (mph)	37.52	63.69	74.78	67.11
Beverage Delivery	Maximum Driving Speed (mph)	36.29	56.55	68.05	56.77
Food Delivery	Maximum Driving Speed (mph)	30.71	65.61	79.15	67.26
Linen Delivery	Maximum Driving Speed (mph)	41.37	64.82	75.04	65.10

Of all vocations examined as part of this project, the parcel delivery vocation had the highest acceleration and deceleration rates. This can be partly attributed to the small vehicle size compared to the food and beverage delivery vocations; however, the aggressiveness of the cycle as identified by acceleration rates can also be attributed to the vocational drive cycle behavior associated with parcel delivery. Parcel delivery vehicles in comparison with similarly sized linen delivery vehicles make many more stops over the course of their daily operation, typically resulting in more aggressive stop-and-go behavior.

Table 6. Average Acceleration Rates by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Average Acceleration (ft/s/s)	0.79	1.76	2.56	1.73
Beverage Delivery	Average Acceleration (ft/s/s)	0.27	0.89	1.59	0.90
Food Delivery	Average Acceleration (ft/s/s)	0.53	1.06	1.53	1.05
Linen Delivery	Average Acceleration (ft/s/s)	0.53	1.18	1.82	1.17

Table 7. Average Deceleration Rates by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Average Deceleration (ft/s/s)	–2.98	–1.99	–0.85	–1.96
Beverage Delivery	Average Deceleration (ft/s/s)	–2.02	–1.03	–0.28	–1.03
Food Delivery	Average Deceleration (ft/s/s)	–1.69	–1.18	–0.55	–1.19
Linen Delivery	Average Deceleration (ft/s/s)	–2.19	–1.34	–0.59	–1.32

The average vocational operating times observed were 4.3–6.53 hours, so the vocations examined as part of this study exhibit relatively high utilization rates. Table 8 shows low operating time values for the parcel delivery vocation compared to the other captured vocations. This can be attributed to industry-wide standards of keying off the ignition during deliveries and while evaluating inventory. These data also correlate strongly with the lower percentage of zero-speed time observed for the parcel delivery vocation data shown in Table 4.

Table 8. Operating Time by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Operating Time (h)	0.41	4.33	8.12	4.26
Beverage Delivery	Operating Time (h)	0.32	6.52	23.29	5.88
Food Delivery	Operating Time (h)	1.14	5.56	13.65	4.68
Linen Delivery	Operating Time (h)	0.48	5.13	12.27	4.70

When examining the vocational daily distance traveled, it is interesting to note the range of average driving miles by vocation. Table 9 shows the observed average daily driving distance range between 48–102 miles per day. This is a fairly tight grouping compared to the maximum driving range observed within each vocation during the study. A maximum daily driving distance range of 113–568 miles suggests that, during extreme operating days, the daily driving distance could have a factor of two to five times the typical mileage incurred by a vehicle. This is significant when examining the potential for all electric vehicles as replacements for HEVs and conventional vehicles.

Table 9. Daily Distance Traveled by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Distance Traveled (miles)	8.98	48.00	113.07	44.30
Beverage Delivery	Distance Traveled (miles)	2.51	70.07	339.25	57.62
Food Delivery	Distance Traveled (miles)	5.41	102.17	568.84	86.34
Linen Delivery	Distance Traveled (miles)	1.18	68.65	261.74	64.91

Variation in driving speed is the measure of the variability of a drive cycle. It can be thought of as how much the instantaneous speed of a drive cycle varies compared to its cumulative average speed. Cycles with high variation typically will have higher average speeds and more stops per mile. Table 11 shows that the parcel delivery vocation is regarded as the most aggressive of the vocations; however, the variability in its driving speed, as shown in Table 10, is lower than all the other vocations. This can be attributed to the significantly lower average driving speed and percentage of zero-speed time contained within an average parcel delivery cycle compared to the other vocations examined.

Table 10. Variation in Driving Speed by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Standard Deviation of Speed (mph)	9.98	15.44	28.00	15.57
Beverage Delivery	Standard Deviation of Speed (mph)	2.82	16.81	25.73	16.76
Food Delivery	Standard Deviation of Speed (mph)	5.74	20.54	28.50	22.26
Linen Delivery	Standard Deviation of Speed (mph)	5.48	19.65	28.42	19.99

As discussed previously, the parcel delivery vocation possesses the highest average kinetic intensity and the linen and beverage delivery vocations possess the lowest. However, Table 11 shows significant variability in the daily drive cycle aggressiveness by vocation, as evidenced by the spread between the average and median kinetic intensity values by vocation.

Table 11. Kinetic Intensity by Vocational Vehicle Group

Vocation	Metric	Minimum	Average	Maximum	Median
Parcel Delivery	Kinetic Intensity (1/mile)	0.19	1.74	4.95	1.31
Beverage Delivery	Kinetic Intensity (1/mile)	0.07	0.61	2.41	0.45
Food Delivery	Kinetic Intensity (1/mile)	0.16	0.77	6.62	0.37
Linen Delivery	Kinetic Intensity (1/mile)	0.14	0.57	2.26	0.50

Examples of the stops per miles versus kinetic intensity and stops per mile versus fuel economy for each vocation are shown in Figure 14 and Figure 15, respectively.

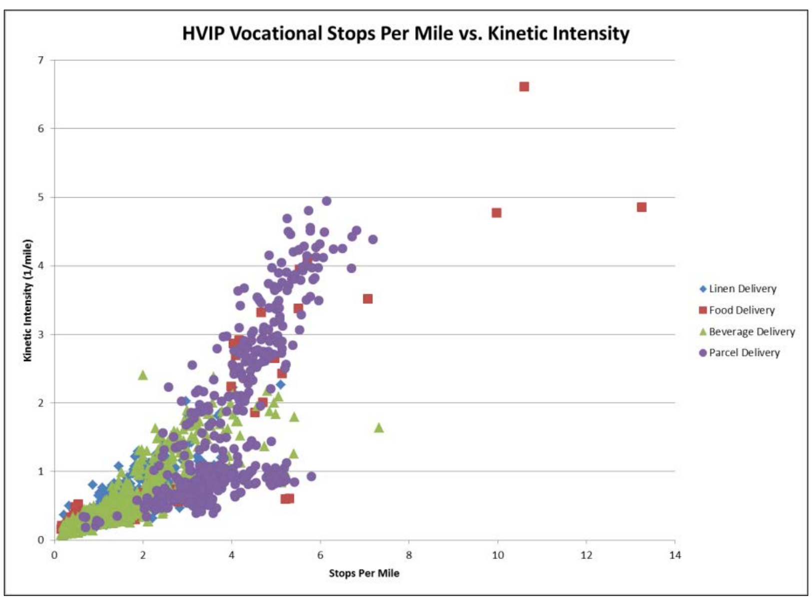


Figure 14. Stops per mile versus kinetic intensity by vocation

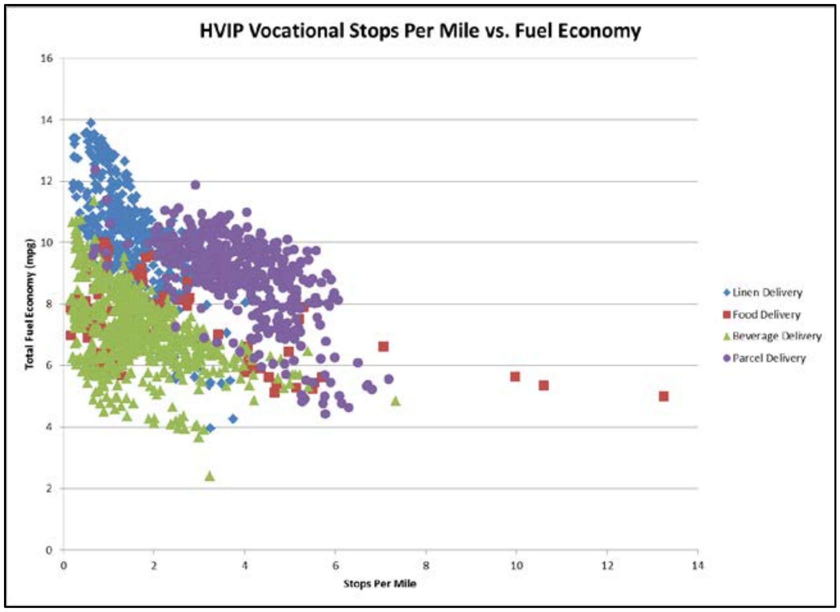


Figure 15. Stops per mile versus fuel economy by vocation

Figure 16 shows the average kinetic intensity for each vocation included in this task relative to that of several standard drive cycles. This analysis was based on over 120 HEVs and conventional vehicles from four vocations and numerous locations across California. This included 46 beverage delivery vehicles, 31 uniform and linen delivery vehicles, 40 parcel delivery vehicles, and 12 food distribution vehicles.

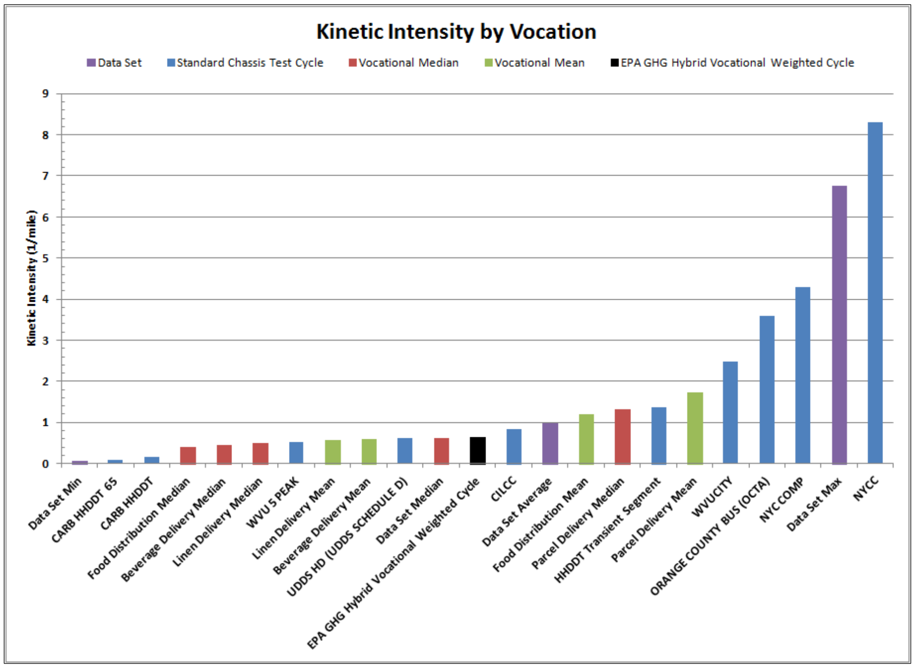


Figure 16. Kinetic intensity by vocation relative to standard drive cycles

Task 4: Chassis Dynamometer Emissions and Fuel Economy Measurement

NREL coordinated the procurement, transportation, and testing of one HEV and one conventional vehicle for comparison purposes from the beverage, linen and uniform, and parcel delivery vocations—in addition to one Hino 195h Class 5 delivery truck, but data results from this vehicle are not included in this report due to issues with the vehicle hybrid drive during chassis dynamometer during testing (Table 12).

Table 12. Vehicles Included on Task 4—Chassis Dynamometer Testing

Vehicle Type	Vocation	Vehicle Class	Model Year
Freightliner M2106	Beverage Delivery	Class 7 Day Cab	2012
Freightliner M2106 Hybrid	Beverage Delivery	Class 7 Day Cab	2010
Hino Hybrid 195h*	Parcel Delivery	Class 5 Delivery	2014
Isuzu Reach	Parcel Delivery	Class 3 Delivery	2012
Freightliner MT45	Parcel and Linen/Uniform Delivery	Class 5 Step Van	2012
Freightliner MT45 Hybrid	Parcel and Linen/Uniform Delivery	Class 5 Step Van	2011

*Data results not included in this report due to issues with vehicle electric drive during chassis dynamometer testing.

Vehicles were obtained from local fleets participating in Task 2 or were rented. All vehicles tested on the chassis dynamometer in Task 4 had model year 2010 or newer engines and were tested using SAE J2711 test procedures. All vehicles were transported to the CE-CERT laboratory in Riverside, California, for chassis dynamometer testing (Figure 17).

Figure 17. CE-CERT chassis dynamometer

Each vehicle was tested over the three or four duty standard cycles identified in Task 3 and shown in Table 13. Fuel economy, gaseous emissions (including nitric oxide [NO], nitrogen dioxide [NO_2], carbon monoxide [CO], carbon dioxide [CO_2], hydrocarbons [HC], ammonia [NH_3], methane [CH_4], and nitrous oxide [N_2O]), and particulate matter (PM) by gravimetric filter analysis, following procedures in Title 40 Code of Federal Regulations Part 1065, were performed. All gaseous emissions were measured in real time except N_2O, which was measured in bags. Exhaust temperatures were measured ahead of the first emissions control system component and after the last emissions control system component by thermocouple or engine controller unit data channel. In addition, current into and out of the battery pack was measured on the HEVs. CARB ultra-low sulfur diesel was used during testing.

Table 13. Test Cycles Used for Chassis Dynamometer Testing

Vehicle Type	Vocation	Test Cycles	Number of Repetitions
Freightliner M2106	Beverage Delivery	WVU, UDDS, and EPA GHG	3-4
Freightliner M2106 Hybrid	Beverage Delivery	WVU, UDDS, and EPA GHG	3-4
Hino Hybrid 195h*	Parcel Delivery	OCTA, HHDDT, and EPA GHG	3-4
Isuzu Reach	Parcel Delivery	NY Comp, HTUF-4, UDDS, and EPA GHG	3-4
Freightliner MT45	Parcel Delivery	NY Comp, HTUF-4, UDDS, and EPA GHG	3-4
Freightliner MT45 Hybrid	Parcel Delivery	NY Comp, HTUF-4, UDDS and EPA GHG	3-4
Freightliner MT45	Linen/Uniform Delivery	NY Comp, UDDS and EPA GHG	3-4
Freightliner MT45 Hybrid	Linen/Uniform Delivery	NY Comp, UDDS and EPA GHG	3-4

*Data results not included in this report due to issues with dynamometer testing with this vehicle

Coast Downs

Based on feedback from CE-CERT about the development of coast-down coefficients for the chassis dynamometer testing, it was decided that a calculation method would be used in place of in-use coast-down measurements for this testing.

An alternate method to physically coasting down the vehicles was developed by WVU and has been used for past CARB chassis testing projects. The methodology calculates the coast-down times from the frontal area, coefficient of drag, rolling resistance, and ambient conditions. Some believe this method is less accurate than physical coast-down data, but practical experience shows in-use coast-down testing may be difficult where slight grade and wind directions can have a significant impact on the results.

To validate this method, CE-CERT performed coast-down tests for a Class 7 conventional beverage delivery truck with a fully loaded 59,200 GVW trailer and an empty 26,320 GVW trailer. The GVWs were based on certified scale measurements.

The average in-use coast-down times are shown in Table 14. Each speed bin represents the average of triplicate north and triplicate south runs at both test weights. North/south runs were averaged to minimize the effects of grade, wind, and other in-use conditions. There was a significant difference between north and south runs, which suggests that coast-down data may vary for different locations.

Table 14. Field Coast-Down Data

Vehicle Weight (lb)	Seconds to Coast Down for mph Range				
	65–55	55–45	45–35	35–25	25–15
59,200	NA[1]	38.4	45.2	61.0	78.1
26,320	NA[1]	21.4	27.2	35.8	55.5

[1] Governed to 55 mph

CE-CERT interpolated between the heavy- and lightweight coast-down times to determine the dynamometer coefficients shown in Table 15. The example coefficients correspond to a trailer being 75% full and 25% full, respectively.

Table 15. Dynamometer Coefficients for the Tests

Test Cycle	Load	A	B	C	hp @ 50
	lb	lb/mph	lb/mph	lb/mph	
Heavy (75% full)	38,975	38.117	11.772	0.0043	85.00
Light (25% full)	30,858	39.860	9.827	0.0231	78.53

A comparison between in-use coast-down measurements and the calculation method is shown in Figure 18 (fully loaded Class 7 tractor) and Figure 19 (unloaded Class 7 tractor). The error bars for the north and south triplicate runs represent one standard deviation. The figures show the calculation method lies between the north and south coast-down data and is below the average of the north/south combined results for the loaded and unloaded trailer. This suggests the calculation method provides a reasonable result that is within the range of conditions found during in-use coast-down measurements. The calculation method did not provide the same in-use coast-down average time result and was consistently low. The reason for the low calculation method is unclear, but the large swing between directions suggests the in-use coast-down data may be less reliable. As such, the calculation method may be more precise and, thus, more repeatable for "A" to "B" comparisons. Therefore, it was decided to use the calculation method for all chassis dynamometer emissions testing under this task, in lieu of doing in-use coast-down measurements of the HEVs and conventional vehicles planned for this project.

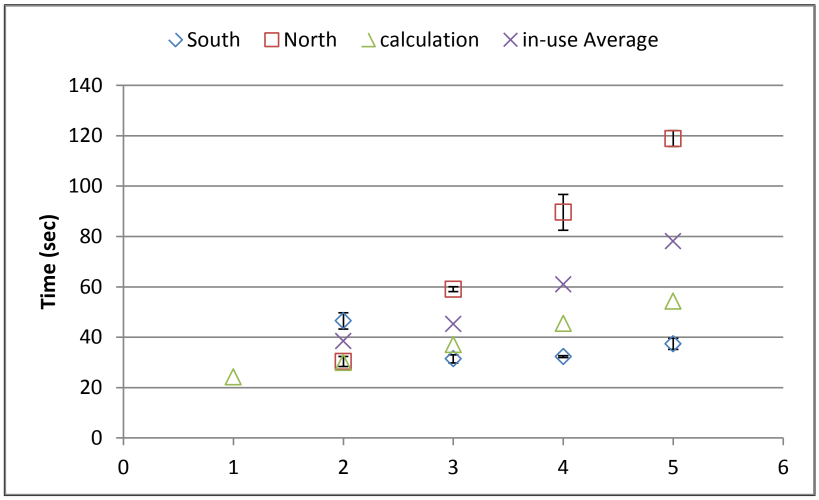


Figure 18. Loaded trailer coast-down data for a Class 7 tractor

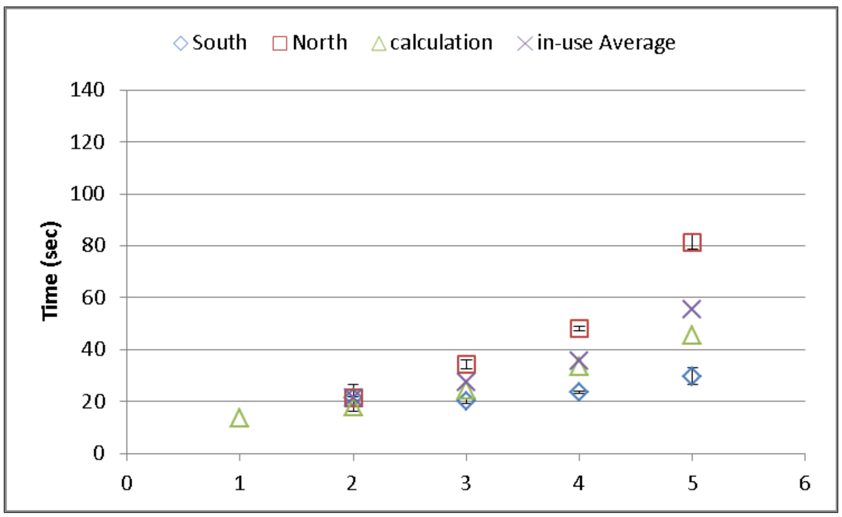


Figure 19. Unloaded trailer coast-down data for a Class 7 tractor

The details of this method for determining coast-down coefficients (1) are as follows. Typical coast-down procedures assume that vehicle loading force is a function of vehicle speed, drag coefficient, frontal area, and tire rolling resistance coefficient and takes the form of equation 1:

$$M\frac{dV}{dt} = \frac{1}{2}\rho A C_D V^2 + \mu M g cos(\theta) + \ M g sin(\theta) \qquad \{1\}$$

Where:

M = mass of vehicle in lb

ρ = density of air in kg/m^3

A = frontal area of vehicle in ft^2

C_D = aerodynamic drag coefficient (unitless)

V = speed vehicle is traveling in mph.

μ = tire rolling resistance coefficient (unitless)

g = acceleration due to gravity = 32.1740 ft/s^2

θ = angle of inclination of the road grade in degrees.

Constant parameters for equation 1 (2)

μ	0.007
C_D	0.75 for truck
	0.79 for bus
	0.80 for refuse truck
g	32.1740 ft/s^2

Assuming that the vehicle loading is characteristic of this equation, speed-time data collected during the coast down test can be used with static measurements (mass, air density, frontal area, and grade) to solve for drag coefficient (C_D) and tire rolling resistance coefficient (μ).

However, experience with vehicles equipped with automatic transmissions has shown that on-road loading is also affected by the transmission characteristics, especially when reverse pumping losses at low speed begin to dominate. Therefore, WVU uses a characteristic coast-down equation with a measured vehicle frontal area (per SAE J1263 measurement recommendations); a μ of 0.007; and a C_D 0.75 (Truck), 0.79 (bus), and 0.80 (refuse truck) in the above equation to calculate coast-down times to be used for calculating the A, B, and C coefficients in equation 2 for the chassis dynamometer operation parameters (2).

$$Y = C(x^2) + B(x) + A \qquad \{2\}$$

The measurement of the frontal area is shown in Figure 20.

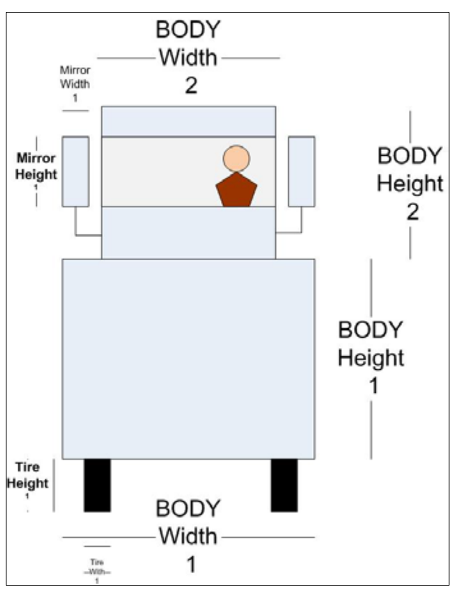


Figure 20. Measurement of frontal area diagram

Test Fuel

The fuel used for this task was California ultra-low sulfur diesel pump fuel, all from the same lot. The test fuel sample was collected on November 5, 2013, from the fuel used for all the chassis dynamometer tests. All the fuel properties are shown in Table 16; some fuel properties were analyzed by Southwest Research Institute and some by NREL's in-house laboratory using various ASTM test methods.

Table 16. Fuel Properties of Test Diesel Fuel

ASTM Test Method	Fuel Property	Result	Units
Southwest Research Institute			
D445*	Viscosity	2.878	cSt
D5186	Aromatics Polyaromatics Monoaromatics Total aromatics	 2.1 16.0 18.1	 mass % mass % mass %
D5291	Carbon Hydrogen	85.86 13.64	wt % wt %
D5453*	Sulfur	6.5	ppm
NREL			
D240	Net heating value	42.879	MJ/kg
D4052	Density	0.8396	g/cm^3
D5773*	Cloud point	–8.3	C
D6890*	Derived cetane number	57.6	

*Indicates method is part of ASTM 975, diesel fuel specification

Results

The chassis dynamometer testing results by vocational set are discussed in the following sections.

Class 7 Day Cab

The chassis dynamometer testing was started on June 11, 2013, with the Class 7 day cab beverage delivery trucks. The HEV was borrowed from a fleet that had agreed to loan a vehicle for this vocation and the conventional truck was leased from a rental company. Because accessing an appropriate 2010 certification baseline conventional Class 7 day cab was difficult, a 2010 certification similarly powered, straight truck was used as a surrogate. Table 17 includes details for both vehicles included in this round of testing. Table 19 shows the emission results from these two vehicles. As shown in this table, the average NO_x increase for HEVs was 122% (81%–166%) on a per-mile basis and the average fuel economy increase for HEVs was 11%. That said, the observed results for this vehicle set are limited and need to be viewed with caution due to the differences in the horsepower rating (Table 17) and emission model year and certification levels (Table 18) for the engines used in these two vehicles. CARB Executive Orders for all the engines tested in vehicles as part of this task are included in Appendix B.

Table 17. HEV/Conventional Beverage Delivery Chassis Test Truck Details

Vehicle MY	2010	2012
Make	Freightliner	Freightliner
Model	M2106	M2106
Fuel Type	Diesel/electric HEV	Diesel
Vehicle Description	Class 7, 16 bay route power	Class 6, straight truck, tested as Class 7
Cargo Mass Assumptions	23,000–30,000 lb	23,000–30,000 lb
Chassis Test Weight	32,500 lb	31,500 lb
Engine MY	2010	2012
Engine	ISB - 325 6.7L	ISB - 220 6.7L
GVWR	34,700	26,000
Axle Ratio	5.63	–
Engine Family	ACEXH0408BAH	CCEX0408BAH

Table 18. HEV/Conventional Beverage Delivery Chassis Test Truck Engine Certification Levels

2010 Cummins ISB 6.7L Engine Family: ACEXH0408BAH												
g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	N/A	N/A	N/A	N/A	15.5	15.5	0.01	0.01	N/A	N/A
FEL	N/A	N/A	0.33	0.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CERT	0.01	0	0.17	0.18	N/A	N/A	0	0	0	0	N/A	N/A
NTE	0.21		0.5		N/A		19.4		0.02		N/A	
2012 Cummins ISB 6.7L Engine Family: CCEXH0408BAH												
g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.2	0.2	N/A	N/A	15.5	15.5	0.01	0.01	N/A	N/A
FEL	N/A	N/A	0.33	0.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CERT	0.01	0.001	0.17	0.18	N/A	N/A	0	0	0	0	N/A	N/A
NTE	0.21		0.5		N/A		19.4		0.02		N/A	

The emissions were measured while the vehicles were operated on a heavy-duty chassis dynamometer over three cycles, as discussed in Task 3 and shown in Table 13, in triplicate. The cycles used were the WVU City (Figure 3), the UDDS (Figure 4), and the EPA GHG (Figure 5).

All the raw and modal data from this testing for the HEV and conventional Class 7 day cab trucks were provided to CARB. In these provided files, the "Integrated" sheet contains the emissions of total hydrocarbons (THC), CH_4, non-methane hydrocarbons (NMHC), CO, NO_x, CO_2, NH_3, and PM in g/cycle for all the tests. The fuel consumption reported in g/cycle was measured by both carbon balance and the readings from the electronic control module. The N_2O emissions were collected in Tedlar bags over the full cycle and the results are reported in ppm. CE-CERT did not have enough bags to collect samples for every cycle and several bags leaked, so there are no valid results for those samples. Average emissions in g/mi and fuel economy in mpg are reported in Table 19 and average emissions in g/bhp-hr are reported in Table 20.

Table 19. HEV/Conventional Average Emissions and Fuel Economy Data for Beverage Delivery Chassis Testing by Cycle

Average Emissions and Fuel Consumption Over the Cycles in g/mi – Conventional					
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**	**mpg**
UDDS	5.72	0.60	0.43	1247	7.76
EPA GHG	14.80	0.22	0.15	1042	9.34
WVU City	3.41	1.39	1.09	1674	5.63
Average Emissions and Fuel Consumption Over the Cycles in g/mi – HEV					
UDDS	5.75	1.09	0.72	1123	8.63
EPA GHG	14.59	0.58	0.41	1109	8.82
WVU City	3.46	3.05	2.32	1347	7.12

Table 20. HEV/Conventional Average g/bhp-hr Emissions for Beverage Delivery Chassis Testing by Cycle

Average Emissions Over the Cycles in g/bhp-hr– Conventional				
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**
UDDS	5.72	0.30	0.21	620
EPA GHG	14.80	0.16	0.11	767
WVU City	3.41	0.53	0.42	639
Average Emissions Over the Cycles in g/bhp-hr – HEV				
UDDS	5.75	0.66	0.43	671
EPA GHG	14.59	0.44	0.31	836
WVU City	3.46	1.77	1.35	785

The "Integrated" sheet also contains averages over the cycle of several temperatures and several engine parameters. The following naming convention was used for all tests: yyyymmddhhmm. The modal results, dynamometer parameters, and Hioki voltage and current measurements (when testing an HEV) are stored in separate folders with the same name as the integrated results. The sheets have the same name as the original file with a suffix at the end to indicate which data are in the file. The sheets are in the order of the file name on the integrated sheet. The suffix for the modal files is MW for the WVU city cycle, MU for the UDDS cycle, and ME for the EPA GHG cycle. The suffix for the dynamometer files is D and for the Hioki files is H.

The modal files contain all the second-by-second data that are used to calculate the information reported in the "Integrated" sheet. The dynamometer files contain all the second-by-second data on the dynamometer operation. The Hioki files contain all the second-by-second data determined from measuring the battery current and voltage.

To compare emissions from HEVs to conventional vehicles per SAE J2711[1] "the data from the hybrid vehicle must be corrected so that the net energy change (NEC) in the rechargeable energy storage system (RESS) is essentially zero." The calculation of NEC[2] is outlined on the sheet labeled "NEC Calc" and the calculation for each test is at the end of each Hioki sheet. If the NEC divided by the total cycle energy (TCE) is between 1% and 5%, the emissions data were corrected. If it is less than 1%, no correction was required. If it is greater than 5%, the data were void and the cycle was repeated. The NCE/TCE was less than 1% for all tests except 201306121247 over the first phase of the EPA GHG cycle.

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[1] SAE J2711, "Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles", Issued 2002-09. Per the scope: "This SAE Recommended Practice was established to provide an accurate, uniform, and reproducible procedure for simulating use of heavy-duty hybrid-electric vehicles (HEVs) and conventional vehicles on dynamometers for the purpose of measuring emissions and fuel economy. This document defines a hybrid vehicle as having both a rechargeable energy storage system (RESS) capable of releasing and capturing energy and an energy-generating device that converts consumable fuels into propulsion energy. RESS specifically included in the recommended practice are batteries, capacitors, and flywheels, although other RESS can be evaluated utilizing the guidelines provided in the document. Further, the recommended practice provides a detailed description of state of charge (SOC) correction for charge sustaining HEVs."

[2] Per SAE J2711, the Net Energy Change (NEC) for a battery = $(SOC_{final} - SOC_{initial})V_{system}$ = $\sum_{Cycle}([I_{Battery}]\Delta t)V_{System}$ Where SOC = State of Charge; $I_{battery}$ = the current flow at the battery system in amperes; A, Δt = the period between successive current measurements in seconds; V_{System} = the battery's nominal system voltage as specified by the manufacturer in volts.

During the third run of the UDDS cycle for the HEV truck, a DPF regeneration occurred. The vehicle was operated until the regeneration completed. After a 20-minute hot soak the UDDS cycle was repeated. The NO_2 was approximately 30% higher than for the first two UDDS cycles. The post-DPF temperature over the first 350 seconds ranged from 42.4 ºC higher than the average of the first two runs at the start of the test to a maximum of 73.9 ºC at 115 seconds, to 27.5 ºC at 350 seconds, and was less than 5 ºC from 477 seconds to the end of the cycle at 1061 seconds; the average temperature of the first two runs at the above times were 191, 214, 164, 194, and 263 ºC, respectively. It was concluded that the higher NO_2 might be related to this and decided that the results from this run should be considered an outlier and not used.

The data and the sum of the NO_x over the first 300 seconds and over the next 500 seconds showed that higher NO_x emissions were primarily in the 300- to 800-second region for both files where the post-DPF temperatures are essentially the same from all three UDDS cycles. Therefore, the high NO_x for the "third" run of the UDDS cycle for the HEV truck was not considered an outlier because of the high post-DPF temperature.

Class 5 Hino

For this project, a Hino 195h hybrid Class 5 delivery truck was also included in the chassis dynamometer emissions testing. This truck was included because it is one of the few vertically-integrated HEVs available in the medium-duty class. Table 21 shows the vehicle specifications.

Table 21. Hino 195h Hybrid Class 5 Delivery Truck Specifications

Model	**Hino J05E-UG (Hybrid)**
Powertrain	Diesel-electric hybrid, 4-cycle, 4-cylinder in-line, water-cooled, dry cylinder liner
Combustion System	Direct injection type
Maximum Output (SAE Gross)	210 hp at 2,500 rpm
Maximum Torque (SAE Gross)	440 lb-ft at 1,500 rpm
Piston Displacement	5L
Intake System	Turbocharged and intercooled
GVW	19,500 lb
Ni-MH Battery	288 V
Traction Motor Maximum Power	36 kW/1,000 rpm
Traction Motor Maximum Torque	258 ft-lb/1,000 rpm

Figure 21 shows a photograph of a Hino hybrid truck during data logging of the Hino 195h hybrids being used in the food distribution vocation in Newark, California.

Figure 21. Hino 195h hybrid Class 5 truck during data logging for in-use operation in the food distribution vocation

On September 10, 2013, NREL rented a Hino 195h hybrid truck and sent it to CE-CERT for emissions testing on its chassis dynamometer. The emissions were measured while the vehicle was operated on a heavy-duty chassis dynamometer over three cycles in triplicate. Figure 22 shows a photograph of the rented Hino hybrid 195h truck on the chassis dynamometer at CE-CERT during emissions testing. Unfortunately, it was not possible for data results from this vehicle to be included in this report due to issues with the vehicle hybrid drive during chassis dynamometer testing. There are current plans to re-test this vehicle along with a conventional version of the Hino 195.

Figure 22. Hino 195h hybrid Class 5 truck during chassis dynamometer testing at CE-CERT

Class 5 Step Vans

The final three vehicles (the hybrid step van, conventional step van, and the Isuzu Reach) were also tested at CE-CERT between November 5 and November 22, 2013. The hybrid and conventional step vans were tested under two different weight conditions to represent the parcel delivery and uniform and linen delivery vocations. The detailed vehicle information is provided in Table 22. As is shown in Table 22 and Table 23, the hybrid and conventional Freightliner step vans provided the best hybrid versus conventional vehicle comparison set for this study in terms of chassis characteristics and engine rating, power, vintage, and certification. The certification levels for the Isuzu Reach are shown in Table 24.

Table 22. Step Van Vehicle Information

MY	2012	2011	2012
Make	Isuzu	Freightliner	Freightliner
Model	Reach	W700HY/MT45	W900/MT45
Fuel Type	Diesel	Diesel/electric HEV	Diesel
Vehicle Description	Class 3 step van	Class 5 step van	Class 5 step van
Cargo Mass – Parcel	3,000 lb	4,000 lb	4,000 lb
Cargo Mass – Uniform/Linen	N/A	7,000 lb	7,000 lb
Chassis Test Weight – Parcel	11,835 lb	14,790 lb	13,550 lb
Chassis Test Weight – Uniform/Linen	N/A	17,790 lb	16,550 lb
Engine MY	2012	2011	2011
Engine	NPR diesel	ISB - 200	ISB – 200
GVWR	12,000	17,000	19,500 (tested as 17,000)
Axle Ratio	5.125	4.1	4.1
Engine Family	CSZXD03.03FA	BCEXH0408BAH	BCEXH0408BAH

Table 23. HEV/Conventional Step Van Parcel and Linen/Uniform Delivery Chassis Test Truck Engine Certification Levels

2011 Cummins ISB 6.7L Engine Family: BCEXH0408BAH												
g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.2	0.2	N/A	N/A	15.5	15.5	0.01	0.01	N/A	N/A
FEL	N/A	N/A	0.33	0.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CERT	0.01	0.001	0.17	0.18	N/A	N/A	0	0	0	0	N/A	N/A
NTE	0.21		0.5		N/A		19.4		0.02		N/A	

Table 24. Conventional Isuzu Reach Parcel Delivery Chassis Test Truck Engine Certification Levels

2012 ISUZU NPR Diesel 3.0L Engine Family: CSZXD03.03FA														
	NMOG [g/mi]		NMHC [g/mi]		CO [g/mi]		NOx [g/mi]		HCHO [mg/mi]		PM [g/mi]		Hwy NOx [g/mi]	
	CERT	STD	CERT	STD	CERT	STD	CERT	STD	CERT	STD	CERT	STD	CERT	STD
@ Useful Life	N/A	N/A	0.005	0.167	0.06	7.3	0.4	0.4	5	21	0.004	0.06	0.02	0.8

The emissions were measured while the vehicles were operated on the CE-CERT heavy-duty chassis dynamometer over four cycles in triplicate. As discussed previously, the cycles used were the EPA GHG (Figure 5), the NYCC (Figure 7), the UDDS (Figure 4), and the HTUF4 (Figure 8).

Table 25 through Table 29 show the NO_x and fuel economy results for the step van and Reach vehicles. For all cycles, the NO_x emissions were higher for the HEV (in some cases more than double) and the fuel consumption was lower for the HEV under all cycles except the EPA GHG cycle under the carbon balance method. For the step vans under the parcel delivery vocation cycles and weight, the average NO_x increase for HEVs was 111% (20%–243%) and the average fuel economy increase for HEVs was 27%. For the step vans under the uniform and linen delivery vocation cycles and weights, the average NO_x increase for hybrids was 146% and the average fuel economy increase for HEVs was 10.4%. For the Reach conventional delivery van, the average NO_x was 1.1 g/mi and the average fuel economy for was 13.3 mpg.

Table 25. Average NO_x Emissions and Fuel Economy for Hybrid/Conventional Freightliner Step Van by Drive Cycle for Parcel Delivery

Average Emissions and Fuel Consumption Over the Cycles in g/mi – Conventional					
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**	**mpg**
EPA GHG	18.72	0.52	0.44	712	13.25
NY Comp	2.53	3.40	3.03	1,308	7.12
HTUF-4	7.40	1.63	1.37	1,011	9.27
UDDS	5.59	0.84	0.77	819	11.46
Average Emissions and Fuel Consumption Over the Cycles in g/mi – Hybrid					
EPA GHG	18.77	1.07	0.85	733	13.24
NY Comp	2.52	5.92	5.38	873	11.21
HTUF-4	7.31	1.96	1.56	800	12.33
UDDS	5.61	2.88	2.22	723	13.55

Table 26. Average NO_x Emissions g/bhp-hr for Hybrid/Conventional Freightliner Step Van by Drive Cycle for Parcel Delivery

Average Emissions Over the Cycles in g/bhp-hr – Conventional				
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**
EPA GHG	18.72	1.06	0.89	1445
NY Comp	2.53	2.11	1.88	825
HTUF-4	7.40	1.29	1.09	799
UDDS	5.59	0.69	0.63	673
Average Emissions Over the Cycles in g/bhp-hr – Hybrid				
EPA GHG	18.77	1.02	0.81	695
NY Comp	2.52	9.20	8.36	1356
HTUF-4	7.31	2.82	2.26	1156
UDDS	5.61	3.51	2.71	883

Table 27. Average NO_x Emissions and Fuel Economy for Hybrid/Conventional Freightliner Step Van by Drive Cycle for Uniform/Linen Delivery

Average Emissions Over the Cycles in g/mi – Conventional					
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**	**mpg**
EPA GHG	18.648	0.500	0.439	744	12.6
NY Comp	2.531	3.399	3.251	1386	6.8
HTUF-4	-	-	-	-	-
UDDS	5.599	0.863	0.789	925	10.3
Average Emissions and Fuel Consumption Over the Cycles in g/mi – Hybrid					
EPA GHG	18.68	1.04	0.74	765	12.7
NY Comp	2.51	6.17	5.68	960	10.2
HTUF-4	-	-	-	-	-
UDDS	5.59	3.03	2.44	761	12.9

Table 28. Average NO_x Emissions g/bhp-hr for Hybrid/Conventional Freightliner Step Van by Drive Cycle for Uniform/Linen Delivery

Average Emissions Over the Cycles in g/bhp-hr – Conventional				
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**
EPA GHG	18.648	0.90	0.79	1345
NY Comp	2.531	1.84	1.76	751
HTUF-4	-	-	-	-
UDDS	5.599	0.59	0.54	636
Average Emissions and Fuel Consumption Over the Cycles in g/bhp-hr – Hybrid				
EPA GHG	18.68	0.95	0.68	703
NY Comp	2.51	8.17	7.52	1271
HTUF-4	-	-	-	-
UDDS	5.59	3.23	2.61	813

Table 29. Average NO_x Emissions and Fuel Economy for Conventional Reach Delivery Vehicle by Drive Cycle

Average Emissions and Fuel Consumption Over the Cycles in g/mi					
Cycle	**Miles**	**NO_x**	**NO**	**CO_2**	**mpg**
EPA GHG	18.66	0.36	0.27	765.00	12.7
NY Comp	2.5	2.59	2.03	962.00	10.2
HTUF-4	7.34	0.62	0.49	646.00	15.7
UDDS	5.54	0.90	0.62	641.00	14.7

The emission test results, including raw and modal data were provided to CARB with separate files for HEVs and conventional vehicles, and for the Reach vehicle. For all vehicles, the summary sheets contain tables summarizing the emissions and fuel consumption in g/engine bhp-h and g/mi. Each summary table cell links to an appropriate cell in other sheets where the results are calculated. The other sheets include: (1) "Integrated", which contains the emissions of THC, CH_4, NMHC, CO, NO_x, CO_2, NH_3, and PM in g/cycle for all tests over the complete cycle. The fuel consumption is reported in g/cycle based on carbon balance and the readings from the electronic control module. The N_2O emissions were collected in Tedlar bags over the full cycle and the results are reported in ppm. An "NS" for N_2O indicates no sample was collected. The N_2O analysis for the first vehicle and two cycles of the second vehicle was performed by Peter Wong at the CARB El Monte laboratory. For these tests, the emissions samples were analyzed by both FTIR and GC-ECD, as he had discovered that water content caused high N_2O readings and decided that the GC-ECD method gave more reliable results. Therefore, only his GC-ECD results are included in this report; (2) Modal (Run No. followed by an M), which contains the second-by-second data from which the integrated data were calculated; (3) The dynamometer data (Run No. followed by a D), from which one obtains the dynamometer horsepower applied to the rear wheels; and (4) The Hioki data for the HEV (Run no. followed by an H), from which the NEC of the battery is obtained. There is also a sheet labeled "NEC Calc," which shows the method to calculate NEC.

The “Integrated” sheet also contains averages over the full cycle of several temperatures and several engine parameters, which are tabulated in the “summary” sheet. The following naming convention is used for all tests: yyyymmddhhmm. The modal results, dynamometer parameters, and Hioki measurements are stored in separate folders with the same file name as the “integrated” results. The sheets have the same name as the original file with an appendage at the end to indicate which data are in the file. The sheets are in the order of the file name on the “Integrated” sheet. The first appendage for the modal files is M, for the dynamometer files it is D, and for the Hioki files it is H, and the second appendage for each file is U for the UDDS cycle, H for the HTUF4 cycle, E for the EPA GHG cycle, and N for the NYCC cycle. Step van emissions tests were conducted for two vehicle test weights, 14,000 lb and 17,000 lb. These test weights are listed in bold type under the column headed Run No. and all results following these bolded headings are for these test weights.

The modal files contain all the second-by-second data that are used to calculate the information reported in the “Integrated” sheet. The dynamometer files contain all the second-by-second data on the dynamometer operation. The Hioki files contain all the second-by-second data determined from measuring the battery current and voltage.

Again, to compare emissions from HEVs to conventional vehicles, the data from the HEV must be corrected so that the NEC in the RESS is essentially zero. The calculation of NEC is outlined on the sheet labeled NEC Calc and the calculation for each test is at the end of each Hioki sheet. The “summary” sheet contains all the information used to calculate the NEC and the NEC divided by the TCE. For all cycles, the NCE/TCE was less than 1% for all tests.

The results for the conventional vehicle are presented in the same format as described above for HEV. However, this was a conventional vehicle, so there are no Hioki results. This vehicle’s emissions tests were conducted for two vehicle test weights, 13,500 lb and 16,500 lb. These test weights are listed in bold type under the column headed Run No. and all results following these bolded headings are for these test weights.

The results for the Reach are presented in essentially the same format as for the other vehicles. However, for this vehicle, there was no access to engine data, so we could not calculate the emissions in g/engine bhp-h. Therefore, the emissions and fuel consumption by carbon balance are presented in g/dynamometer bhp-h. To have an independent measurement of fuel economy, the drum of fuel was placed on an electronic digital scale and the weight of the drum was taken at the beginning and end of the test cycle from the meter and hand recorded to determine the grams of fuel used over the total test cycle.

Task 5: Portable Emissions and Fuel Economy Measurements

To supplement laboratory test results, NREL coordinated on-road emissions testing under real-world driving and environmental conditions of three vehicles: one HEV and one conventional vehicle from the parcel delivery vocation, and one HEV from the beverage delivery vocation.

- One Class 7 day cab hybrid (3 days, 4–6 hours each day of in-use/route on road-operation)
- Two Class 4 step van conventional/HEVs (2 days, 4–6 hours each day of simulated in-use/route on-road operation).

NREL's Semtech DS unit was used along with data collected from fleets in Task 2 to test 2–3 days of simulated on-road operation on each vehicle and compare the results to those obtained in the laboratory to validate the laboratory testing results. All testing was completed on vehicles with model year 2010 or newer engines. Vehicles were tested on routes similar to those measured in Task 2, and tests were conducted with fleet operator or contracted drivers. Only gaseous emissions were collected during this task. Exhaust temperatures and hybrid system data were recorded using the same data logger CAN interface as used in Task 2.

Test Setup

The PEMS used in this project was a Sensors, Inc. Semtech DS. This unit can analyze raw exhaust emissions, measure exhaust flow rates, and log vehicle and engine operating parameters broadcast on J1939 CAN bus. Additional data on the CAN bus were also logged by an independent data logger during this task. The Semtech analyzers were calibrated with zero air and the following span gases: one bottle of a quad mix gas containing 12% CO_2, 1000 ppm CO, 200 ppm NO, 20 ppm propane, and a separate bottle containing 100 ppm NO_2. Leak checks were performed daily.

One day cab hybrid and two step vans (hybrid and conventional) were selected for testing (all Freightliner chassis ISB-powered vehicles). Table 30 and Table 32 provide detailed vehicle specifications. The vehicles were also equipped with the DPF/selective catalyst reduction emission control packaged under the passenger side floor for the step vans and under the cab deck for the day cabs. The turnout tailpipe was removed and the flow tube was fitted under the vehicle bodies. For the step vans, the remaining PEMS equipment was placed inside the rear cargo space with all the required cables and hoses threaded through an opening acquired by removing an electronic lock sensor on the back corner of the cargo body. For the day cab, the remaining PEMS equipment was placed on the cab deck. For the step vans, the vehicles were loaded with sandbags to achieve the desired test weight of a curb weight of 10,790 lb (hybrid) and 9,550 lb (conventional) plus 4,000 lb of cargo for a total test weight of 14,790 lb (hybrid) and 13,550 lb (conventional) in order to be representative of the parcel delivery vocation.

For the day cab, the testing was done during revenue operation with actual cargo, so no ballast was needed. The nominal test cargo mass for the day cabs was 23,000 to 30,000 lbs. The step vans were tested off-duty, with a contracted driver, on an actual route representing a typical parcel delivery duty cycle. The in-use route replicated the UDDS cycle in terms of average speed and kinetic intensity, as discussed in the next section. For the step van each delivery stop was 90 seconds long with the engine off. The stop and engine off time for the day cab varied based on the in-use operation.

Each morning, prior to testing, the PEMS unit was warmed up and the analyzers repeatedly calibrated until they exhibited stabilized operation with no appreciable drift. The sample lines were purged with zero air and leak checks were performed. The vehicles were tested on the same route every day for the step vans, with one stop at roughly midday designated for recalibration and line purge. As such, the data from each day were split into two portions. Each vehicle was tested on two days for the step vans and three days for the day cab. The following photos were taken during PEMS testing in August 2013 in Buena Park and November 2013 in Costa Mesa, and show the Semtech set up for the step van and day cab, calibration activities in progress, step van with ballast, and flow tube installation on step van underbody (Figure 23 through Figure 27).

Figure 23. Class 7 hybrid day cab beverage delivery truck PEMS installation

Figure 24. Class 7 hybrid day cab beverage delivery truck PEMS field testing

Figure 25. Step van parcel delivery truck PEMS installation and calibration

Figure 26. Step van parcel delivery truck PEMS with ballast

Figure 27. Step van parcel delivery truck PEMS flow tube

Route Selection

For the Class 7 day cab hybrid testing, the route was selected based on in-use data collected on vehicles in the beverage delivery vocation during Task 2. Figure 28 shows the in-use kinetic intensity data plotted against average speed along with data points for kinetic intensity versus average speed for three standard drive cycles. A route from the Task 2 in-use data was selected that matched the midpoint of the observed in-use data and was relatively close to the UDDS drive cycle (Figure 4). The route for the PEMS testing is shown as an orange bar on Figure 28. Figure 29 shows a trace of the actual route used during PEMS testing for the Class 7 hybrid day cab from the depot in Buena Park (LA area).

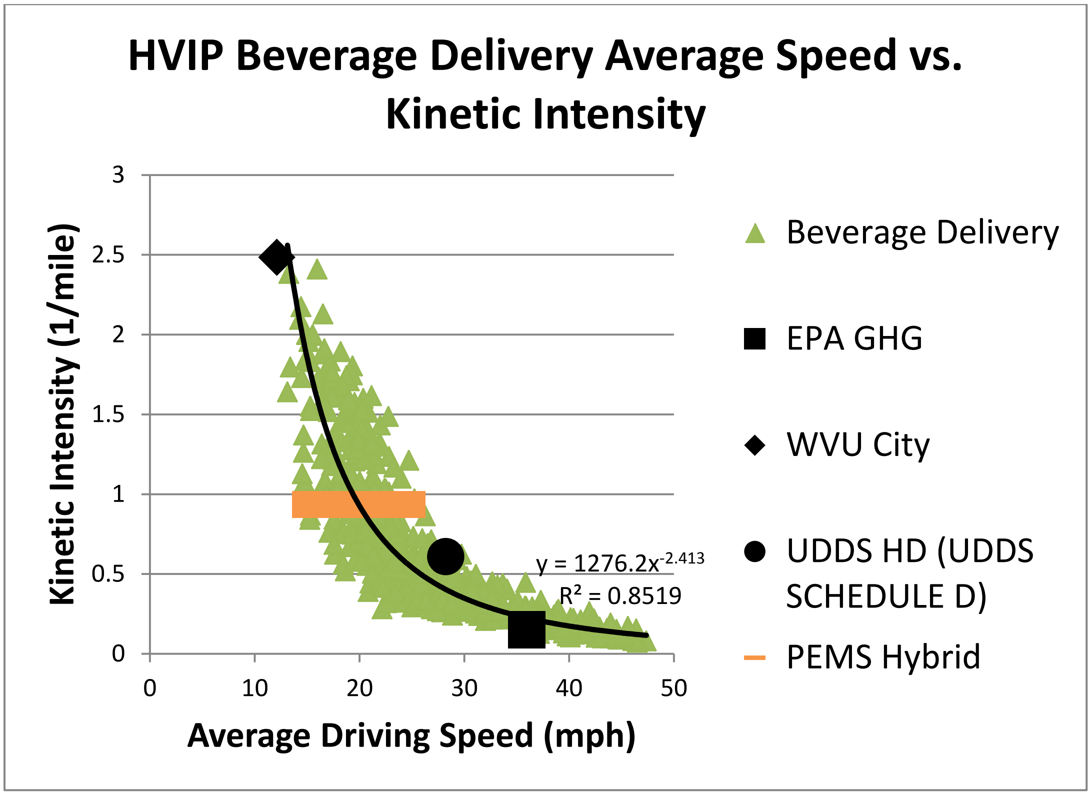

Figure 28. Class 7 day cab PEMS testing route selection

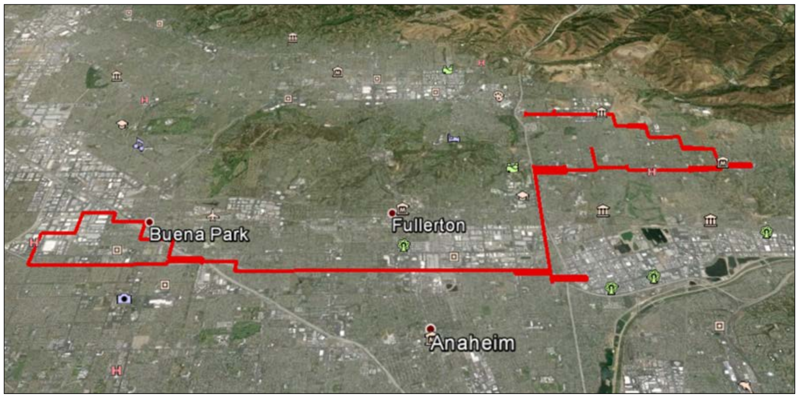

Figure 29. Class 7 day cab PEMS testing route

For the Class 4 parcel delivery step van hybrid and conventional testing, the route was selected based on in-use data collected on vehicles in the parcel delivery vocation during Task 2. Figure 30 shows the in-use average speed data plotted against kinetic intensity along with data points for average speed versus kinetic intensity for four standard drive cycles. The routes from the Task 2 in-use data were selected that matched the midpoint of the observed in-use data and were close to the NY Comp and UDDS drive cycles. The routes for the PEMS testing are shown as orange and blue bars on Figure 30. Figure 31 shows a trace of the actual route used during PEMS testing for the Class 4 step vans out of a depot in Costa Mesa in Orange County. Figure 32 shows a comparison of the target drive trace and the actual PEMS drive trace.

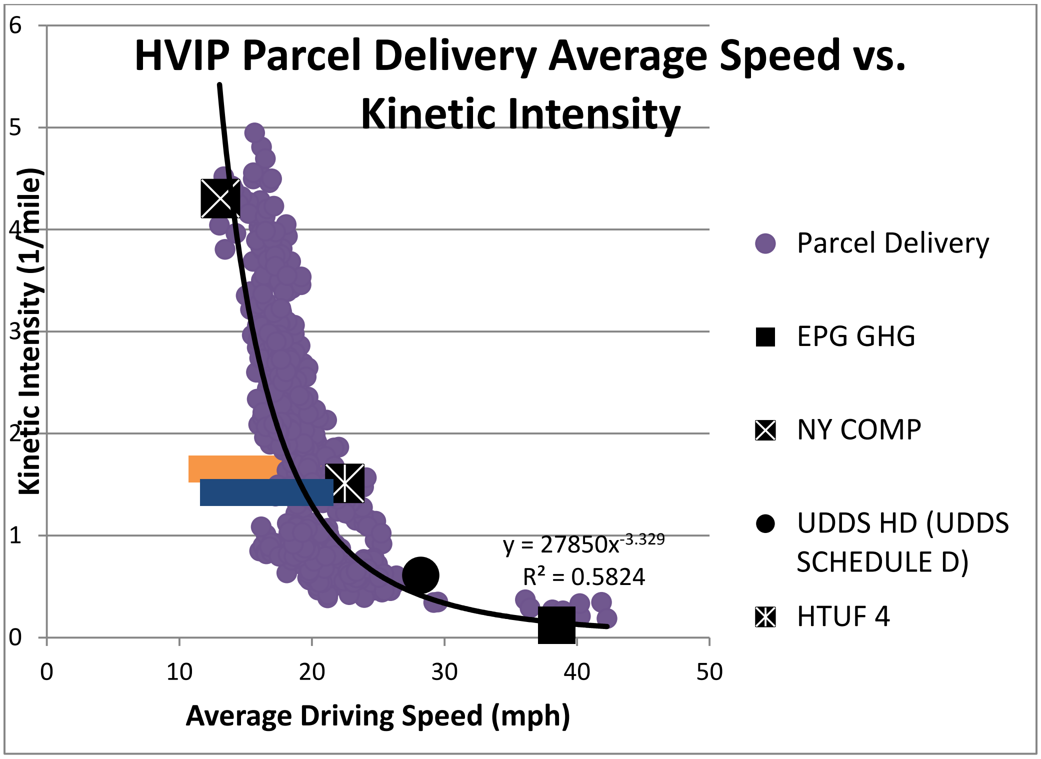

Figure 30. Class 4 step van PEMS testing route selection

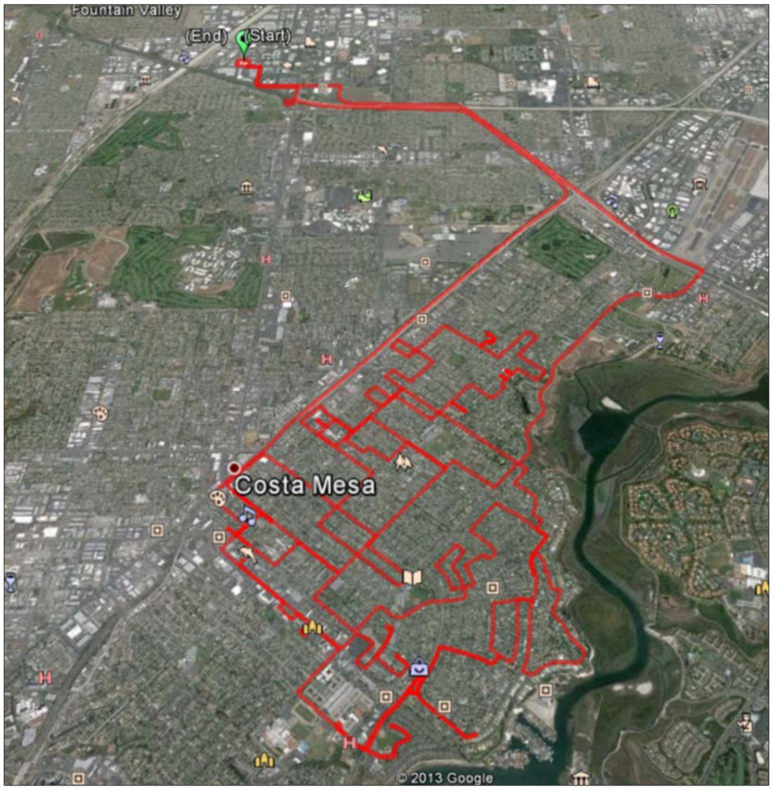

Figure 31. Class 4 step van PEMS testing route

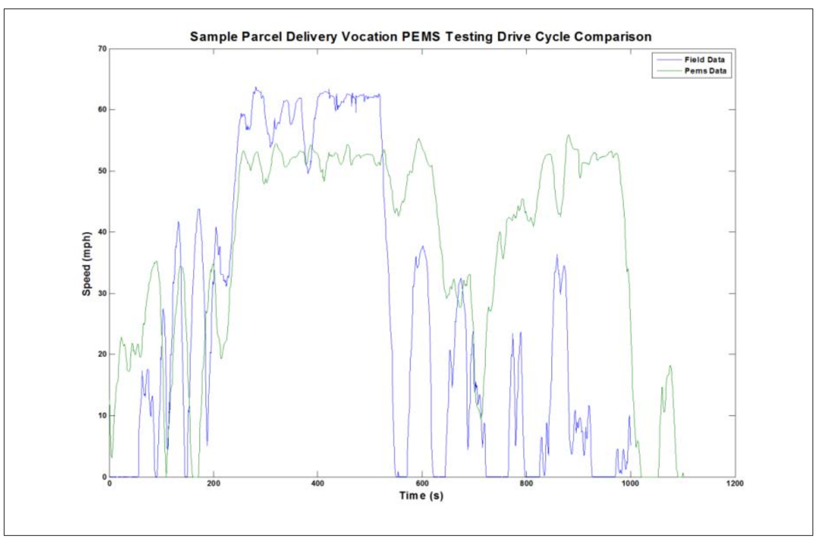

Figure 32. Class 4 step van PEMS testing route target and actual drive trace

Portable Emissions Measured System Results

Class 7 Day Cab Hybrid

NREL performed the PEMS testing using the Semtech DS PEMS on a Class 7 hybrid day cab from a Buena Park beverage delivery fleet for this project. For this testing, three days of on-road emissions data for only the hybrid truck were collected. The conventional truck was not available, and was not included for the Class 7 day cab PEMS testing. The vehicle details are provided in Table 30.

Table 30. PEMS Class 7 Day Cab Vehicle Specifications

MY	2010
Make	Freightliner
Model	M2
Fuel Type	Diesel/Electric HEV
Vehicle Description	Class 7, 16 Bay Route Power
Cargo Mass	23,000–30,000 lb
PEMS Test Weight	Actual
Engine MY	2010
Engine	ISB – 325
GVWR	34,700
Axle Ratio	5.63
Engine Family	ACEXH0408BAH

For this hybrid truck, the average NO_x emissions were 3.2 g/mi and the average fuel economy was 8.32 mpg. For comparison, the average NO_x emissions for the hybrid truck on the chassis dynamometer were 3.05 g/mi on the WVU City cycle and 1.09 g/mi on the UDDS cycle. The average fuel economy was 7.12 mpg on the WVU City cycle and 8.63 mpg on the UDDS cycle. The PEMS on-road emissions results for this truck are shown in Table 31 and all the raw and modal data were provided to CARB.

Table 31. Class 7 Day Cab Hybrid Beverage Delivery Truck PEMS Emissions Data

Class 7 Hybrid Day Cab	Day 1	Day 2	Day 3
Total Distance Traveled (mi)	33.00	45.20	47.50
FE (mpg)	8.28	8.66	8.02
CO_2 (g/mi)	1233	1,178	1,275
CO (g/mi)	3.40	3.29	3.46
NO_x (g/mi)	3.73	3.08	3.03
NO_x (g/mi) (corrected NO_x)	3.67	3.00	2.94
THC (g/mi)	0.04	0.03	0.02

Step Van Hybrid and Conventional

Two step vans in the parcel delivery vocation—conventional and hybrid (two days each, 4–6 hours each day, of in-use/route on-road operation)—were also tested in Costa Mesa, California, under this task. The vehicle details are provided in Table 32 and engine certification levels in Table 33. CARB Executive Orders for all the engines tested in vehicles as part of this task are included in Appendix B.

Table 32. PEMS Step Van Vehicle Specifications

MY	2011	2012
Make	Freightliner	Freightliner
Model	W700HY/MT45	W900/MT45
Fuel Type	Diesel/electric HEV	Diesel
Vehicle Description	Class 5 step van	Class 5 step van
Cargo Mass	4,000 lb	4,000 lb
PEMS Test Weight	~14,790 lb	~13,550 lb
Engine MY	2011	2011
Engine	ISB – 200	ISB – 200
GVWR	17,000	19,500
Axle Ratio	4.1	4.1
Engine Family	BCEXH0408BAH	BCEXH0408BAH

Table 33. HEV and Conventional PEMS Step Van Engine Certification Levels

2011 Cummins ISB 6.7L Engine Family: BCEXH0408BAH												
g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.2	0.2	N/A	N/A	15.5	15.5	0.01	0.01	N/A	N/A
FEL	N/A	N/A	0.33	0.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CERT	0.01	0.001	0.17	0.18	N/A	N/A	0	0	0	0	N/A	N/A
NTE	0.21		0.5		N/A		19.4		0.02		N/A	

The average NO_x emissions for the hybrid step van over both days were 3.6 g/mi; the average NO_x emissions for the conventional van were 2.4 g/mi. That is, an observed NO_x emissions increase for the hybrid of 50% (the average NO_x increase during chassis testing was 20%–243% depending on the duty cycle). NO_x measurements were corrected for humidity and temperature. The average fuel economy for the hybrid step van over both days was 9.0 mpg; the average fuel economy for the conventional step van was 8.1 mpg, which is an observed fuel economy increase for the hybrid of 10%. Table 34 includes a summary of all the preliminary emissions results from the step van PEMS testing for the hybrid and the conventional step vans over both test days.

Table 34. Step Van PEMS Emissions Data

	Hybrid Step Van				Conventional Step Van			
	Day 1 Test 1	Day 1 Test 2	Day 2 Test 1	Day 2 Test 2	Day 1 Test 1	Day 1 Test 2	Day 2 Test 1	Day 2 Test 2
Total Distance Traveled (mi)	15.4	21.5	14.5	23.4	14.4	20.7	14.4	20.8
Overall Fuel Economy (mpg)	9.1	8.6	9.4	8.9	8.3	8.1	8.1	8.1
CO_2 (g/mi)	1,131	1,194	1,090	1,155	1,233	1,265	1,255	1,252
CO (g/mi)	3.4	3.5	3.4	3.4	3.6	2.9	3.7	3.2
NO_x (g/mi)	4.1	3.9	3.7	3.9	2.2	2.6	2.1	2.9
NO_x (g/mi) (corrected NO_x)	3.9	3.6	3.4	3.6	2.1	2.5	2.1	2.9

Measured fuel economy and emissions from each vehicle type during a typical day of operation were collected to confirm laboratory results. Dynamometer drive cycles accurately predicted vehicle performance in operation and the performance improvements of the HEVs compared to the diesel equivalents. Detailed second-by-second (1 hz) data were provided to CARB.

Task 6: Vocational Analysis and Methodology Development

For this task, NREL applied measured fuel usage and emissions data from Task 4 to vocational activity data from Task 2 to develop weighted vocational emissions and fuel consumption inventory estimates for current HVIP fleets that can be applied to vocations from this study and to future HVIP deployments of medium- and heavy-duty HEVs in California.

A methodology was developed and validated using the initial results gathered here. This will enable future projections of additional technology, vocations, and fleet characteristics. The methodology developed will be used to:

- Estimate the emissions and fuel consumption reduction potential of low emissions technologies deployed on specific routes (drive cycles)
- Develop vocational correlations between duty cycle kinetic intensity, fuel economy, daily vehicle miles traveled, and criteria emissions
- Provide a methodology for future analysis of technology options versus variable vocations and drive cycles.

The approach and methodology under this task was intended to develop a predictive NO_x emissions and fuel economy tool based on the data collected in Task 2. It uses a simple high-level methodology to minimize user input requirements. The tool requires a limited set of vehicle and duty cycle inputs from the fleet owners. The vehicle inputs are limited to rolling resistance, drag coefficient, frontal area, total mass, engine type and power, auxiliary loads, transmission efficiency, and, for hybrids, motor power and efficiency and battery energy.

The drive cycle requirements are a second-by-second speed versus time trace that is from representative in-use data or surrogate vocational data. The fleet data for an HVIP applicant can be run through the NREL-developed power-based vehicle model to predict and match NO_x emissions and fuel economy for the applicant vehicle or fleet based on data from this study. The results can then be used to estimate the relative benefit of including the applicant vehicle or fleet of vehicles in the HVIP. The methodology also includes an aggregate function that will allow CARB to assess (i.e., mine) data from the current data set to estimate the NO_x and fuel consumption impacts from future and existing fleets based on the number of vehicles in a given fleet or vocation.

This tool uses fuel consumption and engine power data from the vehicles instrumented in Task 2 as the basis for the mpg estimates, as shown in Figure 33. The tool then takes the user input information for the vehicle and duty cycle, as discussed above, and matches it to vehicles (average for one vehicle for all activity) or vehicle days (average for one vehicle over one day of activity) in the HVIP data set in terms of kinetic intensity and average speed (Figure 34). These matched vehicles are then used to assess the performance of the modeled vehicle in terms of emissions or other parameters.

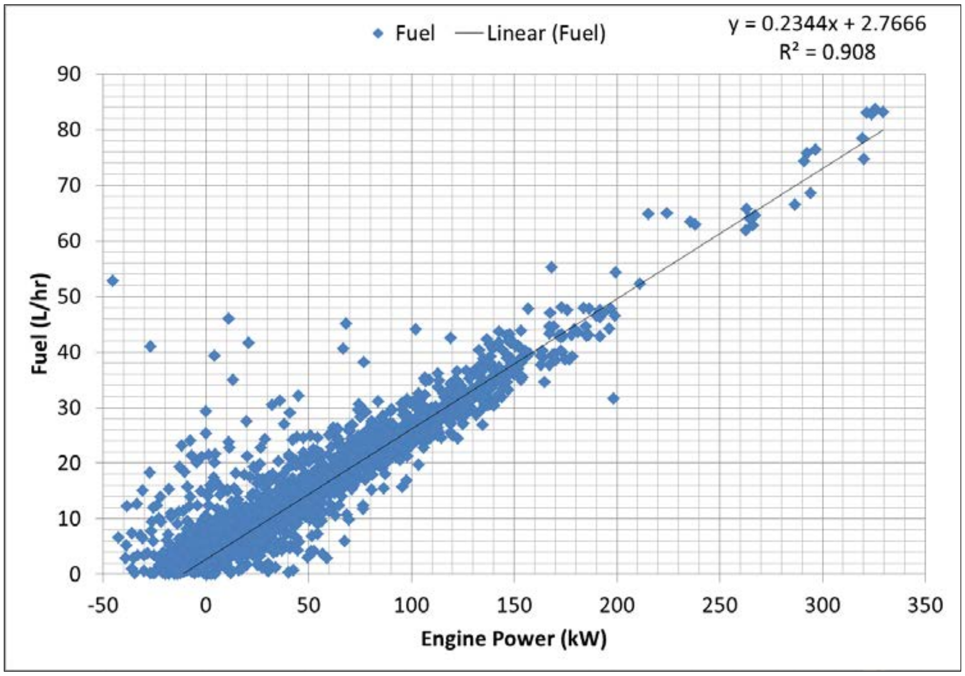

Figure 33. Fuel consumption versus engine power relationship for HVIP instrumented trucks

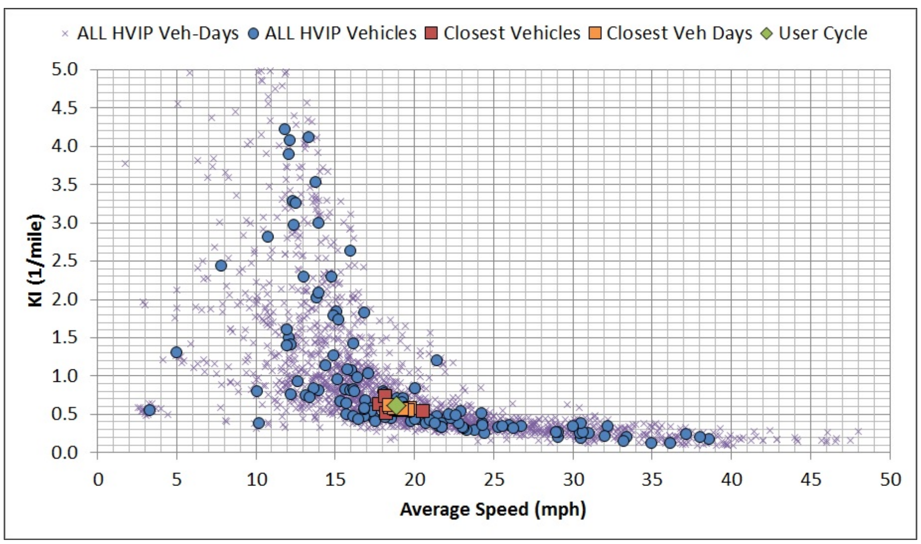

Figure 34. Kinetic intensity versus average speed for HVIP instrumented vehicles

Figure 35 shows the validation of the simulated vehicles with data from the chassis testing part of this project, Task 4, using this tool for four different duty cycles.

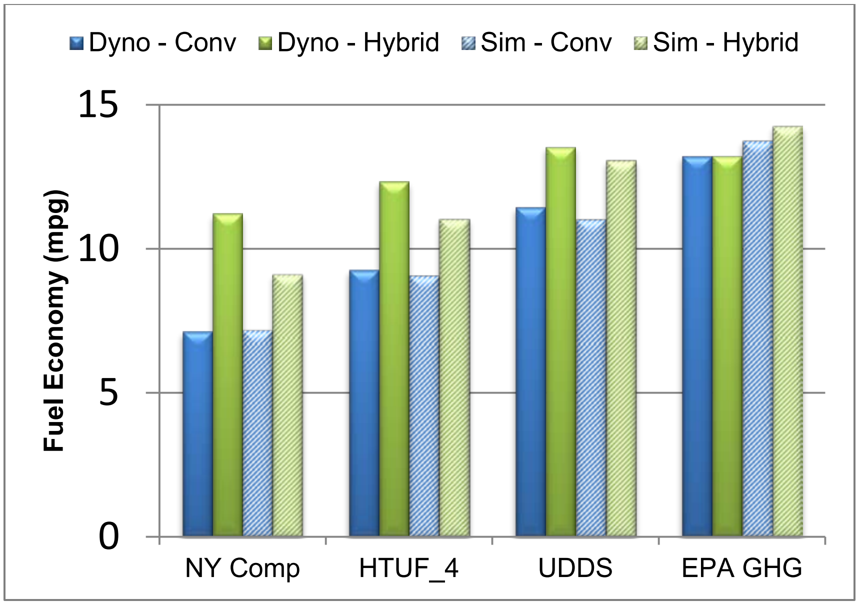

Figure 35. Validation of modeled/simulated fuel economy

Using this tool and the data from Task 2 allowed an assessment of the fuel displacement potential of HEVs operating in the vocations included in this study. Figure 36 shows the average percentage of fuel economy improvement observed from HEVs and the gallons of fuel displaced each week from HEVs in each vocation. The parcel delivery vocation has the highest fuel economy improvement of the four vocations, but does not have the highest fuel displacement figures. This is due to the fuel economy improvement over the baseline and the average trip or daily miles driven for a given vocation. The parcel delivery vocation has the lowest daily mileage (Figure 37), so the fuel displacement is low. Conversely, the food distribution vocation has the highest daily mileage. When combined with the fuel economy improvement for that vocation, this results in the highest fuel displacement potential through hybridization.

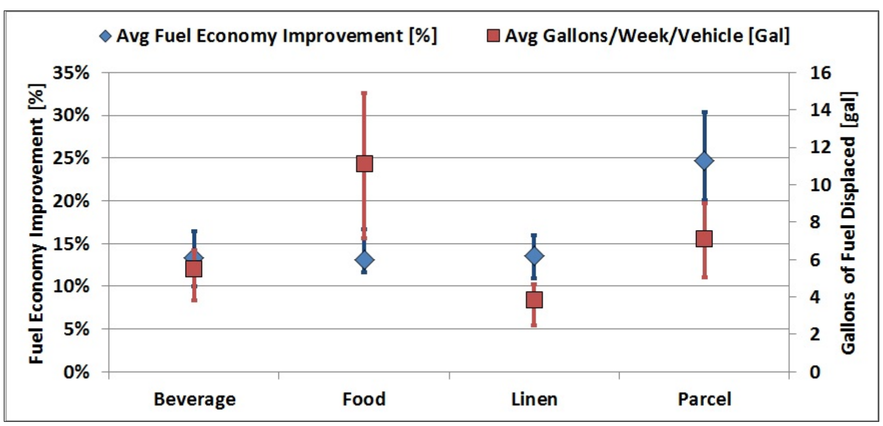

Figure 36. Percent fuel economy improvement and fuel displacement through hybridization for four HVIP vocations

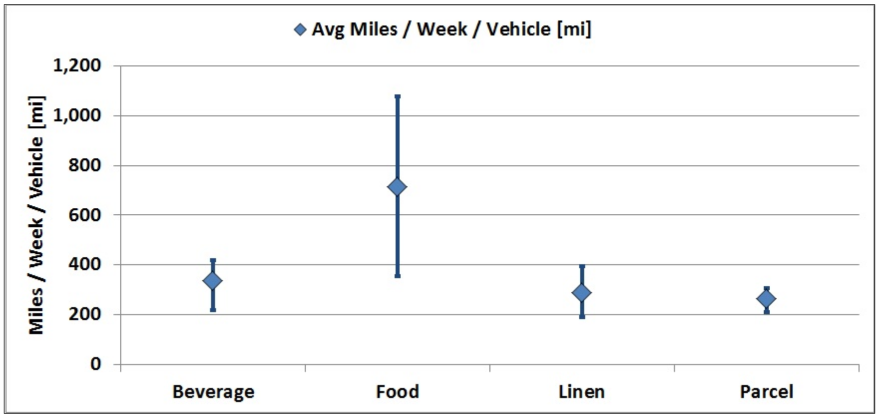

Figure 37. Average weekly miles driven per vehicle by vocation

Conclusions, Analysis of Results, and Recommendations

The objective of this project was to evaluate and quantify the emission impacts of commercially available hybrid medium- and heavy-duty vehicles relative to their non-hybrid counterparts. This effort will allow the California Air Resources Board (CARB) and other agencies to more effectively encourage development and commercial deployment of the most-efficient, lowest emitting hybrid technologies needed to meet air quality and climate goals.

Through this project, NREL captured in-depth duty cycle, emissions and fuel consumption information on key HVIP vocational fleets operating in California. HEVs operating in these fleets consistently showed lower fuel consumption and higher NO_x emissions compared to similar conventional vehicles in similar operating environments. This trend was observed for on-road engine controller unit data, as well as PEMS and chassis dynamometer testing data.

Figure 38 through Figure 40 show the average driving speed versus fuel economy for the in-use data from Task 2 and the chassis dynamometer data from Task 4 for the beverage, uniform and linen, and parcel delivery vocations. A consistent fuel economy improvement trend is seen for both datasets and across all three vocations. Figure 41 shows the fuel economy improvement for all datasets from this project, including the PEMS data, across five duty cycles or in-use cycles that were similar to the standard cycles. The same fuel economy improvement trend can be seen in this figure as well, but for the EPA GHG drive cycle the improvement was consistently small or nonexistent.

Figure 42 shows the NO_x emissions for the same five cycles for all the project datasets. This figure shows the consistent trend of higher NO_x emissions across all the datasets and duty cycles. This higher NO_x trend was observed for both engine-out and tailpipe emissions measurements. These higher emissions trends are likely the result of complex engine, vehicle, and emissions control system strategy interactions and not just exhaust temperatures differences.

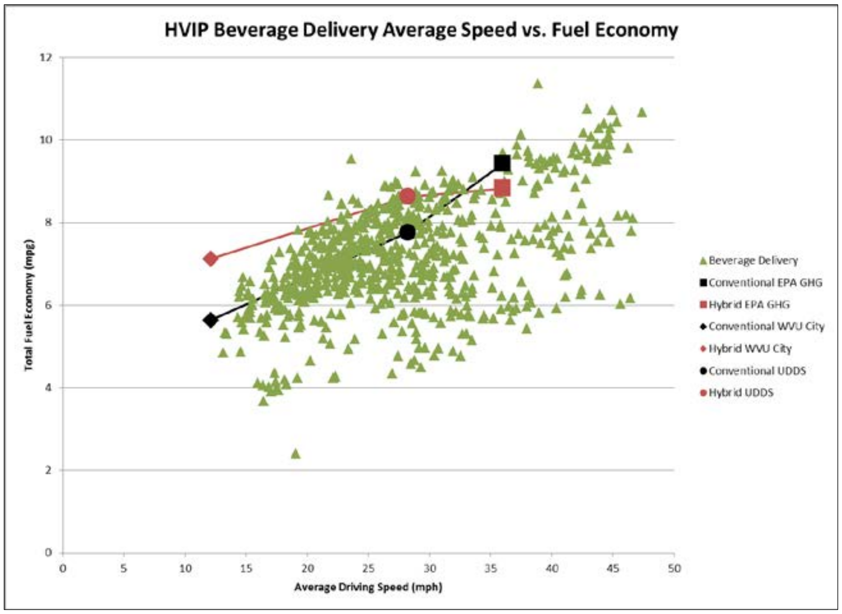

Figure 38. Average speed versus fuel economy for beverage delivery vocation

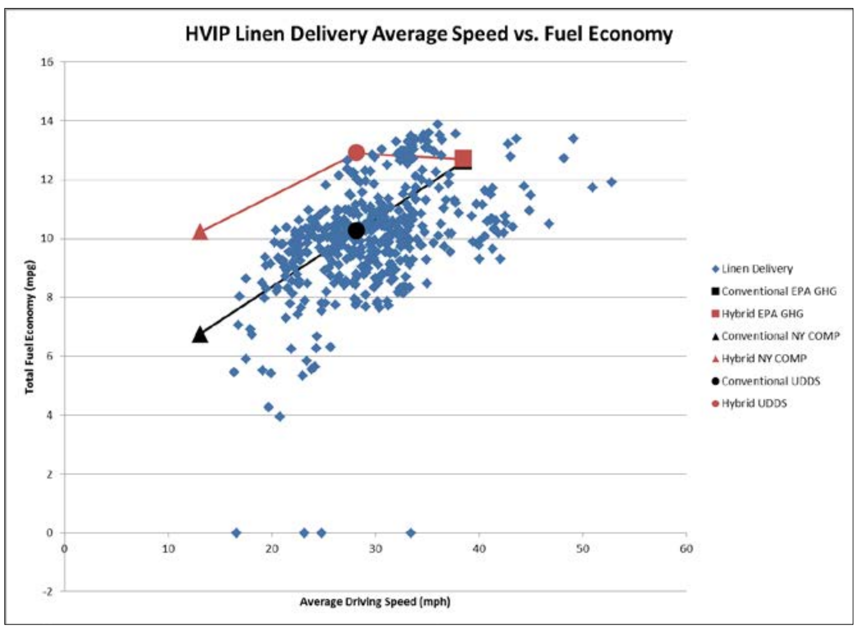

Figure 39. Average speed versus fuel economy for uniform and linen delivery vocation

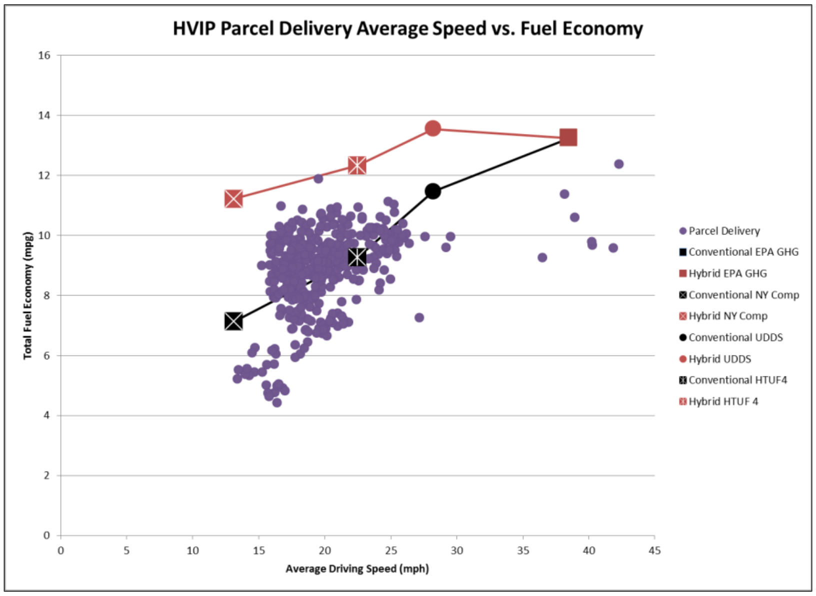

Figure 40. Average speed versus fuel economy for parcel delivery vocation

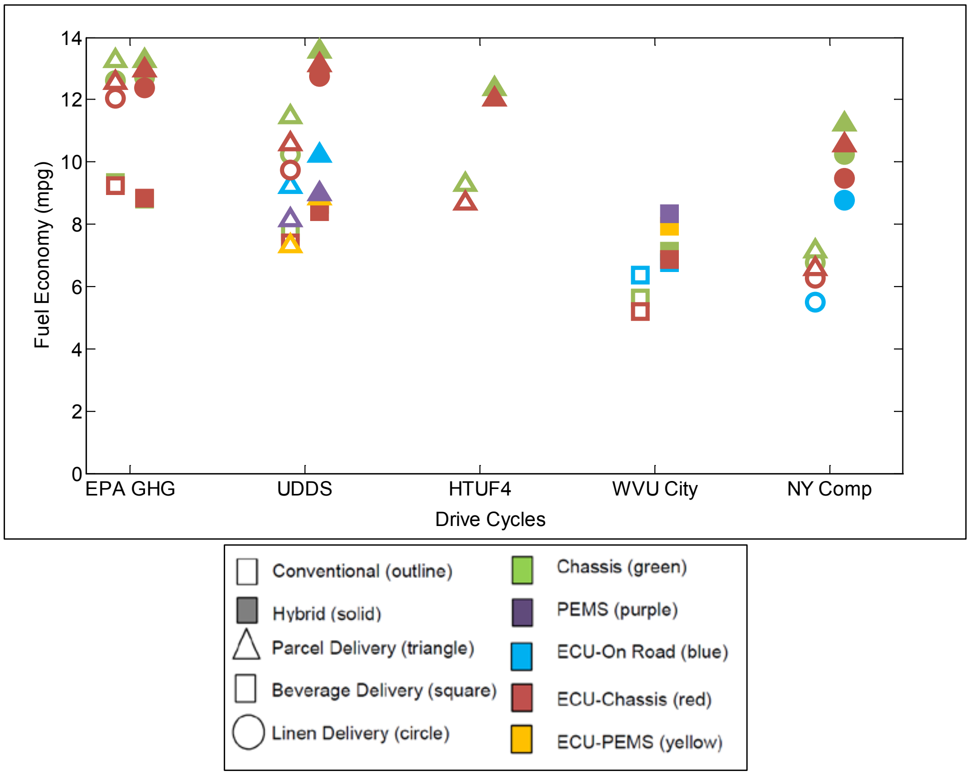

Figure 41. Average fuel economy across all datasets by drive cycle

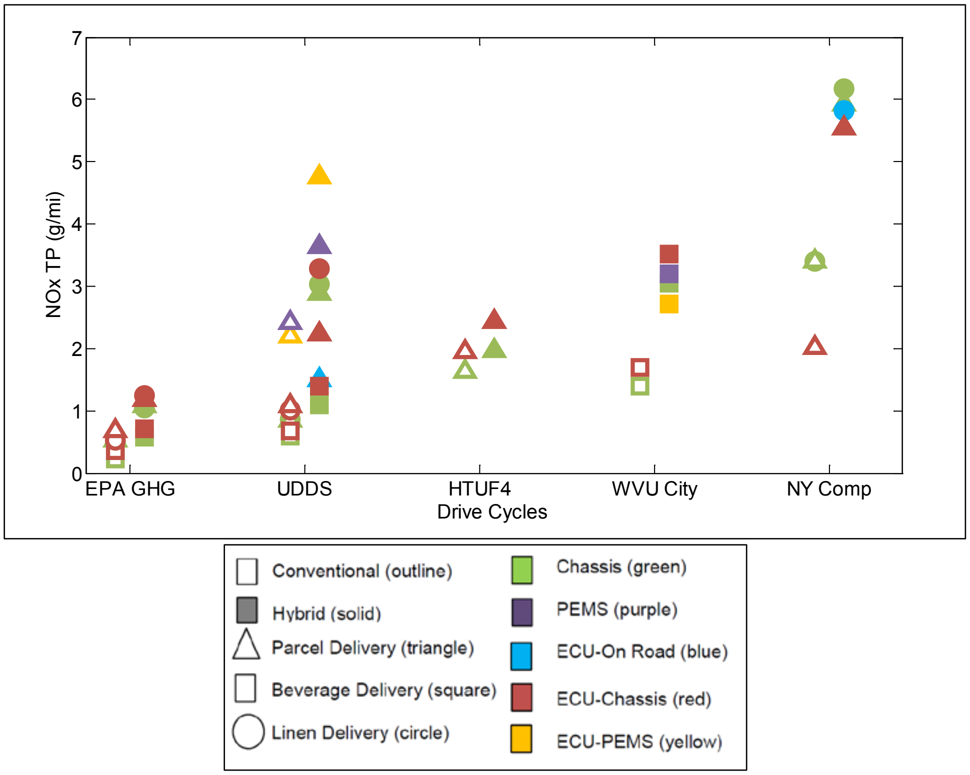

Figure 42. Average NO_x emissions across all datasets by drive cycle

To investigate this issue further a sub-set of the project data was analyzed more thoroughly. The chassis testing of the Class 5 parcel delivery vehicles offered one of the best opportunities for isolating the effects of the hybrid system compared with a conventional vehicle, as both vehicles had the same 2011 Cummins ISB engine with a 200 HP rating and calibration CPL#3070. Both the conventional and hybrid vehicles were built on a Freightliner MT45 chassis with a 4.10 final rear axle ratio. However, the engines operated differently due to differences in internal transmission gearing and control strategies, as well as interaction of the hybrid system. Figure 43 shows the region of engine operation for the hybrid (left) and conventional (right) vehicles over the EPA GHG cycle.

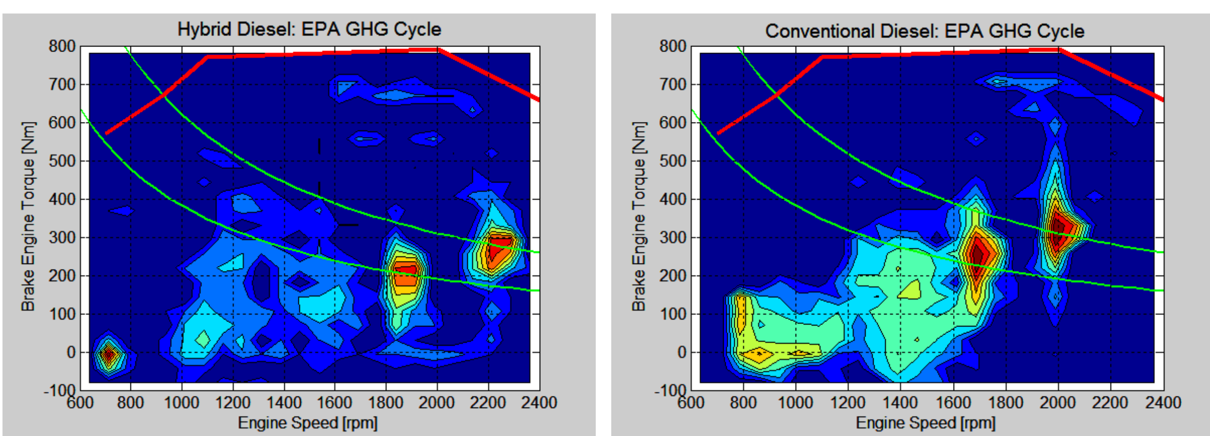

Figure 43. Engine operation over the EPA GHG chassis cycle, hybrid (left), conventional (right), J1939 torque curves (red), and constant power lines (green) for comparison

The two regions of high operation on the right side of each graph are the 55 mph and 65 mph steady-state sections of the cycle. From the constant power lines shown in green, it can be seen that both engines are operating with a similar power output; however, there is a shift to higher engine speed and lower torque for the hybrid vehicle. The conventional diesel was equipped with an Allison 1000HS series transmission with a top (fifth) gear ratio of 0.71, whereas the hybrid vehicle was equipped with an automated manual Eaton Hybrid EH-6EX06B series transmission with a top (sixth) gear ratio of 0.78 accounting for the ~10% shift. On a more transient cycle such as the UDDS, hybrid engine operation still spends a significant amount of time at higher engine speeds due to the gearing just discussed, but also at lower average engine power due to the contribution of the hybrid system, which is directly related to the 18.2% fuel economy savings realized over the cycle (Table 25). Figure 44 shows the engine operation for the conventional and hybrid vehicles over the UDDS cycle along with the 30% power and torque lines which bracket the lower bound of the NTE zone.

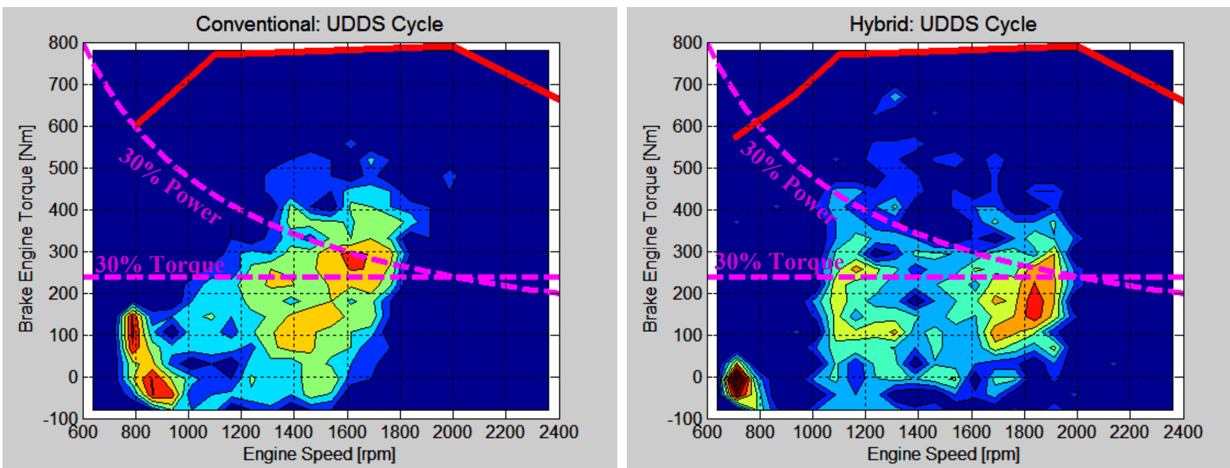

Figure 44. Engine operation over the UDDS chassis cycle, conventional (left), hybrid (right)

Figure 45 below shows the engine-out brake-specific NO_x emissions as measured by the OBD NO_x sensors averaged over all parcel delivery chassis dynamometer test cycles for the conventional and hybrid step vans. Comparing the UDDS operation with corresponding brake-specific NO_x emissions, it can be seen that the areas circled below both see a significant amount of operation during the UDDS cycle, but have drastically different emission levels. It is important to note that these are engine-out levels that can be reduced over the SCR system; however, due to insufficient temperature, NO_2/NO_x ratio, and sensor/calibration constraints, it may not be possible to maintain a high level of conversion under all conditions, particularly for hybrids. Therefore, these high engine-out emissions may contribute significantly to the large increase in tailpipe NO_x emissions observed, but the root cause for the lack of SCR conversion still requires further investigation.

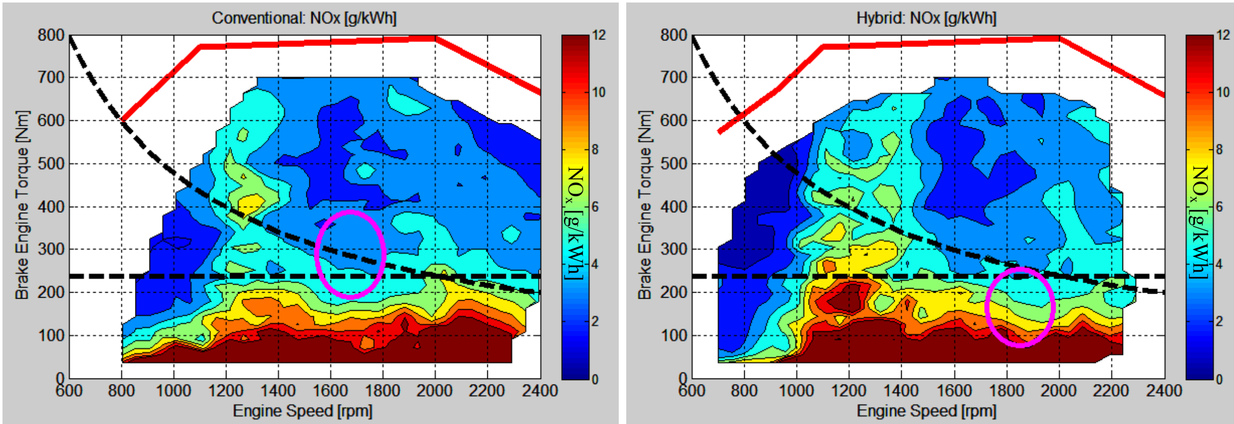

Figure 45. Composite engine-out brake-specific NO_x maps for parcel delivery vehicles

This trend was also observed during in-use data collection. Figure 46 shows a composite of all Cummins ISB data collected from parcel and linen delivery vocations. It can be seen that a significant portion of the hybrid vehicle operation occurred at higher engine speeds and lower engine torque in a region that suffers from higher engine-out NO_x emissions.

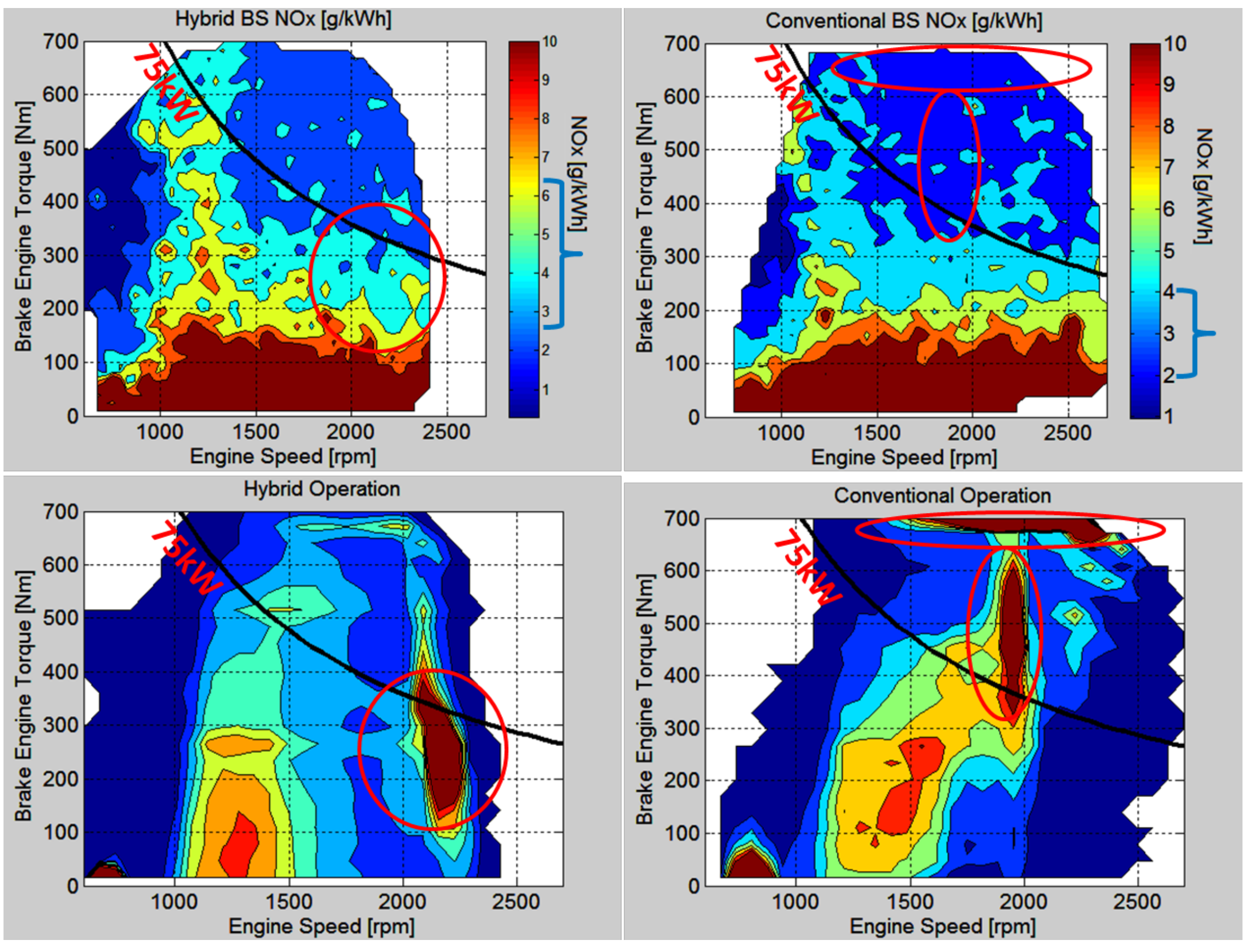

Figure 46. In-use operation and engine-out brake-specific NO_x from Cummins ISB-equipped parcel and linen delivery vehicles

Due to the significant amount of operation at lower torque values, one might consider engine downsizing for the hybrid application. However, there are a number of performance considerations, especially with vocational vehicles, where a long pull with a heavily-loaded vehicle up a steep grade might be common. This type of drive cycle could rapidly deplete the energy stored in the hybrid system, forcing the vehicle to quickly rely on the smaller engine as the only source of tractive force. Under these conditions, the smaller engine would still need to meet the minimum performance requirements for the task. Additionally, for engines in intended service class medium heavy-duty and heavy heavy-duty applications, there are design requirements to allow for engine rebuilds such as piston sleeves and useful life requirements that would have to be met without the assistance of a hybrid system. Currently, the U.S. market does not have many small displacement engines which meet these requirements.

It is important to view these results in the context of the goals for this project, which were to characterize duty cycles and quantify the emissions and fuel use of some HVIP-funded vehicles in California. As such, this should be considered a limited dataset—vehicles were selected based on availability and are not necessarily representative of the in-use vehicle population. Also, the focus was to include HEVs participating in HVIP that are not representative of all vehicles—or even all hybrids—operating in California. Because the study focused on HEVs, comparison data on conventional vehicles were available on only a small sample size, and data on 2010 certification vehicles were difficult to acquire because of limited vehicle availability. In addition, some vocations and vehicle classes were excluded by design—the focus was on vocations with the highest representation in HVIP, so this should not be considered a comprehensive dataset. That said, the observations from this study indicate a need for improved electric drive integration and optimization for the medium-duty and heavy-duty vehicle markets and show that deployment of these vehicles should be approached with an open mind with regard to their potential for fuel reduction and the potential for unintended adverse impacts from the criteria emission perspective if they are not properly designed and certified. Additional analysis is needed to fully understand all of the data and observations gathered during this study in order to fully understand the potential of these vehicles.

The initial impression is that the observed issue related to the increase in NOx emissions associated with the hybrid vehicles has the potential to be easily solved. CARB is currently working with NREL on a second phase to this work to identify the root cause of this issue and recommend solutions for both current and future hybrid vehicles. To better understand the issue, this future project will monitor emissions-control systems for differences in urea dosing and changes in engine operation (e.g., injection timing and exhaust gas recirculation rates), examine the composition of the selective catalytic reduction (SCR) feed gas (NO_2 to NO_x ratio), and look at tailpipe constituents (NH_3, N_2O, HNCO) to better understand SCR operation, among other things. This will be done by using a well-paired conventional and hybrid vehicle (same MY engine calibration/certification, etc.) on NREL's chassis dynamometer (including the Hino hybrid/conventional vehicle vertically integrated platform) and using representative cycles that are known to show fuel economy benefits and NO_x increase. In addition, the future project will explore the potential to tune for fuel economy and low emissions simultaneously by working with industry partners (e.g., engine, transmission, and hybrid system developers) to adjust/optimize control strategies and provide recommendations for the next generation of hybrids to ensure that fuel economy benefits continue to be realized without sacrificing emissions.

References

(1) Wayne, W.S.; Clark, N.N.; Nine, R.D.; Elefante, D. "A Comparison of Emissions and Fuel Economy from Hybrid-Electric and Conventional-Drive Transit Buses," *Energy & Fuels* 2004; 18, 257–270.

(2) SAE 2008-01-1301, and "A Work-Based Window Method for Calculating In-Use Brake-Specific NOx Emissions of Heavy-Duty Diesel Engines," Benjamin C. Shade, Daniel K. Carder, Gregory J. Thompson, and Mridul Gautam, *Journal of Engines*, Vol. 117, 778-793, 2009.

Appendix A: Vehicles Instrumented in Task 2

Table 35. List of All Vehicles Instrumented in Task 2 (Hybrid in Green, Conventional in Black)

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Linen Delivery	2012	Freightliner	MT 55	Diesel/ Electric HEV	20' Walk in Van Body	7000 lb	2011	Cummins 6.7 ISB	Pittsburg	
Linen Delivery	2010	Work Horse	W 62	Diesel	18' Walk In Van Body	7000 lb		Max Force 7	Pittsburg	
Linen Delivery	2010	Work Horse	W 62	Diesel	18' Walk In Van Body	7000 lb		Max Force 7	Pittsburg	
Linen Delivery	2009	Freightliner	MT 45	Diesel	18' Walk In Van Body	7000 lb		Max Force 7	Hayward	
Linen Delivery	2010	Work Horse	W 62	Diesel	18' Walk In Van Body	7000 lb		Max Force 7	Hayward	
Linen Delivery	2012	Freightliner	MT 55	Diesel/ Electric HEV	20' Walk in Van Body	7000 lb	2011	Cummins 6.7 ISB	Hayward	
Linen Delivery	2012	Freightliner	MT 55	Diesel/ Electric HEV	20' Walk in Van Body	7000 lb	2011	Cummins 6.7 ISB	Hayward	
Linen Delivery	2011	Freightliner	MT 45	Diesel	18' Walk In Van Body	7000 lb	2010	Cummins 6.7 ISB	Sacramento	
Linen Delivery	2012	Freightliner	MT 55	Diesel/ Electric HEV	20' Walk in Van Body	7000 lb	2011	Cummins 6.7 ISB	Sacramento	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Hayward	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Hayward	
Beverage Delivery	2012	International	4400 4X2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	Engine, Diesel {MaxxForce DT} 260 HP @ 2200 RPM, 660 lb-ft Torque	Hayward	
Beverage Delivery	2012	International	4300 4X2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	Engine, Diesel {MaxxForce DT} 260 HP @ 2200 RPM, 660 lb-ft Torque	Hayward	

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Beverage Delivery	2010	International	4400 4X2	Diesel	Route Power	23,000-30,000 lb	EPA 07	Diesel {International MaxxForce DT} 300 HP 860 lb-ft Torque @ 1400 RPM	Hayward	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	Rout Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Hayward	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Hayward	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Hayward	
Beverage Delivery	2012	International	4300 4X2	Diesel/ Electric HEV	Route Power	23,000-30,000 lb	EPA 10	Engine, Diesel {MaxxForce DT} 260 HP @ 2200 RPM, 660 lb-ft Torque	Hayward	
Beverage Delivery	2010	International	4400 4X2	Diesel	Route Power	23,000-30,000 lb	EPA 07	Diesel {International MaxxForce DT} 300 HP 860 lb-ft Torque @ 1400 RPM	Hayward	
Beverage Delivery	2010	International	4400 4X2	Diesel	Route Power	23,000-30,000 lb	EPA 07	Diesel {International MaxxForce DT} 300 HP 860 lb-ft Torque @ 1400 RPM	Hayward	
Beverage Delivery	2010	International	4400 4X2	Diesel	Route Power	23,000-30,000 lb	EPA 07	Diesel {International MaxxForce DT} 300 HP 860 lb-ft Torque @ 1400 RPM	Hayward	
Beverage Delivery	2011	International	4400 4X2	Diesel	Route Power 32' Bulk		EPA 10	Diesel {MaxxForce DT}, 270 HP @ 2200 RPM, 860 lb-ft Torque @ 1300 RPM	Buena Park	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Beverage Delivery	2009	International	TK10BAY 52INS	Diesel/ Electric HEV	10 Bay Route Truck		EPA 07	Engine, Diesel {International MaxxForce DT}225 HP 560 lb-ft Torque	Buena Park	

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Beverage Delivery	2009	International	TK10BAY 52INS	Diesel/ Electric HEV	10 Bay Route Truck		EPA 07	Engine, Diesel {International MaxxForce DT}225 HP 560 lb-ft Torque	Buena Park	
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Beverage Delivery	2011	Freightliner	M2	Diesel/ Electric HEV	16 Bay Route Power	23,000-30,000 lb	EPA 10	6.7L - ISB6.7 Cummins	Buena Park	34,700
Food Distribution	2011	Kenworth	T370 - Hybrid	Diesel/ Electric HEV	2 Ax Tractor		2011	P6 / ISB	San Francisco	
Food Distribution	2011	Kenworth	T370 - Hybrid	Diesel/ Electric HEV	2 Ax Tractor		2011	P6 / ISB	San Francisco	
Food Distribution	2013	Kenworth	T370 - Hybrid	Diesel/ Electric HEV	2 Ax Tractor		2013	P6 / ISB	San Francisco	
Food Distribution	2012	Kenworth	T370 - Hybrid	Diesel/ Electric HEV	"B" 24' St Tk		2012	P6 / ISB	San Francisco	
Food Distribution	2011	Kenworth	T270 - Hybrid	Diesel/ Electric HEV	"C" 24' St Tk		2011	P6 / ISB	San Francisco	
Food Distribution	2012	Kenworth	T370 - Hybrid	Diesel/ Electric HEV	"B" 24' St Tk		2012	P6 / ISB	San Francisco	
Food Distribution	2011	Kenworth	T370 - Hybrid	Diesel/ Electric HEV	2 Ax Tractor		2011	P6 / ISB	San Francisco	
Food Distribution	2013	Kenworth	T660 Ext. Day Cab	Diesel	3 Ax Ext Day Cab		2013	ISX-15 500V	San Francisco	
Food Distribution	2013	Kenworth	T660 Day Cab	Diesel	3 Ax Day Cab		2013	ISX-15 455V	San Francisco	
Food Distribution	2013	Kenworth	T660 Day Cab	Diesel	3 Ax Day Cab		2013	ISX-15 455V	San Francisco	

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	35' trailer			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	35' trailer			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	18-bay			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	18-bay			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	18-bay			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	35' trailer			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	18-bay			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T370	Diesel/ Electric HEV	18-bay			P6 - 280	Fresno	34,700
Beverage Delivery	2012	Kenworth	T370	Diesel/ Electric HEV	18-bay			P6 - 280	Fresno	34,700
Beverage Delivery	2011	Kenworth	T800	Diesel	40' trailer		2010	Paccar MX - 430	Fresno	52,000
Beverage Delivery	2011	Kenworth	T600	Diesel	40' trailer		2010	Paccar MX - 430	Fresno	52,000
Beverage Delivery	2012	Kenworth	T370	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k	2011	P6 - 280	Fresno	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	18-bay			ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	18-bay			ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k		ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	18-bay			ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k		ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k		ISB	San Diego	34,700

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	18-bay			ISB	San Diego	
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k	2010	ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k		ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	35' trailer	13-17k lb, up to 20k	2010	ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	18-bay			ISB	San Diego	34,700
Beverage Delivery	2011	Freightliner	M2106	Diesel/ Electric HEV	18-bay		2010	ISB	San Diego	34,700
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2011	Freightliner		Diesel/ Electric HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2012	Freightliner		Diesel/ Hydraulic HEV	Step Van	4000 lb	2010	Cummins ISB-10	Aliso Viejo	
Parcel Delivery	2009	Freightliner		Diesel	Step Van	4000 lb	2007	Cummins ISB-07	Aliso Viejo	
Parcel Delivery	2009	Freightliner		Diesel	Step van	4000 lb	2007	Cummins ISB-07	Aliso Viejo	
Linen Delivery	2011	Freightliner	MT45	Diesel/ Electric HEV	Class 5 Step Van	7000 lb	2010	Cummins ISB-200	Novato	19,000
Linen Delivery	2011	Freightliner	MT55	Diesel/ Electric HEV	Class 6 Step Van	7000 lb	2011	Cummins ISB-200	San Jose	25,500
Linen Delivery	2011	Freightliner	MT55	Diesel/ Electric HEV	Class 6 Step Van	7000 lb	2011	Cummins ISB-200	Concord	25,500
Linen Delivery	2011	Freightliner	MT55	Diesel/ Electric HEV	Class 6 Step Van	7000 lb	2011	Cummins ISB-200	Concord	25,500
Linen Delivery	2011	Freightliner	MT55	Diesel/ Electric HEV	Class 6 Step Van	7000 lb	2010	Cummins ISB-200	Hayward	25,500
Linen Delivery	2011	Freightliner	MT55	Diesel/ Electric HEV	Class 6 Step Van	7000 lb	2011	Cummins ISB-200	Hayward	25,500
Linen Delivery	2011	Freightliner	MT45	Diesel/ Electric HEV	Class 5 Step Van	7000 lb	2011	Cummins ISB-200	Paramount	19,000
Linen Delivery	2011	Freightliner	MT45	Diesel/ Electric HEV	Class 5 Step Van	7000 lb	2011	Cummins ISB-200	Riverside	19,000
Linen Delivery	2011	Freightliner	MT55	Diesel/ Electric HEV	Class 6 Step Van	7000 lb	2010	Cummins ISB-200	Santa Ana	25,500
Linen Delivery	2011	Freightliner	MT45	Diesel/ Electric HEV	Class 5 Step Van	7000 lb	2011	Cummins ISB-200	Santa Ana	19,000
Linen Delivery	2008	Workhorse	W62	Diesel	Class 6 Step Van	7000 lb	2008	Workhorse A-200	Sylmar	23,500
Linen Delivery	2009	Freightliner	MT55	Diesel	Class 6 Step Van	7000 lb	2009	Cummins ISB-200	Sylmar	25,500

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Linen Delivery	2010	Freightliner	MT55	Diesel	Class 6 Step Van	7000 lb	2009	Cummins ISB-200	Sylmar	25,500
Linen Delivery	2009	Freightliner	MT45	Diesel	Class 5 Step Van	7000 lb	2008	Cummins ISB-200	Novato	19,000
Linen Delivery	2008	Workhorse	W62	Diesel	Class 6 Step Van	7000 lb		Workhorse	San Jose	23,500
Linen Delivery	2007	Freightliner	MT55	Diesel	Class 6 Step Van	7000 lb	2006	Cummins ISB-200	Paramount	25,500
Linen Delivery	2009	Freightliner	MT45	Diesel	Class 5 Step Van	7000 lb	2009	Cummins ISB-200	Paramount	19,000
Linen Delivery	2007	Freightliner	MT55	Diesel	Class 6 Step Van	7000 lb	2006	Cummins ISB-200	Riverside	25,500
Linen Delivery	2010	Freightliner	MT55	Diesel	Class 6 Step Van	7000 lb	2009	Cummins ISB-200	Riverside	25,500
Linen Delivery	2010	Freightliner	MT45	Diesel	Class 6 Step Van	7000 lb	2009	Cummins ISB-200	Santa Ana	19,000
Linen Delivery	2009	Freightliner	MT45	Diesel	Class 5 Step Van	7000 lb	2008	Cummins ISB-200	Concord	19,000
Linen Delivery	2013	Freightliner	M2	Diesel	Straight Truck		2012	Cummins ISB-220	Novato	26,000
Food Distribution	2013	Hino	195h	Diesel/ Electric HEV	Class 5 Delivery		2011	Hino J05E-TP	Newark	19,500
Food Distribution	2013	Hino	195h	Diesel/ Electric HEV	Class 5 Delivery		2011	Hino J05E-TP	Newark	19,500
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Costa Mesa	12,000
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Costa Mesa	12,000
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Costa Mesa	12,000
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Costa Mesa	12,000
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Costa Mesa	12,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Costa Mesa	17,000

Vocation	MY	Make	Model	Fuel Type	Vehicle Description	Cargo Mass	Engine MY	Engine	Location	GVWR
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Costa Mesa	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Costa Mesa	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Costa Mesa	17,000
Parcel Delivery	2012	Freightliner	W900 / MT45	Diesel	Step Van	4000 lb	2011	Cummins ISB-200	Costa Mesa	19,500
Parcel Delivery	2012	Freightliner	W900 / MT45	Diesel	Step Van	4000 lb	2011	Cummins ISB-200	Costa Mesa	19,500
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Sun Valley	12,000
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Sun Valley	12,000
Parcel Delivery	2012	Isuzu	Reach	Diesel	Step Van	4000 lb		NPR Diesel	Sun Valley	12,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2011	Freightliner	W700HY / MT45	Diesel/ Electric HEV	Step Van	4000 lb	2011	ISB - 200	Sun Valley	17,000
Parcel Delivery	2013	Freightliner	W900 / MT45	Diesel	Step Van	4000 lb	2012	Cummins ISB-200	Sun Valley	19,500

Appendix B: CARB Executive Orders for Engines Tested as Part of Task 4 and 5

California Environmental Protection Agency AIR RESOURCES BOARD	CUMMINS INC.	EXECUTIVE ORDER A-021-0526 New On-Road Heavy-Duty Engines Page 1 of 2 Pages

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code Sections 39515 and 39516 and Executive Order G-02-003;

IT IS ORDERED AND RESOLVED: The engine and emission control systems produced by the manufacturer are certified as described below for use in on-road motor vehicles with a manufacturer's GVWR over 14,000 pounds. Production engines shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	ENGINE FAMILY	ENGINE SIZES (L)	FUEL TYPE [1]	STANDARDS & TEST PROCEDURE	INTENDED SERVICE CLASS [2]	ECS & SPECIAL FEATURES [3]	DIAGNOSTIC [6]
2010	ACEXH0408BAH	6.7	Diesel	Diesel	MHDD	DDI, TC, CAC, ECM, EGR, OC, PTOX, SCR-U	EMD

PRIMARY ENGINE'S IDLE EMISSIONS CONTROL [5]	ADDITIONAL IDLE EMISSIONS CONTROL [5]
30g	N/A

ENGINE (L)	ENGINE MODELS / CODES (rated power, in hp)
6.7	See attachment for engine models and ratings
*	*
*	*
*	*

* =not applicable; GVWR=gross vehicle weight rating; 13 CCR xyz=Title 13, California Code of Regulations, Section xyz; 40 CFR 86.abc=Title 40, Code of Federal Regulations, Section 86.abc; L=liter; hp=horsepower; kw=kilowatt; hr=hour;

1 CNG/LNG=compressed/liquefied natural gas; LPG=liquefied petroleum gas; E85=85% ethanol fuel; MF=multi fuel a.k.a. BF=bi fuel; DF=dual fuel; FF=flexible fuel;

2 L/M/H HDD=light/medium/heavy heavy-duty diesel; UB=urban bus; HDO=heavy duty Otto;

3 ECS=emission control system; TWC/OC=three-way/oxidizing catalyst; NAC=NOx adsorption catalyst; SCR-U / SCR-N=selective catalytic reduction – urea / – ammonia; WU (prefix) =warm-up catalyst; DPF=diesel particulate filter; PTOX=periodic trap oxidizer; HO2S/O2S=heated/oxygen sensor; HAFS/AFS=heated/air-fuel-ratio sensor (a.k.a. universal or linear oxygen sensor); TBI=throttle body fuel injection; SFI/MFI=sequential/multi port fuel injection; DGI=direct gasoline injection; GCARB=gaseous carburetor; IDI/DDI=indirect/direct diesel injection; TC/SC=turbo/super charger; CAC=charge air cooler; EGR / EGR-C=exhaust gas recirculation / cooled EGR; PAIR/AIR=pulsed/secondary air injection; SPL=smoke puff limiter; ECM/PCM=engine/powertrain control module; EM=engine modification; 2 (prefix)=parallel; (2) (suffix)=in series;

5 ESS=engine shutdown system (per 13 CCR 1956.8(a)(6)(A)(1)); 30g=30 g/hr NOx (per 13 CCR 1956.8(a)(6)(C)); APS=internal combustion auxiliary power system; ALT=alternative method (per 13 CCR 1956.8(a)(6)(D)); Exempt=exempted per 13 CCR 1956.8(a)(6)(B) or for CNG/LNG fuel systems; N/A=not applicable (e.g., Otto engines and vehicles);

6 EMD=engine manufacturer diagnostic system (13 CCR 1971); OBD=on-board diagnostic system (13 CCR 1971.1)

Following are: 1) the FTP exhaust emission standards, or family emission limit(s) as applicable, under 13 CCR 1956.8; 2) the EURO and NTE limits under the applicable California exhaust emission standards and test procedures for heavy-duty diesel engines and vehicles (Test Procedures); and 3) the corresponding certification levels, for this engine family. "Diesel" CO, EURO and NTE certification compliance may have been demonstrated by the manufacturer as provided under the applicable Test Procedures in lieu of testing. (For flexible- and dual-fueled engines, the CERT values in brackets [ ] are those when tested on conventional test fuel. For multi-fueled engines, the STD and CERT values for default operation permitted in 13 CCR 1956.8 are in parentheses.).[4]

in g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	*	*	*	*	15.5	15.5	0.01	0.01	*	*
FEL	*	*	0.33	0.33	*	*	*	*	*	*	*	*
CERT	0.01	0.00	0.17	0.18	*	*	0.00	0.00	0.000	0.000	*	*
NTE	0.21		0.50		*		19.4		0.02		*	

4 g/bhp-hr=grams per brake horsepower-hour; FTP=Federal Test Procedure; EURO=Euro III European Steady-State Cycle, including RMCSET=ramped modal cycle supplemental emissions testing; NTE=Not-to-Exceed; STD=standard or emission test cap; FEL=family emission limit; CERT=certification level; NMHC/HC=non-methane/hydrocarbon; NOx=oxides of nitrogen; CO=carbon monoxide; PM=particulate matter; HCHO=formaldehyde (Rev.: 2007-02-26)

BE IT FURTHER RESOLVED: Certification to the FEL(s) listed above, as applicable, is subject to the following terms, limitations and conditions. The FEL(s) is the emission level declared by the manufacturer and serves in lieu of an emission standard for certification purposes in any averaging, banking, or trading (ABT) programs. It will be used for determining compliance of any engine in this family and compliance with such ABT programs.

BE IT FURTHER RESOLVED: Except in vehicle applications exempted per 13 CCR 1956.8(a)(6)(B), engines in this engine family certified under 13 CCR 1956.8(a)(6)(C) [30 g/hr NOx] and section 35.B.4 of the incorporated "California Exhaust Emissions Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" (HDDE Test Procedures) adopted Dec. 12, 2002, as last amended Sep. 1, 2006, shall be provided with an approved "Certified Clean Idle" label that shall be affixed to the vehicle into which the engine is installed.

California Environmental Protection Agency AIR RESOURCES BOARD	CUMMINS INC.	EXECUTIVE ORDER A-021-0550-1 New On-Road Heavy-Duty Engines Page 1 of 2 Pages

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code Sections 39515 and 39516 and Executive Order G-02-003;

IT IS ORDERED AND RESOLVED: The engine and emission control systems produced by the manufacturer are certified as described below for use in on-road motor vehicles with a manufacturer's GVWR over 14,000 pounds. Production engines shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	ENGINE FAMILY	ENGINE SIZES (L)	FUEL TYPE [1]	STANDARDS & TEST PROCEDURE	INTENDED SERVICE CLASS [2]	ECS & SPECIAL FEATURES [3]	DIAGNOSTIC [4]
2011	BCEXH0408BAH	6.7	Diesel	Diesel	MHDD	DDI, TC, CAC, ECM, EGR, OC, PTOX, SCR-U	EMD

PRIMARY ENGINE'S IDLE EMISSIONS CONTROL [5]	ADDITIONAL IDLE EMISSIONS CONTROL [6]
30g	N/A

ENGINE (L)	ENGINE MODELS / CODES (rated power, in hp)
6.7	See attachment for engine models and ratings

* =not applicable; GVWR=gross vehicle weight rating; 13 CCR xyz=Title 13, California Code of Regulations, Section xyz; 40 CFR 86.abc=Title 40, Code of Federal Regulations, Section 86.abc; L=liter; hp=horsepower; kw=kilowatt; hr=hour;

1 CNG/LNG=compressed/liquefied natural gas; LPG=liquefied petroleum gas; E85=85% ethanol fuel; MF=multi fuel a.k.a. BF=bi fuel; DF=dual fuel; FF=flexible fuel;

2 L/M/H HDD=light/medium/heavy heavy-duty diesel; UB=urban bus; HDO=heavy duty Otto;

3 ECS=emission control system; TWC/OC=three-way/oxidizing catalyst; NAC=NOx adsorption catalyst; SCR-U / SCR-N=selective catalytic reduction – urea / – ammonia; WU (prefix) =warm-up catalyst; DPF=diesel particulate filter; PTOX=periodic trap oxidizer; HO2S/O2S=heated/oxygen sensor; HAFS/AFS=heated/air-fuel-ratio sensor (a.k.a., universal or linear oxygen sensor); TBI=throttle body fuel injection; SFI/MFI=sequential/multi port fuel injection; DGI=direct gasoline injection; GCARB=gaseous carburetor; IDI/DDI=indirect/direct diesel injection; TC/SC=turbo/super charger; CAC=charge air cooler; EGR / EGR-C=exhaust gas recirculation / cooled EGR; PAIR/AIR=pulsed/secondary air injection; SPL=smoke puff limiter; ECM/PCM=engine/powertrain control module; EM=engine modification; 2 (prefix)=parallel; (2) (suffix)=in series;

5 ESS=engine shutdown system (per 13 CCR 1956.8(a)(6)(A)(1)); 30g=30 g/hr NOx (per 13 CCR 1956.8(a)(6)(C)); APS = internal combustion auxiliary power system; ALT=alternative method (per 13 CCR 1956.8(a)(6)(D)); Exempt=exempted per 13 CCR 1956.8(a)(6)(B) or for CNG/LNG fuel systems; N/A=not applicable (e.g., Otto engines and vehicles);

4 EMD=engine manufacturer diagnostic system (13 CCR 1971); OBD=on board diagnostic system (13 CCR 1971.1);

Following are: 1) the FTP exhaust emission standards, or family emission limit(s) as applicable, under 13 CCR 1956.8; 2) the EURO and NTE limits under the applicable California exhaust emission standards and test procedures for heavy-duty diesel engines and vehicles (Test Procedures); and 3) the corresponding certification levels, for this engine family. "Diesel" CO, EURO and NTE certification compliance may have been demonstrated by the manufacturer as provided under the applicable Test Procedures in lieu of testing. (For flexible- and dual-fueled engines, the CERT values in brackets [ ] are those when tested on conventional test fuel. For multi-fueled engines, the STD and CERT values for default operation permitted in 13 CCR 1956.8 are in parentheses.).

in g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.20	0.20	*	*	15.5	15.5	0.01	0.01	*	*
FEL	*	*	0.33	0.33	*	*	*	*	*	*	*	*
CERT	0.01	0.001	0.17	0.18	*	*	0.00	0.30	0.000	0.003	*	*
NTE	0.21		0.50		*		19.4		0.02		*	

* g/bhp-hr=grams per brake horsepower-hour; FTP=Federal Test Procedure; EURO=Euro III European Steady-State Cycle, including RMCSET=ramped modal cycle supplemental emissions testing; NTE=Not-to-Exceed; STD=standard or emission test cap; FEL=family emission limit; CERT=certification level; NMHC/HC=non-methane/hydrocarbon; NOx=oxides of nitrogen; CO=carbon monoxide; PM=particulate matter; HCHO=formaldehyde; (Rev.: 2007-02-26)

BE IT FURTHER RESOLVED: Certification to the FEL(s) listed above, as applicable, is subject to the following terms, limitations and conditions. The FEL(s) is the emission level declared by the manufacturer and serves in lieu of an emission standard for certification purposes in any averaging, banking, or trading (ABT) programs. It will be used for determining compliance of any engine in this family and compliance with such ABT programs.

BE IT FURTHER RESOLVED: Except in vehicle applications exempted per 13 CCR 1956.8(a)(6)(B), engines in this engine family certified under 13 CCR 1956.8(a)(6)(C) [30 g/hr NOx] and section 35.B.4 of the incorporated "California Exhaust Emissions Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" (HDDE Test Procedures) adopted Dec. 12, 2002, as last amended Sep. 27, 2010, shall be provided with an approved "Certified Clean Idle" label that shall be affixed to the vehicle into which the engine is installed.

BE IT FURTHER RESOLVED: That the manufacturer has elected to include engine models in this engine family which are identified for "emergency vehicle use only". These "emergency vehicle use only" engines are exempt from requirements imposed pursuant to California law and the regulations adopted pursuant thereto for motor vehicle pollution control devices per California Vehicle Code Section 27156.2. The manufacturer must clearly label these engines for "emergency vehicle use only" on the engines' emission control label.

BE IT FURTHER RESOLVED: For the listed engine models the manufacturer has submitted the materials to demonstrate certification compliance with 13 CCR 1965 (emission control labels), 13 CCR 1971 (engine manufacturer diagnostic) and 13 CCR 2035 et seq. (emission control warranty).

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code Sections 39515 and 39516 and Executive Order G-02-003,

IT IS ORDERED AND RESOLVED: The engine and emission control systems produced by the manufacturer are certified as described below for use in on-road motor vehicles with a manufacturer's GVWR over 14,000 pounds. Production engines shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	ENGINE FAMILY	ENGINE SIZES (L)	FUEL TYPE [1]	STANDARDS & TEST PROCEDURE	INTENDED SERVICE CLASS [2]	ECS & SPECIAL FEATURES [3]	DIAGNOSTIC [6]
2012	CCEXH0408BAH	6.7	Diesel	Diesel	MHDD	DDI, TC, CAC, ECM, EGR, OC, PTOX, SCR-U	EMD

PRIMARY ENGINE'S IDLE EMISSIONS CONTROL [5]	ADDITIONAL IDLE EMISSIONS CONTROL [5]
30g	N/A

ENGINE (L)	ENGINE MODELS / CODES (rated power, in hp)
6.7	See attachment for engine models and ratings

* = not applicable; GVWR=gross vehicle weight rating; 13 CCR xyz=Title 13, California Code of Regulations, Section xyz; 40 CFR 86.abc=Title 40, Code of Federal Regulations, Section 86.abc; L=liter; hp=horsepower; kw=kilowatt; hr=hour;
[1] CNG/LNG=compressed/liquefied natural gas; LPG=liquefied petroleum gas; E85=85% ethanol fuel; MF=multi fuel a.k.a. BF=bi fuel; DF=dual fuel; FF=flexible fuel;
[2] L/M/H HDD=light/medium/heavy heavy-duty diesel; UB=urban bus; HDO=heavy duty Otto;
[3] ECS=emission control system; TWC/OC=three-way/oxidizing catalyst; NAC=NOx adsorption catalyst; SCR-U / SCR-N=selective catalytic reduction – urea / – ammonia; WU (prefix) =warm-up catalyst; DPF=diesel particulate filter; PTOX=periodic trap oxidizer; HO2S/O2S=heated/oxygen sensor; HAFS/AFS=heated/air-fuel-ratio sensor (a.k.a., universal or linear oxygen sensor); TBI=throttle body fuel injection; SFI/MFI=sequential/multi port fuel injection; DGI=direct gasoline injection; GCARB=gaseous carburetor; IDI/DDI=indirect/direct diesel injection; TC/SC=turbo/super charger; CAC=charge air cooler; EGR / EGR-C=exhaust gas recirculation / cooled EGR; PAIR/AIR=pulsed/secondary air injection; SPL=smoke puff limiter; ECM/PCM=engine/powertrain control module; EM=engine modification; 2 (prefix)=parallel; (2) (suffix)=in series;
[5] ESS=engine shutdown system (per 13 CCR 1956.8(a)(6)(A)(1)); 30g=30 g/hr NOx (per 13 CCR 1956.8(a)(6)(C)); APS=internal combustion auxiliary power system; ALT=alternative method (per 13 CCR 1956.8(a)(6)(D)); Exempt=exempted per 13 CCR 1956.8(a)(6)(B) or for CNG/LNG fuel systems; N/A=not applicable (e.g., Otto engines and vehicles);
[6] EMD=engine manufacturer diagnostic system (13 CCR 1971); OBD=on-board diagnostic system (13 CCR 1971.1);

Following are: 1) the FTP exhaust emission standards, or family emission limit(s) as applicable, under 13 CCR 1956.8; 2) the EURO and NTE limits under the applicable California exhaust emission standards and test procedures for heavy-duty diesel engines and vehicles (Test Procedures); and 3) the corresponding certification levels, for this engine family. "Diesel" CO, EURO and NTE certification compliance may have been demonstrated by the manufacturer as provided under the applicable Test Procedures in lieu of testing. (For flexible- and dual-fueled engines, the CERT values in brackets [ ] are those when tested on conventional test fuel. For multi-fueled engines, the STD and CERT values for default operation permitted in 13 CCR 1956.8 are in parentheses.).

in g/bhp-hr [4]	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.20	0.20	*	*	15.5	15.5	0.01	0.01	*	*
FEL	*	*	0.33	0.33	*	*	*	*	*	*	*	*
CERT	0.01	0.001	0.17	0.18	*	*	0.00	0.00	0.000	0.000	*	*
NTE	0.21		0.50		*		19.4		0.02		*	

[4] g/bhp-hr=grams per brake horsepower-hour; FTP=Federal Test Procedure; EURO=Euro III European Steady-State Cycle, including RMCSET=ramped modal cycle supplemental emissions testing; NTE=Not-to-Exceed; STD=standard or emission test cap; FEL=family emission limit; CERT=certification level; NMHC/HC=non-methane hydrocarbon/hydrocarbon; NOx=oxides of nitrogen; CO=carbon monoxide; PM=particulate matter; HCHO=formaldehyde; (Rev.: 2007-02-26)

BE IT FURTHER RESOLVED: Certification to the FEL(s) listed above, as applicable, is subject to the following terms, limitations and conditions. The FEL(s) is the emission level declared by the manufacturer and serves in lieu of an emission standard for certification purposes in any averaging, banking, or trading (ABT) programs. It will be used for determining compliance of any engine in this family and compliance with such ABT programs.

BE IT FURTHER RESOLVED: Except in vehicle applications exempted per 13 CCR 1956.8(a)(6)(B), engines in this engine family certified under 13 CCR 1956.8(a)(6)(C) [30 g/hr NOx] and section 35.B.4 of the incorporated "California Exhaust Emissions Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" (HDDE Test Procedures) adopted Dec. 12, 2002, as last amended Sep. 27, 2010, shall be provided with an approved "Certified Clean Idle" label that shall be affixed to the vehicle into which the engine is installed.

BE IT FURTHER RESOLVED: That the manufacturer has elected to include engine models in this engine family which are identified for "emergency vehicle use only". These "emergency vehicle use only" engines are exempt from requirements imposed pursuant to California law and the regulations adopted pursuant thereto for motor vehicle pollution control devices per California Vehicle Code Section 27156.2. The manufacturer must clearly label these engines for "emergency vehicle use only" on the engines' emission control label.

BE IT FURTHER RESOLVED: For the listed engine models the manufacturer has submitted the materials to demonstrate certification compliance with 13 CCR 1965 (emission control labels), 13 CCR 1971 (engine manufacturer diagnostic) and 13 CCR 2035 et seq. (emission control warranty).

California Environmental Protection Agency **Air Resources Board**	HINO MOTORS LTD.	EXECUTIVE ORDER A-031-0071-2 New On-Road Heavy-Duty Engines

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code Sections 39515 and 39516 and Executive Order G-02-003;

IT IS ORDERED AND RESOLVED: The engine and emission control systems produced by the manufacturer are certified as described below for use in on-road motor vehicles with a manufacturer's GVWR over 14,000 pounds. Production engines shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	ENGINE FAMILY	ENGINE SIZES (L)	FUEL TYPE [1]	STANDARDS & TEST PROCEDURE	INTENDED SERVICE CLASS [2]	ECS & SPECIAL FEATURES [3]	DIAGNOSTIC [4]
2013	CHMXH05.1JTP	5.123	Diesel	Diesel	LHDD	ECM, EGR, PTOX, OC, TC, CAC, DDI, SCR-U	EMD

PRIMARY ENGINE'S IDLE EMISSIONS CONTROL [5]	ADDITIONAL IDLE EMISSIONS CONTROL [5]
30g	N/A

ENGINE (L)	ENGINE MODELS / CODES (rated power, in hp)
5.123	J05E-TP / 265 (210) ; J05E-TP / 267 (210)
*	*

* =not applicable; GVWR=gross vehicle weight rating; 13 CCR xyz=Title 13, California Code of Regulations, Section xyz; 40 CFR 86.abc=Title 40, Code of Federal Regulations, Section 86.abc; L=liter; hp=horsepower; kw=kilowatt; hr=hour;

1 CNG/LNG=compressed/liquefied natural gas; LPG=liquefied petroleum gas; E85=85% ethanol fuel; MF=multi fuel a.k.a. BF=bi fuel; DF=dual fuel; FF=flexible fuel;

2 L/M/H HDD=light/medium/heavy heavy-duty diesel; UB=urban bus; HDO=heavy duty Otto;

3 ECS=emission control system; TWC/OC=three-way/oxidizing catalyst; NAC=NOx adsorption catalyst; SCR-U / SCR-N=selective catalytic reduction – urea / – ammonia; WU (prefix) =warm-up catalyst; DPF=diesel particulate filter; PTOX=periodic trap oxidizer; HO2S/O2S=heated/oxygen sensor; HAFS/AFS=heated/air-fuel ratio sensor (a.k.a., universal or linear oxygen sensor); TBI=throttle body fuel injection; SFI/MFI=sequential/multi port fuel injection; DGI=direct gasoline injection; GCARB=gaseous carburetor; IDI/DDI=indirect/direct diesel injection; TC/SC=turbo/super charger; CAC=charge air cooler; EGR / EGR-C=exhaust gas recirculation / cooled SCR; PAIR/AIR=pulsed/secondary air injection; SPL=smoke puff limiter; ECM/PCM=engine/powertrain control module; EM=engine modification; 2 (prefix)=parallel; (2) (suffix)=in series;

5 ESS=engine shutdown system (per 13 CCR 1956.8(a)(6)(A)(1)); 30g=30 g/hr NOx (per 13 CCR 1956.8(a)(6)(C)); APS =internal combustion auxiliary power system; ALT=alternative method (per 13 CCR 1956.8(a)(6)(D)); Exempt=exempted per 13 CCR 1956.8(a)(6)(B) or for CNG/LNG fuel systems; N/A=not applicable (e.g., Otto engines and vehicles)

4 EMD=engine manufacturer diagnostic system (13 CCR 1971); OBD(F) / (P) / (S)=full / partial / parts with fine / on-board diagnostic [2009August06]

Following are: 1) the FTP exhaust emission standards, or family emission limit(s) as applicable, under 13 CCR 1956.8; 2) the EURO and NTE limits under the applicable California exhaust emission standards and test procedures for heavy-duty diesel engines and vehicles (Test Procedures); and 3) the corresponding certification levels, for this engine family. "Diesel" CO, EURO and NTE certification compliance may have been demonstrated by the manufacturer as provided under the applicable Test Procedures in lieu of testing. (For flexible- and dual-fueled engines, the CERT values in brackets [ ] are those when tested on conventional test fuel. For multi-fueled engines, the STD and CERT values for default operation permitted in 13 CCR 1956.8 are in parentheses.)

in g/bhp-hr	NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
STD	0.14	0.14	0.20	0.20	*	*	14.4	15.5	0.01	0.01	*	*
FEL	*	*	*	*	*	*	*	*	*	*	*	*
CERT	0.001	0.000	0.17	0.19	*	*	0.01	0.00	0.004	0.001	*	*
NTE	0.21		0.30		*		19.4		0.02		*	

* g/bhp-hr=grams per brake horsepower-hour; FTP=Federal Test Procedure; EURO=Euro III European Steady-State Cycle, including RMCSET=ramped modal cycle supplemental emissions testing; NTE=Not-to-Exceed; STD=standard or emission test cap; FEL=family emission limit; CERT=certification level; NMHC/HC=non-methane/hydrocarbon; NOx=oxides of nitrogen; CO=carbon monoxide; PM=particulate matter; HCHO=formaldehyde. (Rev.: 2007-02-26)

BE IT FURTHER RESOLVED: Certification to the FEL(s) listed above, as applicable, is subject to the following terms, limitations and conditions. The FEL(s) is the emission level declared by the manufacturer and serves in lieu of an emission standard for certification purposes in any averaging, banking, or trading (ABT) programs. It will be used for determining compliance of any engine in this family and compliance with such ABT programs.

BE IT FURTHER RESOLVED: For the listed engine models the manufacturer has submitted the materials to demonstrate certification compliance with 13 CCR 1965 (emission control labels), 13 CCR 1971 (engine manufacturer diagnostic system), and 13 CCR 2035 et seq. (emission control warranty).

BE IT FURTHER RESOLVED: Except in vehicle applications exempted per 13 CCR 1956.8(a)(6)(B), engines in this engine family certified under 13 CCR 1956.8(a)(6)(C) [30 g/hr NOx] and section 35.B.4 of the incorporated "California Exhaust Emissions Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles" adopted Dec. 12, 2002, as last amended Mar. 22, 2012, shall be provided with an approved "Certified Clean Idle" label that shall be affixed to the vehicle into which the engine is installed.

Engines certified under this Executive Order must conform to all applicable California emission regulations.
The Bureau of Automotive Repair will be notified by copy of this Executive Order.
This Executive Order hereby supersedes Executive Order A-031-0071-1 dated October 1, 2012.

Executed at El Monte, California on this 6 day of November 2012.

Annette Hebert

Annette Hebert, Chief
Mobile Source Operations Division

California Environmental Protection Agency AIR RESOURCES BOARD	ISUZU MOTORS LIMITED	EXECUTIVE ORDER A-020-0252 New Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles Page 1 of 2

Pursuant to the authority vested in the Air Resources Board by Health and Safety Code (HSC), Div. 26, Part 5, Chap. 2; and pursuant to the authority vested in the undersigned by HSC Sections 39515-39516 and Executive Order G-02-003;

IT IS ORDERED AND RESOLVED: That the following exhaust and evaporative emission control systems produced by the manufacturer are certified as described below. Production vehicles shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	TEST GROUP	VEHICLE TYPE (PC=passenger car; LDT=light-duty truck; MDV=medium-duty vehicle; LVW=loaded vehicle weight; ALVW=adjusted LVW)	EXHAUST EMISSION STANDARD CATEGORY (LEV=low emission vehicle; TLEV=transitional LEV; ULEV=ultra LEV; SULEV=super ULEV)	EXHAUST/OBD/EVAPORATIVE USEFUL LIFE (UL) (miles)	FUEL TYPE (CNG/LNG=compressed/liquefied natural gas; LPG=liquefied petroleum gas)
2012	CSZXD03.0SFA	MDV: 10001-14000# GVW	LEV II ULEV	120K / *	Diesel

No.	EVAPORATIVE FAMILY (EVAF)	No.	SPECIAL FEATURES & EMISSION CONTROL SYSTEMS (ECS) * = not applicable
1	*	1	DOI HO2S, EGR, NOS(2), CAC, TC, OC, PTOX, SCR-U, OBD (P)
2	*	2	*
3	*	3	*
4	*	4	*
5	*	5	*
6	*	6	*

OC/TWC=oxidizing/3-way cat. ADS/TWC=adsorbing TWC; WU=warm-up cat.; O2S/HO2S=oxygen sensor/heated O2S; AFS/HAFS=air-fuel ratio sensor/heated AFS; EGR=exhaust gas recirculation; NSC=NOx storage catalyst; DDI=Direct Diesel Injection; DPF=Diesel Particulate Filter; PTOX=periodic trap oxidizer; AIR/PAIR=secondary air injection/pulsed AIR; MFI/SFI=multiport fuel injection/sequential MFI; TBI=throttle body injection; TC/SC=turbo/super charger; CAC=charge air cooler; NOS=NOx sensor; SCR-U=selective catalytic reduction-urea; OBD (F)/(P)=full/partial on-board diagnostic; prefix 2=parallel; (2) suffix=series

EVAF No.	ECS No.	ENGINE SIZE (L)	VEHICLE MAKES & MODELS / VEHICLES SUBJECT TO SFTP STANDARDS ARE UNDERLINED
*	1	3.0	ISUZU: NPR DIESEL, WALK IN VAN
*	*	*	

The exhaust and evaporative emission standards (STD) and certification emission levels (CERT) for the listed vehicles are as follows (compliance with the 50 °F testing requirement (for TLEV, LEV, ULEV, SULEV) may have been met based on the manufacturer's submitted compliance plan in lieu of testing). Any debit in the manufacturer's "NMOG Fleet Average" (PC and LDT) or "Vehicle Equivalent Credit" (MDV) compliance plan shall be equalized as required. (For bi-, dual- or flexible-fueled vehicles, the STD and CERT in parentheses are those applicable to testing on gasoline test fuel.)

CH4=methane; NMOG=non-CH4 organic gas; NMHC=non-CH4 hydrocarbon; CO=carbon monoxide; NOx=oxides of nitrogen; HCHO=formaldehyde; PM=particulate matter; RAF=reactivity adjustment factor; 3&2 D (g/test)=3/2 day diurnal+hot soak; RL (g/mi)=running loss; ORVR (g/gallon dispensed)=on-board refueling vapor recovery; (g/mi)=grams/mile; (mg/mi)=milligrams/mile; K=1000 miles; FTP=Federal Test Procedure; SFTP=supplemental federal test procedure

NMOG Fleet Average (g/mi) CERT	NMOG Fleet Average (g/mi) STD		NMOG @ RAF / CH4 RAF = * NMOG CERT (g/mi)	NMHC CERT (g/mi)	NMOG or NMHC STD (g/mi)	CO (g/mi) CERT	CO (g/mi) STD	NOx (g/mi) CERT	NOx (g/mi) STD	HCHO (mg/mi) CERT	HCHO (mg/mi) STD	PM (g/mi) CERT	PM (g/mi) STD	Hwy NOx (g/mi) CERT	Hwy NOx (g/mi) STD
*	*	@ 50K	*	*	*	*	*	*	*	*	*	*	*	*	*
		@ UL	*	0.005	0.167	0.06	7.3	0.4	0.4	8	21	0.004	0.06	0.02	0.3
		@ 50°F & 4K	*	*	*	*	*	*	*	*	*	*	*	*	*

CO (g/mi) @ 20°F & 50K		SFTP 1 = @ 4K (SULEV, ULEV, LEV) or 50K (Tier 1, TLEV); SFTP 2 = @ UL (Tier 1, TLEV)	NMHC+NOx (g/mi) (composite) CERT	NMHC+NOx (composite) STD	CO (g/mi) (composite) CERT	CO (composite) STD	NMHC+NOx (g/mi) (US06) CERT	NMHC+NOx (US06) STD	CO (g/mi) (US06) CERT	CO (US06) STD	NMHC+NOx (g/mi) (SC03) CERT	NMHC+NOx (SC03) STD	CO (g/mi) (SC03) CERT	CO (SC03) STD
CERT	*	SFTP 1	*	*	*	*	*	*	*	*	*	*	*	*
STD	*	SFTP 2	*	*	*	*	*	*	*	*	*	*	*	*

@ UL	EVAP. FAMILY 1 3-D	2-D	RL	ORVR	EVAP. FAMILY 2 3-D	2-D	RL	ORVR	EVAP. FAMILY 3 3-D	2-D	RL	ORVR	EVAP. FAMILY 4 3-D	2-D	RL	ORVR
CERT	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
STD	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

BE IT FURTHER RESOLVED: That for the listed vehicle models, the manufacturer has attested to compliance with Title 13, California Code of Regulations, (13 CCR) Sections 1965 [emission control labels], 1968.2 [on-board diagnostic, full or partial compliance], 2035 et seq. [emission control warranty], 2235 [fuel tank fill pipes and openings] (gasoline and alcohol fueled vehicles only), and "High-Altitude Requirements" and "Inspection and Maintenance Emission Standards" (California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model PC, LDT and MDV).

BE IT FURTHER RESOLVED: That the listed vehicle models are conditionally certified in accordance with 13 CCR Section 1968.2(k) (deficiency and fines provisions for certification of malfunction and diagnostic system) because the on-board diagnostic II (OBD) system of the listed vehicle models has been determined to have nine deficiencies. The listed vehicle models are approved subject to the manufacturer paying a fine of $150 per vehicle for the fourth through ninth deficiencies in the listed test group that is produced and delivered for sale in California. On a quarterly basis, the manufacturer shall submit to the Air Resources Board reports of the number of vehicles produced and delivered for sale in California and pay the full fine owed for that quarter pursuant to this conditional certification. Payment shall be made payable to the State Treasurer for deposit in the Air Pollution Control Fund no later than thirty (30) days after the end of each calendar quarter during the 2012 model-year production period. Failure to pay the quarterly fine in full, in the time provided, may be cause for the Executive Officer to rescind this conditional certification, effective from the start of the quarter in question, in which case all vehicles covered under this conditional certification for that quarter and all future quarters would be deemed uncertified and subject to a civil penalty of up to $5000 per vehicle pursuant to HSC Section 43154.