Draft Proposal

Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles

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Check if applicable:
Animal subjects _______
Human subjects __X____

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Abstract

The implementation of stringent NO_x standards for 2010 heavy-duty engines is an important step for the State of California to meet upcoming ambient air quality standards for ozone and PM. These standards are primarily being met with selective catalytic reduction (SCR) aftertreatment systems. SCR reduces NO_x in the exhaust stream, but requires adequate temperatures (typically at least 200°C) for the reduction to take place. However, there will be times when this temperature requirement is not met, such as right after engine start and during low loads experienced when the engine is idling, or when the vehicle is moving slowly on flat terrain. The frequency of low temperature and low duty operations varies for a truck depending on its type of vocation. In line-haul application a truck operates mostly with high load to maintain high-speed cruise, while the other trucks operate with frequent stops in local goods delivery application. As a truck activity changes, SCR functionality of the truck changes with implications for NO_x reduction using SCR. Therefore, it is critical to characterize heavy-duty diesel truck activity profiles including duty cycles, number of engine starts, and engine soak time distributions, for trucks by vocation. The heavy-duty diesel truck activity profiles are fundamental for updating emission inventories, quantifying real-world NO_x emissions from trucks meeting the new 2010 NO_x certification standard, and determining if the certification standard should be revised.

The objective of this research is to characterize the heavy-duty truck activity profiles (e.g., duty cycles, starts and soak time) for different types of vocational uses (line haul, drayage, delivery, etc.) with the specific goal of identifying what fraction of the vehicle operation may be such that Selective Catalytic Reduction (SCR) functionality is challenged. The research will also put these results in context of the emission certification test cycle and provide an analysis of the representativeness of the certification cycle to real world emissions of nitrogen oxide (NO_x) for the different types of heavy duty vehicles. The results will be used to improve heavy duty NO_x emissions models, and to take a critical look at whether certification and compliance procedures need to be updated to account for the functionality of SCR.

Introduction

For the State of California to meet upcoming ambient air quality standards for ozone and PM, considerable reductions in NO_x emissions are needed. To achieve some of these reductions the NO_x emission standard for heavy-duty on-road engines was reduced by 90 percent in 2010. Diesel engine manufacturers are in most cases using advanced engine exhaust aftertreatment, specifically SCR, to meet the new standard. SCR reduces NO_x in the exhaust stream, but requires adequate temperatures for the reduction to take place. Typically, the SCR needs to be at least 200°C before significant NO_x reduction is achieved. However, there will be times when this temperature requirement is not met, such as right after engine start and during low loads experienced when the engine is idling, or when the vehicle is moving slowly on flat terrain. The frequency of low temperature and low duty operations varies for a truck depending on its type of vocation. In line-haul application a truck operates mostly with high load to maintain high-speed cruise, while the other trucks operate with frequent stops in local goods delivery application. As a truck activity changes, SCR functionality of the truck changes with implications for NO_x reduction using SCR. Therefore, it is critical to characterize heavy-duty diesel truck activity profiles including duty cycles, number of engine starts, and engine soak time distributions, for trucks by vocation. The heavy-duty diesel truck activity profiles are fundamental for updating emission inventories, quantifying real-world NO_x emissions from trucks meeting the new 2010 NO_x certification standard, and determining if the certification standard should be revised.

This draft research proposal is the College of Engineering – Center for Environmental Research and Technology (CE-CERT), University of California at Riverside (UCR) response to the solicitation on "Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles".

Project Objectives

The objective of this research is to characterize the heavy-duty truck activity profiles (e.g., duty cycles, starts, and soak time) for different types of vocational uses (line haul, drayage, delivery, etc.) with the specific goal of identifying what fraction of the vehicle operation may be such that Selective Catalytic Reduction (SCR) functionality is challenged. The research should also put these results in context of the emission certification test cycle and provide an analysis of the representativeness of the certification cycle to real world emissions of nitrogen oxide (NO_x) for the different types of heavy duty vehicles. The results will be used to improve heavy duty

NO_x emissions models, and to take a critical look at whether certification and compliance procedures need to be updated to account for the functionality of SCR.

Project Approach

Collecting data on heavy-duty truck activity and SCR inlet temperatures will greatly help provide a better understanding of the relationship between vehicle operation and SCR performance on a fleet basis. This will allow modelers to quantify the impact of $deNO_x$ performance issues due to low SCR temperatures on the California NO_x inventory. Unfortunately, SCR inlet temperatures are a function of soak time, soak conditions, duty cycle, ECU calibration, model year, vehicle weight, and possibly many other factors, which vary by truck engine, category, and vocational use. There are 68 different SCR-equipped engines sold in California, see Appendix B. Additionally, there are 27 different truck categories in EMFAC2011, see Appendix A, some of which have multiple vocation types. Thus, the approach to data collection in this research needs to be strategic where a combination of data collection methods will be used to collect data from targeted truck categories and vocation types.

This section describes UCR's approach and discusses tradeoffs and recommendations for achieving useful information to help quantify the impact of low temperature SCR performance. The approach to our proposal is slightly different than outlined in the original solicitation. The main differences are regarding the travel diaries, recruiting, and data logging.

We clearly understand the objective of this research as set forth by the California Air Resources Board (CARB), and are strongly confident that we have the necessary skills and experience to accomplish it. In doing so, there are several aspects to the project that need to be considered as discussed in this section to provide the context to our statement of work in the technical plan.

EMFAC screening

California motor vehicle emission inventory model, EMFAC2011, categorizes medium (T6) and heavy (T7) heavy-duty diesel trucks by a combination of their geological operation boundaries and vocational uses (Appendix A). Further truck class categorization by the type of vocation is critical to understand truck activity profiles to estimate SCR functionality and to quantify emissions. For instance, current T6 instate heavy-duty trucks operate in multiple vocations including beverage distribution, mail delivery, local goods delivery and others. It is believed that activity profiles from a mail delivery truck, which may include multiple short trips (short soak time) with low exhaust temperature, will be different from a beverage distribution truck making longer soak duration while loading and unloading. Although the two trucks are in the same T6 instate truck category, the difference of their activity profiles may be statistically significant. The contractor will investigate types of vocations for each truck class in EMFAC2011, and conduct a screening analysis of identifying truck vocational use types by the magnitude of NO_x emissions. Based on this screening analysis results, Tasks 2 and 3 will be conducted.

Recruiting issues

It is not possible to include every truck categories in EMFAC2011 in this research. Instead, only selected truck categories that contribute the most to the state's NO_x emission inventories will be included. Then, major vocation types within the selected truck categories will be identified, and truck activity data from these vocation types collected and analyzed. Since we will sample trucks only from specific categories and vocations types, the recruitment will be quite challenging, especially for an emissions-related project under the current regulatory climate. Perhaps, the truck recruitment will be the most difficult part of this project. At the same time, it is the most critical part as we will not be able to proceed to collect and analyze data without a successful truck recruitment campaign.

Therefore, we are structuring our scope of work slightly different from what is stated in the solicitation. In our draft scope of work, truck recruitment will be a dedicated task that commands a certain amount of time and resources. This task will immediately follow the truck screening analysis and sampling design task. At the middle of the truck recruitment task and before the truck data collection task begins, a project status review will be conducted along with CARB to review the number of trucks successfully recruited. Then, a decision will be made whether and how to move forward with the remaining tasks. If the number of trucks recruited meets a target, then the project can proceed as planned. If the number of trucks recruited misses the target slightly, then additional project time and resources may be given or the targets may be adjusted. However, if it proves too difficult or impossible to recruit trucks that fit specific category and vocation type profiles to participate in this research, then CARB may terminate the project or request that a new proposal with a drastic change in research approach be submitted.

Data collection considerations

Another consideration in this research concerns truck data collection methods and their tradeoffs. Three methods are being considered, including: 1) travel diary survey, 2) ECU data logging, and 3) GPS data logging. A summary of their pros and cons is provided in Table 1.

Table 1. Pros and cons of truck data collection methods being considered

Method	Pros	Cons
Travel diary survey	• Lowest cost per sample, thus allowing for larger sample size • Least invasive, which may make truck recruitment easier • Provide qualitative data (e.g., trip purpose) in addition to quantitative data	• Short data collection period (typically 1-2 weeks) • Semi-subjective and prone to human errors (e.g., underreported trips) • Only provide trip-related data; no detailed vehicle or engine operation data
ECU data logging	• Provide vehicle speed and engine operation data (e.g., engine RPM, fuel rate, etc.), including exhaust temperature, which is the key parameter of interest • High resolution data (e.g., 1 Hz) for long period (several months)	• Expensive data logger (~$1,400 per unit) • Most invasive as the data logger needs to be attached to the vehicle's J1939 port
GPS data logging	• Provide vehicle location data in addition to vehicle speed, thus enabling spatial analyses (e.g., road type identification) • High resolution data (e.g., 1 Hz) for long period (several months) • Inexpensive data logger (~$200-$400 per unit)	• GPS "tracking" sometime leads to privacy concerns although the data will be scrubbed to protect vehicle identity.

- *Travel diary survey plus ECU data logging* – Travel diary surveys can be used to collect truck trip data from a large number of trucks while ECU data logging is used to collect vehicle and engine operation data from a small subset of these trucks.

- *Travel diary survey plus GPS data logging* – Travel diary surveys can be used to collect truck trip data from a large number of trucks while GPS data logging is used to collect vehicle speed and location data from a subset of these trucks.

- *ECU-only or GPS-only data logging* – All quantitative trip information that can be derived from travel diary survey data, including the number of engine starts per day and soak time distribution per day, can also be derived from ECU or GPS data. If the qualitative trip information such as trip purpose is not deemed critical to meeting the objective of this research, then ECU or GPS data logging alone may be used to collect data from a larger number of trucks. While the data collection costs will be higher, the derived trip information will be more accurate. Also, the duty cycles developed will be more representative as they will be based on a larger data set.

- *ECU+GPS data logging* – A GPS receiver can be added to the ECU data logger (at an additional cost) so that the logged data include vehicle location that is time-synchronized with vehicle speed and engine operation data.

We understand that the choice of data collection method(s) will be also based on the costs. We are open to discussion with CARB to find an optimal solution that will satisfy both the objective and budget of this research. As a general idea, we provide rough cost estimates of some example options in Table 3. Detailed cost breakdown for each option is provided in the Budget section.

We feel that the best data collection approach may be a combination of ECU and GPS-only data loggers. This approach reduces the hardware costs as compared to using ECU loggers for all truck samples while still providing both vehicle/engine operation and vehicle location data. The ECU+GPS data loggers can be strategically installed on a subset of truck samples in all the selected truck categories and vocation types. Or, they can be strategically installed on only a few targeted vocation types that are likely to have low-load duty cycles based on some perspective on fleet operations. In addition, there may be some possibility to move the ECU+GPS data loggers around depending on the fleet.

Technical Plan

The following technical plan is broken down in to five tasks. Task 1 focuses on a strategic screening effort using EMFAC2011, Task 2 discusses the travel diary and recruiting efforts, Task 3 describes the recommended data collection method, Task 4 describes the data analysis approach, and Task 5 provides the details on the data reporting.

Task 1. Screening analysis

We will conduct a screening analysis of the 27 truck categories in EMFAC and select a subset of categories that contributes the most to the state's NO_x emission inventories. The screening analysis will rely on EMFAC2011 and, to the extent that is applicable, MOVES2010b. In addition, recent literature on NO_x emissions from different categories of trucks will be reviewed and, if relevant, used to augment the selection of truck categories to be included for the next tasks. After that, we will identify major vocation types within each truck category and design a sampling strategy for truck recruitment. The essence of Task 1 is to identify the magnitude of NO_x emissions by types of vocational uses for heavy-duty diesel trucks.

Task 2a. Truck diary survey

The solicitation recommended performing a truck travel diary surveys to be used to quantify the number of engine starts per day, soak time distribution, and other trip related details. Table 2 shows the list of information recommended as part of the truck travel diary survey.

Table 2. Information Included in Truck Travel Diary Survey

Vehicle and Engine Information	Vehicle and Engine Activity Information
Vocational use	Engine start time
Vehicle type	Engine stop time
Axle configuration	Trip purpose
Vehicle model year	Odometer reading at the first engine start
VIN number	Odometer reading at each engine stop
Vehicle weight	PTO use time (if applicable)
Engine make	
Engine size	
Engine model	
Engine model year	

Based on the discussion above, UCR believes the value of the driver survey is less likely to provide the needed data to characterize the goals of this project. Thus, the truck diary survey is only provided as an optional cost as listed in Table 6 in the Budget section.

Task 2b. Truck recruitment

We will set up one or two subawards specifically for truck recruitment. Each subaward is anticipated to be $25,000 for recruiting 100 trucks. This will require approximately 20 participating fleets assuming an average of five trucks per fleet. We have a good working relationship with the National Renewable Energy Laboratory (NREL) hybrid demonstration team The NREL hybrid team has a large resource of green fleets throughout California. The NREL fleet includes parcel, refuse, bucket, utility, and grocery Class 4, 7, and 8 diesel vehicles. In addition, UCR has good relationships with Tiax, Environ, and Digital Geographic who have completed several vehicle activity studies in the Ports of Los Angeles and Long Beach.

Furthermore, SCAQMD is also very interested in the inventory of NO_x emissions in light of the degraded performance of SCR systems and has agreed to help us find participating fleets. We also have good direct contacts with several local fleets that we can pursue. In addition, UCR realizes that CARB and many of the air districts have fleet contacts that could be utilized to facilitate getting fleet participation over the range of vocation types needed. Thus, we believe that the fleet participation can be addressed in this scope of work where the amount of effort will depend on the final scope of work.

Our approach to perusing recruitment will start with completing Task 1 then use that list of selected vehicle categories to query our sub award participants. Those participants who meet our requirements will be selected. Once the subcontractor is selected, we will work with them to solicit California fleets for our data logging requests. GPS data is an issue with many fleets due to privacy. In the past UCR has shifted the GPS data to make vehicle tracking unavailable. This will be proposed to the fleets if necessary. Those fleets that agree or who are interested will work with UCR for the final data logging installation.

Task 3. Data collection

This task requests that the contractor collect instantaneous engine operation data and develop truck activity profiles for each vocational use. Instantaneous engine operation data can be acquired by engine control unit (ECU) or on-board diagnostic (OBD) data loggers, and should be collected on at least five trucks. As the contractor collects ECU/OBD data from a truck, it is required to collect vehicle and engine information from the truck and to conduct a truck travel diary survey for the truck. In addition to ECU/OBD data, if applicable, it is suggested to collect vehicle position data by global positioning system (GPS), which are time-synchronized with ECU/OBD data. Table 2 shows vehicle and engine information, and ECU/OBD/GPS data to be collected in this task. The contractor should develop truck activity profiles, which include duty cycles, the number of starts per day and the soak time duration per day for each truck use type by vocation, by using the vehicle and engine information and ECU/OBD data, and conduct comparison analysis of the truck activity profiles to the truck diary survey results obtained from the task 2. If GPS data can be collected, the contractor should develop GPS data-based duty cycles and vehicle operation time and speed profiles by road facility type. GPS data-based duty cycles can be developed through a modal modeling concept such as physical emission rate estimator (PERE) applied to U.S. EPA motor vehicle emissions simulator (MOVES).

In general the main goal for Task 3 is to collect ECU data and develop truck activity profiles for each truck use type by vocation

Table 3. Vehicle and Engine Information, ECU/OBD/GPS Data

Vehicle and Engine Information	ECU/OBD/GPS Data
Vocational use	Vehicle speed
Vehicle type	Engine horsepower
Axle configuration	Engine RPM
Vehicle model year	Fuel rate
VIN number	Exhaust temperature
Vehicle weight	Truck location (optional)
Engine make	
Engine size	
Engine model	
Engine model year	

We will discuss with CARB to agree on the most appropriate truck data collection option for this project, and proceed to collect truck data accordingly. In the case of travel diary survey, we will sub one or two contractors to perform the survey. The Transportation Sustainability Research Center (TSRC) at University of California at Berkeley (UCB), who has numerous experiences conducting this type of survey, has committed to be a sub to survey truck fleets in Northern California. In addition, they will assist with data logger installation and serve as an interface with those truck fleets. We are in discussion with another party who will play a similar role in Southern California. In the case of vehicle instrumentation with ECU-only, GPS-only, or ECU+GPS data loggers, we will procure the data loggers, set up wireless data communication channels and data server, and perform the installation. The ECU and GPS data will be logged at 1 Hz (i.e., second-by-second). We will also perform the uninstallation of the data loggers at the end of the data collection period.

Task 4. Analysis

The contractor will analysis of the representativeness of the certification cycle by comparing to the duty cycles developed in Task 3 for truck use types by vocation. The contractor should deliver the difference between the certification cycle and the duty cycle with statistics including speed, travel duration, acceleration, deceleration and others. Thus, the focus of Task 4 is the analysis of the representativeness of the certification cycle to developed duty cycles for each vocational use.

For each truck category and vocation type, we will analyze the ECU and/or GPS data to determine number of (cold) starts per day, soak time distribution per day, and other trip statistics (e.g., average distance, average duration, average speed, etc.). If travel diary survey is added, we will compare these trip statistics with those derived from the survey and make adjustments accordingly. Using second-by-second vehicle speed from the ECU and/or GPS data for each truck category and vocation type, we will also develop a representative chassis duty cycle and compare it with the certification cycle. If the GPS data is available, we will also GPS data-based chassis duty cycles by road facility type. The comparison between the developed duty cycles and the certification cycle will be performed in several ways, including, but not limited to:

- Create joint speed-acceleration frequency distributions of the developed duty cycle and the certification duty cycle, and then calculate the total absolute difference of the speed-acceleration cells.
- Create speed, acceleration, and vehicle-specific power distributions of the developed duty cycle and the certification duty cycle, and then conduct the Kolmogorov-Smirnov test to test a null hypothesis that the distributions of the developed duty cycle and the certification duty cycle are from the same population.

Task 5. Final Report

A final report will be provided to CARB that will include a description of the screening results, recruiting approach, the data logging methods and difficulties, data analysis and results. The results will include vocation type comparison to certification duty cycles including statistics of speed, duration, acceleration, and ECU data if available.

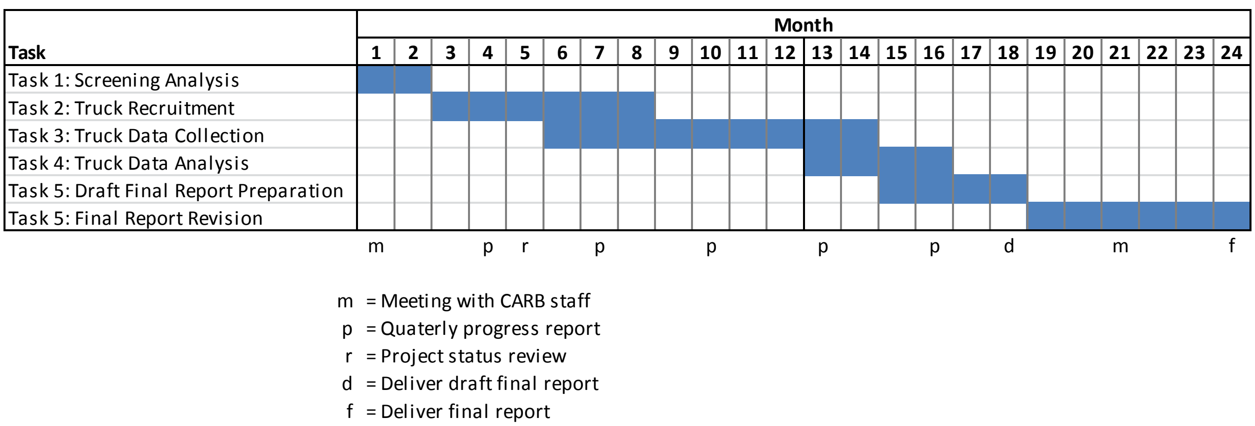
CE-CERT will have a Kick-Off meeting with ARB staff prior to the commencement of the project and prior to commencing the dialoging portion of the project. In addition, at the conclusion of the project, CE-CERT will present the results to CARB staff.

Project Schedule

The duration of this proposed project will be completed in 24 months from the start date. This includes 6 months for CARB review of the draft final report and delivery of a revised final report and data files to CARB. The project schedule is shown in Table 4

Are project review is proposed at the middle of the truck recruitment task and before the truck data collection task begins, to assess the number of trucks successfully recruited. A decision will be made whether and how to move forward with the remaining tasks. If the number of trucks recruited meets a target, then the project can proceed as planned. If the number of trucks recruited misses the target slightly, then additional project time and resources may be given or the targets may be adjusted. However, if it proves too difficult or impossible to recruit trucks that fit specific category and vocation type profiles to participate in this research, then CARB may terminate the project or request that a new proposal with a drastic change in research approach be submitted.

Table 4. Project schedule (in months)



Project Budget

The total cost for the proposed project is $299,527. This total budget includes the screening effort, recruiting 100 trucks from 20 fleets, installing 100 GPS – only data loggers, analyzing the data with a focus on the certification level for NOx emissions and providing a comprehensive summary report. In addition the total cost covers quarterly progress reports, status updates, and technical discussions with ARB.

The budget only includes GPS data loggers. The GPS loggers are capable of providing real time vehicle activity data that can be analyzed for and basic duty cycle information. Engine load can be estimated from accelerations, grade, and other details from this real time data. However, to understand engine load and true SCR performance, UCR recommends installing some ECU loggers on critical vocations. If 20 of the GPS units are replaced with ECU loggers this will provide additional engine related information such as exhaust temperatures, engine load, and other engine related information. The upgrade to 20 ECU loggers and 80 GPS loggers will increase the total project from $299k to $362k. To increase the scope of work from 100 units tested to 200 units would be $452k, see Table 6.

The budget does not include the truck diary surveys as listed in the original solicitation. The truck diary survey can be added to the scope of work. Table 6 shows option 1 with 200 travel diaries and 50 GPS loggers. Several other combinations of ECM, GPS, and travel diaries can be considered and discussed with ARB if needed.

Table 5. Total project budget for 100 GPS no travel diaries

Task	Labor	Fringe Benefits	Sub Awards	Equip	Travel	EDP	Copy Print	Mail Phone Fax	Materials Supplies	Analysis	Misc.	Overhead	Total
1	$ 11,681	$ 5,861	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 6,315	$ 23,857
2	$ 9,639	$ 4,338	$23,000	$ -	$ 2,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 14,032	$ 53,009
3	$ 27,169	$ 14,594	$ -	$ -	$ 4,000	$ -	$ -	$ -	$ 51,900	$ -	$ -	$ 35,158	$ 132,821
4	$ 17,796	$ 9,254	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,738	$ 36,788
5	$ 24,941	$ 13,068	$ -	$ -	$ 1,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 14,043	$ 53,052
Totals	$ 91,226	$ 47,115	$23,000	$ -	$ 7,000	$ -	$ -	$ -	$ 51,900	$ -	$ -	$ 79,286	$ 299,527

Table 6. Optional Task 3 budgets listed by category and overall project cost

Data Options	Op #1	Op #2	Op #3
Description	200 travel diaries 50 GPS	180 GPS 20 ECM	80 GPS 20 ECM
Labor	$ 22,035	$ 37,437	$ 27,169
Fring	$ 11,552	$ 20,677	$ 14,594
Materials	$ 46,400	$ 130,900	$ 80,700
Travel	$ 4,000	$ 4,000	$ 4,000
Subs	$ 100,000	$ 23,000	$ 23,000
Misc	$ 34,837	$ 50,184	$ 32,880
Overhead	$ 13,399	$ 19,301	$ 12,646
Total	$ 232,223	$ 285,499	$ 194,989
Total Project	$ 399,339	$ 452,615	$ 362,105

References

Appendix A

Table A-1. 27 EMFAC2011 T6 and T7 Diesel Vehicle Categories

Truck Category	Description
T6 Ag	Medium-Heavy Duty Diesel Agriculture Truck
T6 CAIRP heavy	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs
T6 CAIRP small	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs
T6 instate construction heavy	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs
T6 instate construction small	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs
T6 instate heavy	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs
T6 instate small	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs
T6 OOS heavy	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs
T6 OOS small	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs
T6 Public	Medium-Heavy Duty Diesel Public Fleet Truck
T6 utility	Medium-Heavy Duty Diesel Utility Fleet Truck
T7 Ag	Heavy-Heavy Duty Diesel Agriculture Truck
T7 CAIRP	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
T7 CAIRP construction	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck

T7 NNOOS	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck
T7 NOOS	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck
T7 other port	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
T7 POAK	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
T7 POLA	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
T7 Public	Heavy-Heavy Duty Diesel Public Fleet Truck
T7 Single	Heavy-Heavy Duty Diesel Single Unit Truck
T7 single construction	Heavy-Heavy Duty Diesel Single Unit Construction Truck
T7 SWCV	Heavy-Heavy Duty Diesel Solid Waste Collection Truck
T7 tractor	Heavy-Heavy Duty Diesel Tractor Truck
T7 tractor construction	Heavy-Heavy Duty Diesel Tractor Construction Truck
T7 utility	Heavy-Heavy Duty Diesel Utility Fleet Truck
PTO	Power Take Off

Appendix B

Table B-1 Certified hhdd and mhdd diesel engines sold in California equipped with SCR

2010			2011			2012			2013		
Name	Type	Disp	Name	Type	Disp	Name	Type	Disp	Name	Type	Disp
Cum	hhdd	8.9	Cum	hhdd	8.9	Cum	hhdd	8.9			
Cum	hhdd	14.9	Cum	hhdd	14.9	Cum	hhdd	14.9	Cum	hhdd	14.9
Cum	hhdd	11.9	Cum	hhdd	11.9	Cum	hhdd	11.9	Cum	hhdd	11.9
Cum	mhdd	6.7	Cum	mhdd	6.7	Cum	mhdd	6.7	Cum	mhdd	6.7
Cum	mhdd	8.3	Cum	mhdd	8.3	Cum	mhdd	8.3			
Cum	mhdd	8.9	Cum	mhdd	8.9	Cum	mhdd	8.9	Cum	mhdd	8.9
DDC	hhdd	12.8	DDC	hhdd	12.8	DDC	hhdd	12.8	DDC	hhdd	12.8
DDC	hhdd	14.8	DDC	hhdd	14.8	DDC	hhdd	14.8	DDC	hhdd	14.8
DDC	hhdd	15.6	DDC	hhdd	15.6	DDC	hhdd	15.6	DDC	hhdd	15.6
			FORD	mdde	6.7	FORD	mdde	6.7	FORD	mdde	6.7
			GM	mdde	6.6	GM	mdde	6.6	GM	mdde	6.6
hino	hhdd	7.68	hino	hhdd	7.68	hino	hhdd	7.68	hino	hhdd	7.68
hino	mhdd	7.68	hino	mhdd	7.68	hino	lhdd	5.12			
						hino	mhdd	7.68	hino	mhdd	7.68
paccar	hhdd	12.9	paccar	hhdd	12.9	paccar	hhdd	12.9			
			udtruck	mhdd	7	udtruck	mhdd	7			
Volvo	hhdd	10.8	Volvo	hhdd	10.8	Volvo	hhdd	10.8	Volvo	hhdd	10.8
Volvo	hhdd	12.8	Volvo	hhdd	12.8	Volvo	hhdd	12.8	Volvo	hhdd	12.8
Volvo	hhdd	16.1	Volvo	hhdd	16.1	Volvo	hhdd	16.1	Volvo	hhdd	16.1
Volvo	mhdd	7									
			iveco	mdde	3						
	Total	16			19			19			14
										Grand Total	68

Table B-2 Certified ub and lhdd diesel engines sold in California equipped with SCR

2010			2011			2012			2013		
Name	Type	Disp	Name	Type	Disp	Name	Type	Disp	Name	Type	Disp
Cum	ub	8.9	Cum	ub	8.9	Cum	ub	8.9	Cum	ub	8.9
			Cum	ub	11.9	Cum	ub	11.9	Cum	ub	11.9
Cum	ubh	6.7	Cum	ubh	6.7	Cum	ubh	6.7			
			FORD	lhdd	6.7	FORD	lhdd	6.7	FORD	lhdd	6.7
			GM	lhdd	6.6	GM	lhdd	6.6	GM	lhdd	6.6
Izuzu	lhdd	5.2	Izuzu	lhdd	5.2	Izuzu	lhdd	5.2	Izuzu	lhdd	5.2
			iveco	lhdd	3						

MY 2010 – 2013 (and expected for 2014 -2015) Navistar engines do not use SCR technology and thus were avoided. Future Navistar engines will roll out with Cummins SCR technology and possibly ECM heat calibration approach for cold temperature exhaust.