

Managing emissions from non-road vehicles

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INTRODUCTION

Non-road vehicles,¹ mainly agricultural and construction equipment, are a key source of pollution in many countries and regions: In the United States, they account for almost three quarters of the fine particulate matter (PM_{2.5}) and one quarter of the nitrogen oxides (NO_x) emitted from mobile sources.² In Europe, non-road vehicles contribute approximately one quarter of the PM_{2.5} and more than 15% of the NO_x emitted from mobile sources.³ This is mostly because the emission-control strategy for non-road vehicles, including tailpipe emission standards and in-use compliance, lags years behind that of heavy-duty vehicles, although the vehicles share many similarities in the design of diesel engines and exhaust emission control technologies. As a result of the quickly expanding market and better control of emissions for on-road vehicles, non-road vehicles will soon become the dominant source of air pollution in the world.

A comprehensive strategy is required to control emissions from both new and in-use non-road vehicles. Many countries have gradually tightened emission standards for new non-road vehicles, forcing implementation of advanced emission-control technologies on non-road vehicles as those technologies are successfully adopted on heavy-duty vehicles. But this is far from enough—there are still few requirements or regulatory programs in place that impact the emissions of the in-use fleet of non-road vehicles. Regulation of the in-use fleet, including a registration system and emission compliance programs, is essential for tracking the ownership, usage, and status of non-road vehicles and emission-control systems. In addition, regulatory compliance programs can serve to monitor emissions from vehicles to ensure that they comply with the required standards throughout the regulated useful life of the vehicles.

The United States and certain countries in Europe have begun to manage in-use non-road diesel equipment, which can provide insight on the issue. This report provides an overview of those regulation programs in two parts. The first part offers examples of registration or labeling systems for non-road equipment adopted in the State of California, London, England, and Hong Kong. The second part focuses on advanced non-road diesel compliance programs designed by the U.S. Environmental Protection Agency (EPA) and California Air Resources Board (CARB).⁴ The report further compares the compliance tools for non-road vehicles with those for heavy-duty vehicles.

¹ This classification excludes locomotives, marine vessels, and aircraft. It typically covers agricultural equipment, including tractors and combine harvesters; and construction equipment, including crawlers, excavators, wheel loaders, and off-highway trucks.

² U.S. Environmental Protection Agency. (2015a). 2011 National Emissions Inventory Data, Version 2. Retrieved from <http://www3.epa.gov/ttnchie1/net/2011inventory.html>

³ European Environment Agency. (2015). Air Pollutant Emissions Data Viewer. Retrieved from <http://www.eea.europa.eu/data-and-maps/data/data-viewers/airemissions-viewer-lrtap>

⁴ The European Union has no active compliance efforts or programs that target the non-road diesel engine sector.

SECTION I: Examples of Non-Road Vehicle Registration Programs

Non-road vehicles like those used for agricultural applications or those used in the construction industry are typically not registered or licensed in the U.S. or European Union. This lack of registration poses problems for tracking the emissions compliance of non-road equipment as government officials have no official record of ownership for this equipment. Unique non-road regulatory programs in California; London, England; and Hong Kong have created a need for non-road vehicle registration or labeling programs that have been implemented to assist with emissions compliance efforts on non-road equipment. These non-road registration or labeling programs are used for compliance with specific in-use equipment regulations. They are not used for compliance with new non-road engine emission standards. Details of these three non-road vehicle registration programs are provided below.

A. California's Diesel Off-Road On-Line Reporting System (DOORS)

California's Air Resources Board (CARB) regulates emissions from in-use, off-road equipment as a part of their broad Diesel Risk Reduction Program. These regulations (in very general terms) require off-road fleets operating in California to reduce emissions over time, largely by turning over equipment/engines to newer, cleaner models. Details of CARB's in-use, off-road fleet rule can be found in fact sheets and other documents posted on CARB's website at: <https://www.arb.ca.gov/msprog/ordiesel/knowcenter.htm>. This off-road fleet regulation has requirements that depend on fleet size (small, medium, and large fleets). In order to track the emissions compliance of non-road equipment covered by these regulations, CARB created an on-line reporting system (DOORS) that fleet owners must populate with information concerning the equipment they own on an annual basis.

DOORS was created by ARB staff and launched in the second half of 2008. DOORS is both a registration tool and a fleet emissions compliance tool. Fleet average emissions are calculated within DOORS using the information provided by the fleet owner on the engines contained in his off-road fleet. The engine serial number, model/model year, displacement, and power rating defines a specific emissions rating that is based on the engine's emission certification designation (e.g., what Tier emission standards was the engine certified to). This specific emissions rating of the engine can be modified if a verified retrofit technology is applied (DOORS automatically calculates the adjusted emissions rating for a retrofitted engine). In simple terms, CARB's off-road fleet regulation reduces the average fleet emission level each year, and DOORS is used to calculate this fleet average for each registered fleet to determine compliance with the regulation. CARB also provides fleet calculator spreadsheets that fleet owners can use to estimate their fleet average emissions based on their fleet characteristics (available at: https://www.arb.ca.gov/msprog/ordiesel/knowcenter.htm#doors_user_guide).

The type of information that fleet owners must submit into the DOORS database includes:

- Owner/contact information

- Vehicle & engine information (serial number, manufacturer, model/model year, engine displacement, engine power rating)
- Special information such as participation in any California emissions-related incentive programs
- Retrofit emission technology information (if a piece of equipment has been retrofit with a verified technology)
- Low use or other exemptions associated with a particular piece of equipment

A fleet owner inputs the data for his off-road fleet to begin the process and asks for CARB staff to check the information for accuracy or missing inputs. Once the inputs are approved by CARB staff, the non-road equipment that is registered in DOORS receives an equipment identification number (EIN) from CARB. This EIN must be displayed on each piece of equipment. The fleet owner is required to update his DOORS information and show compliance with the fleet regulation early in the new year for the fleet he owned at the end of the previous compliance year. In addition to this DOORS update, the fleet owner must sign and submit a form to CARB that states his fleet is in compliance with the off-road fleet regulation (this form is called the Responsible Official Affirmations of Reporting form, or ROAR form).

CARB does not use this database to track how off-road equipment is being used or where it is being used (although there are exemptions associated with low usage rates in terms of hours of annual use that must be confirmed with readings from an engine's hours of operation meter). CARB's off-road fleet regulations only control the overall fleet emission level. CARB does not have any restrictions on how or where the equipment may be used (there can be local or contract requirements that dictate the emission level of equipment used on a specific construction project in California). Anyone can use the EIN to obtain information about the registered equipment using the public database access point found here: https://www.arb.ca.gov/doors/public_info.html. If equipment is added to the fleet, the fleet owner has 30 days to update his fleet information in DOORS.

CARB has created a DOORS users guide that details how to input information into the database and what their annual reporting requirements are (again, using the DOORS database for annual compliance reporting). The CARB DOORS users guide is available at: <https://www.arb.ca.gov/msprog/ordiesel/documents/doors/userguide-eroar.pdf>. Additional information about DOORS including an on-line training video are available at: <https://www.arb.ca.gov/msprog/ordiesel/ordiesel.htm> and <https://www.arb.ca.gov/msprog/ordiesel/knowcenter.htm>. Fleet owners can access the DOORS database at: https://ssl.arb.ca.gov/ssldoors/doors_reporting/doors_login.html.

Non-compliance with CARB's off-road fleet regulations (including failure to register in DOORS, registering with false information, or not complying with fleet emission standards) can result in significant fines (as high as \$10,000 per vehicle per day for particulate matter [PM] violations and \$500 per vehicle per day for NO_x violations). CARB is still phasing in implementation of their off-road fleet regulations across all fleets (small fleet emissions performance requirements begin January 1, 2019; medium fleet performance requirements began January 1, 2017; and

large fleet performance requirements began January 1, 2014). CARB's enforcement division uses on-site inspections of fleets to check on compliance with this regulation. Equipment identification numbers can be checked versus DOORS information in an initial inspection. CARB also receives information from the public and from compliant fleet owners about fleets that may not be in compliance. Since implementation of this off-road fleet rule is still in progress, CARB's enforcement division has not yet published any statistics concerning compliance rates with this off-road fleet regulation.

B. London Non-Road Mobile Machinery Register

London, England, has created low-emission construction zones across greater London and a set of regulations that establish minimum emissions performance requirements for non-road mobile machinery (NRMM) used in major construction projects that occur within the low-emission construction zones (there is no registration required for construction equipment operating outside of the London low-emission construction zones and no information published about the typical numbers or population of equipment operating within the London low emission construction zones). The regulatory requirements associated with these low-emission construction zones began on September 1, 2015, and increase in stringency on September 1, 2020, as follows:

- Regulation from September 1, 2015
 1. Major development sites within Greater London, NRMM required to meet Euro Stage IIIA emission standards
 2. Any development site within the Central Activity Zone or Canary Wharf, NRMM required to meet Euro Stage IIIB emission standards
- Regulation from September 1, 2020
 1. Any development site within Greater London, NRMM will be required to meet Euro Stage IIIB emission standards
 2. Any development site within the Central Activity Zone or Canary Wharf, NRMM will be required to meet Euro Stage IV emission standards

Options to comply with these low-emission construction zone emission limits include:

- Reorganization of a NRMM fleet so that only compliant equipment is used in London
- Replacing equipment (with new or secondhand equipment that meets the policy)
- Install retrofit emission-control technologies (retrofit technology must be registered and endorsed by the Energy Saving Trust NRMM certification scheme; see: <http://www.energysavingtrust.org.uk/business/transport/non-road-mobile-machinery-nrmm-certification>). The register of the currently endorsed retrofit products is found here: <http://www.energysavingtrust.org.uk/business/products/emissions-reduction-systems>.
- Re-power with a compliant engine
- If eligible, apply for an exemption

The contractor/builder typically must register the equipment planned for use with the construction project as part of the permitting/contract process. Local authorities review this registration to make sure it complies with the regulation before finalizing the contract and issuing any required permits.

With respect to exemptions, the current exemption policy (dated March 2016, available at: <http://nrmm.london/sites/default/files/upload-docs/NRMM%20LEZ%20exemption%20and%20retrofit%20policy%20-%20March%202016%20update.pdf>) includes three types of potential exemptions:

1. Block exemptions: The type of NRMM plant is not currently manufactured at the EU stage stated in the regulation or there is an insufficient quantity of compliant equipment in the UK supply chain and retrofit is unviable. This exemption is valid until September 1, 2018. The current March 2016 exemption policy provides block exemptions to truck mounted cranes and constant speed engines/generators.
2. Viability exemptions: The NRMM plant is not currently manufactured to meet the EU stage as stated in the regulation or there is an insufficient quantity of compliant plant in the UK supply chain for the task, however, it meets the next best available EU stage standards and retrofit is unviable, following robust consideration. This exemption is valid for 12 months after approval of the exemption.
3. Short term exemptions: The NRMM plant is on site for a period of no greater than 30 days to account for a range of potential circumstances where equipment is urgently required or for a very short period.

The exemption policy document is reviewed and updated on an annual basis. Exemptions must be approved by the Greater London Authority. An NRMM Policy Committee also exists to provide input to the Greater London Authority on policies associated with London's Low Emission Construction Zones (including the exemption policy and retrofit policies). Members of this committee include government agencies, construction industry groups, environmental NGOs, university experts, and representatives of the construction labor industry.

An inventory of all NRMM must be kept on the construction site stating the emission limits for all equipment. All machinery should be regularly serviced (according to the manufacturers service recommended schedules) and service logs kept on-site for inspection. This documentation should be made available to local authority officers as required. Fleets must register using an available website with information about deployment date/duration, equipment type/engine type, retrofit type, exemptions, etc. Local authorities use construction site inspections to ultimately determine if the construction site registration matches with the equipment found at the construction site (e.g., inspectors look at engine labels/plates to determine what emission standard the engine conforms to and confirms that this information matches the registration information). This low-emission construction zone registration program does not include any in-use testing efforts of equipment to confirm the emissions performance of the engines (or retrofits) used at the construction site. Penalties will depend on the individual borough and their planning enforcement teams. Options available include

delaying sign-off of the construction permits or building control approval (these delays can impact the final completion of the project which could have an implied financial cost for the company concerned).

Complete details concerning London's NRMM low-emission construction zones and the NRMM fleet registration program are available at: <http://nrmm.london/nrmm>.

C. Hong Kong Non-Road Mobile Machinery Labeling Program

Hong Kong's Environmental Protection Department (EPD) began implementing new regulations for controlling emissions from non-road mobile machinery (NRMM) in June 2015. Under these regulations, NRMMs, except those exempted, are required to comply with prescribed emission standards. From September 1, 2015, all regulated machines sold or leased for use in Hong Kong must be approved or exempted with a proper label in a prescribed format issued by the Hong Kong EPD. Starting from December 1, 2015, only approved or exempted NRMMs with a proper label are allowed to be used in specified activities and locations including construction sites, container terminals and back-up facilities, restricted areas of the airport, designated waste disposal facilities, and specified processes. In March 2015 Hong Kong EPD estimated that there were approximately 14,200 non-road mobile machines in operation in Hong Kong, with more than 11,000 of these machines in operation at construction sites across Hong Kong.

Hong Kong's NRMM emission standards are as follows:

1. Compression-ignition engines

Rated engine power output (P) in kW, emission standards adopted:

$37 \leq P \leq 560$ China National III, EU Stage IIIA, U.S. Tier 3 or Japan MoE standards*

$19 < P < 37$ China National III, EU Stage IIIA, U.S. Tier 2 or Japan MoE standards*

2. Positive-ignition engines

Rated engine power output (P) in kW, emission standards adopted:

$19 < P \leq 560$ U.S. Tier 2 or Japan MoE standards*

* Standards specified in Announcement No.72 made by Japan Ministry of Environment ("MoE") in 2006. Detailed non-road emission standards are found in Hong Kong's NRMM regulations available at: <http://nrmm.epd.gov.hk/application/common/legislation>.

Exemptions were made available for existing NRMMs which were already in Hong Kong on or before November 30, 2015. A period of 6 months (from June 1, 2015 to November 30, 2015) was allowed for the existing NRMMs to apply for exemptions with Hong Kong EPD. Exemptions may also be granted to specialty equipment with no feasible alternative available with engines that comply with Hong Kong's NRMM emission standards. Hong Kong EPD may choose to issue an exemption that restricts the location or duration of use of the exempted machine.

Applications for approval or exemption of NRMMs, or for modification of approved/exempted NRMMs can be submitted via Hong Kong EPD's web-based NRMM system (<http://nrmm.epd.gov.hk/application/common/home>). In order to obtain approval for NRMMs, supportive information and documents (e.g. third-party emission certificates, model and serial number of the machine and engines, etc.) for each NRMM should be provided with the on-line application to Hong Kong EPD to prove that the concerned NRMM meets the prescribed emission standards. Applicants can also check whether a particular NRMM has been approved or exempted by EPD via this on-line system.

Each approved or exempted NRMM is required to bear a unique label with a reference number issued by Hong Kong EPD in accordance with the requirements specified in their regulation. The label must be painted or securely fixed on the machine or vehicle and be displayed at a conspicuous position of the machine or vehicle. The label must be of a size of at least 200 mm in width and 130 mm in height. Example labels are shown here: http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/air_problems/regulatory-control-emissions-nrmm.html. Hong Kong EPD carries out site inspections at construction sites, the airport, and port terminals to enforce their non-road regulation (labels present, label information matches with machine information and information included in the NRMM database, etc.). Fines of up to HK\$200,000 and six months in prison can be issued for violations of the regulations.

Additional information on Hong Kong's non-road emission regulations and labeling program is available at: http://www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/air_problems/regulatory-control-emissions-nrmm.html.

D. Lessons learned/Best practices

There are very few examples of off-road equipment registration or labeling efforts besides the three programs discussed in this memo. Therefore, it is difficult to discuss best practices over a very limited number of examples. The examples discussed here require fleet owners/managers to input emissions certification information that should be available on the engine labels of non-road equipment. These labels can be difficult to find, hard to read, and even, no longer present on the equipment. End users need to be educated about these labels and the kind of information they contain so that they can register their equipment correctly in one of these databases. With these non-road registration systems, regulatory resources are needed to assist end users with the registration process (i.e., making sure the correct engine/equipment information is input in the database). Using on-line, electronic databases makes these databases easily accessible, but some end users may not be comfortable with providing information via a computer. CARB also provides forms that can be filled out and submitted by fleet owners who may not be comfortable with computers. Adding an identification number or specific machine label that must be displayed on the equipment is an important feature of both the DOORS and Hong Kong efforts. This provides an easy first visual check that the equipment has been registered. Providing public access to the database (as in done with DOORS) allows

anyone to do a quick check to see if the registered piece of equipment matches the equipment that displays the identification number. This helps to minimize the use of fraudulent identification numbers. CARB's off-road fleet regulation is very complex (there are lots of compliance options, special situations, exemptions, etc.), making the DOORS reporting/registration process also complex. This regulatory complexity requires extensive end user education/training for using DOORS. The regulatory and DOORS complexity also requires significant CARB staff resources to manage and enforce the program. Compliance and enforcement of an in-use fleet emissions regulation or a low-emission construction zone has to start with a robust registration process, and the basics of a good on-line registration program appear to be captured with these examples.

SECTION II: U.S. Non-Road Vehicle Emission Compliance Programs

This section summarizes non-road diesel emissions compliance tools that are used by the U.S. EPA and CARB to ensure that new non-road diesel engines comply with adopted emission standards. The focus of this report is on non-road diesel engines used in agricultural and construction equipment that must comply with U.S. Tier 4 final or European Stage IV emission standards (no reciprocity exists; engines/equipment sold in the U.S. must be certified to U.S. standards). These compliance tools include both actions that the regulatory agencies are responsible for conducting and actions that are the responsibility of the engine manufacturer (or emissions certificate holder). Figure 1 provides a schematic summary of EPA/CARB diesel engine emissions compliance tools versus a timeline of the engine design, production, and the regulated useful life of the engine, with EPA/CARB actions noted above the timeline and engine manufacturer actions noted below the timeline (TPEM actions or transition program for equipment manufacturers are the responsibility of the equipment manufacturer). Figure 1 contains all of the compliance tools available to EPA/CARB for use with diesel engines certified for highway or non-road applications. Non-road diesel engine compliance tools are a subset of the compliance tools summarized in Figure 1, as some of these tools are only applicable to heavy-duty, highway diesel engines (e.g., manufacturer-run production line testing and emissions warranty reporting to CARB). The European Union has no active compliance efforts or programs that target the non-road diesel engine sector.

Figure 1. EPA/CARB Diesel Engine Emissions Compliance Tools Overview

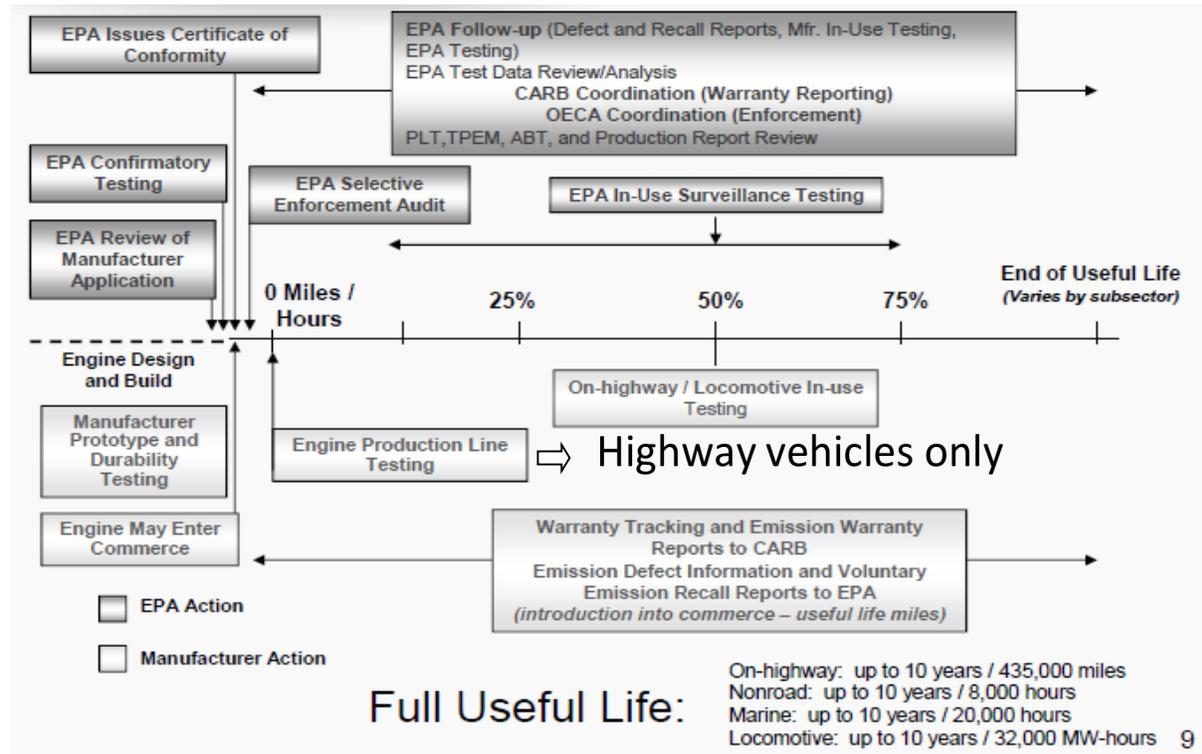


Figure 1 is taken from similar compliance overview charts that have been published in EPA Vehicle & Engine Compliance Reports that have been published since 2008. These EPA reports are available at: <https://www.epa.gov/vehicle-and-engine-certification/compliance-activity-reports-vehicles-and-engines> (the most current of these compliance reports was published in October 2015 for the 2012-2013 model years; these reports are mostly focused on light-duty vehicles and heavy-duty highway engines). In Figure 1, TPEM refers to the transition program for equipment manufacturers (discussed in detail later in this report). PLT refers to production line testing conducted by engine manufacturers (only applicable to highway diesel engines, not applicable to non-road diesel engines). ABT refers to emissions credit averaging, banking, and trading programs that are a part of the highway or non-road emissions regulatory program. OECA refers to EPA’s Office of Enforcement and Compliance Assurance. CARB utilizes many of these same compliance tools in granting Executive Orders (similar to EPA’s certificate of conformity) to highway or non-road engine manufacturers. For example, CARB completes a detailed review of the manufacturer’s application for an Executive Order, CARB can do confirmatory testing, manufacturers must file emissions defect reports with CARB and inform CARB of any voluntary recalls, and CARB can conduct in-use surveillance testing. In the non-road sector, the engine manufacturer is responsible for obtaining the certificate of conformity or Executive Order (responsible for meeting the engine emissions standards). The equipment manufacturer is responsible for ensuring that the correct certified engine is used in the equipment depending on the model year or provisions of the TPEM program that they have been approved for by EPA. The equipment manufacturer can not “tamper” with the certified

engine in the equipment installation process in any way that might alter the emissions performance of the engine.

As shown in Figure 1, compliance tools can be grouped by the engine design/production/regulated useful life timeline as follows:

- Compliance tools available prior to engine production
 - Detailed review of manufacturers' application for certification
 - Ensure proper emission control design
 - Confirmatory testing
 - Ensure test results for certification engines are accurate
 - Review of reporting results and compliance testing performance from previous model years (EPA and CARB may use problems or issues identified with compliance reporting or the certification process from previous model years to target manufacturers that will be given extra attention or scrutiny in approving a new certification application)
- Compliance tools available at time of engine production
 - Selective enforcement audits (SEAs) of manufacturers' engine production lines
 - Ensure conformity of production engines to certification engine/application
 - Includes audit of manufacturers' labs to ensure compliance with testing requirements (testing labs must be compliant with all of the engine testing procedures and methods laid out in the U.S. Code of Federal Regulations, Title 40, Part 1065: <http://www.ecfr.gov/cgi-bin/text-idx?SID=f3d1fcc84cf7294e677460b82f867d3c&mc=true&node=pt40.37.1065&rqn=div5>).
- Compliance tools available after an engine is sold into commerce
 - EPA or CARB-run in-use surveillance testing (engine dyno and/or PEMS testing)
 - Non-road diesel engine manufacturers are not currently required to do mandatory in-use emissions testing as is the case with heavy-duty highway engine manufacturers (i.e. PEMS testing for not-to-exceed compliance)
 - EPA/CARB procures and tests non-road equipment already introduced into commerce
 - Ensure engines comply with emissions standards (e.g., Tier 4 non-road emission limits/not-to-exceed emissions limit) in real-world operating conditions (i.e., emissions testing of engines that have been operated in the field within the regulatory useful life timeframe)
 - Current non-road diesel targets for in-use testing are Tier 4 final engines certified without DPFs (more than half the Tier 4 final engine families certified without DPFs in model year 2015 for engine power ratings between 37 and 560 kW)
 - Emission-related defect and recall reporting
 - Ensures emission defects identified and corrected as needed
 - Provides poor quality deterrent; encourages future improvements

Additional details on some of EPA/CARB's non-road diesel engine compliance tools will be provided following a brief overview of current and future U.S. and European non-road diesel emissions standards.

A. U.S./European non-road diesel engine emissions standards

Figure 2 provides a summary of U.S. and European Union (EU) emission standards for non-road diesel engines used in mobile source applications associated with the agricultural industry, construction equipment, and miscellaneous industrial applications. The U.S. non-road standards are designated as Tier 1 through Tier 4 final, while EU non-road mobile machinery standards are designated as Stage I through Stage IV. Currently the U.S. is implementing the Tier 4 final non-road standards while the EU is implementing Stage IV non-road emission standards. Note in Figure 2 that the EU Stage I through Stage IV non-road standards do not cover the very small (under 19 kW) and very large (greater than 560 kW) engine power ratings that are included in U.S. Tier 1 through 4 non-road diesel engine standards. Both the U.S. and EU introduced ultra-low sulfur diesel fuel for the non-road sector (15 ppm sulfur max. in the U.S., 10 ppm sulfur max. in the EU) prior to the 2011 implementation dates associated with U.S. Tier 4 interim/EU Stage IIIB non-road standards.

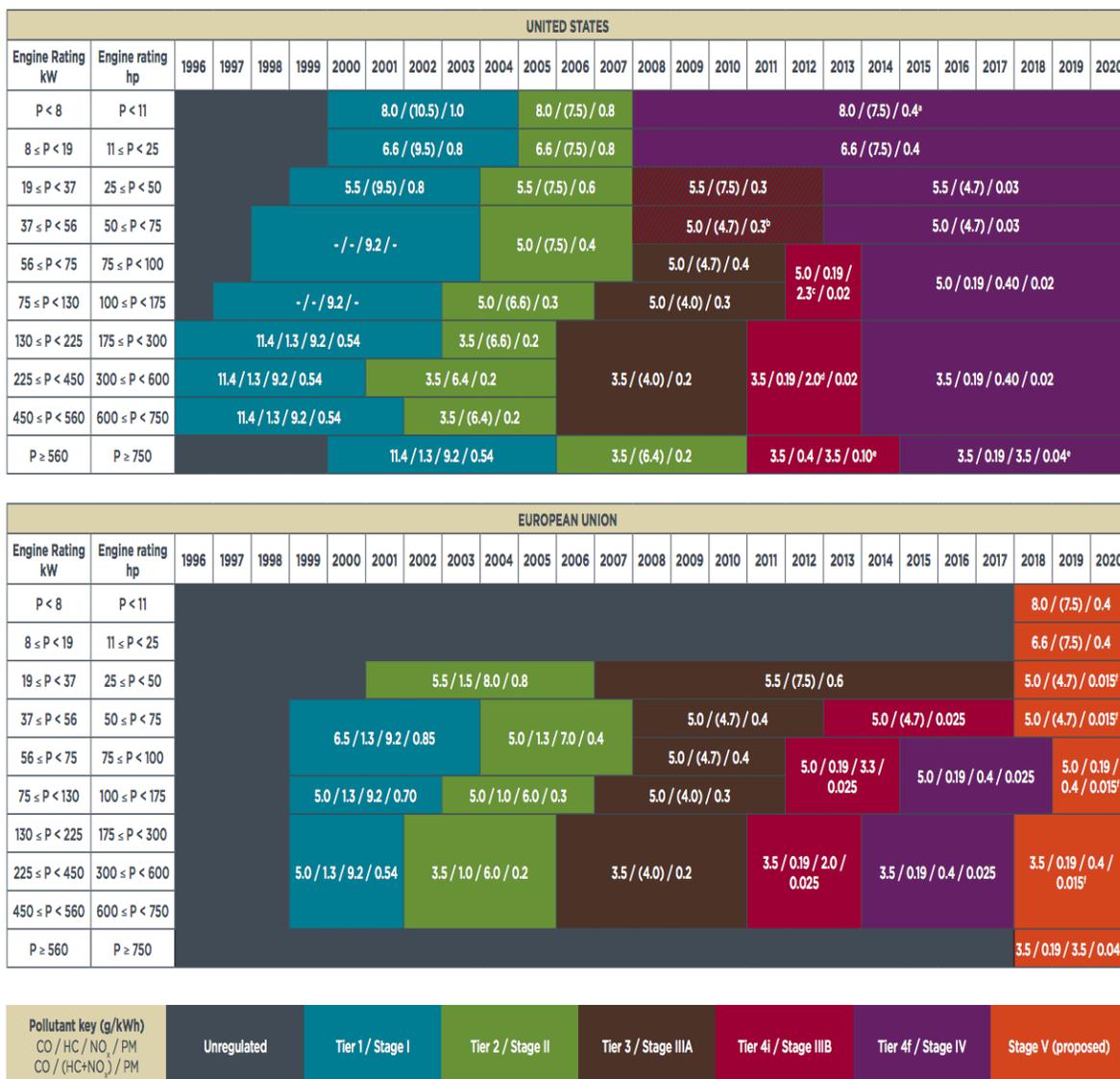
The non-road diesel sector emission standards are relatively harmonized between the U.S. and EU with similar levels of stringency, similar regulatory test cycles, and similar implementation timelines associated with EU Stage IIIB/U.S. Tier 4 interim and EU Stage IV/U.S. Tier 4 final non-road diesel standards. The U.S. Tier 4 non-road standards were finalized in 2004 and assumed that engine and emission control technologies developed for compliance with EPA's 2007-2010 heavy-duty, highway diesel regulations would migrate into the non-road sector for Tier 4 compliance (i.e., DPF+SCR emission controls would be needed to meet Tier 4 final PM and NOx emission standards). However, since the U.S. Tier 4 final non-road standards are less stringent with respect to both PM and NOx compared to U.S. 2010 heavy-duty highway standards (and due to the continued evolution of diesel engine/combustion technology), engine manufacturers have been able to certify Tier 4 non-road engines with a broader range of exhaust emission control technology configurations compared to the DPF+SCR compliance pathway used to certify heavy-duty highway diesel engines to EPA's 2010 emission standards. In fact, examination of EPA's 2015 non-road engine certification database reveals that more than 50% of the engine families with power ratings between 37 and 560 kW were certified to Tier 4 final emission levels with the use of SCR for NOx control, but without DPFs. Many of these non-DPF certified Tier 4 final non-road diesel engines have small compliance margins with respect to PM compared to Tier 4 final non-road diesel engines certified with DPFs. A more complete discussion of U.S. and EU non-road emission standards and the technology pathways used for compliance with these standards is provided in a September 2016 ICCT report available at: <http://www.theicct.org/technology-pathways-for-non-road-diesel-engines>. A summary of EPA's non-road diesel engine emission standards by Tier, including information on the regulated useful life definition and emissions warranty period by engine power rating is available at: <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1000A05.pdf>.

Concerns over diesel PM emissions/exposure from non-road Stage IV engines type approved without DPFs led the European Union to recently finalize Stage V standards for non-road mobile machinery. These Stage V non-road standards begin their implementation in the 2018-2019 timeframe as shown in Figure 2. In addition to a more stringent mass-based PM standard compared to the Stage IV standards, Stage V also introduces a particle number standard of 10^{12} particles/kWh for non-road diesel engines rated between 19 and 560 kW (The EU has previously put in place particle number [PN] standards for light-duty diesel vehicles, light-duty gasoline direct injection vehicles, and heavy-duty diesel highway engines as part of their Euro 5 light-duty diesel, Euro 6 light-duty gasoline, and Euro VI heavy-duty diesel standards). Compliance with the Stage V particle number standard is expected to force the use of DPFs across all non-road diesel engines produced with these power ratings. Stage V standards also include emission standards for very small and very large non-road diesel engine power ratings that were not covered by previous EU non-road engine emission standards. The EU Stage V non-road standards also introduce an in-use emissions monitoring program for gaseous emissions that will utilize portable emission measurement systems. This Stage V non-road gaseous emissions monitoring program is based on the in-use emissions testing program associated with the EU VI heavy-duty highway standards. A summary of the EU Stage V non-road emission standards is provided in a November 2016 ICCT report available at: <http://www.theicct.org/EU-stage-V-policy-update>. EPA and CARB have not yet initiated any activities related to aligning future non-road diesel engine standards with the European Stage 5 regulations.

Non-road diesel engine emission standards based on U.S. or European non-road standards are also in place in a few other countries including:

- U.S. Tier 3/EU Stage IIIA-equivalent standards in Brazil
- U.S. Tier 3/EU Stage IIIA-equivalent standards in India for agricultural and construction equipment
- U.S. Tier 3/EU Stage IIIA-equivalent standards in Turkey (U.S. Tier 4 interim/EU Stage IIIB-equivalent standards are optional)
- U.S. Tier 4/EU Stage IIIB, IV-equivalent standards in Japan and South Korea (Turkey intends to begin implementation of these same standards starting in 2018-2019)

Figure 2. U.S./European Union Non-road Diesel Engine Emission Standards (taken from ICCT’s September 2016 “Technology pathways for diesel engines used in non-road vehicles and equipment” report available at: <http://www.theicct.org/technology-pathways-for-non-road-diesel-engines>)



B. EPA Non-Road Flex-Engine Program

Typically, if new engine-based emission standards apply in a given model year, equipment manufactured in that calendar year must have engines certified to the new standards. Given significant engine design changes associated with the transition to Tier 4 non-road emission standards (i.e., addition of emission controls like DPFs and SCR catalysts), EPA believed it was important to provide time/flexibility to downstream equipment manufacturers to adapt their equipment designs to these new engines. EPA’s flex-engine or transition program for equipment manufacturers (TPEM) allows non-road equipment manufacturers to produce

equipment with engines subject to less stringent emission standards after the Tier 4 emission standards begin to apply. This flexibility provided over a 7 year transition period. Manufacturers are given a certain number of previous Tier engine allowances to manage over the transition period (e.g., 700 units or 80% of production). This non-road regulatory flexibility enables manufacturers to focus redesign efforts on their most critical equipment models first. The European Union Stage IIIB/Stage IV non-road standards have a similar (but less complicated) transition flexibility built into their non-road emission regulations. Some additional details of the EPA's Tier 4 non-road TPEM or flex-engine program are provided below.

Equipment manufacturers have the option of starting the seven-year period in which flexibility engines (often shortened to "flex-engines") may be used in either the first year of the interim Tier 4 standards or the first year of the final Tier 4 standards. For engines between 25 and 75 hp, the final Tier 4 standards may begin in 2012 or 2013 depending on whether the manufacturer chooses to comply with the interim 2008 Tier 4 standards. An equipment manufacturer who does not use flexibilities in 2008 may need flexibilities as early as 2012. Specific non-road Tier 4 TPEM flexibilities include:

- **Percent-of-Production Allowance:** Each equipment manufacturer is allowed to install engines not certified to the Tier 4 emission standards in a limited percentage of machines produced for the U.S. market. These engines will instead have to be certified to the standards that would apply in the absence of the Tier 4 standard. The percentage applies separately to each of the Tier 4 power categories and is expressed as a cumulative percentage equal to no more than 80 percent of a manufacturer's total annual production spread out over the seven years beginning when the Tier 4 standards apply in a category. No exemptions will be allowed after the seventh year. The allowance applies to individual power brackets and to previous Tiers (Tiers 1,2,3 had their own flex-engine programs, separate from the Tier 4 flex-engine program). Early use of Tier 4 flexibilities will be permitted to bridge the gap with the end of the Tier 3 flexibility period.
- **Technical Hardship Flexibility:** This provision adds an additional flexibility in order to provide additional needed lead time in an individualized circumstance based on a showing of extreme technical or engineering hardship, available to Tier 4 power categories between 25 and 750 hp only. The equipment manufacturer must demonstrate the existence of extreme technical or engineering hardship conditions that are outside of its control. The full allowance is limited to the first two years of Tier 4. The manufacturer may receive up to an additional 70 percent annual production allowance for each of the three power categories. Additional information concerning hardship relief, including an EPA pre-screening tool that assists in determining eligibility for hardship relief, is available at: <https://www.epa.gov/vehicle-and-engine-certification/hardship-relief-participants-transition-program-equipment>.

- **Small Volume Allowance:** This provision allows any equipment manufacturer to exceed the percent-of-production allowances during the same seven period, provided the manufacturer limits the number of exempted engines to 700 total over the seven years, and to 200 in any one year. Additionally, manufacturers making use of this provision must limit exempted engines to a single engine family in each Tier 4 power category. Engines over 130 kW have a cap of 350 units and engines up to 130 kW have a cap of 525 units.
- **Early Use of Tier 4 Flexibilities in the Tier 2/3 Timeframe:** This provision allows equipment manufacturers to start using a limited number of the new Tier 4 percent of production allowances or Tier 4 small-volume allowances once the seven-year period for the existing Tier 2/Tier 3 flex-engine program expires (the Tier 4 flex-engine program is separate from the Tier 2/Tier 3 flex-engine program). The equipment manufacturers may use up to a total of 10 percent of their Tier 4 percent of production allowances or up to 100 of their Tier 4 small-volume allowances prior to the effective date of the Tier 4 standards. This amount of equipment utilizing the early Tier 4 allowances will be subtracted from either the Tier 4 allowance of 80 percent under the percent of production allowance or the applicable limit under the small-volume allowance for the appropriate power category, resulting in fewer allowance once the Tier 4 standards take effect.
- **Early Tier 4 Engine Incentive Program for Equipment Manufacturers:** Equipment manufacturers are allowed to earn early compliance credits that could be used to increase the number of equipment flexibilities above and beyond the levels allowed under the percent of production allowance or small-volume allowance. The program is available to all equipment manufacturers regardless of whether they are integrated or non-integrated. The engine manufacturer can use the incentive program only if an equipment manufacturer uses an early Tier 4 engine but declines to use the early engine flexibility allowance. In such a case, the engine manufacturer could opt to earn either “engine offsets” or ABT credits, but not both. The early Tier 4 engine incentive program for equipment manufacturers will apply to the four power categories above 25 hp where the use of advanced exhaust emission control technology is expected under the Tier 4 standards. In order for an engine to be considered an early Tier 4 compliant engine, it will need to be certified to the final Tier 4 standards for PM, NO_x, and NMHC or to the final PM and NMHC standards and the alternative NO_x standards during the NO_x phase-in years. In order to be an early Tier 4 compliant engine, these engines would also have to certify to the Tier 4 CO standards. In order to provide assurance that early Tier 4 compliant engines are placed into the equipment earlier than would otherwise happen under the Tier 4 program, engine manufacturers will be required to certify and start producing such engines before September 1 of the year prior to the post-2011 Tier 4 standards taking effect or before September 1, 2010 for engines in the 175 to 750 hp category. Similarly, equipment manufacturers will be required to install such engines in equipment before January 1 of the year the post-2011 Tier 4 standards take effect or before January 1, 2011 for engines in the 175 to 750 hp category. In order to be

considered an early Tier 4 complaint engine, such engines would be required to comply with all of the requirements associated with the final Tier 4 standards such as NTE requirements, transient testing and closed crankcase requirements.

- Existing Inventory Allowance: This provision extends the existing provision under the non-road diesel engines for equipment manufacturers to continue to use engines built prior to the effective date of the new standards. The program will be extended for the transition to the Tier 4 standard and also extends the existing provision that provides an exception to the applicable compliance regulations for the sale of replacement engines. However, the previous tiered engines may not be stockpiled. The replacement engines may be sold to the original OEM specification.

Additional information on EPA's non-road TPEM program is available at:

<https://www.epa.gov/vehicle-and-engine-certification/transition-program-equipment-manufacturers-tpem>.

C. Similarities and differences between EPA/CARB's emissions-related programs for heavy-duty, highway and non-road diesel engines

EPA/CARB's emissions compliance programs for heavy-duty, highway diesel engines are more comprehensive than their non-road diesel compliance programs. This added attention to highway diesel engines reflects both the relative importance/size of the highway sector to the overall transportation-related emissions inventory in the U.S. compared to the non-road sector and a prioritization of EPA/CARB's available compliance resources. Key compliance program similarities and differences between the highway and non-road sector include:

- Compliance program similarities between highway & non-road diesel engines
 - Detailed review of certification testing/documents (including disclosure/review of all auxiliary emission control devices [AECDs])
 - Not-to-Exceed emission standards
 - SCR system inducements needed to ensure use of urea-based reductant meeting quality standards
 - Emissions warranty provided by manufacturer
 - Confirmatory testing of certification test results
 - Selective Enforcement Audits (SEAs) can be requested by EPA
 - EPA/CARB in-use surveillance testing
 - EPA/CARB recall authority
 - Defect reporting, voluntary recall reporting to both EPA and CARB
 - Production reporting
 - Reporting of all emissions credit averaging, banking, and trading activities (ABT activities)
- Compliance program differences between highway & non-road diesel engines

- No on-board diagnostics (OBD) requirements for non-road diesel engines
- Flex-engine option available for non-road equipment (transition program for equipment manufacturers, TPEM program)
- No production line testing by the manufacturer for non-road diesel engines
- No manufacturer-based, in-use testing program for non-road diesel engines (except for locomotive engines; note that an in-use monitoring program for gaseous emissions is included with Euro Stage V non-road standards)
- No warranty claim reporting to CARB for non-road diesel engines
- Land-based non-road diesel engines typically are not registered/licensed by states, local authorities, or any other governmental agencies

With respect to in-use surveillance testing, EPA or CARB need to locate well maintained engines that are within the regulated full useful life definition in terms of field service. Testing could be done using PEMS or engines could be removed from the equipment and placed in an engine dynamometer cell for testing. EPA and CARB have the latitude to test these engines under any normal operating conditions to determine compliance versus the applicable standards (including performance under test cycle conditions or over not-to-exceed conditions), validate the performance of disclosed auxiliary emission control devices, detect undisclosed auxiliary emission control devices or strategies, and to validate that emission system controls/strategies perform as designed and approved by the certificate of conformity.

EPA drafted a manufacturer-based in-use test program for non-road diesel engines based on the PEMS testing program developed for highway heavy-duty diesel engines but did not pursue a rulemaking process to put such a non-road in-use compliance program in place (this decision was largely based on EPA compliance priorities/resources for light-duty vehicles and heavy-duty highway engines). EPA could easily initiate a rulemaking effort for a manufacturer-based in-use compliance test program if their own in-use surveillance testing uncovers significant issues with the emissions durability of non-road diesel engines over their regulated useful life. OBD programs are currently the responsibility of CARB to define, approve, and enforce. There has been some interest by CARB to extend highway diesel engine OBD requirements onto non-road diesel engines, but this issue has not been prioritized by CARB due to the attention and resources needed to manage OBD programs for light-duty vehicles and heavy-duty highway engines. The addition of a manufacturer-based in-use test program and OBD requirements for non-road diesel engines would provide additional important compliance tools for the non-road diesel sector.

Additional information on compliance reporting requirements for non-road diesel engines is posted on the EPA website at: <https://www.epa.gov/vehicle-and-engine-certification/compliance-reporting-nonroad-compression-ignition-nrci-engines>.

D. EPA/CARB Review of Emissions Certification Data

EPA and CARB staff conduct a comprehensive review of the emissions certification data submitted by a non-road engine manufacturer. This includes reviews of the following:

- Emissions data collected over appropriate non-road test cycles
 - Non-road Transient Cycle (NRTC) – transient test (cold/hot starts)
 - Discrete-Mode or Ramped Modal Cycle (NRSC) – steady-state test (hot starts)
- Not-to-exceed (NTE) testing
- Infrequent regeneration adjustment factors (e.g., emissions associated with DPF regeneration or SCR desulfation strategies)
- Emissions deterioration factors
 - Service accumulation conducted over a portion of regulatory useful life (service accumulation is typically 50% of the emissions useful life definition)
 - In-use representative durability cycle (manufacturer must demonstrate correlation between in-use emissions performance and emissions after durability cycle testing)
- Emission-control strategies (includes Auxiliary Emission Control Devices or AECDs)
 - SCR controls/strategies to ensure the use of a urea-based reductant meeting ISO quality standards
 - For strategies/calibrations that reduce effectiveness of emission controls, manufacturers must justify why they are needed (examples include EGR calibrations that require less or no EGR outside of standard test cycle conditions or SCR reductant dosing strategies that limit reductant dosing quantities at high engine loads)
 - AECDs are approvable (i.e., not a defeat device) if:
 - Substantially included in a test cycle
 - Limited to engine starting only
 - Necessary for engine/equipment protection (for operation outside the NTE zone)
- Adjustable parameters
 - Ensure against tampering outside of compliant settings
- Maintenance intervals (includes service intervals for DPF ash cleaning and minimum SCR reductant tank size; for non-road engines EPA requires a DEF refill interval at least as long [in engine-hours] as the vehicle’s fuel capacity)

EPA provides information about the engine certification process for non-road diesel engines at: <https://www.epa.gov/vehicle-and-engine-certification/certification-nonroad-compression-ignition-nrci-engines>. EPA uses an internet-based system for manufacturers to submit a certification application and the associated data and reports, called “Verify.”

E. EPA Guidelines for SCR Applications

The application of SCR systems, first in the highway sector and then in the non-road sector, to control NO_x emissions caused EPA (in cooperation with CARB) to author a number of guideline documents that are aimed at minimizing operations of SCR-equipped vehicles without a reductant fluid (diesel exhaust fluid or DEF) that does not meet the quality standards. Operating SCR emission systems without a reductant or with a fluid that does not meet the ISO

standard (e.g., with water instead of a urea-water mixture that conforms to the ISO standard) can result in NO_x emissions that significantly exceed the emission standards. These guidelines cover a number of SCR operational issues including:

- Diesel Exhaust Fluid (DEF) level monitoring and low level inducements
 - Warn operators of low DEF level and provide inducements (e.g., vehicle speed limitation, engine shutdown) to ensure DEF tanks are refilled
- DEF quality monitoring and poor quality inducements
 - Warn operators of poor quality DEF and provide inducements (e.g., vehicle speed limitation, engine shutdown) to ensure appropriate specification DEF is utilized
 - Manufacturers have adopted ISO 22241-1 quality standard for DEF
 - API DEF Quality Licensing Program widely utilized (includes audits & enforcement; for more information on the API DEF quality program, see: www.apidef.org)
- SCR component tampering and inducements
 - Alert operators of SCR component tampering (e.g., disconnected dosing module) and provide inducements (e.g., vehicle speed limitation, engine shutdown) to ensure problems are fixed

In July 2011, EPA staff held a webinar with non-road engine and equipment manufacturers that reviewed issues related to the application of SCR systems on non-road engines and equipment. The presentation slides used for this webinar are available on the EPA website at:

<https://www.epa.gov/vehicle-and-engine-certification/presentation-selective-catalytic-reduction-scr-certification>. Topics addressed in these non-road SCR certification presentation slides include:

- Diesel Exhaust Fluid (DEF) Level Monitoring
- Inducement for Low Level DEF (final engine shutdown or idle with no power should occur when DEF tank is empty)
- DEF Quality Monitoring – DEF quality sensors considered best reasonable technology; should be able to detect poor DEF quality within 30 minutes
- Inducement for Poor Quality DEF (final engine shutdown or idle with no power should occur within 4 hours after detecting poor DEF quality)
- Indicators of Tampering
- Warning and Inducement for Tampering (recommended response within one hour after tampering event occurrence)
- Maintenance Intervals (minimum DEF tank size corresponds to the usage rate associated with the diesel fuel tank size)
- Freeze Protection (example test procedure provided; maximum 70-minute thaw cycle time)
- Unregulated Pollutants (limited ammonia emissions, temperature protection for vanadia SCR catalyst applications [550 C maximum SCR operating temperature for vanadia SCR catalysts])

- DEF Supply Infrastructure (supply infrastructure is the responsibility of the certificate holder; ensure availability at dealerships, non-road distributors; must include a back-up plan to supply reductant when no other supply is available)

A manufacturer is required to submit to EPA and CARB complete details of the SCR system design, operational strategies, and SCR maintenance issues with the certification package.

F. Confirmatory Testing

Engine manufacturers do the bulk of emission certification testing at their own labs. EPA and CARB audits (or confirmatory tests) a subset of those engines at their test labs, contract labs, or manufacturers labs. No statistics have been published by EPA or CARB concerning the number of confirmatory tests that are done in a “normal” non-road diesel certification application cycle. Confirmatory testing by EPA or CARB provides manufacturers with an incentive to perform accurate tests. Confirmatory testing may be done at the EPA or CARB test facilities or at an authorized third-party contractor test facility. Tests conducted include the non-road transient cycle (NRTC), discrete-mode or ramped modal cycle (NRSC), and not-to-exceed (NTE) emissions testing. If the engine should fail the first confirmatory test, the manufacturer will be permitted to make mechanical repairs to the engine before a re-test is initiated (only one re-test is permitted and will be done only upon EPA approval of a second test). Any changes made to the engine must be documented and provided in writing or electronically to EPA certification personnel at the time of testing. If a manufacturer fails a confirmatory test (e.g., the tested engine does not comply with the applicable emission standards), the certificate of conformity is withheld until the manufacturer addresses the root cause of noncompliance. Additional information on confirmatory testing, including a tutorial audio-visual presentation, is available on the EPA website at: <https://www.epa.gov/vehicle-and-engine-certification/confirmatory-testing-engines-and-vehicles>.

G. Selective Enforcement Audits

Selective enforcement audits allow EPA to select engines off the manufacturer’s production line for emission testing. EPA has not published any statistics on how many non-road diesel selective enforcement audits are conducted in a typical model year. A typical enforcement audit requires testing of 5-6 engines minimum to reach a pass/fail decision. This type of audit ensures that production engines comply with emission standards and conform to the engine design indicated in the certification process. The audit also provides EPA (or CARB) with a measure of production variability and allows for audits of manufacturers test labs to ensure that test procedures comply with applicable regulatory requirements. If a manufacturer fails a selective enforcement audit, the certificate of conformity can be suspended until the manufacturer addresses the root cause of noncompliance. Certificates are conditioned upon manufacturers granting EPA access to production facilities to conduct audits. Additional information on selective enforcement audits is found in the U.S. Code of Federal Regulations, Title 40, Part 1068, subpart E: <http://www.ecfr.gov/cgi-bin/text-idx?SID=b34d9a36f0cf838a60b3d5a741c40807&mc=true&node=sp40.37.1068.e&rgn=div6>.

H. Emissions Warranty and Defects

Engine manufacturers must warrant the following to purchasers regarding the engine and all parts of its emission-control system:

- Designed, built, and equipped to conform at the time of sale to applicable regulations
- Free from defects in materials and workmanship that may keep it from meeting applicable regulations

For non-road diesel engines, the required warranty period depends on the engine power rating and is up to 3,000 hours or 5 years of operation. Manufacturers must investigate any indication that engines introduced into commerce have incorrect, improperly installed, or otherwise defective emission-related component (includes defects in design, materials or workmanship). Manufacturers are required to file reports for defects affecting typically 20 or more engines with both EPA and CARB. Excessive defects can lead to EPA ordering recalls by the manufacturer if it is determined that a substantial number of properly maintained and used engines do not conform to regulations during their useful life. The manufacturer is required to submit a plan to EPA that remedies emissions nonconformity if a recall is ordered. Manufacturer are encouraged to conduct voluntary recalls to fix component defects. Manufacturers must inform EPA and CARB of any voluntary recall activities.

EPA's defect reporting thresholds are summarized in the U.S. Code of Federal Regulations, Title 40, Part 1068, subpart F: <http://www.ecfr.gov/cgi-bin/text-idx?SID=b34d9a36f0cf838a60b3d5a741c40807&mc=true&node=sp40.37.1068.f&rqn=div6>.

Manufacturers must send EPA a defect report based on the following number of engines/equipment that have the defect:

- (1) For engines/equipment with maximum engine power at or below 560 kW:
 - (i) For families with annual production below 1,000 units: 20 or more engines/equipment.
 - (ii) For families with annual production from 1,000 to 50,000 units: more than 2.0% of the total number of engines/equipment in the family.
 - (iii) For families with annual production from 50,000 to 550,000 units: more than the total number of engines/equipment represented by the following equation: Reporting threshold = $1,000 + (\text{Production units} - 50,000) \times 0.01$
 - (iv) For families with annual production above 550,000 units: 6,000 or more engines/equipment.
- (2) For engines/equipment with maximum engine power greater than 560 kW:
 - (i) For families with annual production below 150 units: 10 or more engines/equipment.
 - (ii) For families with annual production from 150 to 750 units: 15 or more engines/equipment.
 - (iii) For families with annual production above 750 units: more than 2.0% of the total number of engines/equipment in the family.

I. CARB Emissions Warranty Claims Reporting

CARB requires manufacturers of light-duty vehicles and heavy-duty, highway engines to submit warranty claims information on a quarterly basis when warranty claims exceed certain levels. Warranty claim reporting is not required for non-road diesel engine manufacturers. This program is intended to force manufacturers to produce quality components. Recalls and/or extensions of warranties can be ordered by CARB based on high rates of warranty claims for a given component. Warranty claims in excess of 4% for a specific component associated with an emissions certification family is a typical trigger level for CARB to contact a manufacturer and begin an investigation. Warranty claims are primarily identified through OBD (note that there are no OBD non-road diesel engine regulatory requirements but non-road diesel engines typically include some diagnostic systems that can be helpful in identifying warranty claims). Since 2008, there have been 268 CARB-required recalls and 99 extended warranties ordered affecting some 3.8 million California vehicles (mostly light-duty vehicles). CARB has three types of warranty reports:

- Emissions Warranty Information Report (EWIR)
 - Required when unscreened warranty claims \geq 1% or 25 parts, whichever is greater
- Field Information Report (FIR)
 - Required when unscreened warranty claims \geq 4% or 50 parts, whichever is greater
- Emissions Information Report (EIR)
 - Required when screened warranty claims \geq 4% or 50 parts, whichever is greater

It should be noted that CARB's emissions warranty reporting program has been most effective with light-duty vehicle manufacturers, since these manufacturers are aware that CARB can readily procure and test vehicles to prove emissions exceedances (CARB must prove that the defective component results in emissions that exceed the standards). Many heavy-duty highway emission control components have had warranty claim rates that exceed 20% in the recent past, but recall rates have remained low. Heavy-duty engine manufacturers have relied on "engineering judgement" in determining if a defective component will result in excess emissions. The testing burden of proof for CARB is much higher for heavy-duty diesel engines. Engines need to be identified, procured, and placed in a test cell to measure their emissions performance, an expensive and complicated process for CARB. CARB is currently working with engine manufacturers on amending their emissions warranty reporting program in order to identify clear triggers for corrective action by heavy-duty engine manufacturers when unacceptable high warranty rates exist. A recent CARB workshop held in November 2016 included a discussion of CARB's emissions warranty reporting program and CARB's interest to amend these requirements. CARB's presentation slides from this workshop are available at: https://www.arb.ca.gov/msprog/hdlownox/files/07workshop_11032016-ewir.pdf.

J. EPA/CARB Certification Databases

Both EPA and CARB post on their websites, certification information databases for both on-road and non-road vehicles and engines. This information is available to the public.

EPA's non-road diesel engine certification information spreadsheets are posted by model year and are available on their website at: <https://www.epa.gov/compliance-and-fuel-economy-data/engine-certification-data>.

CARB's non-road diesel engine executive orders are posted by model year on their website at: <https://www.arb.ca.gov/msprog/offroad/cert/cert.php>. This database is searchable by model year first, then by engine manufacturer.