State of California
AIR RESOURCES BOARD

BOARD HEARING TO CONSIDER THE PROPOSED REGULATION TO PROVIDE CERTIFICATION FLEXIBILITY FOR INNOVATIVE HEAVY-DUTY ENGINES AND CALIFORNIA CERTIFICATION AND INSTALLATION PROCEDURES FOR MEDIUM- AND HEAVY-DUTY VEHICLE HYBRID CONVERSION SYSTEMS (INNOVATIVE TECHNOLOGY REGULATION)

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EXECUTIVE SUMMARY

The California Air Resources Board's (ARB) mobile source control program has helped significantly drive down smog-forming emissions over the past fifty years. This progress has relied on a suite of strategies, including lower emission standards, warranty requirements, in-use testing, enforcement, and a robust certification process. This certification process is critical to help ensure engines achieve anticipated emission benefits when new and over their useful life. While the State's air quality progress has been dramatic, California must continue its transition to significantly cleaner, zero- and near zero-emission transportation and freight movement technologies to meet its upcoming air quality and climate goals. These goals include:

- Reducing greenhouse emissions to 40 percent below 1990 levels by 2030[1] and reducing greenhouse gas (GHG) emissions from the transportation sector to 80 percent below 1990 levels by 2050.[2]
- Deploying 1.5 million zero-emission vehicles (ZEVs) by 2025, as directed in Executive Order B-16-2012, and the related goal of deploying one million ZEVs and near-zero-emission vehicles by January 1, 2023, as codified in Health and Safety Code Section 44258.4(b). The California Sustainable Freight Action Plan includes a related goal of deploying 100,000 freight vehicles and equipment capable of zero-emission operation by 2030.[3]
- Meeting federal health-based eight-hour ozone standards as required by 2023 and 2031 in the South Coast, which will require a reduction in oxides of nitrogen (NOx) emissions of approximately 70 percent by 2023 and an 80 percent by 2031 from today's levels.[4]

While a diversity of new zero- and near-zero emission trucks and buses will be needed to meet these goals, ARB's comprehensive heavy-duty engine and vehicle certification requirements may deter early development and deployment of some promising new technologies. This is partly due to the initial certification costs and engineering challenges associated with ARB's robust certification program, and partly due to an uncertain market for new truck and bus technologies. One element of certification – on-board diagnostic (OBD) requirements – can be particularly resource-intensive and challenging for some new technologies. However, OBD, consisting mostly of added software to identify and address potential engine and aftertreatment failures, provides a critical and effective mechanism for ensuring a vehicle's expected emission benefits are achieved and maintained for its useful life

[1] Governor Brown's Executive Order B-30-2015: http://gov.ca.gov/news.php?id=18938 .
[2] Governor Brown's Executive Order B-16-2012: http://gov.ca.gov/news.php?id=17472 .
[3] ARB, *California Sustainable Freight Action Plan*; July 2016: http://www.casustainablefreight.org/app_pages/view/154.
[4] 2016 *Mobile Source Strategy*, May 2016. http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm .

To address this and other certification challenges and encourage technology innovation, staff is proposing the "Regulation to Provide Certification Flexibility for Innovative Heavy-Duty Engines and California Certification and Installation Procedures for Medium- and Heavy-Duty Hybrid Conversion Systems" (Innovative Technology Regulation or ITR). The proposed ITR would provide a more flexible, short-term certification pathway to accelerate the introduction of the following innovative truck and bus technologies.

Innovative new heavy-duty engine technologies:

- A heavy-duty spark-ignition or compression-ignition engine meeting California's optional low-NOx emission standards;
- A heavy-duty engine that will be installed in a hybrid heavy-duty vehicle; and
- A heavy-duty high-efficiency engine that meets the proposed ITR's new optional low-CO_2 emission standards, reflective of a 15 percent carbon dioxide (CO_2) reduction relative to a 2017 baseline engine; and

Hybrid conversion systems:

- Installed on an ARB-certified vehicle between 6,000 and 14,000 pounds gross vehicle weight (GVWR) or ARB-certified engine installed in a vehicle over 8,500 pounds GVWR.

These technologies each play a role in helping California meet its air quality and climate goals, yet each could face certification challenges inherent in certifying a new technology for the first time.

1. Innovative New Heavy-Duty Engines

The proposed ITR would provide short-term, targeted certification flexibility, particularly OBD compliance flexibility, for new heavy-duty engines meeting California's optional low-NOx standards, heavy-duty hybrid engines, and high-efficiency heavy-duty engines. The proposed ITR does not alter existing heavy-duty engine emission testing, warranty, useful life, enforcement, or any other engine certification requirements unless explicitly stated. To be eligible, the engine would be required to be cleaner than required by, and not used to demonstrate compliance with, the applicable mandatory engine emission standards for NOx or CO_2 for the given MY. Proposed ITR structure and certification flexibility, summarized below, is tailored specifically to each proposed technology category in order to accelerate that technology's deployment, while still ensuring it achieves the anticipated in-use emission benefits. Details of the targeted flexibility are provided below and a summary is shown in Table ES-1.

Heavy-Duty Engines Meeting California's Optional Low-NOx Standards. California needs significant deployment of heavy-duty engines meeting ARB's optional low-NOx engine standards to attain the National Ambient Air Quality Standard for ozone, particularly in the South Coast Air Basin, by 2023 and 2031. The proposed ITR would provide a heavy-duty spark-ignition engine meeting California's optional 0.05 or 0.02 grams per brake-horsepower hour (g/bhp-hr) NOx standard and a compression-ignition engine meeting the 0.10, 0.05 or 0.02 g/bhp-hr NOx standard with up to three MYs of modest certification flexibility. This flexibility would be available to manufacturers

through the 2021 MY for a spark-ignition engine, and through the 2024 MY for a compression-ignition engine. This proposed structure recognizes the relative technology readiness of spark-ignition and compression-ignition low-NOx engines, and is intended to encourage certification of a diversity of low-NOx engine sizes and types prior to potential adoption of a mandatory low-NOx standard in the 2024 timeframe.

Heavy-Duty Hybrid Engines. Hybrid trucks and buses, particularly plug-in hybrids with significant AER, can reduce both criteria pollutant and GHG emissions in vocational applications and help pave the way for zero-emission heavy-duty vehicle technology. The proposed ITR would provide an engine certified for use in a hybrid heavy-duty vehicle with up to four or six consecutive MYs of ARB certification flexibility, depending upon whether or not it is certified for use in a vehicle that achieves at least 35 miles uninterrupted AER. This 35 mile AER threshold is based upon discussions with technology manufacturers regarding the point at which, considering battery size and cost, fleets could optimize zero-emission operation and fuel savings over the course of a typical day.

A hybrid engine installed in a vehicle that does not achieve at least 35 miles AER (including non-plug-in hybrids) would be eligible for up to two MYs of significant "Tier 1" certification flexibility, followed by up to an additional two MYs of more modest "Tier 2" certification flexibility, through the 2021 MY. An engine to be installed in a hybrid vehicle that achieves at least 35 miles AER would be eligible for the same Tier 1 and Tier 2 certification flexibility provisions, but with up to four MYs of the Tier 1 and two MYs of Tier 2, through the 2024 MY.

The proposed ITR also includes provisions that would enable an engine originally certified for off-road or light- or medium-duty use to be certified as a range extender in a heavy-duty hybrid that achieves at least 35 miles AER, through the 2024 MY. The engine would have to operate at steady state to charge the vehicle batteries, would be prohibited from directly propelling the vehicle, and must meet other emission and performance criteria. Should this technology gain a market foothold, information gained during ITR implementation will enable ARB to update certification requirements, if appropriate, to allow additional certification after the 2024 MY.

High-Efficiency Heavy-Duty Engine. The proposed ITR would also provide certification flexibility to more efficient heavy-duty engines. In order to encourage manufacturer development and deployment of high-efficiency heavy-duty engines, the proposed ITR identifies optional low-CO_2 emission standards for the 2017 through 2027 MYs, that reflect a 15 percent CO_2 reduction relative to a 2017 baseline engine, and over a ten percent CO_2 reduction relative to Federal Phase 2 GHG Standards for the 2027 MY.[5] These voluntary CO_2 standards target what ARB's *Technology and Fuels Assessment*[6] and interested manufacturers indicate can be achieved by potentially transformational, new heavy-duty engine architecture – such as a

[5] United States Environmental Protection Agency and National Highway Traffic Safety Administration; Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2 (Final Rule); Published August 16, 2016; https://www3.epa.gov/otaq/climate/documents/2016-08-ghg-hd-final-rule-phase2-preamble.pdf .

[6] ARB; Draft Technology Assessment; Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency; June 2015; http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf .

camless or opposed piston engine – that could provide significant efficiency gains but may face initial OBD and other certification challenges. However, the standard is performance-based, such that any heavy-duty engine meeting the standard would qualify. The proposed ITR would provide heavy-duty engines meeting these optional low-CO_2 emission standards with up to four MYs of Tier 1 certification flexibility, followed by an additional two MYs of Tier 2 flexibility, through the 2027 MY.

Table ES-1:
Summary of Proposed New Heavy-Duty Engine Certification Flexibility Structure

Technology	Eligibility Criteria	Certification Flexibility	Sunset Date
Low-NOx Engine	• Spark-ignition engine certifying to 0.05 or 0.02 g/bhp-hr optional low-NOx standard. • Compression-ignition engine certifying to 0.10, 0.05, or 0.02 g/bhp-hr optional low-NOx standard.	• Use of assigned deterioration factors (DF) and modest OBD compliance flexibility for up to three consecutive model-years.	• 2021 model-year for spark-ignition engines. • 2024 model-year for compression-ignition engines.
Hybrid Engine*	• HD hybrid engine that demonstrates at least a ten percent CO_2 reduction and no criteria pollutant emission increase, pursuant to this proposed regulation's hybrid technology test procedures.	• Tier 1: Use of assigned DFs and Engine Manufacturer's Diagnostics rather than heavy-duty OBD for two consecutive model-years (four model-years if the hybrid engine enables at least 35 miles AER). • Tier 2: Modest OBD flexibility for up to two consecutive additional model-years.	• 2021 model-year; or • 2024 model-year if the hybrid enables at least 35 miles AER.
High-Efficiency Engine	A HD engine that meets the proposed Optional Low-CO_2 Standards (a 15% CO_2 reduction relative to a 2017 diesel engine), when certifying to Phase 1 or 2 GHG Standards.	• Use of assigned DFs and EMD+ rather than heavy-duty OBD for up to four consecutive MYs. Maximum 100 engines per manufacturer per MY. • Modest OBD compliance flexibility for up to two consecutive additional MYs. Maximum 200 engines per manufacturer per MY.	• 2027 model-year

* – This proposed regulation also allows certification of a limited number of off-road, light-duty, or medium-duty engines that range extend a truck or bus that achieves at least 35 miles AER. The engine must operate exclusively at steady state, not propel the vehicle, and meet other criteria described in Chapter II, section (C)(3)(f).

2. Truck and Bus Hybrid Conversion Systems

The proposed ITR includes "California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems". These proposed

procedures, included in Appendix E, provide ARB certification criteria, including emissions, diagnostics, warranty, reporting, and other requirements for hybrid truck and bus conversion systems to be sold and installed on a California-certified base engine or vehicle. The proposed ITR would allow a manufacturer to sell increasing California volumes of its hybrid conversion system by certifying to progressively more stringent Tier 1, Tier 2, and Tier 3 requirements, as shown in Table ES-2.

For hybrid conversion systems that do not achieve at least 35 miles AER, the opportunity for conversion system manufacturers to apply for less stringent Tier 1 and 2 certification requirements would sunset on January 1, 2022. For conversions that achieve at least 35 miles AER, the opportunity for manufacturers to apply for Tier 1 and 2 hybrid conversion system certification would sunset on January 1, 2025. A hybrid conversion system first certifying after these sunset dates would be required to meet the more stringent proposed Tier 3/Final certification requirements. This structure is intended to encourage early development and market launch of a diversity of hybrid conversion systems, particularly from the smaller, independent manufacturers that make up today's market, by minimizing initial engineering challenges and certification compliance costs and scaling up certification requirements as the market develops. Staff anticipates that a flourishing market for hybrid conversion systems, particularly in the medium-duty sector, could achieve near-term CO_2 reductions, and encourage larger, original vehicle manufacturers to enter the market with robust, vertically integrated hybrid trucks and buses.

Table ES-2: Summary of Proposed Hybrid Conversion System Certification Pathway

Eligibility Criteria	Certification Provisions	Sunset Date
• Conversion of a 2007+ MY Class 2a (i.e., 6,001 – 8,500 pounds GVWR) non-hybrid base vehicle to achieve at least 35 miles AER. • Conversion of a 2007+ MY medium-duty (i.e. 8,501 – 14,000 pounds GVWR) non-hybrid base vehicle. • Conversion of a 2010+ MY heavy-duty (i.e., >14,000 pounds) non-hybrid base engine. • All conversions must demonstrate no criteria pollutant increase and at least a 10 percent CO_2 decrease.	• Tier 1 allows a manufacturer to sell up to: o 10 units; or o 25 units, if the conversion system achieves at least 35 miles AER. • Tier 2 allows a manufacturer to sell up to: o 500 units; or o 1,000 units, if the conversion system achieves at least 35 miles AER. • Tier 3/Final certification requirements allow for unlimited California sales volumes.	• Manufacturers' ability to apply for Tier 1 and Tier 2 certification sunsets January 1, 2022, and sale of Tier 1 or Tier 2 certified systems is prohibited after January 1, 2027; or • For a hybrid conversion that achieves at least 35 miles AER, 3 additional years are provided to apply and to sell (2025 and 2030 respectively).

3. Hybrid Truck and Bus Technology Emission Test Procedures

Recent studies have illustrated the potential for some hybrid heavy-duty vehicles to emit greater in-use NOx relative to their non-hybrid counterparts.[7] Similarly, an aftermarket hybrid conversion of a previously certified engine or vehicle could result in an emissions increase relative to the pre-converted vehicle configuration. To a lesser extent, carbon monoxide (CO) and hydrocarbons (HC) are also pollutants of concern when hybridizing a truck or bus engine or vehicle. The proposed ITR includes vehicle-based (as opposed to engine-based) hybrid technology test procedures to ensure new heavy-duty hybrid truck and bus hybrid conversion systems do not increase NOx, CO or HC emissions relative to those from the pre-converted vehicle. In order to demonstrate a minimum GHG and vehicle efficiency benefit from hybridization, participating hybrid technology manufacturers would also be required to demonstrate at least a ten percent CO_2 reduction pursuant to Section 7 of the "California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems" (Test Procedures)[8] to be eligible for this regulation's proposed certification flexibility.

Staff's proposed Test Procedures include three options for demonstrating hybrid heavy-duty engines and hybrid conversion systems meet the required emission criteria – testing on a chassis dynamometer, over-the-road emission testing with a portable emission measurement system (PEMS), and use of a post-transmission powertrain vehicle simulation. The proposed Test Procedures identify criteria for emission testing, and comparing emissions of, a hybrid and its non-hybrid vehicle equivalent over duty cycles or test routes that are reflective of the hybrid vehicle's anticipated in-use operation. These proposed procedures leverage advances in PEMS instrumentation to provide a more practical and economical over-the-road emission test option, relative to a heavy-duty chassis dynamometer, for heavy-duty hybrids participating in ITR.

4. Conclusion

California must transition to the next generation of zero and near-zero emission truck and bus technologies to meet and maintain its long-term air quality and climate goals and challenges. Existing OBD and other certification requirements are a key component of our mobile source program, but may deter early deployment of key new truck and bus technologies. The proposed ITR would address the need for targeted, short-term certification flexibility to encourage accelerated deployment of innovative truck and bus technologies, while maintaining the ability to ensure these technologies' emission benefits are maintained in-use. Lessons learned while implementing this proposed regulation, if adopted, could also inform future regulatory efforts to encourage early development and deployment of the next generation of innovative engine, vehicle and equipment technologies, including technologies in other sectors.

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[7] National Renewable Energy Laboratory; *Data Collection, Testing, and Analysis of Hybrid Electric Trucks and Buses Operating in California Fleets - Final Report*; June 2015; www.nrel.gov/docs/fy15osti/62009.pdf .

[8] See Appendix E of this Staff Report for the "California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems".

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Table of Acronyms

AER..... ..... All-electric Range
AQIP..... ..... Air Quality Improvement Program
ARB..... ..... California Air Resources Board
ARE..... ..... Air Resources Engineer
CCR .... California Code of Regulations
CEC..... ..... California Energy Commission
CEQA..... ..... California Environmental Quality Act
CNG .... Compressed Natural Gas
CO..... ..... Carbon Monoxide
CO_2 .... Carbon Dioxide
DF .... Deterioration Factor
DOE .... United States Department of Energy
ECU..... ..... Electronic Control Unit
EGR .... Exhaust Gas Recirculation
EMA .... Truck and Engine Manufacturers Association
EMD .... Engine Manufacturer Diagnostic System
ePTO..... ..... Electronic Power Take Off
FTP .... Federal Test Procedure
g/bhp-hr..... ..... Grams of Pollutant per Brake-Horse Power Hour
GHG……..Greenhouse Gas
GGRF..... ..... Greenhouse Gas Reduction Fund
GVWR..... ..... Gross Vehicle Weight Rating
HC..... ..... Hydrocarbon
HVIP..... ..... Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program
ITR .... Innovative Technology Regulation
IUMPR..... ..... In-Use Monitoring Performance Ratio
LEV .... Low Emission Vehicle
LPG..... ..... Liquefied Petroleum Gas
MECA..... ..... Manufacturers of Emission Controls Association
MIL .... Malfunction Indicator Light
MY..... ..... Model Year
NHTSA..... ..... National Highway Traffic Safety Administration
NOx..... ..... Oxides of Nitrogen
NREL..... ..... National Renewable Energy Laboratory
OBD .... On-Board Diagnostic System
PEMS..... ..... Portable Emission Measurement System
PM..... ..... Particulate Matter
SAE..... ..... Society of Automotive Engineers
SCAQMD .... South Coast Air Quality Management District
SCR..... ..... Selective Catalytic Reduction
U.S. EPA..... ..... United States Environmental Protection Agency
VMT..... ..... Vehicle Miles Traveled
ZEV .... Zero-emission Vehicles

I. INTRODUCTION AND BACKGROUND

Staff is proposing a regulation to provide targeted, short-term certification flexibility to accelerate early deployment of innovative truck and bus technologies California needs to meet its long-term air quality and climate goals. The California Air Resources Board's (ARB or Board) existing certification requirements provide an increasingly critical and effective mechanism to help ensure truck and bus technologies achieve and maintain anticipated emission benefits in-use. However, some resource intensive requirements, such as the use of comprehensive on-board diagnostic (OBD) systems to monitor engine, aftertreatment, and other emission-related components, may deter some manufacturers from developing promising new technologies, particularly if low initial sales volumes are anticipated.

This proposed regulation's certification flexibility is tailored to encourage development and market launch of heavy-duty engines meeting California's optional low oxides of nitrogen (NOx) emission standards, robust heavy-duty hybrid engines (particularly hybrids with significant zero-emission range), and high-efficiency heavy-duty engines. This proposed regulation would also define certification and installation procedures for truck and bus hybrid conversion kits, to encourage near-term hybridization of the in-use truck and bus fleet. Proposed certification pathways for both new truck and bus engine technology and hybrid conversion systems would provide near-term certification flexibility – primarily OBD compliance flexibility – to encourage technology launch. Proposed certification flexibility would sunset between 2021 and 2027, as each technology has an opportunity to gain a market foothold.

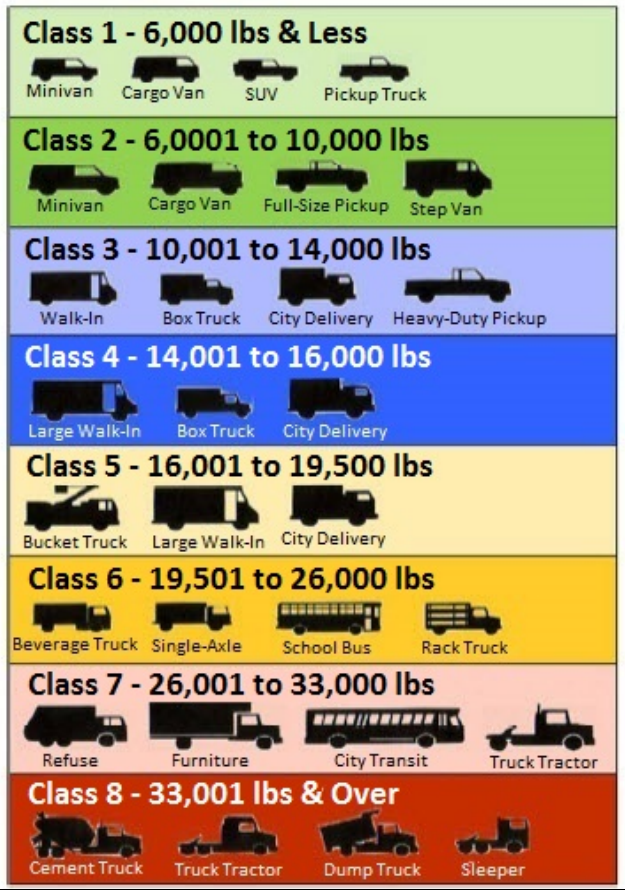
A. EXISTING NEW VEHICLE AND ENGINE CERTIFICATION REQUIREMENTS

1. Overview of Criteria Pollutant Emission Certification

California law requires new motor vehicles and engines to be certified by ARB for compliance with emission standards before they are legal for sale, use, or registration in California. (Health and Safety Code, §43100 et. Seq.) New light- and medium-duty vehicles are typically certified compliant with criteria pollutant emission standards as complete vehicles on a chassis dynamometer, while heavy-duty engines are certified on an engine dynamometer. Figure I-1 provides examples of vehicles in each class and their respective typical emissions certification pathway.

Similar light-and medium-duty *vehicles* typically meet certification and OBD requirements as part of a common "vehicle family" or "test group", while similar heavy-duty *engines* are certified as part of an "engine family". Engines within an engine family share common characteristics, such as manufacturer, engine model year (MY), fuel type, and emission control strategy. ARB certification requirements mandate that for each MY, a heavy-duty engine manufacturer must demonstrate its engine families will comply with the applicable emission standards of the engine's MY over its full useful life.

Figure I-1: Vehicle Classes and Typical Criteria Pollutant Certification Emission Testing Approach



Light- and Medium-Duty Vehicles
Class 1 through 3 passenger cars, pickup trucks, vans and other light- and medium-duty vehicles are typically chassis certified to meet emission standards, meaning the complete vehicle must demonstrate emission compliance on a chassis dynamometer.

Heavy-Duty Engines (>14,000 pounds)
Engines used in Class 4 and heavier vehicles typically demonstrate compliance with emission standards on an engine dynamometer, meaning only the engine is emission tested. Once a heavy-duty engine is certified, it may be installed on a heavy-duty vehicle. A complete Class 4 or heavier truck or bus is typically not emission tested during the certification process, due to the diversity of potential vehicle configurations and greater challenge of chassis testing larger trucks and buses.

Certification requirements for a new vehicle family and an engine family include, but are not limited to, the following:

- Demonstrate the new vehicle/engine family complies with applicable emission standards, both when new and over its useful life, when tested in conformity with specified test procedures;
- Demonstrate durability for the useful life of the vehicle or engine family;
- Meet the applicable labeling requirements;
- Provide emissions warranty to the engine or vehicle purchaser; and
- Demonstrate compliance with OBD requirements.

a. *Hybrid Heavy-Duty Vehicles.* In December 2013, the Board adopted the "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric and Other Hybrid Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes", providing voluntary vehicle-based certification procedures to demonstrate emission

benefits of new hybrid trucks and buses.[9] These optional chassis-based certification procedures include duty-cycles that are more indicative of real world hybrid heavy-duty vehicle activity, and provide manufacturers an opportunity to generate criteria pollutant emission credit for certification of a complete heavy-duty hybrid vehicle that is lower-emitting than its non-hybrid counterpart. To date, however, manufacturers have continued to use California's engine-based certification procedures to certify engines used in heavy-duty hybrid vehicles, in lieu of ARB's voluntary chassis-based hybrid heavy-duty vehicle certification procedures. This may be because of a hybrid manufacturer's perceived risk of failing a chassis-based certification procedure, and/or manufacturer's lack of need for criteria pollutant emission reduction credits that could potentially be generated by such a procedure.

b. *Zero-Emission Trucks and Buses.* Certification protocols for zero-emission heavy-duty vehicles are in the development process. In the interim, manufacturers may sell heavy-duty electric vehicles and non-combustion hybrid vehicles in California without an Executive Order. Under the current process, at a manufacturer's request, ARB issues a letter of approval for heavy-duty vehicles – such as battery-electric or hydrogen fuel cell vehicles – that do not utilize a combustion engine or fuel-fired heater and do not emit any regulated vehicle exhaust emissions or fuel-based evaporative emissions.[10] These vehicles are not subject to ARB emission tests or diagnostic requirements and are therefore not addressed in this proposed regulation.

2. <u>On-Board Diagnostics Systems</u>

The OBD program is an important emission control program that is critical to California's achievement of its air quality goals. OBD consists mostly of added software in the relevant powertrain control modules that monitor virtually every component that can cause an emission increase, including, but not limited to, all emission controls and all electronic components (such as sensors and actuators) that affect emissions or are used to monitor other emission controls. A robust OBD system is critical for identifying and addressing engine and aftertreatment system malfunctions that can lead to excess in-use emissions. OBD monitors an engine and vehicle's emission related components, identifies emission threshold exceedances, and provides owners with an early warning of malfunctions by way of a dashboard "Check Engine" light (also known as a Malfunction Indicator Light, or MIL). By providing this early warning, OBD not only ensures reductions of in-use motor vehicle and motor vehicle engine emissions through improvements of emission control system durability and performance, but also protects consumers by helping them identify minor problems before they require major repairs. Recent studies suggesting that a subset of improperly maintained or malfunctioning

[9] ARB; Heavy-Duty Hybrid Electric Vehicle Certification Procedures; Adopted December 12, 2013; http://www.arb.ca.gov/regact/2013/hdghg2013/hdghg2013.htm .

[10] More information regarding heavy-duty zero-emission vehicle approval letters can be found at: www.arb.ca.gov/msprog/cihd/approvals/approvals.php .

engines and aftertreatment systems are responsible for a disproportionate share of in-use truck and bus emissions underscore the critical need for OBD.[11]

a. *Heavy-Duty Engine OBD Requirements.* The OBD implementation schedule in the United States has been tied to gross vehicle weight rating (GVWR), progressing from light-duty passenger vehicles in the 1990's to medium-duty vehicles in the 2000's and finally to heavy-duty engines beginning in 2010. In 2004, the Board adopted basic Engine Manufacturer Diagnostic (EMD) System Requirements for heavy-duty engines, with implementation required beginning with the 2007 engine MY (California Code of Regulations, title 13, §1971). Heavy-duty EMD requirements began phasing in minimal diagnostic requirements for heavy-duty engines – diagnostic monitoring of the performance and durability of the fuel system, exhaust gas recirculation system (if so equipped), particulate trap, and other emission-related electronic components. EMD requirements do not necessitate standardization of diagnostic equipment or data generated by such equipment (allowing manufacturers to use their own scan tools), nor does it tie diagnostic alerts to specific emission level exceedances.

   The heavy-duty OBD regulation, implemented between the 2010 and 2013 MYs for most heavy-duty engines, phased-in comprehensive monitoring requirements for the engine and all emission-related components. (California Code of Regulations, title 13, sections 1971 and 1971.5.) The heavy-duty OBD regulation requires the engine to have the following diagnostic capabilities:

   - Monitor the fuel, catalyst, exhaust gas recirculation, cooling, particulate filter, and all other emission-related systems;
   - Ensure the OBD system properly detects malfunctions in emission controls before the emission standard is exceeded by a defined threshold, illuminating the MIL and storing the applicable fault code as required to enable diagnosis and repair;
   - Ensure diagnostic information can be reliably generated and made available for vehicle repair and roadside inspections. The on-board computer must also provide the vehicle identification number, software calibrations, and other information for enforcement purposes;
   - Ensure OBD monitors run with a specified minimum frequency in-use (i.e., the in-use monitoring performance ratio or IUMPR). Manufacturers must collect and provide ARB with OBD data from a sample of in-use vehicles to ensure a minimum IUMPR is being achieved; and
   - Output data to scan tools must meet standardization requirements defined by the Society of Automotive Engineers (SAE), to enable repair technicians to find and fix faults before they cause damage to the engine, emission controls, or other vehicle components.

[11] ARB; Evaluation of Particulate Matter Filters in On-Road Heavy-Duty Diesel Applications; May 8, 2015; http://www.arb.ca.gov/msprog/onrdiesel/documents/DPFEval.pdf .

Due in part to their anticipated lower sales volumes, alternate-fueled (i.e., compressed natural gas (CNG) or liquefied petroleum gas (LPG)) heavy-duty engines in California are subject to EMD monitoring requirements instead of heavy-duty OBD requirements between the 2010 and 2017 MYs, with comprehensive OBD required beginning in the 2018 MY. Virtually every new heavy-duty engine certified in the United States meets California OBD requirements because the United States Environmental Protection Agency (U.S. EPA) deems heavy-duty engines that meet ARB OBD requirements as also compliant with U.S. EPA requirements.

3. Medium- and Heavy-Duty Vehicle Phase 1 and Phase 2 Greenhouse Gas Emission Standards

In 2014, ARB adopted Phase 1 greenhouse gas (GHG) emission standards for medium- and heavy-duty engines and vehicles, harmonizing with the U.S. EPA and National Highway Traffic Safety Administration's (NHTSA) Phase 1 GHG Standards adopted nationally in 2011. The Phase 1 GHG Standards establish limits on GHG emissions from new heavy-duty trucks and engines, including new engine and vehicle carbon dioxide (CO_2) emission standards for Class 2b through Class 8 vehicles. Phase 1 GHG Standards organize truck compliance into three groupings – trucks and vans between 8,500 and 14,000 pounds, vocational vehicles, and combination tractors. The rule requires new trucks to be certified to emission standards which apply not only to the engine but also to the full vehicle. Compliance requirements began with the 2014 MY, with increasing stringency levels through the 2018 MY. (More information is available at: http://www.arb.ca.gov/msprog/onroad/phaselghg/phaselghg.htm)

ARB staff have worked closely with U.S. EPA and NHTSA on the next phase of federal GHG emission standards for medium- and heavy-duty vehicles (Federal Phase 2 GHG Standards). Federal Phase 2 GHG Standards build on the improvements in engine and vehicle efficiency required by the Phase 1 GHG Standards, and represent an opportunity to achieve further GHG reductions in 2021 and later MY heavy-duty vehicles.[5] While the Federal Phase 2 GHG Standards envision deployment of a diversity of advanced truck and bus GHG reduction technologies, including hybrid technology, California needs these technologies on an accelerated timeframe to meet its 2030 and 2050 climate targets. California regulations, such as the potential Advanced Clean Transit Regulation, incentive funding programs, and other technology-advancing strategies, including the proposed ITR, will be critical for accelerating deployment of robust hybrid and zero-emission technology beyond what would occur due to the Federal Phase 2 GHG Standards alone.

California is also developing of its own Phase 2 GHG Standards Regulation. As the only state in the nation with authority under the Clean Air Act to develop its own motor

[5] U.S. EPA and NHTSA; Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2 (Final Rule); Published August 16, 2016; https://www3.epa.gov/otaq/climate/documents/2016-08-ghg-hd-final-rule-phase2-preamble.pdf .

vehicle emission standards, California strives to harmonize its standards with the federal standards as much as possible to achieve a comprehensive, unified national program, while ensuring that California's emission reduction needs are met. ARB anticipates that it will harmonize with Federal Phase 2 GHG Standards by adopting equivalent standards for California in 2017, with some modifications designed to help meet California's unique air quality and climate challenges. More information regarding California's Phase 2 GHG rule development efforts can be found at: http://www.arb.ca.gov/msprog/onroad/caphase2ghg/caphase2ghg.htm.

4. Experimental Permits

Health and Safety Code Section 43014 grants ARB the authority to issue permits for the testing of experimental or prototype vehicles and engines which appear to have very low emission characteristics. An experimental permit is typically issued to allow a manufacturer to test and evaluate performance and emissions from a promising new, low volume vehicle technology by placing it with a California fleet for demonstration purposes. The manufacturer is prohibited from leasing or selling the vehicle to the fleet, and must retake possession of the vehicle at the conclusion of the experimental permit period. An experimental permit requires the applicant to specify the proposed vehicle technology and vehicle(s) on which it shall be installed: give the name of each fleet or user operating the vehicle; specify a defined test program for obtaining vehicle drivability, fuel economy, and emission impact information; and provide the time period of the test program. Finally, ARB requires all experimental permit applicants to submit an experimental program report upon completion of experimental testing. An experimental permit typically has a duration of one year, but may be renewed.

Experimental permits are often issued for truck and bus technology demonstration projects, such as plug-in hybrid drayage trucks or transit buses funded by ARB's Greenhouse Gas Reduction Fund (GGRF) and other technology demonstration incentive programs. The limited permit approval timeframe and prohibition on sale or lease of the technology to the end user make the experimental permit useful for technology demonstration; however this process is not optimal for early commercial deployment. Zero Emission Vehicles (ZEVs) (i.e., vehicles with no exhaust or tailpipe emissions) are not required to obtain an experimental permit to operate in California.

B. CERTIFICATION OF AFTERMARKET CONVERSION SYSTEMS

Vehicle Code 27156 and California Code of Regulations, title 13, sections 1900 et Seq. prohibit the sale, offer for sale, advertisement, or installation of any device that alters or modifies the original design or performance of a certified engine or its vehicle emission control system, unless that device has been exempted by ARB. ARB only exempts modifications to a certified engine or vehicle if the modifications do not cause the emissions from the modified or altered vehicle to exceed the applicable emission standards for the MY of the vehicle being modified or converted, or the emission increase relative to the unmodified base vehicle is less than ten percent.

ARB's aftermarket conversion approval process is structured to address two specific categories of aftermarket parts typically applicable to passenger vehicles or motorcycles, namely legal add-on or modified parts and catalytic converters. These are categorized as "modified parts," defined in California Code of Regulations, title 13, section 1900, subdivision (b)(17) as, in part, "aftermarket parts intended to replace an original emission-related part." ARB's aftermarket part evaluation and approval process, originally developed for these add-on or modified parts, is not ideal for evaluation of potentially innovative new emission-reduction technology, such as a truck or bus hybrid conversion system, since the existing process is crafted to certify a replacement part with the same function as the originally certified part. Thus hybrid conversion systems are unique in that these systems are added equipment that were not part of the original vehicle's certified configuration, and change how the engine and vehicle typically operate.

ARB has adopted two regulations in recent years to define specific criteria for ARB certification of an innovative aftermarket conversion system. Unlike certification criteria for add-on or modified parts, these two regulations include tiered requirements to facilitate near-term certification, in recognition of the benefits of advancing plug-in and alternative fuel vehicle technology:

- The *Plug-In Hybrid Electric Vehicle Test Procedure Amendments and Aftermarket Parts Certification Requirements* (adopted May 2009)[12] provide criteria for ARB certification of conversion kits that transform a non-plug-in hybrid light- or medium-duty vehicle to operate as a plug-in hybrid vehicle. This regulation includes tiered emission testing, OBD, durability, warranty, and other requirements that increase in stringency as each manufacturer's California conversion system sales volumes increase.

- *Proposed Amendments to Alternative Fuel Certification Procedures* (adopted September 2013)[12] provide criteria for ARB certification of an aftermarket kit that converts a light-, medium-, or heavy-duty vehicle to operate on an alternative fuel, such as CNG. This regulation provides for flexibility with regard to emission testing, OBD, warranty, and other requirements for an alternative fuel vehicle conversion system to receive an exemption and be sold in California. Many provisions of this regulation sunset in 2018 to coincide with implementation of more stringent new light-duty Low Emission Vehicle (LEV) III standards.

Concepts from these two existing ARB regulations, and experience implementing these programs thus far, have informed development of staff's proposed ITR.

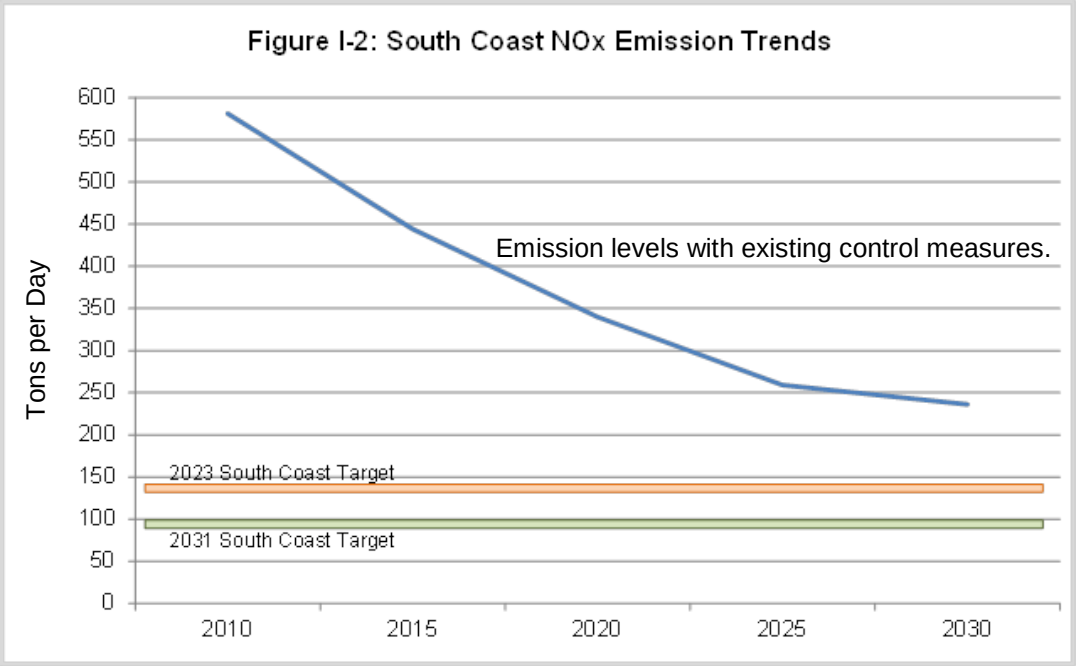
C. CALIFORNIA'S AIR QUALITY AND CLIMATE CHALLENGES

California has led the nation and the world in developing and implementing pioneering strategies to reduce smog-forming emissions from motor vehicles, power plants, consumer products, and virtually every other source of air pollution. Since 1990,

[12] Title 13, CCR, section 1961, 1962, 1962.1, 1976, and 1978.
[12] Title 13, CCR, section 2030 and 2031.

California's population has increased by 29 percent, the number of registered vehicles in the State increased by 32 percent and the economy grew by 83 percent.[13] During the same period, statewide emissions of smog-forming pollutants decreased by over 50 percent, and emissions of toxic air contaminants and the resulting cancer risk to residents have declined by 80 percent.[14]

While California's air quality improvement has been substantial, some of our greatest challenges lie ahead. Both the South Coast Air Basin and the San Joaquin Valley, home to over half of California residents, are classified by U.S. EPA as extreme nonattainment areas for the 2008 8-hour federal ozone standard.[15] Mobile sources – cars, trucks, and off-road equipment – and the fuels that power them are still responsible for about 80 percent of NOx emissions in California.[5] Figure I-2, below, illustrates the scope of NOx emission reductions still needed, beyond what is expected to be achieved by existing control strategies, to attain federal ozone standards.



Source: ARB 2016 Mobile Source Strategy (May 2016)

In addition, increased atmospheric GHG levels are causing changes to the earth's climate that are already being experienced in California and throughout the world. California is now forced to adapt to increases in the frequency and intensity of wildfires,

[13] California Air Pollution Control Officer's Association; California's Progress Towards Clean Air; 2015; www.capcoa.org/wp-content/uploads/2015/04/2015%20PTCA%20CAPCOA%20Report%20-%20FINAL.pdf .

[14] California Air Resources Board; California Almanac of Emissions and Air Quality – 2013 Edition; www.arb.ca.gov/aqd/almanac/almanac13/almanac13.htm .

[15] ARB; Proposed 2016 State Strategy for the State Implementation Plan; May 17, 2016; http://www.arb.ca.gov/planning/sip/2016sip/2016statesip.pdf .

[5] ARB; 2016 Mobile Source Strategy, May 2016; http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm

severity of droughts, rising sea levels, and extreme weather patterns.[16] Research also suggests that higher temperatures, longer and more frequent heat waves, a longer ozone season, and other impacts of climate change will result in more frequent, multi-day high ozone episodes.[15]

Heavy-duty vehicle CO_2 emissions have steadily risen since 2000 due to the growth in truck population and vehicle miles traveled (VMT).[17] While Phase 1 and 2 GHG Standards will play a significant role in curbing the CO_2 emissions from heavy-duty trucks, additional actions will be needed to meet California's 2030 and 2050 climate targets.[19] California's passenger and freight transportation system must transition to zero- and near-zero-emission technologies for the State to meet its post-2020 air quality and climate goals. These goals include:

- Reducing greenhouse emissions to 40 percent below 1990 levels by 2030, as directed in Governor Brown's Executive Order B-30-2015;[2]
- Reducing GHG emissions from the transportation sector to 80 percent below 1990 levels by 2050, as directed in Governor Brown's Executive Order B-16-2012;[3]
- Meeting the Governor's goal of deploying 1.5 million ZEVs by 2025 as directed in Executive Order B-16-2012, and the related goal of deploying one million ZEVs and near-zero emission vehicles by January 1, 2023, as codified in Health and Safety Code Section 44258.4(b). The California Sustainable Freight Action Plan includes a related goal of deploying 100,000 freight vehicles and equipment capable of zero-emission operation by 2030;[4] and
- Meeting federal health-based eight-hour ozone standards as required by 2023 and 2031 in the South Coast Air Basin, which will require a NOx reduction of approximately 70 percent by 2023 and 80 percent by 2031 from today's levels.[5]

Achieving and maintaining these goals will require California's truck and bus fleets to transition to more efficient, zero- and near-zero emission technologies.

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[16] ARB; First Update to the Climate Change Scoping Plan: Building on the Framework Pursuant to AB 32; May 2014;
[15] California Air Pollution Control Officer's Association; California's Progress Towards Clean Air; 2015; www.capcoa.org/wp-content/uploads/2015/04/2015%20PTCA%20CAPCOA%20Report%20-%20FINAL.pdf .
[17] ARB: Draft Supporting Information for Technology Assessments: Truck and Bus Sector Description; April 2016; http://www.arb.ca.gov/msprog/tech/techreport/t&b_sector_description.pdf .
[19] ARB: Draft Supporting Information for Technology Assessments: Truck and Bus Sector Description; April 2016; http://www.arb.ca.gov/msprog/tech/techreport/t&b_sector_description.pdf .
[2] Governor Brown's Executive Order B-30-2015: https://www.gov.ca.gov/news.php?id=18938 .
[3] Governor Brown's Executive Order B-16-2012: http://gov.ca.gov/news.php?id=17472 .
[4] ARB, *California Sustainable Freight Action Plan*; July 2016: http://www.casustainablefreight.org/app_pages/view/154.
[5] ARB; 2016 Mobile Source Strategy, May 2016; http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm .

II. PROPOSED INNOVATIVE TECHNOLOGY REGULATION

A. DESCRIPTION OF PROBLEM PROPOSAL IS INTENDED TO ADDRESS

California's mobile source emission control program – including certification requirements to ensure engines achieve anticipated emission benefits when new and in-use – have helped significantly drive down vehicle emissions over the past fifty years.[18] However, ARB's engine and vehicle approval paradigm is geared towards traditional technologies. Comprehensive OBD compliance, in particular, may be challenging and resource intensive for a new, innovative heavy-duty engine or vehicle technology that is uncertain to achieve market acceptance. Such a dynamic can lead a manufacturer to choose not to develop and introduce innovative new truck or bus technologies for which initial certification costs may be high and initial sales volumes low.

To address these challenges and encourage additional needed technology innovation, the proposed ITR would provide a more flexible short-term certification pathway, described in detail below, for the following innovative truck and bus technologies.

- New heavy-duty engine technologies:
    - A heavy-duty spark-ignition engine (through the 2021 MY) or a heavy-duty compression-ignition engine (through the 2024 MY) meeting California's optional low-NOx emission standards;
    - A heavy-duty engine that will be installed in a hybrid heavy-duty vehicle (hybrid engine) through the 2021 or 2024 MY, depending upon whether or not the vehicle is capable of at least 35 miles AER; and
    - A heavy-duty engine that meets the proposed ITR optional low-CO_2 emission standards, reflective of a 15 percent CO_2 reduction relative to a 2017 baseline engine, through the 2027 MY; and
- Hybrid conversion systems: A hybrid conversion system installed on a truck or bus (specifically, an ARB-certified vehicle between 6,000 and 14,000 pounds GVWR or ARB-certified engine installed in a vehicle over 8,500 pounds GVWR).

These technologies each play a role in helping California meet its air quality and climate goals, yet each could face certification challenges inherent in certifying a new technology for the first time.

1. *New Heavy-Duty Engine Technologies.* This proposed regulation would allow an eligible new heavy-duty engine that achieves a NOx or CO_2 emission reduction beyond what is required by existing new engine emission standards for the applicable MY (i.e., whose emission reductions are "surplus" to existing engine NOx or CO_2 emission certification standards for the given engine MY) to receive flexibility

[18] ARB; History of the Air Resources Board (October 22, 2015); http://www.arb.ca.gov/knowzone/history.htm .

when applying to ARB for criteria pollutant emission standard certification. The proposed ITR primarily provides heavy-duty engine OBD certification flexibility, with many flexibility provisions reflective of the phased-in EMD and OBD requirements for 2007 through 2013 MY heavy-duty engines. This proposed regulation does not alter existing heavy-duty engine emission testing, warranty, useful life, enforcement, or any other engine certification requirements unless explicitly stated.

While U.S. EPA and ARB's existing heavy-duty engine certification requirements are virtually identical, this proposed regulation would provide targeted certification flexibility to new heavy-duty engines when applying to ARB for certification with California criteria pollutant emission standards only. Such California-certified engines would be eligible for sale only in California and in states that adopt this regulation pursuant to section 177 of the federal Clean Air Act.[19] U.S. EPA has indicated that it may deem a low-NOx heavy-duty engine family receiving certification flexibility pursuant to this proposed ITR as compliant with federal OBD requirements due to the relatively modest OBD compliance flexibility provided, facilitating sale of these engines nationally. ARB continues to discuss opportunities for U.S. EPA to recognize engines meeting California's OBD requirements pursuant to the proposed ITR as also compliant with federal OBD, in order to streamline federal certification of ARB-certified innovative engines families.

2. *Hybrid Conversion Systems.* This proposed regulation's "California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems" provide criteria, including emissions, diagnostics, warranty, reporting, and other requirements for hybrid truck and bus conversion systems to be certified by ARB, and sold and installed on a California-certified base engine or vehicle. The proposed ITR would allow a manufacturer to sell increasing California volumes of its hybrid conversion system by certifying to progressively more stringent Tier 1, Tier 2, and Tier 3 requirements.

   The proposed flexibility is structured to encourage early development and market launch of a diversity of hybrid conversion systems, particularly from the smaller, independent manufacturers that make up today's market, by minimizing initial engineering challenges and certification compliance costs and scaling up certification requirements as the market develops. Staff anticipates that a flourishing market for hybrid conversion systems, particularly in the medium-duty sector, could achieve near-term CO_2 reductions, and encourage larger, original vehicle manufacturers to enter the market with robust, vertically integrated hybrid trucks and buses.

Sections B.1, C.1, D.1 and E.1 provide additional description of the certification challenges the proposed ITR is intended to address to encourage early deployment of

[19] The states that have adopted one or more California on-road motor vehicle regulations are: Connecticut, Delaware, Georgia, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington.

heavy-duty low-NOx engines, hybrid engines, high-efficiency engines, and hybrid conversion systems, respectively. The remainder of this chapter describes and provides justification for the ITR provisions staff is proposing to address these challenges.

B. LOW-NOx HEAVY-DUTY ENGINES

1. Background

In December 2013, ARB adopted "Optional Reduced Emission Standards for Heavy-Duty Engines" to encourage development and deployment of engines with lower NOx emissions than were required by the existing mandatory NOx emission standard. These optional low-NOx heavy-duty engine emission standards were 0.10, 0.05, and 0.02 g/bhp-hr NOx, which are 50 percent, 75 percent, and 90 percent, respectively, below the mandatory NOx emission standard of 0.20 g/bhp-hr for 2010 MY and newer heavy-duty engines.

As shown in Figure II-1, implementation of the existing mandatory heavy-duty engine NOx emission standard, California's Truck and Bus Regulation, incentive funding, and other strategies will achieve a 70 percent reduction in heavy-duty vehicle NOx emissions by 2023 in the South Coast Air Basin. However, the pace of emission reductions from existing strategies flattens at this point, and is never projected to achieve the emission reductions needed to meet the federal ozone standard in South Coast by 2023 or 2031. This indicates that while current programs achieve substantial reductions, truck and bus emissions must continue to decrease, and at a more rapid pace, to meet ozone attainment needs. ARB's 2016 Mobile Source Strategy identifies low-NOx engines, combined with renewable fuel, as the most viable approach to concurrently meet 2030 GHG and 2031 ozone attainment targets, with about 400,000 trucks that are at least 90 percent cleaner than today's standards needed to meet the 2031 ozone standard.[20]

A diversity of low-NOx engines will be needed in both spark-ignition (i.e., typically natural gas) and compression-ignition (i.e., diesel) configurations, and in multiple sizes, to enable deployment in California's diverse truck and bus vocations, including interstate, long haul, and rural applications where alternative fueling infrastructure may not be consistently available. Early deployment of a variety of spark- and compression-ignition low-NOx engines will not only achieve critical near-term NOx reductions, it will enable development of a more robust and effective lower mandatory low-NOx standard. The proposed ITR is crafted to encourage manufacturers to accelerate development and ARB certification of a greater diversity of low-NOx engines by addressing potential near-term low-NOx engine certification challenges, particularly potential resource and engineering challenges associated with demonstrating OBD compliance.

[20] ARB; 2016 Mobile Source Strategy, May 2016; http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm

ARB and the South Coast Air Quality Management District (SCAQMD), in partnership with the California Energy Commission (CEC) and other agencies, are funding research to develop both spark- and compression-ignition heavy-duty low-NOx engines of various engine sizes. This research has helped enable development and ARB certification of the first heavy-duty spark-ignition engine meeting one of California's optional low-NOx emission standards – a 2016 MY Cummins 8.9 liter (L) 0.02 g/bhp-hr NOx natural gas engine suitable for transit, refuse hauler, and other heavy-duty applications (See Figure II-2).[21] Cummins has also certified a 2017 MY 6.7 L heavy-duty engine meeting the 0.10 g/bhp-hr NOx standard.[22] Neither of these ARB certified low-NOx engines is equipped with heavy-duty OBD since, as mentioned earlier, alternative fuel engines are not subject to most heavy-duty OBD requirements until the 2018 MY. Staff anticipates additional spark-ignition heavy-duty engines will be certified to meet the 0.10, 0.05 and 0.02 g/bhp-hr NOx standards in the next several years, with compression-ignition engines meeting low-NOx certification levels becoming commercially available shortly thereafter.

Figure II-2:
Cummins Westport ISL Spark-ignition Alternative Fuel 9 Liter Engine Certified to 0.02 g/bhp-hr NOx

2. Proposed Eligibility Criteria

The proposed ITR would provide heavy-duty engines meeting California's optional low-NOx standard with up to three consecutive MYs of modest certification flexibility through the 2021 or 2024 MYs, as shown in Table II-1. Certification flexibility would primarily be OBD-related, and would provide modest encouragement to manufacturers to bring a low-NOx engine to market sooner than might otherwise occur while preserving the integrity of the OBD system. A spark-ignition heavy-duty engine meeting a 0.10 g/bhp-hr NOx standard would not be eligible for this proposed regulation, since emission testing conducted as part of heavy-duty natural gas engine certification indicates that multiple alternative fuel heavy-duty engines can already meet a 0.10 g/bhp-hr or lower NOx emission limit, and a spark-ignition engine meeting the most stringent 0.02 g/bhp-hr standard has already been certified by ARB.

[21] ARB; Executive Order A-021-0630 (New On-Road Heavy-Duty Vehicle Engines); September 10, 2015; http://www.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2016/cummins_mhdd_a0210630_8d9_0d02-0d01_ng.pdf .

[22] ARB; Executive Order A-021-0650 (New On-Road Heavy-Duty Vehicle Engines); April 28, 2016; http://www.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2017/cummins_mhdd_a0210650_6d7_0d10-0d01.pdf .

a. *Spark-Ignition Low-NOx Engines.* The proposed ITR would provide each manufacturer of a spark-ignition low-NOx engine with up to three consecutive MYs, through the 2021 MY, of certification flexibility for all of its eligible spark-ignition low-NOx engines. Each engine manufacturer's eligibility would begin in the first MY any of its spark-ignition low-NOx engines are certified by ARB pursuant to this proposed regulation. For example, if an engine manufacturer receives certification of a 0.02 or 0.05 g/bhp-hr NOx spark-ignition engine pursuant to this proposed regulation's certification flexibility in the 2018 MY, all of that engine manufacturer's 0.02 or 0.05 g/bhp-hr NOx spark-ignition engines would be eligible for this proposed regulation's certification flexibility in the 2018, 2019, and 2020 MYs. If an engine manufacturer first receives ARB certification of a 0.02 or 0.05 g/bhp-hr NOx spark-ignition engine pursuant to this proposed regulation's certification flexibility in the 2020 MY, all of that manufacturer's 0.02 or 0.05 g/bhp-hr NOx spark-ignition engines would be eligible for the proposed ITR certification flexibility in the 2020 and 2021 MYs. However, as illustrated in Table II-1, below, that manufacturer's spark-ignition low-NOx engines would not be eligible for this proposed regulation's certification flexibility after the 2021 MY, even though the manufacturer had only received two years of certification flexibility up to that point.

Table II-1: Proposed Low-NOx Engine Eligible Model Years

Model Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Spark-Ignition - 0.05 or 0.02 g/bhp-hr	Up to Three Consecutive MYs per Manufacturer							
Compression-Ignition - 0.10, 0.05 or 0.02 g/bhp-hr	Up to Three Consecutive MYs per Manufacturer							

b. *Compression-Ignition Low-NOx Engines.* The proposed ITR would provide each manufacturer of a compression-ignition low-NOx engine up to three consecutive MYs of certification flexibility, with each manufacturer's eligibility timeline beginning independently for each of the three low-NOx engine emission standards. For example, if an engine manufacturer first certifies a 0.10 g/bhp-hr NOx compression-ignition engine pursuant to this proposed regulation in the 2018 MY, all of that manufacturer's 0.10 g/bhp-hr NOx engine families would be eligible for this proposed regulation in the 2018, 2019, and 2020 MYs, but would not be eligible in the 2021 MY or thereafter. However, that engine manufacturer's three MY eligibility window for its compression-ignition engines meeting the 0.05 and 0.02 g-bhp-hr low-NOx standard would not be triggered, since the three MYs of eligibility for low-NOx compression-ignition engine families are discrete for each of the three low-NOx engine emission standards. If that same manufacturer first certified a 0.05 g/bhp-hr NOx compression-ignition engine in the 2020 MY and a 0.02 g/bhp-hr NOx engine in the 2023 MY, all of its 0.05 g-bhp-hr engines would be eligible in the 2020, 2021, and 2022 MYs, and all of its 0.02 g/bhp-hr engines would be eligible in the 2023 and 2024 MY. The 2024 MY would be the last MY of eligibility for a compression-ignition low-NOx engine, as shown in Table II-1, above.

Staff's proposed approach to spark-ignition and compression-ignition eligibility and sunset provisions is based upon the relative technology readiness and anticipated commercialization timelines for each engine type. A spark-ignition alternative fueled heavy-duty engine certified to the 0.02 g/bhp-hr NOx emission standard is commercially available, with a diversity of alternative fuel engines meeting all three low-NOx standards anticipated in the near term.

Unlike with spark-ignition engines, staff anticipates compression-ignition low-NOx engine technology to mature progressively, with a 0.10 g/bhp-hr NOx heavy-duty diesel engine expected in the next few years, followed by heavy-duty diesel engines meeting the 0.05 and, potentially, the 0.02 g/bhp-hr NOx emission standard. As such, this proposed regulation would provide a manufacturer with up to three years of certification flexibility for compression-ignition low-NOx engines meeting each of the three low-NOx engine standards independently, to reflect these technologies' anticipated sequential commercialization timelines. This approach would ensure that certification flexibility for a 0.10 g/bhp-hr compression-ignition engine does not preclude a manufacturer's subsequent eligibility for a 0.05 or 0.02 g/bhp-hr NOx engine, in order to encourage manufacturers to accelerate certification of technologies that meet all three low-NOx standards. The sunset MY for low-NOx compression-ignition engines recognizes their later anticipated commercialization timeline relative to spark-ignition engines, while encouraging early commercialization to support potential implementation of a mandatory heavy-duty low-NOx emission standard in this timeframe.

ARB's Mobile Source Strategy envisions ARB adopting a mandatory heavy-duty low-NOx emission standard, with implementation potentially beginning as soon as the 2024 MY. Since this proposed regulation requires that NOx emission reductions achieved by a low-NOx engine go beyond what is required by existing mandatory engine emission standards for a given MY, implementation of a mandatory low-NOx standard beginning with the 2024 MY could result in a low-NOx engine being ineligible for this proposed regulation in the 2024 MY. Continued eligibility of a low-NOx engine for this proposed regulation in the 2024 (or earlier) MY would depend upon how an eventual mandatory low-NOx engine standard is structured, and would be considered as part of any mandatory low-NOx heavy-duty engine standard regulatory development.

3. <u>Proposed Certification Flexibility Provisions</u>

The proposed ITR does not change the existing heavy-duty engine certification process for criteria pollutants, and would not alter current certification requirements, including submittal of a certification application, emission testing, warranty, enforcement, and other requirements, except where specified. This proposed regulation would, however, provide a manufacturer of an eligible low-NOx engine with the flexibility to use an assigned deterioration factor (DF) and provide modest OBD compliance flexibility, as described below, when applying to ARB for certification of an eligible low-NOx engine. This proposed suite of proposed flexibility provisions is based upon extensive

discussions with engine manufacturers and other stakeholders, and reflects staff's assessment of the certification flexibility needed to encourage development of a diversity of low-NOx engines while maintaining the ability to ensure anticipated emission benefits of the technology are achieved and maintained in-use. Proposed certification flexibility provisions are summarized below, and are described in more detail in Appendix A.

a. *Assigned Deterioration Factors.* A heavy-duty engine must typically demonstrate at the time of application for certification that its emissions do not exceed specified emission thresholds over its useful life by emission testing the engine after it has been aged to the end of its required useful life. However, engine aging can be time and resource intensive, and both U.S. EPA and ARB have provisions for small volume manufacturers to utilize "assigned deterioration factors" to help determine the deteriorated emission levels from engines that have not been fully aged.[23] The proposed ITR would allow a manufacturer to use assigned DFs in lieu of conducting high mileage emission tests when certifying an eligible low-NOx engine with ARB.

b. *On-Board Diagnostics Flexibility Provisions.* An eligible low-NOx engine family would be subject to all existing heavy-duty OBD requirements, as described in California Code of Regulations, title 13, sections 1971.1 and 1971.5, with the following exceptions:

- *OBD System Demonstration:* California Code of Regulations, title 13, section 1971.1, subdivision (i)(2.2.3) requires that manufacturers provide ARB with OBD emission test data from one or more durability demonstration test engines. A manufacturer certifying one to five engine families in a MY must provide these data for at least one engine rating, a manufacturer of six to ten engine families must do so for at least two engine ratings, and a manufacturer of eleven or more engine families must do so for at least three engine ratings. To minimize the test burden on manufacturers, and to encourage the introduction of low-NOx engines, the proposed ITR would exempt up to three low-NOx engine families from the calculation of a manufacturer's total number of engine families for determining the number of OBD system demonstration engines for a given MY. This proposed provision is intended to eliminate a potential manufacturer disincentive to certify additional low-NOx engine families, by ARB's undertaking a minimal risk of "auditing" a smaller number of engine families in a MY.

- *Calculation of Fines for Deficiencies:* California Code of Regulations, title 13, section 1971.1, subdivision (k) permits ARB to allow certification of heavy-duty OBD systems with "deficiencies" in cases where a good faith effort to fully comply has been demonstrated. Given the potential for challenges integrating new diagnostic systems and technologies, the proposed ITR would provide for up to

[23] US EPA; Dear Manufacturer Letter CCD-00-12 (LDV/LDT/HD/SVM/ICI/); August 24, 2000; http://www.arb.ca.gov/msprog/cihd/_resources/content/regulations/assigned-dfs/ccd-00-12.pdf .

four allowable deficiencies not subject to fines related to monitoring of the low-NOx technology.

- *Emission Threshold Liability:* California Code of Regulations, title 13, section 1971.5, subdivision (d)(3)(A)(ii) requires that major OBD monitors indicate a malfunction and illuminate the MIL before emissions exceed a certain emission threshold. The proposed ITR would increase allowable emission thresholds (to the levels they were for 2013 through 2015 MY engines) to help mitigate a manufacturer's potential risk of an emissions recall for a new engine technology.

- *Production Engine/Vehicle Evaluation Testing:* California Code of Regulations, title 13, section 1971.1, subdivision (l) requires that manufacturers conduct testing on a subset of engines installed in in-use vehicles and provide the results of such testing to ARB within a certain period of time. The proposed ITR would still require this reporting, but would provide flexibility regarding the number of required tests and reporting timelines.

c. *Other Provisions.* The proposed ITR also includes a multiple low-NOx engine option, engine labeling requirements, and a provision that a participating low-NOx engine achieve NOx reductions beyond what is required by the applicable mandatory engine emission standard. These provisions are detailed in Appendix A.

C. HYBRID HEAVY-DUTY VEHICLES

1. Background

Hybrid vehicles typically employ two distinct power sources: a combustion engine and an alternative, rechargeable motive power source, such as an electric or hydraulic motor. The combustion engine can be coupled with the alternative power source to concurrently provide tractive power to move the vehicle, as in a parallel hybrid system, or the engine can act as a generator to power the electric motor, which in turn provides the sole tractive power to move the vehicle, as in a series hybrid system. Deployment of robust hybrid truck and bus technology – particularly hybrids with zero-emission range – can facilitate California's transition to passenger and freight transportation solutions by supporting battery innovation in zero-emission applications, helping build supply chains and a servicing industry for zero-emission components like controllers, motors, and electricity converters, and fostering fleet readiness for, plug-in technology.

The most advantageous duty-cycles for heavy-duty hybrids – in which the rechargeable power source can benefit from more frequent acceleration, deceleration, and regenerative braking – are those with frequent starts and stops, low speeds, and idling. Therefore, vehicles with heavy urban start-and-stop duty-cycles and high idle time, such as refuse haulers, transit buses, and package or beverage delivery trucks are best suited for hybridization. Trucks that utilize an electronic power take-off (ePTO), such as utility bucket trucks, can also achieve fuel economy and emission benefits from

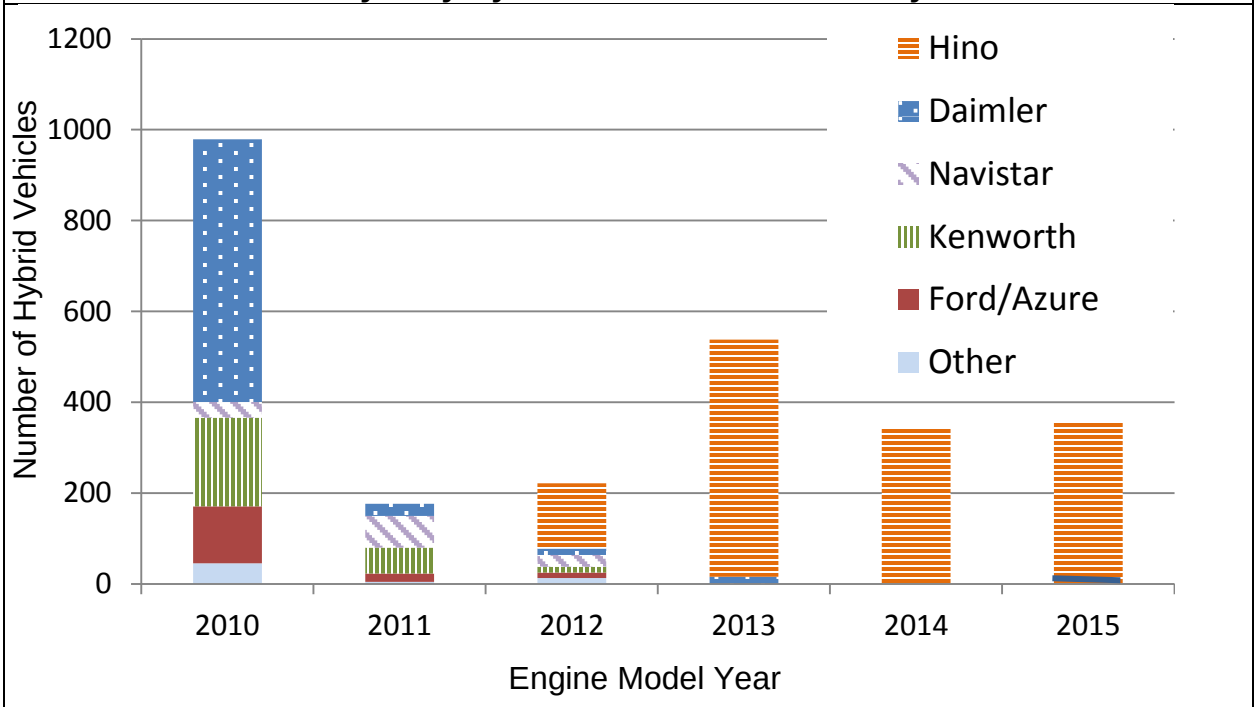
hybridization by employing the hybrid's batteries rather than the vehicle's motive engine at idle to power the ePTO.

Several challenges have influenced staff's proposal for hybrid heavy-duty engine certification flexibility – hybrid truck and bus market challenges, the non-vertically integrated nature of hybrid heavy-duty vehicle manufacturing and related OBD compliance challenges, and potential excess in-use NOx emissions from some hybrid trucks and buses. The remainder of this section describes each of these challenges in turn, followed by a detailed discussion of how the proposed ITR is structured to help address them.

a. *Hybrid Truck and Bus Market Challenges.* The market for hybrid heavy-duty vehicles has been volatile since five major truck manufacturers (i.e. Freightliner, Kenworth, Navistar, Peterbilt and Ford/Azure Dynamics) introduced a variety of hybrid urban delivery and other heavy-duty vehicles for the California market in 2010, coinciding with the launch of ARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP) (see Figure II-3, below). These first generation hybrid trucks, typically utilizing a Cummins heavy-duty engine and an Eaton hybrid driveline, were "non-vertically integrated," as the engine, hybrid driveline, and chassis were produced by different manufacturers. While a handful of large fleets, such as UPS and Coca-Cola, drove strong initial demand for these vehicles, none of these early-adopter fleets subsequently purchased additional hybrid trucks, and the California market for these vehicles stagnated by the end of 2011.

   These five initial manufacturers no longer produce hybrid trucks for the California market, due to a combination of reduced consumer demand and challenges meeting ARB's newly phased-in heavy-duty OBD compliance requirements. Staff discussions with early-adopter fleets indicate those fleets discontinued purchase of hybrid trucks due to performance concerns from the first generation products, with some fleets opting to shift their limited "green" vehicle funding to alternative fuel vehicles in response to lower natural gas prices.

Figure II-3:
Number of Heavy-Duty Hybrid Vehicles Purchased by California Fleets*



* Includes engines purchased as of March 1, 2016. Does not include transit buses.

In 2012, Hino Motor Company, a subsidiary of Toyota Group, entered the California market with a vertically-integrated Class 5 parallel hybrid delivery truck that leverages Toyota Prius technology and complies with ARB's heavy-duty OBD requirements. The Hino hybrid truck is a fifth generation vehicle, originally available in Japan. California demand for Hino hybrid trucks has been driven primarily by smaller California fleets purchasing a handful of vehicles with the help of HVIP incentive funding. California's hybrid heavy-duty vehicle market today consists of the Class 5 Hino hybrid truck, an Autocar hydraulic hybrid refuse truck with a Parker Hannifin hybrid driveline and Cummins diesel engine, and two hybrid transit buses using Allison Transmission and BAE Systems drivelines paired with a Cummins diesel engine. None of these manufacturers offers plug-in hybrid technology capable of zero-emission operation. While funding to help California fleets purchase hybrid trucks and buses continues to be available via HVIP, the scarcity of market offerings, historically low fuel prices, and fleet resistance to unfamiliar technology remain persistent obstacles to increasing fleet demand for hybrid trucks and buses.

b. *Integrated Heavy-Duty Hybrid OBD Compliance.* Most OBD requirements for heavy-duty diesel hybrids certified for sale in California were fully phased-in as of the 2014 MY, and require a single integrated OBD system that monitors the overall engine and hybrid powertrain. OBD requirements can pose a compliance challenge for hybrid heavy-duty engine and drivetrain combinations that are not produced by the

same manufacturer,[24] as manufacturers may be unwilling to share confidential business information needed to develop an integrated OBD system covering both components, and neither the engine nor the drivetrain manufacturer have been willing to take sole responsibility for certifying an OBD-compliant engine-drivetrain combination with ARB. Several hybrid truck engine and driveline manufacturers have opted to exit the still-developing heavy-duty hybrid market rather than devote resources to demonstrating OBD compliance for an integrated hybrid engine and drivetrain.

To enable certification of such systems, ARB staff has worked closely with Allison Transmission, BAE Systems, Parker Hannifin, and Cummins to issue a "dual" Executive Order for the applicable engine and hybrid driveline combination. The engine and driveline manufacturers must demonstrate OBD compliance for the overall engine and driveline system, and each manufacturer is responsible for OBD and warranty compliance for its own componentry under a single ARB Executive Order. While a dual Executive Order does enable non-vertically-integrated hybrids to stay in the California market, a single manufacturer responsible for all componentry – such as with the Hino hybrid system – provides greater opportunity for system integration and predictability should an enforcement issue arise.

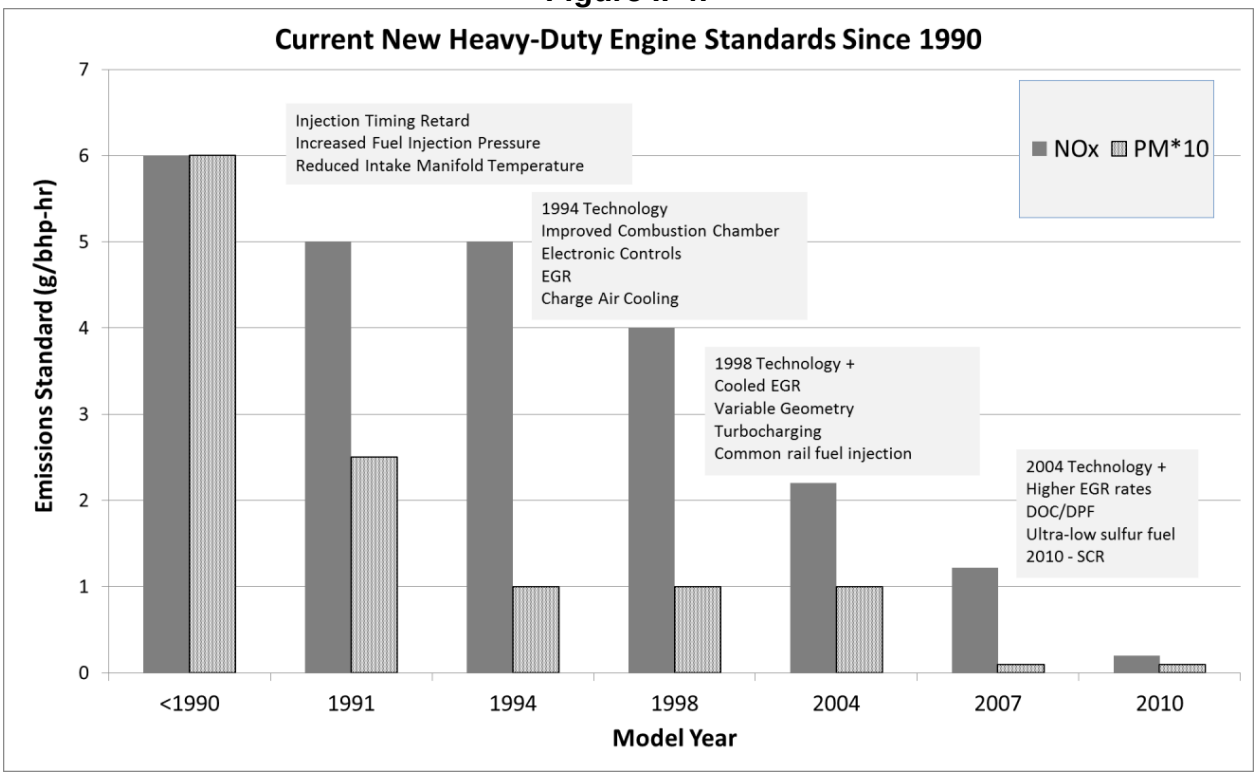
c. *Hybrid Truck and Bus NOx Emissions.* While the case for reduced CO_2 emission reductions from hybrid technology is relatively straightforward, the potential for NOx emission reductions is much less definitive. Some manufacturers have argued that hybrid technology will reduce criteria pollutant emissions because reduced fuel consumption will result in less exhaust emissions. This is true for CO_2 emissions, since the correlation between the amount of fuel combusted and CO_2 emissions is well established. The same conclusion, however, is not necessarily true for NOx emissions, due to the complexity of today's heavy-duty engine and emission control system.

Heavy-duty engine emission standards have steadily declined since 1990, as shown in Figure II-4. The typical new heavy-duty diesel engine employs a sophisticated suite of carefully calibrated engine plus aftertreatment emission control strategies, such as selective catalytic reduction (SCR), to reduce NOx by 98 percent relative to an uncontrolled engine. As previously described, most first-generation heavy-duty hybrids manufactured in the 2010 and 2011 MYs utilized engines from one manufacturer coupled with a driveline from another manufacturer, which were both then installed on a heavy-duty chassis from one of five other heavy-duty truck manufacturers. Unlike the automobile industry, where major components are typically manufactured by (or specifically for) use in a specific passenger car, this structure provides less opportunity for significant integration of the engine,

[24] California Hybrid, Efficient and Advanced Truck Research Center (CalHEAT); CalHEAT Research and Market Transformation Roadmap for Medium- and Heavy-Duty Trucks; February 2013; http://www.calstart.org/Libraries/CalHEAT_2013_Documents_Presentations/CalHEAT_Roadmap_Final_Draft_Publication_Rev_6.sflb.ashx .

aftertreatment strategy, hybrid driveline, and other components to optimize hybrid vehicle and emissions performance.

Figure II-4:



* EGR = Exhaust Gas Recirculation; DOC = Diesel Oxidation Catalyst; DPF = Diesel Particulate Filter

If the hybrid system is well designed and integrated, NOx emissions from a hybrid vehicle can be lower compared to an equivalent conventional vehicle, as demonstrated in a recent study comparing emissions from a series hybrid-electric bus to emissions of a similar conventional bus (Kittelson et al., 2015).[25] However, other studies demonstrate the potential for hybrid heavy-duty vehicles to emit significantly higher NOx relative to their non-hybrid counterparts. A National Renewable Energy Laboratory (NREL) evaluation conducted for ARB of 120 in-use hybrid and non-hybrid vehicles across four common hybrid vehicle vocations determined that some 2010 through 2012 MY hybrid heavy-duty trucks may emit up to 50 percent more NOx in-use than their non-hybrid counterparts.[8] This study concluded that some hybrid engines may operate at a lower torque and engine

[25] David Kittelson, et al., "On-Road Evaluation of Energy Flows and Emissions from New Technology Conventional and Hybrid Transit Buses," 25th CRC Real World Emissions Workshop, March 22-25, Long Beach, California.

[8] National Renewable Energy Laboratory; Data Collection, Testing, and Analysis of Hybrid Electric Trucks and Buses Operating in California Fleets: Final Report; June 2015; www.nrel.gov/docs/fy15osti/62009.pdf .

speed relative to their non-hybrid counterparts in response to the same vehicle power request, resulting in higher brake-specific NOx emissions.

2. Proposed Eligibility Criteria

To be eligible for the proposed ITR certification flexibility, a hybrid engine and drivetrain combination would be required to demonstrate, using a portable emission measurement system (PEMS), chassis dynamometer, or post-transmission powertrain vehicle simulation, that it does not increase NOx, CO, or HC emissions and achieves at least a ten percent CO_2 reduction relative to its non-hybrid counterpart. Section 7 of the proposed ITR's *California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems* (ITR Hybrid Technology Emission Test Procedures) describes the emission test procedures that would apply to both new hybrid heavy-duty engines and hybrid conversions under this proposed regulation. Staff's proposal would provide compliant manufacturers with up to either four or six MYs of ARB certification flexibility for their hybrid systems, with the longer eligibility window for an engine that is installed in a hybrid capable of at least 35 miles of uninterrupted AER. This 35 mile AER threshold is based upon discussions with technology manufacturers regarding the point at which, considering battery size and cost, fleets are likely to optimize their zero-emission operation and fuel savings over the course of a typical day. The ITR Hybrid Technology Emission Test Procedures describe the process for each manufacturer to determine its vehicle's AER.

a. *Heavy-Duty Hybrid with Less Than 35 Miles AER.* A hybrid engine family certified for installation on a plug-in heavy-duty vehicle capable of less than 35 miles AER (including non-plug-in hybrids with no electric range) would be eligible for up to two consecutive MYs of Tier 1 certification flexibility, followed by up two additional consecutive MYs of more modest Tier 2 flexibility. As shown in Table II-2, proposed ITR eligibility for Tier 1 or Tier 2 certification flexibility for such an engine family would end with the 2021 MY. This potential four-year window would begin in the MY in which an engine manufacturer first certifies an eligible hybrid engine family pursuant to the proposed ITR. For example, if an engine manufacturer first certifies a hybrid engine family that does not enable at least 35 miles AER in the 2018 MY pursuant to this regulation, all that manufacturer's hybrid engines that do not enable at least 35 miles AER would be eligible for Tier 1 certification flexibility in the 2018 and 2019 MYs, and would be eligible for Tier 2 flexibility in the 2020 and 2021 MYs. This up-to-four MY eligibility window would apply to all of that engine manufacturer's hybrid engines that do not enable at least 35 miles AER, inclusive of all potential hybrid drivelines with which the engines could be paired.

   A heavy-duty hybrid engine in a transit bus that does not achieve at least 35 miles AER would be ineligible for this proposed regulation's hybrid engine flexibility provisions, as non-plug-in hybrid technology is more common in the transit sector, due in part to the availability of Federal Transit Agency funding. As of March 2015,

690 hybrid transit buses were deployed with transit agencies in California.[26] Staff anticipates additional hybrid and other advanced technology transit buses could be deployed in the years to come if ARB's Advanced Clean Transit Regulation, due to be considered by the Board in 2017, is adopted. As such, the proposed ITR would target certification flexibility only to the most robust plug-in hybrids in the transit bus sector.

Heavy-Duty Hybrid with at Least 35 Miles AER. An engine family certified for installation on a plug-in heavy-duty hybrid vehicle capable of at least 35 miles AER would be eligible for up to four consecutive MYs of significant Tier 1 certification flexibility, followed by up two consecutive additional MYs of more modest Tier 2 flexibility. As shown in Table II-2, proposed ITR eligibility for such an engine would end with the 2024 MY. For example, if a manufacturer first certifies such an engine family in the 2018 MY, all that manufacturer's hybrid engine families that enable at least 35 miles AER would be eligible for this regulation's proposed Tier 1 certification flexibility in the 2018, 2019, 2020, and 2021 MYs, and for Tier 2 flexibility in the 2022 and 2023 MYs. This six MY eligibility window would apply to all of that engine manufacturer's hybrid engines that enable at least 35 miles AER, inclusive of all potential hybrid drivelines with which the engines could be paired.

Table II-2: Proposed Hybrid Engine Eligible Model Years

Model Year	2017	2018	2019	2020	2021	2022	2023	2024
<35 Miles AER	Up to Two Consecutive MYs Tier 1 + Up to Two Consecutive MYs Tier 2 per Manufacturer							
35+ Miles AER	Up to Four Consecutive MYs Tier 1 + Up to Two Consecutive MYs Tier 2 per Manufacturer							

3. Hybrid Heavy-Duty Engine Certification Flexibility Provisions

A hybrid heavy-duty engine and driveline combination that meets the proposed ITR's supplemental emission test and other requirements would be eligible for this proposed regulation's Tier 1 and Tier 2 flexibility when applying to ARB for certification. Staff's proposed Tier 1 and Tier 2 OBD flexibility provisions reflect lessons learned from California heavy-duty engine OBD requirements that phased-in beginning in the 2007 MY. The Tier 1 provision for EMD mirrors the initial diagnostic requirements for all heavy-duty engines between the 2007 and 2010 MYs, while proposed Tier 2 OBD flexibility includes elements of heavy-duty OBD requirements that were phased-in between the 2010 and 2013 MYs. The proposed certification flexibility provisions for heavy-duty hybrid engines are discussed below. For a more detailed description of the provisions, see Appendix A.

[26] ARB; Advanced Clean Transit Regulation Public Workshop Discussion Document; May 2015: http://www.arb.ca.gov/msprog/bus/actdiscussiondocument.pdf .

a. *Tier 1 Certification Flexibility.* Tier 1 would provide a new heavy-duty hybrid engine and its applicable hybrid driveline the following flexibility when applying to ARB for criteria pollutant emission standard certification:

- Assigned DFs: An engine family would be eligible for the same flexibility to use an assigned DF, in lieu of engine aging, as provided for a heavy-duty low-NOx engine pursuant to the proposed ITR.

- Engine Manufacturer Diagnostics (EMD): An engine family would be subject to heavy-duty EMD requirements in lieu of full OBD requirements. Heavy-duty EMD requires diagnostic monitoring of the performance and durability of the fuel system, exhaust gas recirculation system (if so equipped), particulate trap, and other emission-related electronic components.

b. *Tier 2 Certification Flexibility.* This proposed regulation's Tier 2 certification flexibility provisions for a new heavy-duty hybrid engine mirror those proposed for an engine meeting the optional low-NOx emission standard in Section II(B)(3), except for minor differences regarding OBD system demonstrations, production engine evaluation testing, and calculation of fines for deficiencies.

c. *Dual Executive Order.* This proposed regulation would also formalize criteria and a sunset date for ARB provision of a dual Executive Order to provide hybrid driveline and engine manufacturers with greater certainty regarding potential certification options. Manufacturer eligibility for a dual Executive Order when certifying a heavy-duty hybrid engine would be as follows:

- For the 2016 through 2020 MY, a hybrid heavy-duty engine and drivetrain would be eligible for a dual Executive Order.
- For the 2021 through 2024 MY, a hybrid heavy-duty engine and drivetrain would be eligible for a dual Executive Order only if supplemental chassis-based emission testing conducted pursuant to the proposed ITR Hybrid Technology Emission Test Procedures indicates the hybrid engine and drivetrain do not increase criteria pollutant emissions relative to their non-hybrid counterpart.
- For the 2024 and newer MYs, ARB would not provide a dual Executive Order.

This approach would provide engine and drivetrain manufacturers the lead time for engine-drivetrain integration and optimization, if needed, to ensure they can meet required supplemental emission test requirements beginning in the 2021 MY, and to prepare for sole emission compliance responsibility beginning in the 2025 MY. Manufacturers would be eligible for these provisions regardless of whether or not they opt to certify their hybrid engine pursuant to the proposed ITR.

Finally, discussions with hybrid technology manufacturers and U.S. EPA staff indicate that U.S. EPA may be considering a requirement that a single entity take sole responsibility for the engine and hybrid driveline combination when these are certified federally. Should this occur, the proposed ITR requires that a single entity

also take sole responsibility when such a hybrid engine and drivetrain combination is certified in California.

d. *Non-Traditional Heavy-Duty Hybrid Engines.* Several small, independent heavy-duty truck and bus manufacturers have approached ARB to explore opportunities for using a small off-road or light-duty engine to range extend a plug-in heavy-duty hybrid vehicle. Such an engine would operate exclusively at steady state to recharge the hybrid truck or bus battery, which in turn powers the vehicle's tractive motor, and would never directly propel the vehicle. These manufacturers have expressed interest in initially producing limited volumes of Class 5 package delivery trucks, Class 8 drayage trucks, and Class 8 transit buses to evaluate vehicle performance and fleet acceptance. They contend that a properly integrated, lower displacement engine originally certified for off-road equipment or in a plug-in passenger vehicle is adequate to range extend a heavy-duty truck or bus, and does so more efficiently than higher displacement heavy-duty engines. Such an engine would be configured for high-efficiency steady state operation, where emission performance can be more effectively verified and controlled.

The proposed ITR provides a certification pathway for a limited number of such engines. This proposed provision is similar to provisions in Federal Phase 2 GHG Standards for a limited number of off-road engines to be certified for use in heavy-duty hybrid vehicles. However, unlike Federal Phase 2 GHG Standards, the proposed ITR would limit eligibility to zero-emission capable hybrid vehicle configurations that ARB believes are most likely to provide immediate emission benefits and enable development of zero-emission heavy-duty vehicle technology.[27]

i. *Eligibility Criteria.* The proposed ITR would allow for an engine that has been previously certified to meet ARB's off-road engine emission standards, or for use in an ARB light- or medium-duty vehicle, to be considered for certification for use in a heavy-duty vehicle if the engine meets the following conditions:

1. The engine must be installed in a vehicle capable of achieving at least 35 miles AER, as demonstrated pursuant to this regulation's truck and bus hybrid technology emission test procedures;
2. The engine is electronically-controlled with a fully functional electronic control unit (ECU). This is necessary to enable effective monitoring of emission and other performance characteristics and eventual compliance with heavy-duty OBD requirements;
3. The engine may not be mechanically connected to the drivetrain, and may not be capable of directly propelling the vehicle in which it is installed;
4. The engine is a newly manufactured engine;

[27] ARB; Letter from ARB Chair Mary Nichols to U.S. EPA Administrator Gina McCarthy and NHTSA Administrator Mark Rosekind Regarding Proposed Phase 2 Standards Notice of Proposed Rulemaking; October 1, 2015; http://www.arb.ca.gov/msprog/onroad/caphase2ghg/comments/carb_phase_2_comments.pdf .

5. If a diesel engine, it is equipped with a diesel particulate filter;
6. If a gasoline- or liquid petroleum gas-fueled engine, it is installed in a vehicle that complies with heavy-duty vehicle evaporative emission standards pursuant to California Code of Regulations, title 13, section 1976; and
7. The engine may not be certified with a Family Emission Limit (FEL) that exceeds the applicable engine emission standard.

The plug-in hybrid vehicle in which the engine is installed must also be chassis-certified pursuant to the "California Interim Certification Procedures for 2004 and Subsequent Model Hybrid-Electric and Other Hybrid Vehicles, in the Urban Bus and Heavy-Duty Vehicle Classes" (December 2013). These certification procedures require a comparison of emissions from the proposed plug-in truck or bus with those from its non-hybrid counterpart, as both are tested over a chassis dynamometer using the Orange County Bus Cycle and the Heavy-Duty Urban Dynamometer Driving Schedule. The engine would not be required to be re-certified as a heavy-duty engine on an engine dynamometer. Instead, this supplemental chassis-based emission testing is intended to ensure the plug-in truck or bus in which the engine is installed will not exceed anticipated in-use emissions relative to its non-hybrid counterpart.

ii. Proposed Certification Pathway. A hybrid engine family seeking approval of this regulation's "alternate heavy-duty engine emission standards" would be eligible to be certified pursuant to the proposed ITR through the 2024 engine MY. An engine originally certified to off-road standards or for light- or medium-duty use that meets the applicable ITR requirements for a heavy-duty engine meeting alternate emission standards (identified in Section II(3)(f)(i), above) would be considered certified for heavy-duty use, if it meets the following additional requirements:

1. The engine must meet heavy-duty engine OBD requirements, with up to six total MYs of Tier 1 (i.e., EMD+) and Tier 2 certification flexibility provided for heavy-duty hybrids, a maximum four MYs of which may be Tier 1 flexibility. For example, a vehicle manufacturer could opt to sell hybrid vehicles for which the engine meets Tier 1 OBD provisions for up to four MYs, with an annual cap of 100 vehicles per year. If the manufacturer wished to sell up to 200 vehicles per MY, the engine installed in the vehicle would have to meet Tier 2 OBD provisions or achieve full heavy-duty engine OBD compliance. Staff does not believe additional certification flexibility for this technology is warranted at this time. While an off-road engine may have challenges meeting heavy-duty OBD requirements, staff believes the proposed flexibility provisions are sufficient for manufacturers of these engines to plan for and meet the engineering challenges of OBD compliance.

2. The engine must demonstrate compliance with the useful life requirements applicable to the heavy-duty vehicle class in which it will be installed, meaning an engine installed in a light-heavy-duty vehicle would be required to

demonstrate a 110,000 mile useful life, a medium-heavy-duty vehicle must demonstrate a 185,000 mile useful life, and a heavy-heavy-duty vehicle must demonstrate a 435,000 mile useful life. Since these are not experimental permit vehicles, and are eligible to be sold to California fleets, compliance with useful life requirements are necessary to ensure the engine is sufficiently durable for its intended use and will meet the anticipated needs of the end user.

3. The engine must include a warranty that covers the minimum warranty period for the original off-road, light-duty or medium-duty engine, but provides coverage for the engine when operated and properly maintained as intended in the on-road, hybrid heavy-duty vehicle. Staff anticipates this warranty coverage could be provided by the original engine manufacturer or by the hybrid vehicle manufacturer. This requirement ensures the original engine warranty period applies in order to protect the vehicle purchaser, and encourage thoughtful integration of the engine, battery and vehicle.

4. These engines and/or the vehicles in which they are installed must also be equipped to collect the following electronic data, which is to be provided to ARB annually for three years.

    - Total miles traveled (miles to date)
    - Daily miles traveled (miles per day)
    - Speed without idle (miles per hour)
    - Fuel economy (miles per gallon)
    - Percent zero-emission operation;
    - Miles of continuous zero-emission operation at full charge

iii. Allowable Sales Volumes. Due to the inherent uncertainties associated with certifying these non-traditional engines in a heavy-duty application for the first time, each vehicle manufacturer would be limited to a maximum of 100 vehicles per MY of Tier 1 certification flexibility, and 200 vehicles per MY of Tier 2 certification flexibility. A manufacturer would be ineligible to sell more than 200 vehicles per MY under any circumstances, and would be ineligible to certify an off-road, light-, or medium-duty engine in a heavy-duty vehicle pursuant to the proposed ITR after the 2024 MY. Staff believes this regulation provides greater certainty to manufacturers to launch, and opportunity for fleets to evaluate this technology, than would be available under ARB's experimental permit provisions due to specified allowable sales volumes and ability to sell the technology to early adopter fleets. Should this technology gain a market foothold, information gained during chassis-based certification, and from required in-use data, will enable ARB to update certification requirements and sales volume limitations, if appropriate, for 2024 and subsequent MY vehicles.

e. *Hybrid Medium-Duty Vehicles (i.e., between 8,501 and 14,000 pounds GVWR).* Many medium-duty truck and bus manufacturers, such as Ford and General Motors, also manufacture hybrid passenger vehicles. Much as the Hino Class 5 hybrid truck leverages Toyota Prius technology, today's hybrid passenger cars could facilitate development of high-performing hybrid medium-duty trucks and buses. However, few hybrid medium-duty vehicles are commercially available today. Discussions with some large vehicle manufacturers indicate they are hesitant to enter the hybrid medium-duty vehicle market because of low anticipated consumer demand, rather than due to certification compliance challenges. Hybrid medium-duty vehicles do not face the OBD compliance challenges of non-vertically integrated heavy-duty engines and vehicles, and chassis certified medium-duty hybrid vehicles are less likely to have higher NOx emissions in-use. Staff is therefore not recommending, and manufacturers have not requested, that hybrid medium-duty vehicles receive certification flexibility under the proposed ITR.

D. NEW HIGH-EFFICIENCY HEAVY-DUTY ENGINES

1. Background

More efficient heavy-duty engines can play an important role in reducing criteria pollutant and GHG emissions, particularly from long-haul tractor trailers that are responsible for the bulk of heavy-duty vehicle emissions. The U.S. Department of Energy (DOE) is co-funding several demonstration projects to increase engine and vehicle efficiency from heavy-duty tractor trailers, with the most significant being the SuperTruck program. The first phase of the SuperTruck program (SuperTruck I) provided approximately $130 million to four co-funding teams – Cummins/Peterbilt, Daimler, Volvo, and Navistar – that achieved freight efficiency improvements in excess of the program's 50% goal, on a ton-mile-per gallon basis, from Class 8 long-haul trucks. In March 2016, DOE announced the availability of an additional $80 million for SuperTruck II, to achieve a greater than 100% freight efficiency improvement relative to a 2009 baseline, and greater than or equal to 55% engine brake-thermal efficiency.[28]

The proposed ITR complements the goals of the SuperTruck program by providing certification flexibility for the next generation of potentially transformational heavy-duty engine architectures that could provide significant efficiency gains but may face an initial OBD or other certification challenge. ARB's Technology and Fuels Assessment, conducted in conjunction with SCAQMD and developed with extensive public input, provides a comprehensive assessment of vehicle and fuel technologies in order to inform California's air quality planning efforts.[29] ARB's Technology and Fuels

[28] DOE; News Release: DOE Announces $80 Million in Funding to Increase SuperTruck Efficiency; March 1, 2106; http://energy.gov/articles/doe-announces-80-million-funding-increase-supertruck-efficiency .
[29] ARB; Technology and Fuels Assessments Reports; http://www.arb.ca.gov/msprog/tech/report.htm .

Assessment identifies the following as potentially transformational, high-efficiency engine technologies:[7]

- Camless Engine: Conventional valve trains generally have fixed valve lift and timing during the combustion cycle. Such systems result in large parasitic power losses as friction from the camshaft and cam belts consume energy from the system and generally provide only one timing speed. A camless engine enables new technology advances that allow for independent control and scheduling of valve lift and duration, from valve to valve and from cycle to cycle, allowing for optimization of valve motion to the desired engine power output. More torque is made available, improving volumetric efficiency, which helps to reduce emissions while improving fuel consumption. Camless technology is thought to have the potential to deliver as much as 20 percent better fuel efficiency over a conventional engine,[30] and Sturman Industries has developed a camless engine that could achieve up to an 18 percent improvement in fuel efficiency.[31]

- Opposed Piston Engine: Opposed piston engines are two-stroke, compression-ignition engines in which each cylinder has two pistons that come together at top dead center and then expand outward upon combustion. The two pistons cyclically expose the exhaust and intake ports without the use of a camshaft or valve train, resulting in a smaller, lighter weight engine that reduces heat and frictional losses.[32] Opposed piston design enables higher thermal efficiency due to its leaner air/fuel ratio requirements and shorter combustion duration. Research suggests that opposed piston designs could provide a 15 to 24 percent reduction in fuel consumption, depending on the specific application.[33] Achates Power, Inc. is one manufacturer developing an opposed piston engine, which it indicates can achieve a 15 percent CO_2 reduction relative to a 2017 baseline engine.[34]

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[7] ARB; *Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency*; June 2015; http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf .

[30] Free Republic. Valeo in Developmental Contracts for Camless Engine; Projections of Up to 20% Improvement in Fuel Efficiency; December 26, 2006. http://www.freerepublic.com/focus/news/1758531/posts .

[31] Sturman Industries; Improving Efficiency of Spark-Ignited, Stoichiometrically Operated Natural Gas Engines: Final Report (prepared for the California Energy Commission); May 2011; http://www.sturmanindustries.com/Portals/0/Documents/PIR-08-023_Final_Report_FINAL_A.pdf .

[32] Fromm, L. et al. Modernizing the Opposed-Piston Engine for More Efficient Military Ground Vehicle Applications; 2012.

[33] Regner, G. et al. Optimizing Combustion in an Opposed-Piston, Two-Stroke (OP2S) Diesel Engine; 2014.

[34] Achates Power, Inc.; Press Release: Achates Power Ready for Future Efficiency Standards; September 8, 2015; http://achatespower.com/wp-content/uploads/2015/04/Achates-Power_ProposedEmissions_FINAL_9.9.15.pdf .

2. Optional Low-CO_2 Emission Standards

The proposed ITR would create new optional low-CO_2 emission standards, shown in Table II-3 for 2017 through 2027 MY engines, which reflect a 15 percent CO_2 emission reduction relative to a 2017 MY baseline compression-ignition engine. The proposed optional low-CO_2 emission standards were informed by ARB's Technology and Fuels Assessment, manufacturer comments on Federal Phase 2 GHG Standards, and discussions with interested technology manufacturers regarding what could be achieved by camless or opposed piston engine architecture over the next decade. The proposed standards are performance-based, with all engines required to meet the proposed optional low-CO_2 emission standards identified in Table II-3 to be eligible. While spark-ignited heavy-duty engines may face greater challenges achieving these standards, staff believes it is appropriate for the spark-ignited standards to be equivalent to the comparable compression-ignition standards since the compression-ignition standards reflect the most stringent CO_2 targets achievable by a camless or opposed piston engine over the next decade.

A heavy-duty engine family that certifies to an optional low-CO_2 emission standard identified in Table II-3 pursuant to Phase 1 or Federal Phase 2 GHG Standards in a given MY would be considered a high-efficiency heavy-duty engine for the purposes of this proposed ITR, and would be eligible for this proposed ITR's certification flexibility when applying to ARB for certification of that engine for criteria pollutant purposes in the same MY. For example, a heavy-heavy-duty tractor engine certified at or below 387 g/bhp-hr CO_2 as tested over the Supplemental Emission Test pursuant to Phase 1 or Phase 2 GHG Standards would be eligible for this proposed regulation's flexibility provisions when applying to ARB for criteria pollutant emission standard engine certification in the same MY. A hybrid engine that meets the optional low-CO_2 emission standards would be addressed pursuant to the hybrid engine element of the proposed ITR, and would be ineligible for certification flexibility pursuant to the optional low-CO_2 emission standards provisions.

Much like hybrid engines participating in the proposed ITR, high-efficiency engines would be prohibited from participating in averaging, banking, or trading programs. Therefore, certification levels lower than the applicable emission standards could not be used to generate credits. Further, the high-efficiency engine family also would have to meet the applicable Phase 1 or Phase 2 emission standards for methane (CH_4) and nitrous oxide emissions (N_2O), identified in 40 CFR §1036.108. The Phase 1 and Federal Phase 2 GHG Standards allow an engine to meet the CH_4 and N_2O standards by over-complying with the CO_2 standard, based upon each pollutant's GHG equivalent.[35] Such practice would be prohibited for an ITR high-efficiency engine, as the engine's lower-than-required CO_2 emissions would be enabling an increase in emissions of other regulated pollutants.

[35] 40 California Code of Regulations, Part 85.525.

Table II-3: Proposed Optional Low-CO_2 Compression-Ignition and Spark-Ignition Engine Emission Standards and Associated Benchmarks (in g/bhp-hr)						
	Spark-Ignition Engine	**Compression-Ignition Engine**				
	All-FTP*	**LHD-FTP****	**MHD-FTP****	**HHD-FTP****	**MHD-SET*****	**HHD-SET*****
2017 Baseline Emissions	627	576	558	525	481	455
Phase 2 Standard in 2027 MY	627	552	535	503	457	432
Proposed Optional Low-CO_2 Emission Standards (15 percent below 2017 Baseline)	**490**	**490**	**474**	**446**	**409**	**387**
Percent Below Federal Phase 2 Standards (2027 MY)	-22%	-11%	-11%	-11%	-11%	-11%

* – Reflects CO_2 emission certification levels of all heavy-duty spark-ignited engines, as tested over the Federal Test Procedure to demonstrate compliance with Phase 1 or Phase 2 GHG Standards.
** – Reflects CO_2 emission certification level of a light-heavy-duty (i.e., LHD = 14,000 – 19,500 pounds GVWR), medium-heavy-duty (i.e., MHD = 19,501 – 33,000 pounds GVWR) and heavy-heavy-duty (HHD = 33,000+ pounds GVWR) vocational engine, respectively, as tested over the Federal Test Procedure to demonstrate compliance with Phase 1 or Phase 2 GHG Standards.
*** – Reflects CO_2 emission certification level of a medium- and heavy-heavy-duty tractor engine, respectively, as tested over the Supplemental Emission Test to demonstrate compliance with Phase 1 or Phase 2 GHG Standards.

The proposed ITR would add the proposed optional low-CO_2 emission standards identified in Table II-3 to California Code of Regulations, title 13, section 1956.8 and the incorporated "California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Diesel Engines and Vehicles and California Exhaust Emission Standards and Test Procedures for 2004 and Subsequent Model Heavy-Duty Otto-Cycle Engines and Vehicles," included in Appendix D, in order to enable implementation and enforcement of the high-efficiency engine element of the proposed ITR. While optional low-CO_2 emission standards are based upon what can likely be achieved by a camless or opposed piston engine, adoption of such standards does not constitute a determination by ARB that such standards are necessarily achievable by 2027.[36] Instead, the optional low-CO_2 emission standards provide a target for manufacturers wishing to receive certification flexibility, with the recognition that such flexibility could help accelerate development and deployment of potentially-transformative, highly-efficient new engine architectures.

This proposed ITR would not address strategies that do not modify an engine's architecture in a meaningful way, such as predictive cruise or alternate engine mapping. Staff believes engines employing these non-intrusive strategies – primarily engine

[36] For more information regarding the technology feasibility and potential emission benefits of heavy-duty camless or opposed piston engines, see ARB; *Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency*; June 2015; http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf .

software – can be approved pursuant to ARB's existing certification procedures, and are unlikely to face the same significant OBD compliance challenges as fundamentally new engine architecture. Staff encourages interested manufacturers to meet with ARB certification staff in advance of applying for certification of an engine employing predictive cruise, alternate engine mapping, or other similar strategies to discuss their proposed technology and potential certification implications.

3. Proposed Flexibility Provisions

A camless or opposed piston engine would require sophisticated software and electronic controls, with potential for advanced engine diagnostic capability. However, these engine's new architecture and operational characteristics may also pose initial OBD compliance challenges. Staff's proposed Tier 1 and Tier 2 certification flexibility provisions and annual sales allowances mirror those proposed for an off-road or light-duty engine in a heavy-duty hybrid that achieves at least 35 miles AER. Both represent new heavy-duty engine architectures that may face initial certification uncertainties and OBD compliance challenges, but that also have potential to achieve significant in-use emission reductions.

The proposed ITR would provide an eligible engine meeting the optional low-CO_2 emission standards with up to six total MYs of the same Tier 1 and Tier 2 certification flexibility provided to hybrid engines, a maximum four MYs of which may be Tier 1 flexibility. For example, a vehicle manufacturer could opt to sell an engine that meets Tier 1 provisions for up to four MYs, with an annual cap of 100 engines per year. If the manufacturer wished to sell up to 200 engines meeting the optional low-CO_2 emission standards per MY, the engine would have to meet Tier 2 certification provisions.

Eligibility for both Tier 1 and Tier 2 certification flexibility would expire in the 2027 MY. After the 2027 MY, or after up to six consecutive MYs of Tier 1 and Tier 2 flexibility, whichever comes first, a manufacturer certifying a high-efficiency heavy-duty engine would be ineligible for this proposed regulation's certification flexibility. Staff's proposed annual sales allowances are intended to enable certification of a potentially transformational new engine architecture that are likely to initially be sold in low volumes, while minimizing the risks inherent in certifying an engine with reduced diagnostic capability. Proposed manufacturer annual sales volume limits are based upon staff's analysis of potential volumes for these technologies based upon historical sales data for heavy-duty hybrid, alternative fuel, and other advanced technology engines, and evaluation of what initial sales volumes may be needed to successfully launch potentially transformative truck and bus technologies.[37]

[37] ARB; Innovative Technology Regulation Staff Discussion Document: New Engine or Vehicle Certification Public Work Group Meeting; May 27, 2015; http://www.arb.ca.gov/msprog/itr/documents/itrconcepts052715.pdf .

E. MEDIUM AND HEAVY-DUTY VEHICLE HYBRID CONVERSION SYSTEMS

1. Background

Truck or bus hybrid conversion system – also commonly referred to as hybrid conversion kits, aftermarket kits, upfits, or retrofit systems – typically install battery-electric and other hybrid technology on a non-hybrid truck or bus to enable it to operate as a hybrid. Hybrid conversion systems must receive an exemption from ARB prior to sale or installation, to ensure they do not increase emissions from the originally certified engine or vehicle. (Vehicle Code 27156.) However, ARB's aftermarket conversion approval process is structured to address two specific categories of aftermarket parts: legal add-on or modified parts, and catalytic converters (California Code of Regulations, title 13, section 1900(b)(17)). The aftermarket part approval process for add-on or replacement parts, typically installed on passenger cars and motorcycles, is not tailored to effectively evaluate and certify medium- or heavy-duty vehicle hybrid conversion systems.

a. *Hybrid Conversion System Certification Challenges.* While a hybrid conversion system typically provides a CO_2 emission benefit, care must be taken to ensure the installed hybrid system does not adversely impact the original vehicle's criteria pollutant emission control strategy. For example, an engine that operates less or at lower loads due to hybridization can have lower exhaust temperatures, reducing the effectiveness of SCR or other aftertreatment technology. A hybrid system in which the engine stops and starts more frequently may also generate more cold start emissions. In addition, a plug-in hybrid in which the engine rarely turns on could undermine the original engine's evaporative emission control strategy, which requires an engine to run in order to purge hydrocarbon emissions. These examples underscore the complexity of modern engine and vehicle emission control strategies and the need to ensure criteria pollutant emissions do not increase due to truck or bus hybridization.

   It can also be challenging to ensure the base engine's ARB-certified OBD system continues to function as intended. The original engine or vehicle manufacturer is typically unwilling to share proprietary information with hybrid conversion system manufacturers regarding engine computer functions needed to ensure the original system continues to function properly after conversion. Many hybrid conversion system manufacturers also lack the resources or engineering expertise to ensure the original OBD system is compliant, or to demonstrate diagnostic functionality on the conversion system.

b. *Market Overview.* An increasing number of manufacturers have expressed interest in introducing truck or bus hybrid conversion systems into California, including AMP/Workhorse, Crosspoint Kinetics, Lightning Hybrid, Odyne, U.S. Hybrid, VIA Motors, Wrightspeed, and XL Hybrid. To date, ARB has approved hybrid conversion systems from the following three manufacturers, based upon a case-by-case determination, that the conversion system, when installed on the proposed base

vehicles did not reduce the effectiveness of the certified base engine or vehicle pollution control strategy, or cause the original engine or vehicle to exceed its applicable emission standards:[38]

- Odyne has received ARB Executive Orders for its plug-in hybrid system as installed on specified 2013 through 2015 MY heavy-duty diesel engine and chassis combinations. This plug-in system provides for electric operation of these vehicles' overhead bucket trucks, typically for utility service operation.
- VIA Motors has received Executive Orders for 100 units of its plug-in hybrid conversion system as installed on a 2014 MY 4.8L Chevrolet G2500 Express Van and 50 units of its plug-in hybrid conversion system installed on a 2014 MY 4.3L Chevrolet 1500 Silverado Class 2a (i.e., 6,001 to 8,500 pounds GVWR) pick-up truck. This conditional certification requires VIA Motors to show that all on-board computers demonstrate readiness, and that OBD monitors still function as designed. U.S. DOE-funded evaluations of VIA plug-in hybrids deployed in 2014 indicate that these vehicles achieve about 45 miles AER.[39]
- XL Hybrid has received ARB Executive Orders approving its parallel hybrid conversion system to be installed on specified 2012 through 2016 MY General Motors medium-duty gasoline powered vehicles (Executive Orders D-731, D-731-1, D-731-2, and D-731-3).

While these conversion systems may provide purchasing fleets with near-term fuel economy benefits and cost savings, hybrid trucks and buses manufactured and warrantied by a single entity may ultimately be needed to optimize hybrid truck and bus technology performance, diagnostic capability, and emission reduction potential. A truck or bus on which a hybrid conversion system is installed may not take any credit for a CO_2 emission benefit from the conversion system as part of Phase 1 or Phase 2 GHG Standard compliance purposes, since they do not meet the originally-certified vehicle's OBD, warranty, useful life, and other requirements. Staff is likely to recommend maintaining this approach when it adopts California Phase 2 GHG Standards in 2017.

2. Proposed Eligibility Criteria

The proposed ITR would define mandatory ARB certification requirements that would replace the existing case-by-case certification process for truck and bus hybrid conversion systems. The proposed ITR would specify that a hybrid conversion system must demonstrate that it achieves at least a ten percent CO_2 reduction and no increase

[38] ARB approvals as of March 1, 2016. A hybrid conversion system Executive Order query is available by visiting: http://www.arb.ca.gov/msprog/aftermkt/devices/amquery.php . Under List Executive Orders by Device, Select Device Type = "Hybrid conversion system (non-PEV)" or "Off-vehicle charge capable conversion system".

[39] Electric Power Research Institute, Plug-in Hybrid Medium-Duty Truck Demonstration: Final Report; September 2015; http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006566 .

in criteria pollutant emissions relative to the pre-converted vehicle configuration, pursuant to this proposed regulation's Hybrid Technology Emission Test Procedures.

a. Eligible Base Vehicles. The following base vehicles would be eligible for conversion pursuant to the proposed ITR:

- A 2007 or newer MY ARB-certified Class 2a (i.e., 6,001 to 8,500 pounds GVWR) non-hybrid base vehicle that achieves at least 35 miles AER when converted with the applicable hybrid system;
- A 2007 or newer MY ARB-certified medium-duty (i.e., 8,501 to 14,000 pounds GVWR) non-hybrid base vehicle; and
- A 2010 or newer MY engine certified by ARB for installation in a vehicle above 8,500 pounds GVWR.

Staff's proposal would exclude older MY base engines and vehicles that are certified to less stringent emission limits and diagnostics requirements. ARB's "Regulation to Reduce Emissions of Diesel PM, NOx, and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles" (In-Use Truck and Bus Regulation, California Code of Regulations, title 13, section 2025) will ensure that virtually all heavy-duty vehicles on the road in California will have a 2010 MY or newer engine by 2023. In addition, limiting the scope of this regulation to newer MY base vehicles and engines originally certified to meet similar diagnostic and other requirements provides for a simpler, more transparent hybrid conversion system certification regulatory framework, by enabling all hybrid conversions to be subject to the same approval criteria. Finally, interested conversion system manufacturers have indicated that purchasing fleets are typically more interested in converting vehicles with significant remaining useful life.

The proposed ITR's base vehicle eligibility criteria recognizes the lack of hybrid truck and bus offerings in these weight ranges from original vehicle manufacturers. Conversion of the proposed base engine and vehicle classes provides an opportunity for California fleets to purchase, evaluate, and become familiar with hybrid truck and bus technology. Early fleet adoption of hybrid conversion systems can also promote installation of charging infrastructure, training for fleet mechanics and other personnel, development of battery technology supply chains, and other dynamics that help support a zero-emission truck and bus market. Hybrid conversion system manufacturing can also drive down the cost of electric vehicle componentry, such as batteries and controllers, as volumes increase. Finally, hybrid conversion systems provide the opportunity to demonstrate fleet demand that may be needed for original vehicle manufacturers to be incentivized to enter the market with new, vertically-integrated commercial hybrid trucks and buses. Limiting Class 2a base vehicle eligibility to conversions that achieve at least 35 miles AER reflects the commercial availability of non-plug-in hybrid passenger vehicles approaching this size, such as the hybrid Nissan Pathfinder and Toyota Highlander. This approach provides an opportunity for hybrid conversion technology to make inroads

in the California commercial truck and bus fleet, while encouraging vertically-integrated hybrids to evolve from passenger vehicles to heavier applications.

3. Proposed Hybrid Conversion System Tiered Certification Pathway

This proposed regulation would allow a hybrid conversion system to comply with increasingly stringent Tier 1, Tier 2, and Tier 3/Final diagnostic, warranty, and other requirements, with each tier allowing for increasing California sales volumes. For example, Tier 1 certification would require a converted vehicle to demonstrate minimal diagnostic functionality, have a 3 year/50,000 mile conversion system warranty, and allow for an engineering analysis to demonstrate compliance with this proposed regulation's exhaust emission requirements. These and other basic Tier 1 requirements are intended to provide significant certification flexibility to encourage initial demonstration of potentially innovative hybrid conversion systems. The relatively low allowable Tier 1 California sales volumes minimize potential emission and other risks associated with proposed modest Tier 1 certification requirements.

Tier 2 has more rigorous certification requirements, such as greater diagnostic functionality, a longer minimum warranty period, and chassis-based emission testing, and would therefore allow for higher allowable sales volumes. As shown in Table II-4, a conversion system that achieves at least 35 miles AER would be allowed higher Tier 1 and Tier 2 sales volumes than one that does not, due to its significant zero-emission operation and greater potential to enable development and market acceptance of zero-emission technology. A manufacturer's ability to certify to less stringent Tier 1 and Tier 2 certification requirements, and to sell or lease such systems, would provide an opportunity for the hybrid truck and bus conversion systems market to grow.

Table II-4: Proposed Hybrid Conversion System Certification Structure

		Tier 1	Tier 2	Tier 3/Final
Conversion Does Not Achieve 35 Miles AER	Allowable Sales Volume	10	500	Tier 3 certified systems have no sales volume limits or certification/ installation sunset dates
	Tier 1 and 2 certification applications not accepted as of Jan. 1, 2022; Tier 1 or 2 certified systems may not be sold or installed as of Jan. 1, 2027			
Conversion Achieves 35+ Miles AER	Allowable Sales Volume	25	1,000	
	Tier 1 and 2 certification applications not accepted as of Jan. 1, 2025; Tier 1 or 2 certified systems may not be sold or installed as of Jan. 1, 2030			

Proposed sales volumes would apply to each individual hybrid conversion system manufacturer, and be inclusive of all of that manufacturer's conversion system and base vehicle combinations. For example, if a manufacturer has received Tier 2 certification for three hybrid conversion systems that do not achieve at least 35 miles AER (including non-plug-in hybrids), it could sell a total of 500 units total for all three conversion

systems. If the same manufacturer has received Tier 2 certification for two hybrid conversion systems that do achieve at least 35 miles AER, that manufacturer could sell an additional 1,000 units total for these two systems combined. This approach is intended to provide the predictability needed to plan for certification and sale of specific conversion system and base vehicle combinations within each tier, while providing ARB with certainty regarding the maximum allowable number of vehicles converted pursuant to less rigorous Tier 1 and Tier 2 requirements.

Tier 1 and 2 Sunset Dates. A manufacturer would no longer be eligible to apply to ARB for certification of a hybrid conversion system meeting Tier 1 requirements beginning on January 1, 2022 for conversions that do not achieve at least 35 miles AER, and beginning on January 1, 2025 for conversions that do achieve at least 35 miles AER, as shown in Table II-4. These proposed sunset dates mirror this proposed regulation's proposed 2021 and 2024 MY sunset dates for newly manufactured hybrids. Any hybrid conversion system wishing to be certified after these sunset dates must comply with the Tier 3/Final certification requirements. Tier 3 certified systems are not subject to a sales volumes limitation or installation sunset date.

This proposed regulation's sunset dates would provide more than four calendar years for a conversion system that does not achieve 35 miles AER to be certified pursuant to Tier 1 and 2 requirements. Staff believes this provides sufficient time for conversion system manufacturers to identify and address Tier 3 diagnostic engineering challenges, provide the longer required Tier 3 warranty, and meet other Tier 3 requirements. The later Tier 1 and 2 sunset date for conversions that achieve at least 35 miles AER recognizes that no newly manufactured plug-in hybrid trucks or buses are currently available, and that the market for new plug-in vehicles will likely continue to lag behind that for non-plug-in hybrids in the years to come. Plug-in conversions tend to also be more intrusive of the original vehicle's OBD system, which can make it more challenging to demonstrate that the converted vehicle continues to be OBD compliant. Finally, the January 1, 2025 Tier 1 and 2 sunset date for conversions achieving 35 miles AER is intended to help achieve the Governor's Executive Order B-16-2012 for 1.5 million zero-emission vehicles (including plug-in vehicles) to be deployed on California roads by 2025.

This proposed regulation also requires that no Tier 1 and Tier 2 certified conversion systems be installed or sold for California use as of January 1, 2025 for hybrid conversions that do not achieve at least 35 miles AER and January 1, 2030 for hybrid conversions that do achieve at least 35 miles AER. For example, a manufacturer of a hybrid conversion system or systems that achieve 35 miles AER and are Tier 2 certified could sell or have up to 1,000 of these systems installed through January 1, 2030. Sale or installation of these systems after January 1, 2030 would require Tier 3 certification. This "sell by" date is intended to provide ample time for a manufacturer to sell existing certified systems, while ensuring vehicles meeting lesser diagnostic and other requirements are not placed into service after a date certain.

4. Emission Performance Requirements

A hybrid conversion system must comply with the evaporative and exhaust emission requirements identified in this proposed ITR's Hybrid Technology Emission Test Procedures, as summarized below.

a. *Evaporative Emissions.* Evaporative emission test requirements are structured to ensure evaporative emissions do not increase from the original base engine or vehicle's certified emission limits, while recognizing that some hybrid conversions are unlikely to impact evaporative emissions.

b. *Exhaust Emissions.* As previously discussed, careful engine and driveline integration is critical to ensure no NOx, CO, HC, or PM emission increase from a hybridized vehicle. Proposed exhaust emission performance requirements would allow for a less resource-intensive technology evaluation in Tier 1, and more sophisticated in-use emission testing in subsequent tiers:

   - Tier 1 Exhaust Emission Performance: Tier 1 certification would require a conversion system manufacturer to provide an engineering analysis or other independent, verifiable data that the hybrid conversion system achieves at least a ten percent reduction in CO_2 emissions and does not increase criteria pollutant emissions.
   - Tier 2 and Tier 3 Exhaust Emission Performance: Tier 2 or Tier 3 certification would require in-use emission testing demonstrate that the hybrid conversion system achieves at least a ten percent reduction in CO_2 emissions and does not increase NOx, CO, HC, or PM emissions. A hybrid conversion system and base vehicle or engine combination that has met this requirement as part of Tier 2 certification may forgo emission testing as part of its Tier 3 certification application. The Executive Officer may find, if so demonstrated by the manufacturer, that a set of proposed base vehicle test groups or engine families are sufficiently similar to one another as to allow certification of multiple conversion system and test group or engine family combinations based upon emission test results from a "worst case" or representative converted vehicle or engine. A manufacturer must also provide an engineering analysis demonstrating to the satisfaction of the Executive Officer that the hybrid conversion system does not increase PM emissions.

   Additional information regarding hybrid conversion system exhaust emission test requirements can be found in Appendix A and the Hybrid Technology Emission Test Procedures (i.e., Section 7 of Appendix E: "California Certification and Installation Procedures for Medium- and Heavy-Duty Vehicle Hybrid Conversion Systems").

c. *Declaration of Potential CO_2 Emission Benefit.* Aftermarket conversion manufacturers are typically prohibited from identifying their systems as achieving an emission benefit. However, manufacturers have suggested this prohibition is unwarranted if required emission testing conducted pursuant to the proposed Hybrid

Technology Emission Test Procedures indicates the system achieves a significant CO_2 reduction. Manufacturers believe that identifying a system's potential CO_2 benefit would provide a valuable marketing tool and provide greater certainty to fleets regarding potential CO_2 reductions and commensurate fuel economy benefits.

Staff concurs, and this proposed regulation stipulates that a conversion system's Executive Order would identify a hybrid conversion system that achieves at least a 20 percent potential CO_2 emission reduction, as demonstrated pursuant to this proposed ITR's Hybrid technology Emission Test Procedures. The Executive Order would specify that actual in-use CO_2 reductions may vary based upon the vehicle operator, route driven, and other variables, and are based upon a newly manufactured and installed conversion system. The ARB Executive Order would make no claim regarding ongoing CO_2 benefits of a certified hybrid conversion system once in-use, and these reductions may not be claimed or used for any emissions compliance purpose. Manufacturers may make no claim of any criteria pollutant or other emission benefits of a certified hybrid conversion system, as this regulation's emission test procedures do not require a conversion system to be emission tested at high mileage to evaluate emissions from a deteriorated system.

5. OBD System Requirements for Hybrid Conversion Systems

As previously mentioned, a hybrid conversion system installed on an ARB-certified non-hybrid base engine may change how the base engine and its electronic controls typically operate, and degrade the functionality of its OBD system. Significant resources and engineering expertise is typically required to ensure a converted engine continues to be OBD compliant subsequent to conversion. In addition, manufacturers of hybrid conversion systems, particularly plug-in systems which require greater integration, may lack proprietary information from the base engine needed to develop fully-integrated diagnostics for the base engine and hybrid conversion system.

The proposed ITR would address these challenges by providing an OBD compliance pathway that enables hybrid conversion system manufacturers to meet progressively more stringent diagnostic requirements as their sales volumes increase and they gain the necessary engineering expertise. The progressively more stringent OBD requirements for the three hybrid conversion system certification tiers are as follows:

- Tier 1 would require that the hybrid conversion system meet EMD+ requirements. In addition, Tier 1 would: allow the conversion system to utilize a separate diagnostic link connector than the base engine; not set or enforce a minimum IUMPR; allow for changes to the base engine OBD system to prevent false malfunction determinations; and require manufacturers to test a sample of converted vehicles to ensure the diagnostic system can communicate with a generic scan tool.
- Tier 2 would build upon Tier 1 by also requiring that: monitors for major emission control systems demonstrate readiness; manufacturers conduct data durability vehicle (DDV) testing to spot check that diagnostic systems identify a malfunction before emissions exceed the allowable threshold; and submit additional IUMPR data.

- Tier 3 would require the base engine or vehicle return to fully OBD compliant status, and the hybrid conversion system demonstrate basic diagnostic functionality. This most stringent hybrid conversion system compliance tier would build upon Tier 2 by requiring additional monitoring functionality for the hybrid system, and more stringent DDV testing requirements for the vehicle, although integration of the hybrid conversion diagnostic system with the base vehicle diagnostic system would not be required.

Additional information regarding proposed Tier 1, Tier 2, and Tier 3 OBD requirements are included in Appendix A.

6. Installation Requirements

Proper installation of an ARB-certified hybrid conversion system is critical for the system to perform as expected, and to ensure emission compliance. The proposed ITR would require a hybrid conversion system manufacturer have a written contractual relationship with its hybrid conversion system installer(s), and to provide their business name(s) and contact information to ARB. Conversion system manufacturers must provide their authorized installer(s) with the specific, written instructions regarding installation procedures needed to comply with the diagnostics, labeling, and other requirements of this regulation, and a description of any special tools or techniques required for proper conversion system installation, maintenance, or operation.

Installers of hybrid conversion systems would also be required to warrant to the vehicle owner and subsequent vehicle owners that the conversion system will not fail to meet hybrid conversion system certification requirements due to incorrect installation, and that no part on the base engine or vehicle will be damaged due to incorrect installation. Installers of hybrid conversion systems may install only those systems of a certified configuration and must agree to cover the cost of repair of any vehicle upon which a noncertified configuration was installed. In addition, the installer is responsible for any tampering fines that may be imposed as a result of improper installation of the hybrid conversion system. The warranties and agreements begin on the date of installation and would be effective for 3 years or 50,000 miles, whichever occurs first. The warranty must cover customer service and the full repair or replacement costs, including the cost of diagnosis, labor, and parts, including any part on the converted vehicle that is damaged due to incorrect installation of the conversion system.

7. Conversion System Warranty Coverage

The proposed ITR would require hybrid conversion system manufacturers to provide consumer warranties to help ensure manufacturers build components that are durable and function as designed and certified, and provide a minimum level of consumer protection to purchasing California fleets. The required warranty would be of similar duration and coverage as the warranties required by ARB for alternative fuel conversion

systems and hybrid to plug-in hybrid light- and medium-duty vehicle conversions.[40,41] The warranty period begins from the date of installation and covers customer service, the full repair or replacement costs, including the cost of diagnosis, labor, and parts, and any part of the converted vehicle that is damaged due to a defect in the conversion system. Conversion system manufacturers would be required to warrant to the person having the vehicle converted, and to each subsequent purchaser of the vehicle, that the conversion system:

- is designed and manufactured to conform with the applicable base vehicle and hybrid conversion system certification requirements; and
- is free from defects in materials and workmanship which would cause the conversion system to fail to conform with this proposed regulation's conversion system requirements or cause damage to any part on the converted vehicle.

For example, if the original vehicle manufacturer designed a part for non-hybrid operation, and the hybrid conversion required the part to be used more often or in a different way than originally intended, this could contribute to early failure. If the vehicle is still under the original warranty, the conversion system manufacturer would be responsible for replacement or repair of the part. Table II-5 shows the warranty requirements for hybrid conversions.

Table II-5: Minimum Manufacturer Warranty Periods

Conversion System Certification Level	Hybrid conversion system minimum warranty period
Tier 1	3 years or 50,000 miles, whichever comes first*
Tier 2	5 years or 60,000 miles, whichever comes first*
Tier 3	7 years or 70,000 miles, whichever comes first**

* – Hybrid conversion systems with electronic power take-off may include a 3,000 hour warranty period in lieu of a minimum required mileage.
** – Hybrid conversion systems with electronic power take-off may include a 4,200 hour warranty period in lieu of a minimum required mileage.

8. Reporting Requirements

The proposed regulation includes manufacturer reporting requirements designed to ensure that the number of conversions do not exceed allowable Tier 1 or Tier 2 sales volume limits, and to identify and address potential catastrophic or other safety-related conversion system failure. Conversion system manufacturers are required to collect the following information regarding each hybrid conversion system that receives Tier 1 or Tier 2 certification, which must be current as of the hybrid conversion system

[40] ARB; California Certification and Installation Procedures for Alternative Fuel Retrofit Systems for 2004 and Subsequent Model Year Motor Vehicles and Engines; Adopted August 8, 2014; http://www.arb.ca.gov/regact/2013/altfuel2013/altfuel20132004test.pdf
[41] ARB; California Certification and Installation Procedures for Off-Vehicle Charge Capable Conversion Systems for 2000 and Subsequent Model Year Hybrid Electric Vehicles; Adopted December 2, 2009; http://www.arb.ca.gov/regact/2008/phev09/aftermarketcert.pdf .

installation date. This information must be kept for at least five years from the hybrid conversion system's installation date and provided to ARB within ten days upon request.

- Vehicle make, model, MY, identification number (VIN), and California license plate number;
- Vehicle owner's physical address, e-mail address, and phone number;
- Vehicle operator's name and physical address (if different than the vehicle owner);
- Conversion system installer name, physical address, e-mail address, and phone number;
- Location, date, and odometer reading at time of hybrid conversion system installation; and
- ARB certification Tier (i.e., Tier 1 or 2).

The conversion system manufacturer must also submit a warranty report to ARB within 30 calendar days if, at any time, the cumulative number of valid warranty claims for the same part or component of the hybrid conversion system in California exceeds one percent of the cumulative California sales or leases for the hybrid conversion system or ten units sold, whichever is greater. Where valid warranty claims exceed one percent of sales or ten units sold in California, whichever is greater, ARB may deny Tier 2 or Tier 3 certification of the hybrid conversion system or may modify, revoke, or suspend the existing ARB certification. Where valid warranty claims exceed four percent of California sales or twenty five units sold in California, whichever is greater, ARB may order a recall of the hybrid conversion system under California Code of Regulations, title 13, section 2111, et Seq..

9. Recall Provisions

The proposed regulation establishes recall provisions, similar to those for newly manufactured light-, medium- and heavy-duty vehicles (California Code of Regulations, title 13, sections 2111 through 2121), that specify the conditions for triggering and completing an influenced recall. These recall provisions are necessary to protect the purchaser from conversion system defects or improper installations and to protect the public health by ensuring that improperly functioning conversion systems that are likely to increase emissions or create a safety hazard are replaced.

If ARB determines, after a review of an applicant's warranty report or any other information, that a hybrid conversion system has the potential to experience catastrophic or safety related failure for the same part or component of the hybrid conversion system, has valid warranty claims in excess of four percent of sales or 25 units sold, whichever is greater, or a substantial number of units experience a failure of an operational feature, ARB would require the manufacturer to submit a recall plan and conduct a recall. In the event of a recall, ARB would provide notification to the applicant that includes a description of the nature of the conversion system failure and the factual

basis for the determination, and would designate a date by which the applicant must submit a recall plan for review and approval to address the failure.

III. JUSTIFICATION FOR ADOPTION OF REGULATIONS DIFFERENT FROM FEDERAL REGULATIONS CONTAINED IN THE CODE OF FEDERAL REGULATIONS

ARB's 2016 Mobile Source Strategy provides a roadmap to simultaneously meet air quality standards, achieve GHG targets, reduce petroleum consumption, and decrease health risk from the transportation sector over the next fifteen years.[4] This roadmap will inform California State Implementation Plans for meeting federal air quality standards, the Sustainable Freight Strategy to transition California to a more efficient, zero- and near-zero-emission freight system, and ARB's Climate Change Scoping Plan Update.

The 2016 Mobile Source Strategy calls for a suite of heavy-duty engine and vehicle regulations and other strategies to be developed, adopted, and implemented within the next 15 years, including:

- Improve In-Use Emission Performance Level: This strategy includes measures such as revising ARB's Periodic Smoke Inspection Program and Heavy-Duty Vehicle Inspection Program, and development of a "smog check" program for trucks, in order to ensure that in-use trucks and buses continue to operate at their cleanest possible level. Much as it has for light-duty vehicles, widespread implementation of heavy-duty OBD could enable implementation of cost-effective emission reduction strategies for the in-use truck and bus fleet by systematically identifying and facilitating repair of malfunctioning or improperly maintained heavy-duty engines and aftertreatment systems. Other measures to improve the emission performance of the in-use truck and bus fleet include revising the applicable heavy-duty engine warranty period and useful life definition, and revising the existing in-use compliance testing protocol to allow for effectively assessing whether in-use heavy-duty engines remain in compliance with the emission standards to which they were originally certified.

- Low-NOx Engine Standard: In 2013, ARB adopted optional heavy-duty engine low-NOx emission standards of 0.10, 0.05, and 0.02 g/bhp-hr, which are 50, 75, and 90 percent, respectively, below the existing mandatory heavy-duty engine NOx emission standard. The goal of this concept is to develop a mandatory low-NOx emission standard, potentially as low as 0.02 g/bhp-hr NOx, beginning as early as the 2024 MY.

- Zero-Emission Heavy-Duty Vehicle Regulations: Potential Advanced Clean Transit, Last Mile Delivery and Zero-Emission Airport Shuttle Bus measure concepts would utilize incentives, memoranda of understanding, regulations, or a combination of

[4] ARB, 2016 Mobile Source Strategy, May 2016; http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc.htm .

these to accelerate use of zero-emission technology in truck and bus vocations that may be most suited to early adoption of zero-emission technology.

- Innovative Technology Regulation: The 2016 Mobile Source Strategy also identifies the Innovative Technology Regulation as a foundational measure needed for development of effective technology advancing regulations in the truck and bus sector. This proposed ITR balances the need for near-term certification flexibility to encourage accelerated deployment of critical new innovative truck and bus technologies, with the need for robust diagnostics capability to expeditiously identify and address malfunctions that can lead to excess in-use truck and bus emissions.

The proposed ITR and proposed amendments to California Code of Regulations, title 13, section 1956.8 ("amendments") (collectively, "proposed regulatory actions") complement technology advancing regulations, incentive programs and other strategies by providing defined, near-term ARB certification and aftermarket part approval flexibility to help facilitate market launch of the next generation of truck and bus technologies that California needs to meet its air quality and climate goals. ARB plans to submit its 2016 Mobile Source Strategy to U.S. EPA later this year, including, if adopted, the proposed ITR, as part of its State Implementation Plan to demonstrate attainment with federal air quality standards in the South Coast, San Joaquin Valley, and other California regions.

A. Enable Robust Technology-Advancing Regulations

Early deployment of innovative truck and bus technology not only achieves direct emission reductions sooner than would otherwise occur, it also supports development of more robust technology advancing rulemaking, by encouraging early deployment of innovative new truck and bus technologies in a diversity of heavy-duty engine and vehicle types. For example, early technology deployment of low-NOx engines will enable manufacturers, fleets, ARB staff, and others to assess technology feasibility, consumer acceptance, benefits and costs, and prepare necessary infrastructure, supply lines and workforce training. Likewise, this regulation encourages accelerated development of robust plug-in hybrid heavy-duty vehicle technology that will enable implementation of ARB's Advanced Clean Transit Regulation and Last Mile Delivery Regulation, if adopted. Early, accelerated technology deployment helps reduce per unit technology cost as production volumes increase in advance of regulatory requirements. Finally, early deployment provides an opportunity for manufacturers to anticipate and address potential technology failures before more widespread deployment is required by regulation.

B. Support Effective Deployment of Incentive Funds

The proposed regulatory actions are also geared to support implementation of California's portfolio of funding programs that demonstrate and deploy the next generation of clean vehicles and equipment. ARB's Air Quality Improvement Program (AQIP) and Greenhouse Gas Reduction Fund (GGRF) have invested over $500 million over the past seven years to accelerate California's transition to zero- and near-zero

emission vehicles and equipment. These programs' Fiscal Year 2016-17 Funding Plan, approved by the Board on June 23, 2016, will invest an additional $59 million to demonstrate, and $116 million to deploy, the next generation of truck and bus technologies (contingent upon funding appropriation by the Legislature).[42]

The GGRF and AQIP provide significant funding to demonstrate zero- and near-zero-emission emission heavy-duty vehicles and equipment, and to deploy hybrid, zero-emission, and low-NOx trucks and buses. However, only two heavy-duty engines meeting the optional low-NOx standard and two hybrid heavy-duty engines (neither of which enable zero-emission operation) have been ARB certified as of August 1, 2016. The proposed regulatory actions are intended to facilitate near-term certification of these technologies, enabling a greater diversity of promising heavy-duty engines and vehicles to be eligible for California's air quality investments. The proposed regulatory actions are particularly timely given California's financial commitment to these heavy-duty vehicle demonstration and deployment projects.

IV. ENVIRONMENTAL IMPACTS ANALYSIS

A. Introduction

This chapter provides an environmental analysis for the proposed regulatory actions. This analysis describes the reasonably foreseeable compliance responses for manufacturer participation with the proposed ITR and amendments, and the potential for adverse environmental impacts associated with those proposed regulatory actions. Environmental benefits expected from implementing the proposed ITR and amendments are also discussed.

Based on ARB staff's review, implementation of the proposed ITR and amendments would not result in any potentially significant adverse environmental impacts. The basis for reaching this conclusion is discussed further under Section D below.

B. Environmental Review Process

ARB is the lead agency for the proposed ITR and amendments and has prepared this environmental analysis pursuant to its regulatory program certified by the Secretary of the Natural Resources Agency (14 CCR 15251(d); 17 CCR 60005-60007). In accordance with Public Resources Code (PRC) section 21080.5 of the California Environmental Quality Act (CEQA), public agencies with certified regulatory programs are exempt from certain CEQA requirements including, but not limited to, preparing environmental impact reports, negative declarations, and initial studies (14 CCR 15250). ARB staff has prepared this environmental analysis (EA) to assess the potential for

[42] ARB; Proposed Fiscal Year 2016-17 Funding Plan for Low Carbon Transportation and Fuels Investments and the Air Quality Improvement Program, Approved June 23, 2016; http://www.arb.ca.gov/msprog/aqip/fundplan/proposed_fy16-17_fundingplan_full.pdf and ARB Board Resolution 16-7 (Agenda Item 16-6-1); June 23, 2016; http://www.arb.ca.gov/board/res/2016/res16-7.pdf .

significant adverse and beneficial environmental impacts associated with the proposed ITR and amendments, as required by ARB's certified regulatory program (17 CCR 60005(b)). The resource areas from the CEQA Guidelines Environmental Checklist were used as a framework for assessing the potential for significant impacts (17 CCR 60005(b)).

If comments received during the public review period raise significant environmental issues, staff will summarize and respond to the comments in the Final Statement of Reasons (FSOR) for the proposed regulatory actions. The written responses to environmental comments will be approved prior to final action on the proposed ITR and amendments (17 CCR 60007(a)). If the proposed regulatory actions are adopted, a Notice of Decision will be posted on ARB's website and filed with the Secretary of the Natural Resources Agency for public inspection (17 CCR 60007(b)). A courtesy copy will also be filed with the State Clearinghouse.

C. Proposed Innovative Technology Regulation and Proposed Amendments to Section 1956.8

1. Description

As previously described in Sections I(C) of this Staff Report, California must transition to the next generation of zero- and near zero-emission truck and bus technologies to meet the federal ozone standard in the South Coast in 2023 and 2031 and to meet the State's climate goals for 2030 and 2050. These technologies include engines meeting California's optional low-NOx standards, hybrid heavy-duty trucks and buses, and significantly more efficient heavy-duty engines, including low-CO_2 engines. However, ARB's existing heavy-duty engine certification requirements can pose a resource and engineering challenge, particularly for new technologies, that may deter some manufacturers from voluntarily developing and producing these cleaner engines.

The proposed ITR would provide short-term, targeted certification flexibility, particularly OBD compliance flexibility, to increase heavy-duty engine manufacturer willingness to voluntarily develop, certify, and deploy these lower-emission truck and bus technologies. The proposed ITR would also strengthen emission test requirements, as described in Section II(C), for participating heavy-duty hybrids to be eligible for the proposed certification flexibility. Finally, as described in Section II(E), the proposed ITR includes mandatory certification and installation requirements for all aftermarket hybrid conversion systems installed on non-hybrid vehicles over 6,000 pounds GVWR, which would replace existing case-by-case evaluation protocols for these systems. Proposed hybrid conversion system certification and installation procedures provide short-term, targeted certification flexibility, with increasing OBD, warranty, and other ARB certification requirements as each manufacturer's California sales volumes increase over time. Both the innovative new heavy-duty engine and hybrid conversion system elements of the proposed ITR would sunset between 2021 and 2027, depending upon the technology type, providing these innovative technologies an opportunity to achieve a foothold in California's truck and bus market.

2. Methods of Compliance

Neither the proposed ITR, nor the proposed amendments, would impose new requirements on heavy-duty engine manufacturers. However, manufacturers of heavy-duty low-NOx engines, hybrid engines, or high-efficiency engines, as described in Sections II(B), (C), and (D) of this Staff Report, could opt to receive the proposed ITR's flexibility when certifying these engines with ARB, including when certifying an engine to meet the proposed amendments' new optional low-CO_2 standards.. Each participating manufacturer would be required to demonstrate that the engine achieves emission reductions beyond what is required by mandatory new engine standards. A participating hybrid engine would have to meet the proposed ITR supplemental emission criteria in order to be eligible, which requires in-use emission testing with a PEMS, chassis dynamometer, or a post-transmission vehicle simulation. Neither the proposed ITR, nor the proposed amendments, would otherwise substantially change how these engines are certified.

The proposed ITR would also formalize California certification and installation procedures for hybrid conversion systems for motor vehicles over 6,000 pounds GVWR. Manufacturers of hybrid conversion systems wishing to install, sell or make such systems available for sale in California would be required to meet the proposed ITR application, reporting, OBD, emission testing, vehicle labeling, and warranty requirements, which are described in Section II(E) of this Staff Report. Many proposed ITR certification requirements are part of ARB's existing case-by-case evaluation and approval process for hybrid conversion systems. The proposed ITR would provide short-term OBD flexibility, while increasing reporting and product and installation warranty requirements, relative to existing procedures. Businesses that manufacture or install hybrid conversion systems would benefit from clarity regarding certification and installation requirements (as opposed to case-by-case evaluations), and OBD flexibility provisions could enable manufacturers, particularly small volume manufacturers, to certify their systems sooner.

D. Environmental Impacts

As previously mentioned, the proposed ITR provides short-term certification flexibility to encourage voluntary, early certification of heavy-duty engines meeting California's optional low-NOx standards (that are 50 to 90 percent cleaner than required), hybrid engines that demonstrate at least a 10 percent CO_2 emission reduction and no increase in NOx, HC, CO and PM, and engines that achieve at least a 15 percent CO_2 reduction relative to a 2017 baseline under the proposed amendments.

Staff has concluded that neither the proposed ITR nor the proposed amendments would have a significant impact on the following resource areas: aesthetics; agricultural and forestry resources; biological resources; cultural resources; energy demand; geology and soils; greenhouse gases; hazards and hazardous materials, hydrology and water quality; land use planning; mineral resources; noise; population and housing; public

services; recreation; traffic and transportation; or utilities and service systems. These areas would not be impacted because compliance with the proposed ITR and amendments, as applicable, does not require any action that could affect these resources, either directly or indirectly.

The only part of the proposed regulatory actions that has the potential to affect any environmental resource area are the proposed certification flexibility provisions related to the OBD system, which are likely to indirectly result in a modest emission benefit. If traditional engine technology were eligible for the proposed ITR, an emission increase would be likely, due to potential reduced functionality of the OBD system relative to existing certification requirements. However, as described in Section II, only innovative, lower-emitting technologies would be eligible for the proposed certification flexibility. For each eligible innovative technology category, the benefits of the cleaner engine technology outweigh the potential disbenefit of that engine technology being exempt from the specified certification requirements. For example, the minimal OBD compliance flexibility proposed for an engine meeting California's optional low-NOx standard would apply only to engines that emit 50 to 90 percent lower NOx than required. However, the proposed modest, short-term certification flexibility for these engines described in Section II(B)(3) would have a negligible negative impact on the OBD system functionality and emissions.

The proposed ITR would provide hybrid heavy-duty engines with greater short-term certification flexibility due in part to their more significant potential certification challenges. However, proposed supplemental emission testing requirements for a hybrid heavy-duty engine help ensure the technology will not increase NOx as compared to a hybrid engine that does not participate in the proposed ITR. As described in Section II(C)(1)(c), proposed ITR eligibility criteria for hybrid engines would exclude those hybrids that emit excess NOx emissions. For heavy-duty hybrids, supplemental vehicle-based emission testing to ensure these vehicles do not increase in-use NOx emissions (which is not otherwise captured by existing engine-based certification requirements) outweighs the potential emission increase associated with proposed ITR certification flexibility.

For hybrid conversion systems, the proposed ITR defines a certification process that is now conducted on a case-by-case basis. The proposed ITR would permanently strengthen hybrid conversion system certification procedures by imposing new minimum installation, warranty, and other requirements, but would balance this with near-term certification flexibility (relative to existing case-by-case evaluation procedures) for a limited number of Tier 1 and Tier 2 certified conversion systems. Staff anticipates the proposed hybrid conversion procedures would enable more manufacturers to certify hybrid conversion systems in the near-term, achieving a net CO_2 reduction from the existing truck and bus fleet. For both innovative new engines and hybrid conversion systems eligible for the proposed ITR, potential modest emission increases due to proposed certification flexibility would be more than offset by the emission benefit of the cleaner technology being deployed, and, more significantly, by helping pave the way for the needed fleet transformation. Depending upon the technology, proposed ITR

certification flexibility would sunset between 2021 and 2027, as these new truck and bus technologies have the opportunity to achieve market acceptance.

In summary, the proposed ITR's certification flexibility, if applied to traditional truck and bus technology, would likely result in a net emission increase, because of the proposed reduced certification requirements. However, since the proposed ITR would only apply to eligible, new, cleaner-than-required truck and bus technologies, including those certifying to the proposed amendments, the potential slight emission increase associated with engines certified with reduced OBD capability would be more than offset by the cleaner-than-required eligible technology. Taken together, staff anticipates the proposed ITR and amendments will have a modest direct air quality benefit (depending upon the extent of manufacturer participation) from accelerated technology deployment of low-emission truck and bus technology, and a more significant indirect air quality benefit from helping enable California's transition to zero- and near-zero-emission trucks and buses (as described in Section III of this Staff Report).

No discussion of alternatives or mitigation measures is necessary because no significant adverse environmental impacts were identified for these resource areas.

V. ENVIRONMENTAL JUSTICE

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.[43] ARB is committed to making environmental justice an integral part of its activities. The Board approved its Environmental Justice Policies and Actions on December 13, 2001, to establish a framework for incorporating environmental justice into ARB's programs consistent with the directives of State law. These Environmental Justice Policies and Actions apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities.

While staff's proposed regulatory actions do not have a direct emission impact on low-income and minority communities, there is a potential, non-quantifiable benefit of reduced emissions to some residents who live or work near freight corridors or in urban areas. Many of these areas tend, on average, to be lower income than those neighborhoods farther away from freight corridors or urban areas. Staff anticipates early deployment of engines meeting California's optional low-NOx emission standards may initially occur in California's freight corridors. Hybrid and zero-emission vehicle are more likely to be deployed in urban areas, where hybrid technology achieves greater fuel economy benefits (due to greater stop-and-go operation) and plug-in technology can return daily to centrally located charging infrastructure. Low-NOx heavy-duty engines and hybrid trucks and buses are also eligible for, and likely recipients of, ARB GGRF investments. Twenty-five percent of this funding is statutorily required to benefit

[43] Office of Planning and Research. Government Code (GC) Section 65040.12(c) (July 1, 2013)

disadvantaged communities[44], and ARB typically directs well over 50 percent of its heavy-duty vehicle GGRF investments to benefit disadvantaged communities.[43] By encouraging early deployment of these advanced technology vehicles, the proposed regulatory actions are likely to have a modest, unquantifiable benefit to low-income and minority communities located in urban areas or near freight corridors.

VI. ECONOMIC IMPACTS

A. Summary

As previously discussed, the proposed regulatory actions include two elements:

1. Eligible new heavy-duty engines may opt to receive this regulation's specified flexibility when certifying to demonstrate compliance with criteria pollutant emission standards; and
2. Hybrid conversion systems for vehicles over 6,000 lbs GVW must meet this regulation's certification and installation criteria to be installed or sold in California.

Since the new heavy-duty engine element is optional, it includes no mandated incremental costs to a potentially affected business. Costs to a new engine manufacturer would be incurred only if it chooses to certify an eligible new engine pursuant to this proposed regulation. If no new engine manufacturers opt to participate, this element of the regulation would have no cost or savings.

For an engine manufacturer that does opt to certify an eligible heavy-duty engine pursuant to the proposed regulatory actions, including the proposed amendments, the proposal would provide cost savings by not requiring emission testing of an engine that has been aged to its full useful life (i.e., use of an assigned deteriorating factor (DF)), and the provision of allowable OBD compliance flexibility. Participating new heavy-duty engines would incur costs related to proposed engine labeling requirements, as well as supplemental emission test requirements and reporting requirements applicable to specific technology categories. These potential costs and benefits are described in this section and are summarized in Table VI-1.

The hybrid conversion system certification and installation procedures would replace ARB's existing case-by-case evaluation of such systems, as authorized by Vehicle Code 27156. The hybrid conversion system element would entail some costs and some savings relative to what is required by ARB's existing case-by-case evaluation and approval procedures. The proposal would provide overall cost savings relative to

[44] Senate Bill 535 (DeLeon, Statutes of 2012, Chapter 830)
[43] ARB; Proposed Fiscal Year 2016-17 Funding Plan for Low Carbon Transportation and Fuels Investments and the Air Quality Improvement Program, Approved June 23, 2016; http://www.arb.ca.gov/msprog/aqip/fundplan/proposed_fy16-17_fundingplan_full.pdf and ARB Board Resolution 16-7 (Agenda Item 16-6-1); June 23, 2016; http://www.arb.ca.gov/board/res/2016/res16-7.pdf .

existing procedures by providing OBD compliance flexibility for conversion systems that are certified pursuant to Tiers 1 or Tier 2. Hybrid conversion systems would incur additional costs due to proposed warranty, reporting, and enhanced emission test requirements. These potential costs and savings are described in this section and are summarized in Table VI-2.

The proposed regulatory actions do not levy any requirement on technology purchasers. Staff anticipates that California fleets may benefit from a greater diversity of innovative truck and bus technologies that would be eligible for ARB incentive program funding. Early deployment of these technologies would enable greater consumer choice for early adopter fleets, and result in more robust technology if and when California adopts regulations to require heavy-duty low-NOx engines, zero-emission capable vehicles, and other innovative technologies needed to meet the State's air quality and climate goals.

B. Legal Requirements

Sections 11346.3 and 11346.5 of the Government Code require state agencies to assess the potential adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulatory actions on California jobs, business expansion, elimination or creation, and the ability of California businesses to compete.

State agencies are also required to estimate the cost or savings of any state or local agency and school districts in accordance with instruction adopted by the Department of Finance. This estimate is to include any nondiscretionary costs or savings to local agencies and the costs or savings in federal funding to the state.

C. Economic Costs and Benefits of Proposed Regulation

Staff anticipates that there will be net cost savings from the proposed regulatory actions. In addition, we expect air quality and health benefits that cannot be directly quantified. California fleets are unlikely to switch from purchasing traditional truck and bus technologies to the proposed eligible technologies without incentive funding. ARB's 2016 Mobile Source Strategy, Senate Bill 1204 (Lara, Chapter 524, Statutes of 2014)[45], and the FY 2016-17 AQIP and GGRF Funding Plan underscore ARB's commitment to providing significant funding to enable heavy-duty engine manufacturers to launch these key truck and bus technologies. California fleets are therefore unlikely to be economically impacted by potential modest price reductions due to this proposed

[46] Senate Bill 1204 created the California Clean Truck, Bus, and Off-Road Vehicle and Equipment Technology Program in Health and Safety Code Section 39719.2 to fund the development, demonstration, pre-commercial pilot, and early commercial deployment of zero- and near zero-emission technologies with priority given to projects that benefit disadvantaged communities.

regulation's certification provisions. Staff also anticipates that truck and bus engine, driveline and aftermarket hybrid conversion system manufacturers will benefit from an expanded market for their technology. Finally, the proposed regulatory actions include direct, quantifiable economic costs and savings to technology manufacturers related to the proposed certification flexibility and related emission testing, warranty, and other requirements.

1. New Engine Certification Flexibility

Participation in the new engine element of the proposed regulatory actions is voluntary in that there is no requirement for a business to participate. The proposed certification flexibility is structured differently for each of the three eligible innovative new engine technologies, as needed to encourage early deployment while ensuring that the technology's anticipated in-use emission benefits are achieved in-use. For example, manufacturers are already beginning to develop and certify low-NOx engines in anticipation of a mandatory low-NOx engine standard in the 2024 timeframe. Low-NOx engines may face certification challenges beyond what is required of new engines meeting existing heavy-duty engine NOx emission standards, but staff is confident that these challenges are not insurmountable. The regulation therefore proposes modest certification flexibility geared to encourage a manufacturer developing low-NOx engine technology to certify such an engine sooner than it otherwise would have, or to certify a greater diversity low-NOx engine families. This modest certification flexibility would provide modest cost savings to engine manufacturers.

For hybrid heavy-duty engines, the proposed regulation would provide more significant OBD flexibility to address compliance challenges related to integrating an engine and hybrid driveline manufactured by different entities, and to encourage reluctant manufacturers to bring hybrids to market. The hybrid element also includes costs related to supplemental chassis-based emission testing, which would be required in order to ensure participating hybrids do not increase NOx, HC, or CO emissions relative to their non-hybrid counterparts. The hybrid element therefore includes significant certification cost savings and modest additional costs for participating manufacturers. The high-efficiency heavy-duty engine element would provide certification flexibility for engines meeting the optional low-CO_2 emission standards identified in the proposed amendments; however, heavy-duty engine technology meeting these optional low-CO_2 emission standards is not anticipated to come to market until at least 2020, and overall costs would be limited by an allowable sales cap for each manufacturer.

Table VI-1: Estimated Economic Impact of New Engine Certification Element*

	Incremental Cert. Costs (per engine family)	Incremental Cost per Engine Sold	Total Cost Over Lifetime of Regulation
Low NOx Engine Cert. Flexibility*** - Multiple Low NOx Engines^^	($0.9M-$2.9M) ($1.3M)	($1.3k-4.2k) ($2.7k)	($3.6M-$11.6M) ($1.3M)
- Range of Costs	($1.0M-$3.0M)	($1.3k-4.2k)	-
- Subtotal	-	-	($4.9M-$12.9M)
Hybrids*****			
- Tier 1 Cert. Flexibility	($0.5M-$1.4M)	($1.6k-$4.4k)	($2.5M-$7.0M)
- Tier 2 Cert. Flexibility	(0.1M-$1.3M)	($1.3k-$21.0k)	($2.1M-$6.5M)
- Engine Labeling^	$1.2k-$4.8k	$12	$3.6k-$14.4k
- Volume Reporting^^^^	$0.1k-$0.4k	$1	$0.1k-$0.4k^^
- Data Reporting^^^^	$0.2M-$0.7M	$1.8k	$0.2M-$0.7M^^
- Supplemental Emission Tests^^^	$25,000 - $56,000	$25-$326	$100k-$224k
- Range of Costs	$0.1M-($1.3M)	$500-($18.9k)	-
- Subtotal	-	-	($4.3M-$12.5M)
High-Efficiency Engines******			
- Tier 1 Cert. Flexibility	($0.5M-$1.4M)	($2.9k-$3.5k)	($1.0M-$2.8M)
- Tier 2 Cert. Flexibility	($0.4M)	($1.1k-$2.1k)	($0.8M)
- Engine Labeling^	$1.9k-$4.8k	$12	$3.8k-$9.6k
- Range of Costs	($0.4M-$1.4M)	($1.1k-$3.5k)	
- Subtotal	-	-	($1.8M-$3.6M)
Absolute Range of Costs**	($0.4M-$3.0M)	$500-($18.9k)	-
Total Costs***	-	-	($11.0M-$29.0M)

* Parentheses represent a cost savings.
** Incremental costs are the absolute lowest and highest costs across all vehicle categories and certification tiers. Absolute range of costs assumes the incremental cost of each tier (e.g., Tier 2) is independent from the previous tier (e.g., Tier 1).
*** Incremental costs are not additive across vehicle category types (e.g., hybrids, low-NOx engines, high-efficiency engines) or certification tiers within a vehicle category. Only the total cost over the lifetime of the regulation are additive across vehicle types and certification tiers.
**** Assumes two manufacturers participate in this category with one engine family each.
*****Assumes five manufacturers participate in this category with one engine family each.
^Applies only to the ITR engine for the multiple low-NOx engine option, Tier 1 hybrids, Tier 1 high-efficiency engines, and hybrids derived from off-road or light- or medium-duty engines; assumes a total of three hybrid manufacturers with one engine each; labeling costs for the multiple low-NOx engines are imbedded in the costs.
^^Assumes one manufacturer participates in this category with one engine.
^^^Low end of cost range is for PEMS testing; high end of cost range is for chassis dynamometer testing; this cost applies to all new hybrid vehicles except for those that are range-extended with an engine originally certified as an off-road or light-duty engine; assumes only one hybrid engine family was originally certified as an off-road or light-duty engine.
^^^^Reporting costs only apply to new heavy-duty vehicles that are range-extended with an engine originally certified as an off-road or light-duty engine.

2. Hybrid Conversion System Installation and Certification Procedures

The proposed hybrid conversion system element of the proposed ITR has a range of potential costs depending upon the number of companies that develop and wish to certify a hybrid conversion system for the California truck and bus market. Companies that choose to sell aftermarket hybrid conversion systems in California would be required to follow the proposed procedures to receive approval. Tier 1 and Tier 2 certification would provide diagnostic compliance flexibility relative to the existing case-by-case approval process, which is consistent with this regulation's proposed Tier 3 diagnostic system requirements. Tier 1 and Tier 2 would therefore provide significant cost savings to participating manufacturers relative to existing procedures through the Tier 1 and 2 sunset dates. Hybrid conversion system manufacturers and installers could incur additional savings due to the proposed regulation's allowance for heavy-duty engine conversions to demonstrate emissions compliance via PEMS testing rather than chassis dynamometer testing. The proposed ITR's minimum warranty requirements, vehicle labeling requirements, and reporting requirements would result in additional certification costs. These potential costs and savings are identified in Table VI-2.

Table VI-2: Estimated Economic Impact of Hybrid Conversion System Element*

	Incremental Certification Costs per Conversion System Make/Model	**Incremental Cost per Unit Installed and Sold**	**Total Cost Over Lifetime of Regulation**
Tier 1 Certification **	($0.7M-$1.6M)	($64k-$70k)	($4.2M-$9.6M)
Tier 2 Certification **	($1.8M-$2.7M))****	($2.9k-$4k)****	($10.8M-$16.2M)****
PEMS Emission Testing***	($31k)	--	($62k)
Warranty Requirements**	$510k-$1M	$1k	$60k-$150k^ $3M-$6M^^
Vehicle Labeling**	$6.1k-$12.3k	$12	$36.6k-$73.8k
Vehicle Reporting**	$0.5k-$1k	$1	$3k-$6k
Absolute Range of Costs	($0.2M-$0.6M)^ ($1.3M-$1.7M)^^	($63k-$69k)^ ($1.9k-$3k)^^	-
Total Costs	-	-	($12.0M-($19.6M)

* Parentheses represent a cost savings.
** Assumes six manufacturers make one conversion system each.
*** Option for Tier 2 heavy-duty vehicle conversion systems; assumes two HDV conversion manufacturers will use the PEMS testing option.
****Tier 2 costs assumes the costs or savings accrued in Tier 2 are independent from Tier 1.
^ Tier 1 certified systems.
^^ Tier 2 certified systems.

If manufacturers choose to develop eligible innovative truck and bus technologies and certify them pursuant to the proposed ITR and amendments, these proposed regulatory actions are projected to result in lifetime cost savings to businesses and individuals ranging from $23.0 million to $48.6 million. This range reflects the low and high end of the range of potential costs for supplemental emission testing, manufacturer reporting, engine labeling, and other ITR eligibility requirements, and the range of potential OBD and other certification compliance cost savings provided by the proposed ITR.

3. Costs and Savings to an Individual

The costs or savings for the manufacturer, if entirely passed on to the consumer, is expected to range from a cost of $500 to a savings of $69,000 per vehicle. The incremental costs or savings to the consumer or individual is highly dependent upon the total volume of engines produced for an engine family, the vehicle category, and the certification tier for the engine or conversion system. In general, vehicle categories and certification tiers that have more significant OBD certification allowances and have small production numbers will generate the largest incremental cost savings. The incremental costs or savings were calculated by first determining the costs or savings associated with the reduced OBD requirements. These costs or savings were calculated on an engine family or hybrid conversion system basis since this is the smallest entity that can be certified. The costs or savings associated with reduced testing requirements, calibration requirements, and delayed or reduced OBD monitor algorithm development are examples of some of the costs or savings that were involved in the analysis.

Once the engine family or conversion system costs were determined, they were divided by a range of potential sales volumes for the different ITR categories to determine the incremental costs or savings to the consumer. For example, the $500 incremental cost for new Tier 2 hybrid vehicles that are derived from off-road or light-duty or medium-duty engines was calculated by taking the projected maximum costs per engine family of $1.3 million and summing miscellaneous costs such as engine labeling, volume reporting, and data reporting before dividing it by a minimum projected volume of 100 engines to obtain an incremental cost of $500 per engine. A similar analysis was conducted to determine the minimum and maximum incremental cost or savings for each vehicle category and certification tier.

4. Reporting Costs

The proposed regulation includes requirements for a manufacturer to report production volumes and data for selected vehicle categories. Production vehicle reporting is required for manufacturers of hybrids that are derived from off-road or light- or medium-duty engines, Tier 1 hybrid conversions, and Tier 2 hybrid conversions while low-NOx engine and high-efficiency engine categories have no reporting requirements. The manufacturers of these vehicle categories are required to report annual and cumulative sales volumes for participating engines to ensure volume caps maintained. The production volume reporting costs for a typical manufacturer are estimated to range from $100 to $400 per year. If a hybrid conversion manufacturer produces a total of 100 to 400 hybrids within an engine family, the reporting costs for an affected

manufacturer are estimated to be around $1 per vehicle. In addition, hybrid manufacturer are required to report data that are derived from off-road or light-duty or medium-duty engines. The cost to accommodate a data logging system is estimated to be about $1,800 per vehicle annually for 3 years. The total reporting costs for a new hybrid conversion manufacturer would then amount to $2,200 per year (i.e., volume reporting costs of $400 plus data reporting costs of $1,800).

Staff anticipates there are between 25 and 50 businesses that could be directly affected by the proposed regulatory actions. These include new heavy-duty engine, vehicle and hybrid driveline manufacturers, and manufacturers and installers of aftermarket hybrid conversion systems. Indirectly affected are the thousands of truck and bus fleets in California, particularly larger fleets that are most likely to be early adopters of zero- and near-zero-emission truck and bus technology.

A. Potential Impacts on Jobs

The proposed regulatory actions are not expected to eliminate any jobs in the state of California, since it is anticipated to provide certification compliance savings for participating manufacturers. To the extent that these manufacturers are able to certify their systems in California, staff anticipates the proposed regulatory actions could lead to some minor level of job creation, particularly for hybrid conversion system manufacturers and installers as the market expands.

B. Potential Impact on Business Creation, Elimination, or Expansion

The proposed regulatory actions are not expected to eliminate any businesses in California. Currently, one hybrid heavy-duty vehicle manufacturer and two hybrid truck conversion system manufacturers have facilities in California. Should these procedures increase the number of manufacturers able to certify their systems in California as a result of the proposed ITR, staff anticipates the proposed regulatory actions could lead to some business expansion as the market for innovative truck and bus technology expands.

C. Potential Impact on Small Businesses

The proposed regulatory actions are anticipated to provide a potential net economic benefit to participating innovative technology manufacturers. While few manufacturers have existing, certified innovative technologies that could potentially be eligible for the proposed regulatory actions, staff anticipates that these numbers could increase as the technologies mature. In general, existing heavy-duty low-NOx, and hybrid engine technology tends to be manufactured and certified by larger, multi-national businesses. Staff anticipates that manufacturers of engines meeting the new optional low-CO_2 emission standards, as identified in the proposed amendments, would also be larger businesses. Hybrid conversion system manufacturers, on the other hand, typically purchase a truck or bus chassis from large original vehicle manufacturers, and retrofit these vehicles with their hybrid conversion systems. Staff anticipates that hybrid conversion systems will continue to be manufactured almost exclusively by small

businesses for the foreseeable future. Table VI-2 identifies this potential economic impact.

D. Potential Impact on Business Competitiveness

The proposed regulatory actions are expected to have no noticeable effect on the ability of California businesses to compete with businesses in other states. The proposal would apply to all eligible innovative new heavy-duty engines and hybrid conversion systems sold, leased, offered for sale, or offered for lease in California, irrespective of where they are produced.

E. Fiscal Impact to State and Local Agencies

The only cost to ARB is to support certification of innovative truck and bus technologies pursuant to the proposed regulatory actions. Based on an analysis of provisions required by the proposal, ARB estimates that two additional Air Resources Engineers (ARE) would be needed to support review, certification, and testing of eligible technologies. The certification process is particularly labor intensive for emerging technologies. Evaluation of new technology requires technical evaluation of a more diverse innovative truck and bus engines, drivelines, aftermarket systems, and their impact on OBD compliance, review of complicated technical documents, and ongoing discussions with manufacturers that may be unfamiliar with ARB certification requirements. The ARB anticipates that the cost of two additional engineering staff persons would be approximately $290,000 per year beginning in the 2017-2018 fiscal year and for subsequent years thereafter. The proposal would not affect other state or local agencies nor does it affect federal funding of state programs.

F. Major Regulations

For a major regulation proposed on or after November 1, 2013, a standardized regulatory impact analysis is required. A major regulation is one “that will have an economic impact on California business enterprises and individuals in an amount exceeding fifty million dollars ($50,000,000) in any 12-month period between the date the major regulation is filed with the Secretary of State through 12 months after the regulation is estimated to be fully implemented, as estimated by the agency.” (Government Code Section 11342.548). The economic impacts of the proposed regulatory actions do not exceed $50 million.

For purposes of Health and Safety Code Section 57005(b), “major regulation” means any regulation that will have an economic impact (compliance cost) on the state’s business enterprises in an amount exceeding ten million dollars ($10,000,000) in any year, as estimated by the board, department, or office within the agency proposing to adopt the regulation in the assessment. This proposed regulatory actions will result in overall cost savings and does not impose compliance costs in excess of $10 million in any year on affected businesses and individuals.

VII. SUMMARY AND RATIONALE FOR EACH REGULATORY PROVISION

This section in provided in Appendix B.

VIII. ANALYSIS OF ALTERNATIVES

California Government Code section 11346.2 requires ARB to consider and evaluate reasonable alternatives to the proposed regulatory actions, and to provide reasons for rejecting those alternatives. This section discusses alternatives evaluated and provides reasons why these alternatives were not included in the proposed regulatory actions. ARB staff did not find any of the alternatives considered to be more effective in carrying out the purpose for which the proposed regulatory actions are proposed or to be as effective as or less burdensome to affected businesses than the proposal.

1. <u>Reasonable Alternatives to the Proposed Regulation and Reasons for Rejecting the Alternatives</u>

   a. Leave Heavy-Duty Engine Certification and Medium- and Heavy-Duty Vehicle Hybrid Conversion System Certification and Installation Requirements Unchanged

   The first alternative is to leave heavy-duty engine and medium- and heavy-duty vehicle hybrid conversion system certification and installation requirements unchanged. This alternative was rejected because California needs accelerated deployment of the innovative truck and bus technologies addressed by the regulation. The proposed regulatory actions would alleviate one potential engineering and resource challenge to accelerating deployment of these critical technologies, while maintaining ARB's ability to ensure their emission reductions are achieved in-use.

   b. Exempt Proposed ITR Technologies from OBD Compliance Requirements

   This alternative would exempt eligible low-NOx engines, heavy-duty hybrid engines, high-efficiency engines, and medium- and heavy-duty vehicle hybrid conversion systems from OBD requirements through the proposed ITR eligible MY or calendar years (i.e., 2021 through 2027, depending upon the technology category). This alternative was rejected because OBD is an increasingly critical tool for ensuring trucks and buses achieve and maintain emission compliance in-use. While OBD can pose an engineering and resource challenge for new technologies, a blanket exemption could result in significantly higher in-use emissions. The proposed regulatory actions provide targeted OBD flexibility geared to address each technology's near-term certification challenges, while providing a pathway for manufacturers to ramp up to meet full OBD requirements.

   c. Do Not Require Supplemental Vehicle-Based Emission Testing of Hybrid Heavy-Duty Engines to be Eligible for the Proposed ITR

This alternative would maintain proposed ITR certification flexibility provisions, but would not require a new heavy-duty hybrid engine opting for the proposed ITR certification flexibility to demonstrate that it does not increase NOx, CO, HC, or PM emissions relative to its non-hybrid counterpart. This alternative was rejected because of the need to ensure heavy-duty hybrids do not increase criteria pollutant emissions in-use. As previously discussed, while a new heavy-duty hybrid engine must be certified to meet criteria pollutant emission standards on an engine dynamometer, studies indicate that NOx, and to a lesser extent CO and HC emissions, may increase significantly without careful engine and driveline integration. The proposed ITR requirement for supplemental emission testing is needed to encourage more robust hybrid technology, and ensure real world emission reductions from hybrid truck and bus technology.

2. Small Business Alternative

ARB staff have not identified any alternatives that would lessen any adverse impact on small businesses.

IX. PUBLIC PROCESS FOR DEVELOPMENT OF PROPOSED ACTIONS

ARB staff developed the proposed regulatory actions through an extensive public process. Staff made a considerable effort to inform, involve, and update the public and stakeholders of its progress during development of the proposed regulation and amendments. ARB held stakeholder meetings, conducted public workshops, and met with interested parties to discuss issues and seek comments. This section presents a summary of these efforts.

1. Public Workshop and Work Group Meetings

ARB conducted three public workshops and 12 topic-specific public work group meetings to discuss issues and seek comments. Interested stakeholders participated in the workshop in person or via webinar. The workshop and work group meeting notices were posted on the Innovative Technology Regulation webpage at: http://www.arb.ca.gov/msprog/itr/itr.htm and distributed to subscribers on the *ITR_Listserve*, which includes over 700 subscribers as of August 1, 2016.

Table IX-1: Public Workshops and Work Group Meetings	
Outreach Event	**Date**
Innovative Technology Regulation Public Workshops	March 9, 2015, September 28, 2015 July 13, 2016
Innovative Technology Regulation New Engine or Vehicle Certification Flexibility Work Group Meetings	March 24, 2015, May 2, 2015, August 17, 2015, January 27, 2016, February 25, 2016
Innovative Technology Regulation Hybrid Conversion System Certification and Installation Procedures Work Group Meeting	April 2, 2015, July 7, 2015, January 26, 2016, February 25, 2016
Innovative Technology Regulation Medium- and Heavy-Duty Vehicle Hybrid Technology Emission Test Procedures Work Group Meeting	January 27, 2016 May 31, 2016 July 26, 2016

2. Stakeholder Meetings

a. Truck and Engine Manufacturers Association (EMA) and Manufacturers of Emission Controls Association (MECA)
Staff met with the EMA's Emission Measurement and Testing Committee on June 8, 2015 and January 8, 2016, and with MECA on June 23, 2015 and May 23, 2016 to discuss development of the proposed ITR and solicit feedback. Over 20 industry representatives and other stakeholders were present at each meeting.

b. Meetings with Individual Manufacturers and Other Interested Parties
ARB also held numerous meetings and teleconferences with interested stakeholders to solicit feedback and comments on the proposed regulation. Discussions were held both before and after each public workshop to discuss issues and address specific stakeholder concerns. Staff held meetings or conference calls with 35 manufacturers, organizations, and other interested parties throughout the process, meeting with them over 70 times. Staff also presented draft proposed regulatory concepts to, and solicited feedback from, over fifty CalStart industry members via a webinar hosted by CalStart on February 16, 2016.

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