MECA STATEMENT
ON THE ENVIRONMENTAL PROTECTION AGENCY'S CONSIDERATION OF CALIFORNIA'S REQUEST FOR A WAIVER OF PREEMPTION FOR THE "OMNIBUS" LOW-NOx REGULATION

August 2, 2022

MECA would like to provide comments in strong support of EPA's granting of a waiver of preemption for the California Air Resources Board's (CARB) Heavy-Duty Low-NOx Omnibus Regulation. We support CARB's ongoing leadership in the effort to reduce the environmental footprint of transportation to meet the state's SIP and climate goals, including technology advancing regulations that provide pathways to clean up the heavy-duty vehicle fleet. We believe an important opportunity exists to continue to reduce criteria emissions and greenhouse gases from medium- and heavy-duty engines and vehicles through the application of advanced technologies on engines and powertrains that can be combined with low carbon fuels and electrification as system solutions to environmental challenges.

MECA is an industry trade association of the world's leading manufacturers of clean mobility technology. Our members have nearly 50 years of experience and a proven track record in developing and commercializing emission control, efficiency and electric technology for a wide variety of on-road and off-road vehicles and equipment in all world markets. Our members provide the technologies that enable heavy-duty on-road vehicles to meet the most stringent NOx and PM emission standards, as well as electrified, all-electric and fuel cell technologies that reduce emissions of all pollutants, criteria and climate, and allow commercial vehicles to be the cleanest possible. Our industry has played an important role in the environmental success story associated with light- and heavy-duty vehicles in the United States and has continually supported state and federal efforts to develop innovative, technology-advancing, regulatory programs to deal with air quality and climate challenges.

MECA members represent over 70,000 of the nearly 300,000 North American jobs building the technologies that improve the fuel economy and reduce emissions of today's vehicles. The jobs supported by clean mobility suppliers include thousands of union jobs in manufacturing as well as engineering jobs developing the technologies that will drive innovation and maintain U.S. leadership in the transportation transition. These jobs are located in nearly every state in the United States – the top 10 states in the U.S. are Michigan, Texas, Illinois, Virginia, New York, Indiana, North Carolina, Ohio, Pennsylvania, and South Carolina. The mobile source emission control industry has generated hundreds of billions of dollars in U.S. economic activity since 1975 and continues to grow and add more jobs in response to environmental regulations. Clean mobility manufacturers invest billions of dollars each year in developing the technologies that reduce emissions from mobile sources.

MECA supports the granting of a waiver to California to enforce its Omnibus Regulation starting with MY 2024 engines and vehicles. The following points summarize our position:

1. California has compelling air quality needs. In order to meet the National Ambient Air Quality Standards in the time frames identified in the California State Implementation Plan, California needs NOx benefits as soon as possible.
2. CARB included OEMs and suppliers on the advisory group that participated in the demonstration program and rulemaking process that began in 2014. CARB held numerous workgroups and public workshops starting in 2016 to inform stakeholders of the regulatory provisions.
3. It is possible to achieve the MY 2024 FTP standard of 50 mg/bhp-hr with improved calibrations applied to improved aftertreatment systems allowing industry to get familiar with the new testing provisions in 2024, additional hardware in 2027 and longer durability in 2031.
4. Technology has advanced and demonstration testing has continued since the Omnibus was finalized.
5. Emission control suppliers have made investments in improved catalysts that can be deployed in current aftertreatment architectures to help OEMs develop engines that meet the MY 2024 standards.
6. The concern of a pre-buy is likely to be alleviated by the fact that improved versions of existing technology will be supported by longer warranty in 2022 and 2027 to bring value and better fuel economy to truck owners.

California has compelling and extraordinary conditions that merit a Clean Air Act waiver for this regulation.

MECA recently sponsored an emission inventory and air quality modeling analysis based on the emission limit values and durability requirements proposed by CARB to quantify the air quality benefits if a national standard were set by U.S. EPA under the CTI to align with the CARB proposed limits and implementation dates [1] [2]. The analysis did not incorporate the compliance program changes or warranty revisions into our model assumptions. The foundation of the evaluation was the current U.S. EPA inventory projection for 2028. The 2028 inventory projection is that of the 2016v1 emissions modeling platform. It is a product from the agency's National Emissions Inventory Collaborative and includes a full suite of the base year (2016) and the projection year (2023 & 2028). This part of the analysis is referred to as the "2028 Base Case" inventory in this study and corresponds closely with a 2027 implementation date for the CTI rule. From that inventory foundation, two new inventory scenarios were developed as follows.

- The "2035 Base Case" inventory was developed to include an on-road fleet projection to 2035 with no change in the underlying regulatory context.
- The "2035 Control Case" inventory was developed to include both the 2035 fleet projection and the impacts of adoption of federal FTP standards for heavy-duty trucks of

0.05 g/bhp-hr beginning with MY 2024 and 0.02 g/bhp-hr beginning with MY 2027, as proposed by CARB, on on-road vehicle emissions.

The 2035 on-road fleet projection estimated hours, VMT and vehicle populations at the county, roadway type, fuel type and vehicle class level. The resources used to create the fleet projection were U.S. EPA's 2023 and 2028 activity projections (used to capture trends at the desired resolution by county, roadway type, fuel type and vehicle class level) and the current version of the Energy Information Administration (EIA) *Annual Energy Outlook 2019* (used for national-level vehicle and VMT projections on which the trends were renormalized to match the national growth rate estimated by the EIA). The fleet-turnover impacts included in the 2035 inventories – both with and without the impacts of the CTI – were modeled with U.S. EPA's MOVES2014b model (MOVES2014b-20181203, which includes the December 2018 technical update). Fleet-turnover effects were modeled relative to the 2028 Base Case with MOVES at the national scale. Inputs into this modeling included U.S. EPA's 2028 age distribution data aggregated to the national level – assumed unchanged for 2035 – and emission factor updates to include the impacts of the CTI.

Results from the inventory analysis show that the new modeled FTP limits would result in a California statewide reduction of nearly 35,000 tons per year of NOx in 2035. When taking a more refined look at the location of the NOx benefits at the county level, those counties currently in nonattainment or maintenance with the 2015 ozone NAAQS will receive some of the highest NOx reductions (e.g. > 145 tons NOx in 2035) from a 0.02 g/bhp-hr heavy-duty engine FTP standard. These estimates likely represent conservative values of real-world NOx reductions because the version of MOVES (MOVES 2010b) available at the time of this analysis did not have the latest emission factors representing low-load and low-speed truck operation. U.S. EPA recently updated MOVES (MOVES3) to represent emissions in these challenging duty-cycles more accurately. A more stringent NOx standard is expected to bring real world NOx emissions down further once the emission factors of future certification that includes a low-load cycle are factored into the model. In addition to NOx reductions, the proposed standards are projected to yield reductions in VOCs and carbon monoxide in 2035.

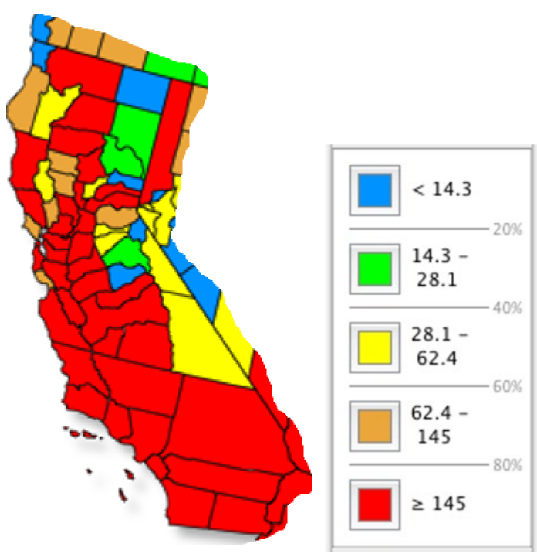

Figure 1. Federal NOx Standard Annual Benefit in California in 2035 (tons reduced)

The companion air quality analysis concluded that ozone levels would decline in several California counties in 2035 as a result of the NOx reductions estimated by the inventory analysis discussed above. The greatest ozone reduction impact of the strategy is seen in urban areas and along highway corridors with reductions of up to 6.5 ppb seen in San Bernardino. In addition, the model predicts that 8-hour ozone design values would decline by 5 ppb or more in the counties of El Dorado, Fresno, Kern, Placer, Riverside, Sacramento, and (as already mentioned) San Bernardino. It is important to note that even though in 2020 the EPA decided to retain the 2015 ozone NAAQS at 70 ppb, U.S. EPA's Clean Air Scientific Advisory Committee (CASAC) supported a range of 60-70 ppb for the 8-hour primary ozone standard. Prior to applying the projected national low-NOx truck strategy, nearly 300 monitoring sites in the U.S. are projected to have 8-hour ozone design values between 60 and 70 ppb, and the proposed truck strategy will reduce these by an average of 2.35 ppb and up to a max of 5 ppb.

It is possible to achieve 0.05 g/bhp-hr NOx emissions on the FTP with current aftertreatment designs.

Engine calibration and thermal management combined with advanced catalysts and substrates have improved to the point where a current engine plus 435,000 mile aged aftertreatment system can achieve FTP emissions of approximately 0.02 g/bhp-hr NOx, well below the MY 2024 FTP standard of 0.05 g/bhp-hr NOx, which provides compliance margins that OEMs need for full useful life durability [3]. During cold-start and low-load operation, engine calibration and thermal management, can be applied to reduce engine out NOx emissions and provide additional heat to aftertreatment systems. Improved catalysts and urea dosing systems can achieve high NOx conversion during lower temperature operation. Further compliance margins can be achieved through modest increases in catalyst volume, while still maintaining the size of future emission controls below those on model year 2010 trucks [4]. CARB's phase-in approach to their 2024 through 2031 requirements provides suppliers and our OEM customers that ability to gradually introduce certification and compliance requirements in 2024 without significantly altering the aftertreatment systems. This provides time to understand the implications of the new low-load certification cycle and three-bin moving average compliance testing requirements on existing engines and aftertreatment before requiring hardware modifications in 2027 and then additional durability and warranty provisions in 2031.

The approaches discussed for meeting 2024 NOx limits utilize improvements in thermal management and engine calibration, with existing aftertreatment system designs. Some engine manufacturers may choose to include a light-off SCR catalyst before the DOC in a twin SCR system arrangement with dual urea dosing, to gain experience with the types of strategies that may be needed for lower NOx limits in 2027. Simulations of 435,000 mile aged commercial catalysts over a low load cycle show that low temperature ammonia delivery through the use of heated urea dosing can deliver NOx emissions below 0.2 g/bhp-hr over the LLC, representing extended low-speed operation and idling [4].

Work conducted in 2017 by Southwest Research Institute (SwRI) included a screening of emission control architectures to evaluate the potential low NOx performance of various combinations of aftertreatment technologies and engine control strategies [5] [6] [7] [8].

Although the objective of that work was to identify system approaches to meeting a 0.02 g/bhp-hr FTP limit, the researchers were able to meet a 0.05 g/bhp-hr limit on the composite FTP cycle by simply using better catalysts, engine calibration and heated dosing.

Since the above study, MECA has continued to evaluate the latest generation of catalysts and substrates being offered to engine manufacturers for 2024 model year applications. Next generation catalysts may combine both iron and copper zeolites in a layered structure or zone-coated with two catalyst formulations on the front and rear of a single substrate. This latest work was based on dynamometer testing of a set of fully aged (435,000 mile) exhaust systems on a commercial heavy-duty engine without the benefit of a modified engine calibration. The engine testing was conducted on a MY 2014 13-liter diesel engine. The engine testing focused only on hot start FTP cycles to emphasize catalyst performance. Cold-start emission control is heavily dependent upon engine calibration, which we did not have the ability to control but an OEM would use to optimize cold start emissions performance and minimize fuel consumption. The hot start operation over the FTP can show how advanced catalysts can lead to improvements in NOx conversion, which was of primary interest in this work.

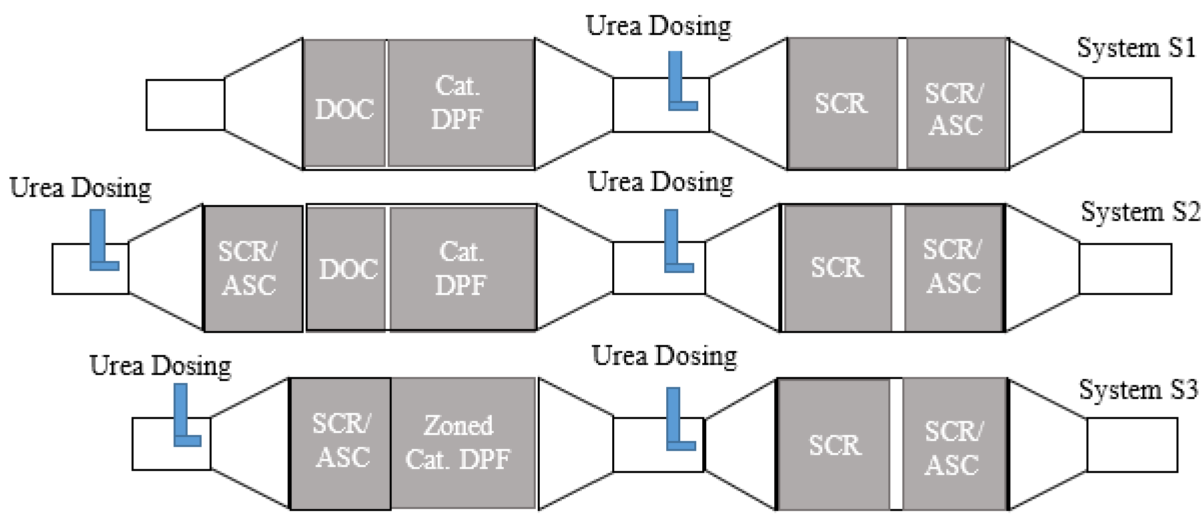

Figure 2. System configurations tested to demonstrate the feasibility of 2024 engine emissions. System S1 is based on 2019 engines in production today. System S2 employs a light-off SCR in a twin SCR arrangement. System S3 employs a light-off SCR in a twin arrangement as well as replaces the DOC and catalyzed DPF with a zoned catalyzed DPF that functions as both a DOC and DPF.

A second study used a modified engine calibration developed by SwRI as an input to an emissions model and simulated the emissions from a fully aged 2019 commercial exhaust aftertreatment system. Several scenarios were modeled, including emissions from the latest commercial catalysts and substrates over cold-start and hot-start FTP as well as low load cycles. The models also provide an evaluation of how increased catalyst and substrate volumes can affect emissions over certification cycles. Finally, the benefit of heated dosing was demonstrated over both the FTP and the low load cycle (LLC-7) developed at SwRI [9].

The system configurations for engine testing and modeling are shown in Figure 2 and include a traditional system layout (S1) and two advanced system layouts (S2 & S3). The system architectures displayed in Figure 8 demonstrate several options available to OEMs when designing exhaust controls for MY 2024 engines. System S1 has a similar architecture as current emission control systems but utilizes the latest generation of SCR catalysts, which are commercially available today. System S2 is a twin arrangement with light-off SCR, which adds a smaller SCR system, consisting of a second urea doser, SCR catalyst and ammonia slip catalyst, upstream of today's emission control architecture. This configuration is slightly larger than S1 but still significantly smaller than typical MY 2010 emission control systems. Finally, system S3 retains the twin SCR arrangement but combines the DOC and catalyzed DPF on to a single substrate. This zoned catalyzed DPF includes a catalyst coated on the front section of the DPF substrate that functions as a DOC and the remainder of the DPF coated with a commercial catalyzed washcoat to facilitate DPF regeneration. The zoned catalyzed DPF reduces the volume of the system to that of current system architectures and offers some reduction in thermal mass.

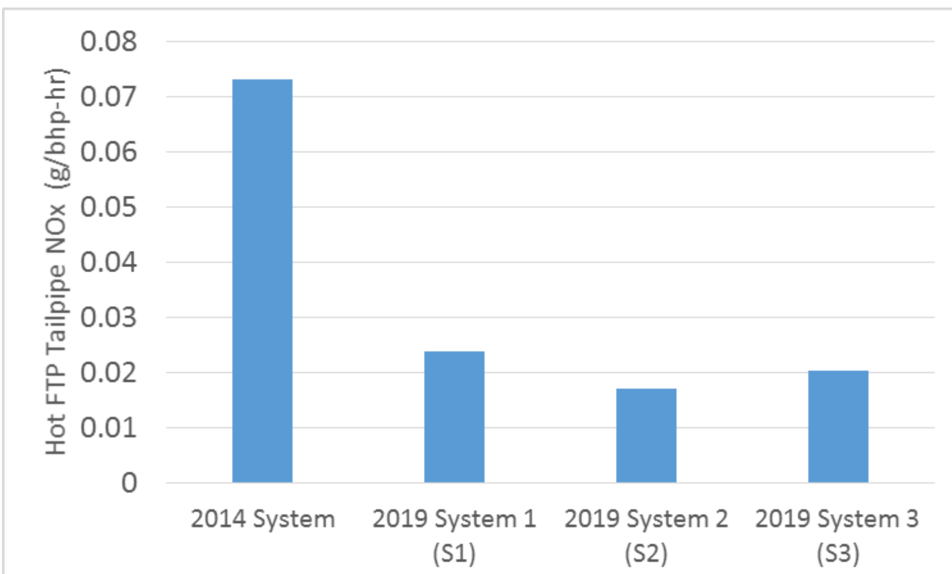

Figure 3. NOx emissions from FTP hot-start tests with four variations of emission control systems. Note: Please refer to Figure 2 and above text for description of systems.

Figure 3 shows results from engine testing of the aftertreatment system configurations shown in Figure 2. In all of the engine tests, no attempt was made to modify the calibration or optimize urea dosing for the exhaust systems tested since that capability lies only with the engine manufacturers. A baseline 2014 emission control system was able to reduce hot-start FTP tailpipe NOx to less than 0.075 g/bhp-hr. Improvements in catalyst technology since 2014 have enabled trucks that employ 2019 emission control systems to meet tailpipe NOx levels over the hot-start FTP of 0.017 to 0.024 g/bhp-hr. The engine testing demonstrates that the most recent generation of SCR catalysts in a traditional emission control system architecture can yield tailpipe NOx emissions over the hot-start FTP of close to 0.02 g/bhp-hr. The addition of light-off SCR in a twin arrangement can deliver tailpipe NOx emissions below 0.02 g/bhp-hr. It should be emphasized that all of these hot-start results were achieved without the benefit of optimized engine or urea dosing calibration nor other thermal management strategies that could be employed on MY 2024 engines to further increase NOx control performance while simultaneously delivering lower CO_2 and GHG emissions.

A model analysis was conducted using an improved engine calibration and advanced commercially available catalysts in a conventional S1 architecture from Figure 2. The emissions simulation model has been developed over ten years of commercial system testing and correlation with field parts. The model inputs include real engine out emissions from a commercial engine that was calibrated by SwRI under the CARB Low NOx Demonstration Program using an advanced cold start strategy. The catalyst conversion parameters input into the model were derived from commercially available accelerated aged catalysts under conditions that represent full useful life of 435,000 miles of operation. An industry average system SCR volume was used for the analysis. Besides in-cylinder thermal management, the model assumes no additional active thermal management, such as an additional fuel injector upstream of the DOC, and utilizes only the engine out temperature data provided by SwRI. Finally, the model assumes a conventional urea dosing strategy, based on the configuration shown in S1 (Figure 2), initiated at 170°C.

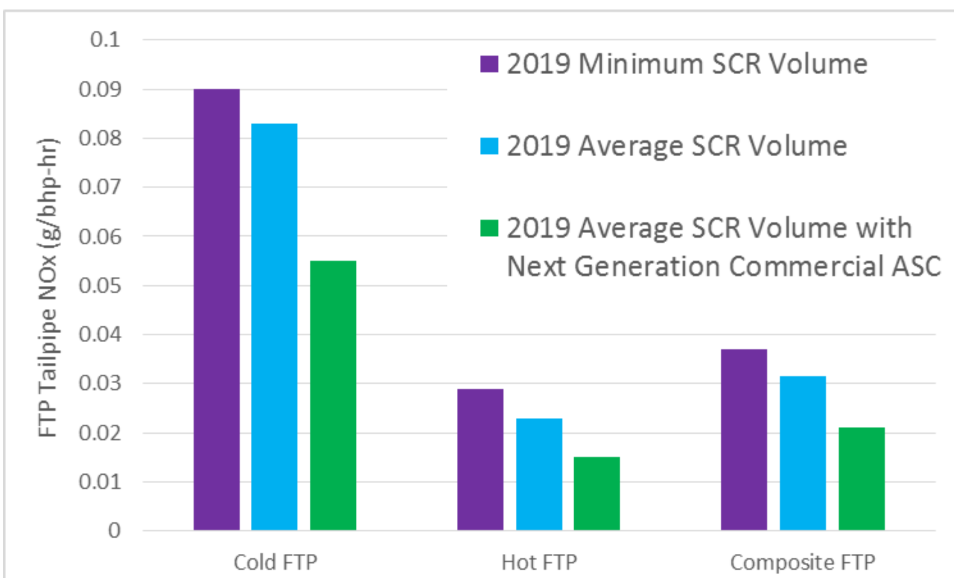

Figure 4. Modeled composite FTP NOx emissions from the latest generation commercially available SCR catalyst and two different SCR system volumes.

Figure 4 shows the predicted emissions from a commercial 2019 emission control systems with different design options. The results of the analysis indicate that currently available emission control systems at a minimum commercial SCR volume in the market today can achieve weighted composite FTP NOx emissions of less than 0.04 g/bhp-hr. The emissions over the composite FTP can be further reduced to approximately 0.03 g/bhp-hr by increasing the SCR catalyst volume to a level representing an average SCR volume found on 2019 trucks. Finally, replacing the baseline ammonia slip catalyst (ASC) with an improved, currently commercial ASC can achieve 0.02 g/bhp-hr on a composite weighted FTP cycle. This result allows for a compliance margin of 60% at an FTP NOx emission standard of 0.05 g/bhp-hr. It should be noted that the modeled hot-start FTP result was between 0.015 and 0.029 g/bhp-hr, which compares favorably with the engine test results described in the previous engine dynamometer study (Figure 3).

Technologies have evolved and demonstration testing has continued since the Omnibus was finalized.

Over the course of the multi-year SwRI demonstration program, the technology innovation was not static, and in fact new technologies came on midstream as they became commercially viable. Even the aftertreatment components that remained fundamentally unchanged from today's systems on trucks benefitted from substrate improvements and new catalyst formulations that occurred over the 8 years of testing under this program. Further improvements in catalysts and architectures have been tested in the latest EPA-led portion of the test program that built on the learnings of the CARB funded portion of the program.

Catalyst suppliers have already developed another generation of SCR catalysts with higher NOx reduction efficiency and better durability compared to the Stage 3 parts tested in the SwRI demonstration program. Through the use of sophisticated models that incorporate the latest learnings on both thermal and chemical aging effects, it is possible to project the gains in efficiency provided by these new materials. A similar methodology was used to that discussed in the MECA 2027 white paper [4], incorporating exhaust information from the latest engine calibration from SwRI and an optimized dosing calibration for the new downstream SCR catalyst. The catalysts were laboratory aged both thermally and chemically using sulfur containing simulated exhaust gas to represent 435,000 miles of equivalent engine aging. The catalysts were modeled over the FTP, RMC and LLC certification cycles and demonstrated lower emissions than the Stage 3 system at SwRI. The not yet published results suggest that the latest generation SCR catalyst would provide OEMs with additional margin to a 0.02 g/bhp-hr standard.

Catalyst technologies continue to evolve. For example, a recent paper published at the 2022 SAE WCX conference in Detroit describes high-porosity honeycomb substrates with thinner wall thickness and high cell density that can be coated with SCR catalyst. This substrate enables higher surface area exposed to exhaust and lower thermal mass, which improves coating efficiency, reduces catalyst heat-up time, and reduces pressure drop. Performance improvements that are especially prominent at low temperature operation include a 14% higher NOx conversion efficiency at exhaust temperatures as low as 175°C [10] [11].

This example of continual improvement and optimization is a testament to the ongoing innovative technology development occurring in the industry between suppliers and their OEM customers. Each time a test is run, new information is obtained and applied to the next iteration. This has been going on continually over the past 15 years of advanced emission controls on trucks. In fact, over the life of the SwRI program, catalyst suppliers have deployed new catalyst formulations and coating techniques to continually improve the durability and performance of the SCR system in order to build greater compliance margin relative to the program targets. Our industry has seen a tremendous amount of innovation on both engines and aftertreatment since the U.S. 2010 on-road diesel standards were implemented. This learning has been applied to improve manufacturing and reduce variability that has allowed systems to be downsized by about 60% and reducing their costs by about 30%.

A most recent development from the demonstration program at SwRI has quantified the impact of closing the crankcase on tailpipe NOx emissions. Originally, it was assumed that the crankcase emissions would have minimal impact on tailpipe emissions, especially since many medium-duty engines already close their crankcases. However, there are several larger on-highway engines that do not currently close their crankcases, including the engine used in the demonstration program. Rather than closing the engine's crankcase, an OEM can measure the blowby emissions and account for them as additional to the tailpipe emissions. The testing thus far has been conducted in this conventional treatment of crankcase emissions from heavy-duty engines. Recently, SwRI found that blowby NOx emissions can be a significant portion of the low-NOx tailpipe standard, and elimination of blowby NOx emissions would yield significant additional margin (approximately 18-35%) to the standard beyond what was already demonstrated. Better closed-crankcase filtration and ventilation (CCV) technologies exist than currently used on trucks because the high NOx limits don't warrant the added cost. EPA estimated the incremental cost of upgrading CCV technology to be about $36 [11]. Closing an engine's crankcase with these better CCV systems enable routing of the blowby gases through the exhaust aftertreatment systems to eliminate the NOx. Light-duty and most medium-duty engines have had closed crankcases for many years. Furthermore, closed crankcase ventilation systems are being deployed on medium- and heavy-heavy-duty CNG engines certified to the California optional low-NOx standard for the past six model years across three engine displacements from 6.7 to 12 liters.

Suppliers have made significant investments to prepare for the future needs of their customers.

Technology commercialization has a long cycle, including design, testing, vehicle integration and real-world deployment across many trucks in the field to make sure systems are reliable and durable. This cycle is why long-term regulatory certainty and stringent standards are a critical signal to industry to begin making investments in technologies that will be needed in the future. As a result of the past eight years of the SwRI demonstration program and the outreach that CARB staff has done during that time with industry, MECA members have been engaged in developing a large portfolio of technology options that can be installed on a vehicle to optimize the lowest NOx and CO_2 emissions. MECA supports standards founded on technologically feasible and cost-effective solutions that allow communities to meet their air quality goals.

Over 5 years ago, CARB initiated its rulemaking process on the next set of heavy-duty engine standards. The technical work process started in 2013 when SwRI was granted a contract to demonstrate the technical feasibility for achieving a 90% reduction in NOx emissions below current standards while not negatively impacting CO_2, N_2O, methane, ammonia and other criteria pollutants including PM. CARB held numerous workgroup and public workshops from 2016 through 2020 to provide industry with advanced knowledge of regulatory concepts and received input throughout that time. Now that the regulation has been finalized, the granting of a waiver to California will provide certainty to suppliers and their OEM customers. In contrast, if the waiver is not granted, suppliers who have made investments based on the regulation as well as interest from their customers will be left with stranded assets.

Pre-buy concerns are likely to be mitigated by the design of the regulation, technology evolution and current economic and supply chain conditions.

Following 10 years of real world experience with DPF plus SCR aftertreatment systems on trucks, OEMs and end users are very familiar with selective catalytic reduction (SCR) technology, urea dosing and maintenance practices that have been employed on all on-road engines since 2010 and most off-road engines since 2014. It should also be noted that CARB's Omnibus does not change the durability and warranty requirements for MY 2024, which provides even more certainty of being able to use current systems to meet the standards in the first few years of the Omnibus. CARB's step 1 warranty being considered by a parallel waiver review, does bring in a transitional warranty in 2022 of 350,000 miles or 5 years for a Class 8 tractor and is a substantial improvement beyond today's 100,000 mile/5 year warranty. The longer durability requirements as well as the Step 1 and Step 2 warranty requirements will deliver additional value to end users and offset additional capital costs, which could also alleviate some pre-buy concerns.

Furthermore, CARB set the implementation dates for the Omnibus Regulation to correspond with the HD Phase 2 GHG standards, which also step down in 2024 and 2027. This harmonization of the dates when standards phase in will provide industry the flexibility to optimize the engine, aftertreatment and vehicle to meet both criteria and GHG requirements. Furthermore, the step down of HD Phase 2 GHG standards in 2024 and 2027 will offer payback on capital costs incurred by end users to meet tighter standards through fuel savings as technologies are applied to meet the CO_2 standards.

EPA has previously addressed concerns of pre-buy raised by some commenters by citing research done on this issue with sales numbers for the years before and after implementation of past rulemakings [11]. Rittenhouse and Zaragoza-Watkins explored pre-buy in the seven months preceding EPA HD rulemakings with compliance deadlines in 1998, 2002, 2007, and 2010. The researchers also measured low-buy in the seven months after the standards. While some pre-buy and low-buy was found for 2002 and 2007, Rittenhouse and Zaragoza-Watkins did not find evidence of pre-buy and/or low-buy for the standards that went into effect in 1998 and 2010. One hypothesis is that pre- and low-buy are less likely to occur when a rulemaking will not require major changes to vehicle emission control components. In 2007, exhaust aftertreatment was first introduced on trucks with the addition of DPFs; however, the Omnibus standards in MY

2024 and 2027 will be met with an evolution of known technologies and minor changes to current vehicles.

Conclusion

California's authority has been critical in driving innovation in our industry. For over 50 years, California has played a leadership role in advancing vehicle standards and air quality policies that created a market for clean vehicle technologies first in California, then the U.S. and eventually around the world. This is a successful model, where California acts as a laboratory for new technology that allows manufacturers to gain experience that benefits the rest of the nation. The Clean Air Act envisioned this role for California as a co-regulator of mobile source emissions.

MECA supports the granting of a waiver to California to enforce its Omnibus Regulation starting with MY 2024 engines and vehicles. California has compelling air quality justification and needs significant NOx benefits as soon as possible to meet their ozone NAAQS commitments for 2031 and 2037. It is possible to achieve the MY 2024 FTP standard of 50 mg/bhp-hr with an evolution of current aftertreatment hardware architecture that employs the latest commercially available catalysts and substrates. Industry has been participating alongside CARB staff for almost a decade during the low-NOx demonstration program and rulemaking process. Suppliers have been preparing to do their part and deliver cost-effective and durable advanced emission control and efficiency technologies to the heavy-duty sector to assist in simultaneously achieving lower GHG and NOx emissions, while also meeting other criterial pollutant standards.

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