



**Manufacturers of Emission Controls Association**

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**COMMENTS OF THE MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION  
ON THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S PROPOSED  
REVISION OF TIER 4 CRITERIA POLLUTANT STANDARDS, PART 1: AMENDMENTS TO  
PHASE-IN SCHEDULE FOR LIGHT-DUTY AND MEDIUM-DUTY VEHICLES  
EPA-HQ-OAR-2025-3297**

**EXECUTIVE SUMMARY**

The Manufacturers of Emission Controls Association (MECA) offers the following comments on the United States Environmental Protection Agency's (EPA) Proposed Revision of Tier 4 Criteria Pollutant Standards, Part 1: Amendments to Phase-in Schedule for Light-Duty and Medium-Duty Vehicles. Our industry relies on technologically feasible criteria pollutant standards that can be met through multiple pathways. MECA believes an important opportunity exists for performance-based standards to continue to cost effectively reduce NO<sub>x</sub>, VOCs and PM from vehicles through the application of a diversity of cost-effective emission control technologies that provide consumers affordable choices in the cars they drive.

We support the Tier 4 standards that become effective for MY 2027 for both light- and medium-duty vehicles, and we do not believe a delay achieves the goals of greater flexibility for industry, or increased vehicle choice or lower vehicle cost for consumers. Technology suppliers rely upon these standards as they provide regulatory stability and market predictability. Sudden delays and changes to these standards will strand billions of dollars invested in developing and manufacturing the technologies to allow vehicles to comply with the 2027 and 2028 phased-in standards and risk the associated jobs. Model year 2027 vehicles are already on the assembly line, and 2028 vehicles have already been designed and the associated supply chain secured, making a two-year delay unnecessary.

MECA is a non-profit industry association of the world's leading manufacturers of technologies for clean mobility. Our members have supported this industry for over 50 years and have a proven track record in developing and manufacturing emission control, engine efficiency, and propulsion components for all mobile sources in all world markets. Our industry has played a critical role in the environmental success story associated with

light-, medium- and heavy-duty vehicles in the United States, and has continually supported efforts to develop innovative, technology advancing, emission reduction programs to improve ambient air quality while simultaneously yielding fuel savings to consumers.

MECA members are a part of the clean mobility supplier industry that employs nearly 400,000 North American skilled workers building the technologies that reduce emissions and improve the fuel economy of on-road and non-road vehicles. Suppliers create two-thirds to three-quarters of all automotive jobs in the U.S., and these jobs are in nearly every state in the United States – the top 10 states being 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 necessary and well-designed air quality policies and regulations such as the Tier 4 criteria pollutant standards. Clean mobility technology manufacturers invest billions of dollars each year in developing the technologies that reduce emissions from mobile sources.

MECA encourages EPA not to delay Tier 4 standards set to begin implementation with MY 2027 vehicles. Suppliers have made major investments in technology innovation, development and manufacturing of components to enable automakers and engine makers to achieve Tier 4 standards, including those for MY 2027 and 2028 vehicles. Delaying these standards puts those investments at risk and will result in lost jobs in the automotive supplier industry. The current regulation includes a phased-in implementation structure that provides compliance flexibility to light-duty vehicle OEMs.

The record supports that the criteria pollutant standards for model year 2027 and 2028 vehicles are achievable without relying on EVs and those model years have already been designed and sourced. Furthermore, vehicles that weigh over 6000 lbs, representing some of the more challenging applications, have until 2030 to comply with Tier 4. Therefore, we believe that there is no need to delay implementation of the 2027-2028 requirements, and we urge EPA to continue to leave these standards in place. Clean mobility suppliers invest in developing technology over 10 years in advance of implementing new standards and depend on policy stability to avoid stranded investments.

MECA would like to provide comments on the following issues that were requested in the current NPRM. More details will be provided on each issue later in this document.

1. The EPA requested comment (C-7) on “the economic impacts of potential noncompliance with MYs 2027 and 2028 standards, including costs associated with revised product plans and sunk development costs, to adjust the economic analysis.” EPA also requested comment (C-10) on “whether regulated parties have any significant reliance interests with respect to MYs 2027 and 2028 Tier 4 criteria pollutant standards only...” and the Agency acknowledged that it “is aware that manufacturers, importers, and sellers have already expended resources complying with Tier 4 criteria pollutant standards for MYs 2027 and 2028, because many

compliance costs are incurred as part of research and development and during manufacturing.” EPA further elaborated that it “does not believe reliance interests in the timing of the Tier 4 standards, if any exist at this point, outweigh the need to reconsider the Tier 4 program as proposed here.” The EPA requested comment (C-4) on “whether the Tier 3 program should be extended for three MYs, through MY 2029, instead of two MYs.”

MECA supports Tier 4 standards beginning with MY 2027 vehicles as originally finalized in 2024. Our comments herein describe that keeping the standards without delay is predicated on our demonstrated reliance interests and technological feasibility of meeting the standards. Thus, the Tier 3 program should neither be extended for two nor three model years. Suppliers have made major investments in technology innovation, development and manufacturing of components to enable automakers and engine makers to achieve Tier 4 standards, including those for MY 2027 and 2028 vehicles. Delaying these standards puts those investments at risk. MECA believes that finalizing a delay to Tier 4 will result in tens of thousands of lost jobs in our industry. Finally, because other auto producing regions like Europe and Asia continue to deploy criteria pollutant emission control technologies, there is a likelihood of engineering and future manufacturing investment shifting from the U.S. to other countries. This would effectively cede our leadership to foreign nations and put U.S. companies at a competitive disadvantage and potentially repeat the history of the 1970s when U.S. automakers were outcompeted by smaller, more efficient Japanese companies.

2. The EPA requested comment (C-8) on “the challenges associated with integrating GPFs on light- and medium-duty vehicles in MYs 2027 or 2028, especially regarding what has changed that renders the extensive public record insufficient to justify manufacturers installing this technology.” Gasoline particulate filters (GPF) have been commercially deployed in Europe for over ten years to comply with stringent particulate standards. GPFs have also been deployed in China since 2021 and India since 2023 including on U.S. manufactured vehicles exported to these three regions. Most importantly, GPFs have already been deployed by eight manufacturers on over 96 vehicle models certified by the EPA and CARB for the 2026 model year with at least 36 additional models entering the market in 2027. The experience with GPFs, in the U.S. and abroad highlights that manufacturers are well positioned to meet the Tier 4 PM standards phase-in without delay.
3. EPA requested comment (C-1) on “all aspects of this proposed rule, including all elements of this preamble, the proposed regulatory changes, and the DRIA (including projected impacts), that are not otherwise enumerated within the preamble.” MECA provides comments herein on EPA’s cost analysis in the DRIA, including the per vehicle cost estimates to comply with Tier 4 NMOG+NO<sub>x</sub> and PM standards as well as the assumptions made by EPA in aggregating the total savings to automakers that would accrue from a delay by two years as proposed. While EPA’s per vehicle costs for GPFs and catalyst upgrades are within reason, we do not agree with EPA’s assumption for savings to automakers due to this proposed delay

because MY 2027 vehicles are already in production, MY 2028 vehicles are designed, and the associated supply chain has been mobilized.

4. EPA requested comment (C-9) on “the projected MYs 2027 and 2028 BEV sales estimates used for assessing the cost and emissions impacts of this proposal, as detailed in the Draft RIA.” Recent changes in policies and market realities have led to slower than anticipated EV uptake. We agree with EPA that the rates of electrification estimated for compliance with EPA’s final GHG rules for MY 2027 and later vehicles were ambitious. While electric vehicle technology is mature at this point, there is still considerable uncertainty in the timeline for market penetration. We remain concerned about the rate of charging infrastructure build-out as well as short and medium-term availability of sufficient critical minerals to support domestic industry investments. In addition, unforeseen disruptions in electrical power availability have occurred as our nation’s electrical grid is stressed by increased demand coupled with aging infrastructure.<sup>1</sup> However, we will provide additional readiness analysis that the Tier 4 MY 2027 and 2028 criteria pollutant emission standards can be achieved independent of BEV sales.
5. The EPA requested comment (C-3) on “the use of the ABT program for NMOG+NOx emissions in MYs 2027 and 2028...” MECA supports continuation of fleet averaging for NMOG+NOx standards, including the ABT program. Fleet averaging has been used for NOx since Tier 2 began phasing in with MY 2004 and NMOG+NOx since Tier 3 began phasing in with MY 2017. This program combined with ABT provides automakers with compliance flexibility and has been supported by the auto industry for over 20 years.
6. The Agency has also requested comment (C-2) on “if the Agency should add to the Tier 3 program the additional NMOG+NOx Bins in the Tier 4 program for MYs 2027 and 2028.” EPA added that “doing so could provide additional flexibility to vehicle manufacturers for demonstrating compliance with the NMOG+NOx fleet average standard. First and foremost, MECA supports retention of the MY 2027-2028 Tier 4 standards with no delay. We acknowledge that the addition of Bins in Tier 4 does provide further flexibility to OEMs. Therefore, we support including these Bins for compliance with Tier 3 standards.

MECA appreciates the time and effort that EPA staff put into the regulatory process. We thank EPA staff for their dedication in receiving and incorporating feedback from a broad range of stakeholders. We look forward to continuing to discuss our suggestions with Agency staff as you work to finalize this Part 1 regulation and propose Part 2 later this year. We provide additional detail to support our recommendation below.

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<sup>1</sup> <https://www.utilitydive.com/news/energy-infrastructure-transmission-transformers-civil-engineers/743698/>

## **TECHNICAL JUSTIFICATION FOR RETAINING THE 2027 AND 2028 TIER 4 STANDARDS**

### **Suppliers Rely on Regulatory Stability to Prevent Stranding of Investments in Technologies Commercialized to Meet Criteria Pollutant Standards (C-4, C-7, C-10)**

MECA supports technologically feasible criteria pollutant standards that can be cost-effectively achieved by a diversity of powertrains, including internal combustion engines, hybrids and fully electric vehicles. These standards, when designed appropriately, simultaneously promote technological progress and improve health and welfare for all Americans. Delaying implementation of the Tier 4 standards would adversely affect the automotive clean technology supplier industry for several reasons. First, EPA's proposal reduces regulatory stability that in turn leads to market uncertainty for our industry. This results in delays and cancellations of current programs already started by OEMs and their suppliers. It also leads to cancelled investments toward future research and development as well as infrastructure projects that include manufacturing facilities. Second, the proposal will lead to stranded investments made to manufacture technologies for the 2027 and 2028 model years and subsequent loss of manufacturing jobs. Since we support retaining Tier 4 standards for MY 2027 and 2028, MECA does not support extending Tier 3 through MY 2029. Our comments throughout this document respond to EPA's proposal that focuses on MY 2027 and MY 2028. However, the information provided herein supports Tier 4 standards for MY 2029 vehicles.

Tier 4 standards were finalized in 2024 to provide OEMs lead time to work with their suppliers on certification of compliant vehicles. That process has played out in the growing number of models certifying to Bin 20. Changing course at this late date, with only a few months before the start of implementation, is particularly damaging for our industry and increases the likelihood of stranded investments ranging from \$1.7 to \$4.4 billion due to this proposal. In reliance on the standards, suppliers have been working with their customers to prepare for introduction of MY 2027 engines and vehicles for several years now. This includes substantial investments over 10 years to conduct the engineering analyses and testing that have resulted in the completion of design of MY 2027 and 2028 engines and vehicles. Furthermore, supply chains have been secured to deliver the tooling needed in the manufacturing process.

Companies that design and manufacture emission control and efficiency technology products to meet criteria pollutant and fuel economy standards employ nearly 400,000 people at over 2000 facilities across the United States.<sup>2</sup> The clean mobility industry exists largely because of technologically feasible and cost-effective regulations for vehicles and fuels. The goal of these regulations, consistent with EPA's mission, is to reduce emissions to achieve improved air quality that results in a healthier American population. Feasible vehicle regulations save billions of dollars in medical expenses, attract investment in our economy, and have spurred an entire industry that generates hundreds of billions of dollars annually in U.S. GDP. Furthermore, suppliers invest billions of dollars each year

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<sup>2</sup> <https://www.bluegreenalliance.org/resources/bluegreen-alliance-unveils-latest-auto-industry-map-for-domestic-manufacturing-advocates/>

in research and development of technological innovation that gets exported around the world. In fact, automotive technology suppliers account for approximately 40% of the auto R&D conducted in the U.S. each year.<sup>3</sup>

The additional uncertainty created by this NPRM may potentially jeopardize new investments in American manufacturing of advanced clean car technologies. The long-term impacts of stranded investment may lead companies to question the risk of future investments in the U.S. when other regions offer regulatory stability. Investments that would have been made in the U.S. have already started to go to other countries where criteria pollutant standards continue to be progressively tightened. Furthermore, delays or deregulatory changes to Tier 4 standards will likely result in litigation that could take years to resolve. This extended period of regulatory instability would only provide additional impetus for companies to look at other automotive producing regions, where tighter criteria pollutant regulations are more stable, for making new manufacturing investments instead of the U.S. Due to the economics of long-term investments in manufacturing and supply chain management, there is a very low chance of jobs and investments returning to the U.S. once they are moved overseas because the overseas markets will be more mature, and it may be more cost effective to ship parts from abroad rather than building manufacturing capacity in the U.S.

Automotive suppliers represent the largest sector of manufacturing jobs in the nation and have made long-term investment decisions based on Tier 4 standards set in 2024. In fact, automotive suppliers have seen an overall 23 percent increase in employment since 2012, which can partly be attributed to advanced technology development spurred by progressive technologically feasible emission standards. While supplier direct employment in the U.S. is highest in Michigan, Ohio, and Indiana, the highest growth in recent years has been seen in the Southeast region.<sup>4</sup> Elimination of the standards will cause adverse economic impacts, including the loss of an estimated 40,000 jobs. Initial job losses will most likely be in application engineering, with several other job functions being impacted.

### **PM Standards are Achievable with Globally Accepted Technology that is Commercially Available (C-8)**

EPA should not reconsider nor delay the implementation of the Light- and Medium-Duty PM standard of 0.5 mg/mile, including all updated certification test procedures in the rule, because the existing record demonstrates that the standard can be met by internal combustion engine vehicles with gasoline particulate filter (GPF) technology and advanced fuel injection already commonly used in most other automotive regions of the world. EPA designed the standard to be met on an individual vehicle basis, therefore being independent of electric vehicle sales.

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<sup>3</sup> Motor & Equipment Manufacturers Association, Moving America Forward (2013), <https://www.mema.org/resource/2013-economic-impact-study-moving-america-forward>

<sup>4</sup> [https://www.mema.org/sites/default/files/resource/MEMA\\_ImpactBook.pdf](https://www.mema.org/sites/default/files/resource/MEMA_ImpactBook.pdf)

EPA based the 0.5 mg/mile PM standard on several research studies as well as actual testing by the Agency during the rulemaking development. This testing not only proved the feasibility of a vehicle achieving the standard during all operating conditions, but it also demonstrated the feasibility of collecting and measuring PM at the necessary detection limits for certification. This measurement feasibility was conducted via a round-robin measurement program that included three independent laboratories using existing CFR test methods that would require no additional test burden on manufacturers. Moreover, car and truck OEMs have been conducting exhaust PM research for decades and are well versed in the appropriate PM collection methodology that reduces sampling errors to enable ultralow limits of detection.

As of today, two-thirds of the major automotive producing regions of the world, including Europe, China and India, are meeting even tighter PM emission standards than the U.S. 2027 requirements. To meet tightening particulate standards in other global regions, fuel injection and GPF suppliers have continued to improve their commercially available technologies. In fact, nearly every European GDI engine car is currently certified with a GPF. China has gone as far as requiring all diesel and gasoline cars to be equipped with the best available control technology, based on wall flow GPF and DPF filters, that diesels have used in the US since 2007.

Table 1. Model Year 2026 Vehicle Models Certified with GPFs.

Manufacturer	Vehicle Classes	Powertrains	# Models	Models Include
BMW	PC, LDT2, LDT3	ICE, HEV, PHEV	30	X3 xDrive 30, X2, X1, 228, 330i, 340i, 430i, 440i, 550e, Mini Countryman ALL4,
FERRARI	PC	ICE, PHEV	8	12 Cilindri, Roma Spider, Daytona, 296 GTB
FORD	PC, LDT2, LDT4	ICE, HEV	17	F150 3.5L, Expedition 3.5L, Explorer 2.3L, Mustang 2.3L, Maverick 2L, Bronco Sport 2L Lincoln Nautilus, Navigator
HYUNDAI	PC	HEV	3	Palisade
JAGUAR LAND ROVER	LDT4	HEV	12	Defender, Range Rover
LOTUS	PC	ICE	1	Emira
MASERATI	PC	ICE	3	GT2 Stradale, MC20, MC20 Spyder
PORSCHE	PC	ICE, HEV	14	911 Carrera, 911 Carrera TARGA
VOLKSWAGEN	PC, LDT2	ICE	8	Tiguan, Taos, Audi Q5 Quattro and Sportback

Based on evolution of control technologies, future Euro 7 standards will expand the operating window to include lower temperature, higher altitude and towing. In anticipation of these tighter limits over extended duty operation, suppliers have improved fuel injection<sup>5</sup> as well as diesel and gasoline particulate filters.<sup>6</sup> U.S. and international

<sup>5</sup> Yamaguchi, A., Dillner, J., Helmantel, A., Koopmans, L. et al., SAE 2023-01-0239;

<sup>6</sup> Obata, S., Furuta, Y., Ohashi, T., and Aoki, T., SAE 2023-01-0394.

OEMs are exceeding requirements in other global markets equivalent to or more stringent than the 0.5 mg/mile standard beginning in the U.S. for 2027.<sup>7</sup>

MECA's industry assessment, which is corroborated by others,<sup>8</sup> concluded that a GPF will cost approximately \$50-\$300 per vehicle, depending on engine displacement and technology implementation strategy. In a recent update of GPF costs, ICCT has found that costs have come down by about 20% since their 2023 report as a result of manufacturing optimization and industry learning. For engine displacements ranging from 1.5L to 7.0 L, uncoated GPF direct manufacturing costs range from \$72 to \$187 while catalyzed GPF costs are estimated as \$65 to \$152 based on saving due to smaller TWC.<sup>9</sup> Since 2024, our members have been working with their OEM customers to integrate this technology onto MY 2026 vehicles ahead of the MY 2027 implementation date of the Tier 4 standards. In fact, as shown in Table 1, there are 96 vehicle models certified by nine vehicle manufacturers equipped with GPFs in model year 2026, with about 36 additional models expected by 2027 and another 18 models in 2028. Based on these projections, we believe OEMs are already well on their way to implementing technologies across their fleets to meet the 0.5 g/mile PM standard. Indeed, changing this provision in the rule at this late date would disproportionately create hardships for technology suppliers, resulting in stranded investments, lost jobs and idle manufacturing capacity. In addition, changing this provision would penalize vehicle manufacturers for their early compliance while effectively rewarding those manufacturers that have delayed action.

MECA conducted a study that showed this PM standard alone will result in annual decreases in PM pollution, reaching over 110,000 tons reduced in the year 2050 and delivering hundreds of millions of dollars in health benefits to Americans.<sup>10</sup> Notably, those benefits can be achieved independent of the number of electric vehicles sold. Figure 2 illustrates this for the Energy Information Agency (EIA) Annual Energy Outlook 2022 (AEO2022) electrification forecast of 17% new EV sales in 2050.

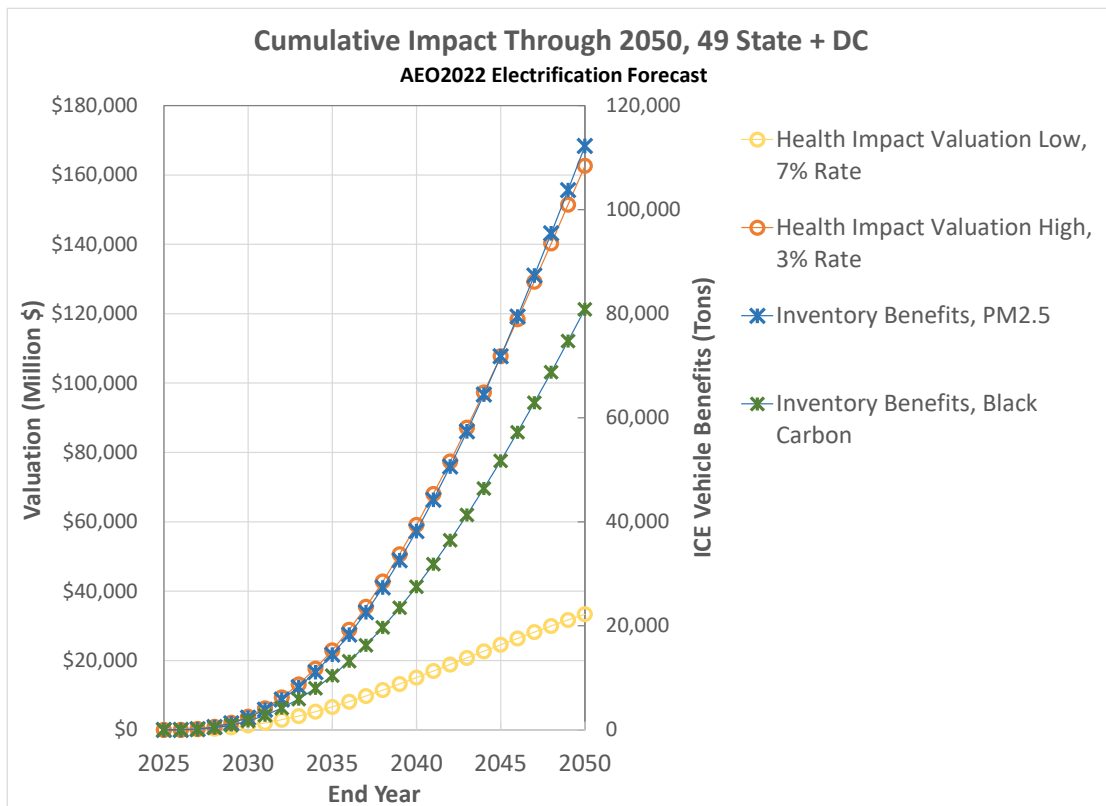
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<sup>7</sup> <https://circabc.europa.eu/sd/a/fdd70a2d-b50a-4d0b-a92a-e64d41d0e947/CLOVE%20test%20limits%20AGVES%202020-10-27%20final%20vs2.pdf>

<sup>8</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1019VPM.pdf>; <https://theicct.org/wp-content/uploads/2023/11/ID-48-%E2%80%93-U.S.-GPF-fact-sheet-letter-70112-v3.pdf>

<sup>9</sup> <https://theicct.org/icct-comments-on-epa-proposed-revision-tier-4-criteria-pollutant-standards-part-1-amendments-to-phase-in-schedule-for-light-duty-and-medium-duty-vehicles/>

<sup>10</sup> [https://www.meca.org/wp-content/uploads/2023/06/LDV\\_PM\\_Standard\\_Final\\_Report\\_06272023.pdf](https://www.meca.org/wp-content/uploads/2023/06/LDV_PM_Standard_Final_Report_06272023.pdf)



**Figure 2. Cumulative Benefits of 0.5 mg/mile PM Standard Assuming Low EV Sales.**

**MY 2027-2029 NMOG+NO<sub>x</sub> Standards are Achievable with Commercially-Available Technology already deployed on Tier 3 vehicles of all sizes and weights (C-1, C-4)**

EPA requested comments on “all aspects of this proposed rule, including all elements of this preamble, the proposed regulatory changes, and the DRIA (including projected impacts), that are not otherwise enumerated within the preamble.” EPA also requested comment “on whether the Tier 3 program should be extended for three MYs, through MY 2029, instead of two MYs.”

EPA should not reconsider the technology neutral light-duty NMOG+NO<sub>x</sub> fleet average standards of 25 mg/mile in 2027 and 23 mg/mile in 2028 as it reviews the full Tier 4 implementation standards. EPA ran several compliance scenarios when the Tier 4 standards were finalized in 2024, including ambitious and mild projections of electric vehicle penetration. When EPA finalized the NMOG+NO<sub>x</sub> standards, it found that they were “feasible for ICE-based vehicles without taking into consideration the possibility of averaging with zero-emitting vehicles.”<sup>11</sup> ICE and hybrid cars and pick-up trucks of all sizes and weights being sold today are already reporting certification levels well below MY 2027 and 2028 standards by employing targeted calibration of currently available engine and aftertreatment technologies.

<sup>11</sup> <https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P1019WE6.pdf>, page 1057.

Our analysis of currently available certification data<sup>12</sup> supports that vehicle manufacturers have made substantial progress on the path to the Bin 30 fleet average level. In fact, we estimate that, under the revised bin structure adopted in the Tier 4 Rule, OEMs are poised to comply with the MY 2027 NMOG+NO<sub>x</sub> fleet average of 25 mg/mile with today's sales mix that includes modest uptake of HEVs, PHEVs and BEVs. It has now been over 22 years since the first vehicle was certified to Bin 30 and 15 years since the first Bin 20. As of June 2025, over 400 vehicle models meet Bin 30 while 30 are certified to Bin 20. The U.S. new vehicle fleet is made up of about 500 unique light-duty models of which 70 are BEVs, indicating that nearly all light-duty vehicles are complying with Tier 3 and about 20% are at Bin 20 or lower. Each OEM applies its actual sales volumes of these available models for a given model year to calculate its fleet average.

Advances in catalyst technology and honeycomb substrates have evolved to achieve NMOG+NO<sub>x</sub> emission levels well below 20 mg/mile. In fact, there are already 212 different vehicle models available for sale that emit under 15 mg/mile based on certification test data. That is more than triple the number just two years ago and illustrates the tremendous progress that suppliers and their OEM customers have made to continuously improve emissions from ICE vehicles. Today, even pick-up trucks, larger SUVs and mini vans with conventional and hybrid powertrains are emitting at levels low enough to be certified down to Bin 15.<sup>13</sup>

A selection of Bin 20 and Bin 30 certified vehicles is shown in Figure 3. The horizontal arrows at the top of the figure represent vehicle groupings within Bin 20 and Bin 30. A sampling of compact cars, mid-size sedans, SUVs and even LDT4 category full-size pick-up trucks and SUVs are listed along the x-axis. The blue vertical bars show the actual levels emitted by these vehicles over the FTP cycle, which are reported to EPA per certification requirements. It is evident that many vehicles sold today have significant margins below today's fleet average emissions limit. This sample set represents the vehicles employing advanced emission control technology and includes pure ICE, hybrid and plug-in hybrid powertrains all incorporating a combustion engine. The agency provided three years of lead time and a generous phase-in of the Tier 4 fleet average standards to provide OEMs time to deploy technologies discussed below and across additional models. Based on EPA's certification data, there is no correlation between a vehicle's ability to emit at ultra-low NMOG+NO<sub>x</sub> levels below 20 mg/mile and characteristics like mass, size or powertrain.

It is important to note that vehicle manufacturers develop compliance product strategies which include de-risking by achieving certification levels which can allow vehicle models to readily transition to lower bins with little or no changes. At present, certification records show that many vehicles certified to Bin 30 could immediately transition to Tier 4 Bin 25, Bin 20 and Bin 15 with few or no technology changes beyond the availability of additional bins.

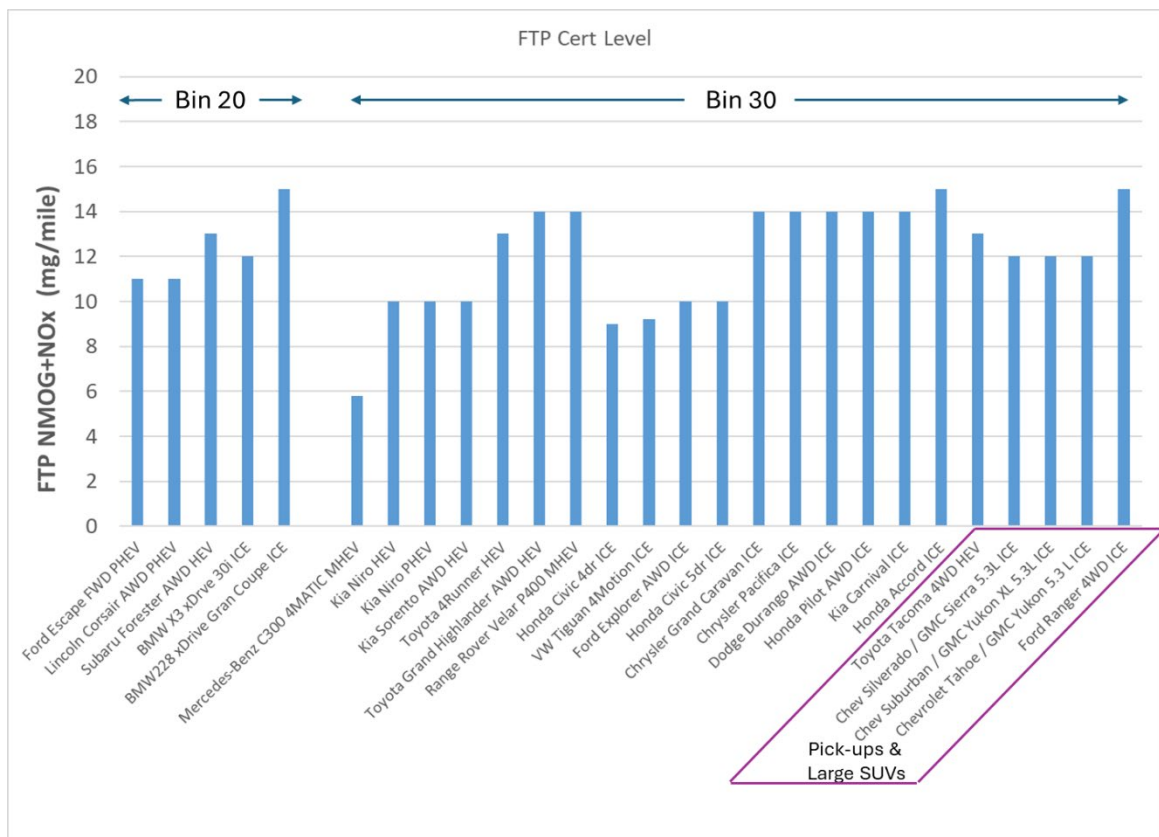
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<sup>12</sup> <https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-engines-and-equipment#Ct>

<sup>13</sup> MY 2026 Volvo XC90 B5 AWD per EPA certification data referenced in footnote 50.

As an example, in model year 2025, there were 10 “Vehicle Test Groups” certified to the Bin 20 standard with an approximate average NMOG+NOx Certification Level of approximately 13.5 to 14 mg/mile – 6 to 6.5 mg/mile (or ca. 33%) margin below the Bin 20 limit. There were 155 “Vehicle Test Groups” certified to Bin 30 in model year 2025. Applying a 33% margin, there are 45 Bin 30 certified “Vehicle Test Groups” with Certification Levels  $\leq 14$  mg/mile that could certify to the Bin 20 limit in model year 2027 at a  $>30\%$  margin.

Alternatively, there are 43 current Bin 30 “Vehicle Test Groups” that have NMOG+NOx Certification Levels of  $\leq 17$  mg/mile which could likely certify to Tier 4 Bin 25 in model year 2027 at 33% margin. In short, 57% of model year 2025 Bin 30 certified “Vehicle Test Groups” are immediate candidates for certification to Bin 20 or 25 at 33% margin below the bin standard. This highlights that vehicle manufacturers are well positioned to meet the Tier 4 model year 2027 and 2028 NMOG+NOx vehicle fleet average with their MY 2025 fleet without technology upgrades, reliance on BEVs in their fleet, or ABT credits. Of course, the way an OEM applies credits or calculates its fleet average depends on sales volume of any engine family. This information is not publicly available and only reported to regulatory agencies. We request that the Agency make this information available for public review and comment.



**Figure 3. Model Year 2024-2025 NMOG+NOx Certification Data for Selected Vehicles.**

The use of existing engine, hybrid powertrains, and exhaust emission control architectures has also facilitated cost effectively achieving the lowest Bin 20 and Bin 30 NMOG+NOx emission levels. Further technology improvements coupled with thorough engine mapping and improved calibration continue to be incorporated into new production vehicles to enable compliance with the declining NMOG+NOx fleet average independent of electric vehicle sales. MECA members are commercializing these engine, aftertreatment, and electrified technologies that will enable Tier 4 NMOG+NOx fleet average standards.

To comply with lower NMOG+NOx and PM emissions standards over all certification cycles, manufacturers will employ improved engine maps and calibration strategies of existing engines and emission control related systems. Other design changes to system architecture can be deployed to manage engine-out emissions and exhaust flows, reduce catalyst light-off times, increase exhaust temperatures during periods of low-load or idle and reduce excessive warmed-up and hot running emissions to protect engine and emission control components which are susceptible to deterioration from extended exposure to higher exhaust temperatures.

Several choices can be made to improve and optimize emission control performance. For gasoline engines, the technology base of advanced three-way catalysts deposited on high cell density (as high as 1200 cells per square inch or cpsi), thin-walled substrates (approaching 0.05mm) has evolved dramatically for light- and medium-duty chassis certified vehicles to comply with Tier 3 standards. Recent advances have yielded high porosity, low thermal mass substrates with narrow pore size distributions, which enable high emission reduction efficiency with less precious metal loading.<sup>14</sup> Catalyst coating technology based on layered or zoned architectures combined with targeted precious metal placement has been successful in controlling costs considering rising raw material prices. Thus, we estimate the cost to bring a Bin 30 vehicle down to Bin 15 to be less than \$100 per vehicle. Moreover, the introduction of additional certification bins will provide greater certification flexibility to manufacturers. Our industry is on course to deliver the technologies that will allow our OEM customers to meet the 2027 and 2028 phase-in fleet average without delay and without a need to sell more electric vehicles. Numerous analyses project consumer interest will drive a market-based increase in EV sales over the next several years, which will add to OEM options for compliance with Tier 4.

In summary, our review of the industry data submitted to EPA over the last two years, since the Tier 4 standards were finalized, has further strengthened the argument made in the 2023 analysis that led the agency to conclude that the MY 2027-2028 NMOG+NOx fleet average standards can be met without a reliance on EV sales. The automotive industry, including MECA members, has continued to integrate better technology into vehicles, resulting in a tripling of the number of models emitting between 10-25 mg/mile limit in the 2025 model year. Looking ahead, MECA members are currently

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<sup>14</sup> T. Asako, D. Saito, T. Hirao and E. Popp, SAE 2022-01-0543; J. Warkins, T. Tao, M. Shen and S. Lyu, SAE 2020-01-0652.

working with their OEM customers on ICE powertrain programs to meet Bin 15 and Bin 10 certification. This compelling evidence confirms that meeting the 2027-2028 phased-in NMOG+NOx limits is achievable without delay.

### **Cost Effective Technologies are Already Designed into MY 2027 and 2028 Vehicles (C-1)**

EPA requested comment on “all aspects of this proposed rule, including all elements of this preamble, the proposed regulatory changes, and the DRIA (including projected impacts), that are not otherwise enumerated within the preamble.” MECA provides comment herein on EPA’s cost analysis in the DRIA, including the per vehicle cost estimates to comply with Tier 4 NMOG+NOx and PM standards as well as the assumptions made by EPA in aggregating the total savings to automakers that would accrue from a delay by two years as proposed. While EPA’s per vehicle costs for GPFs and catalyst upgrades are within reason, we do not agree with EPA’s assumption for savings to automakers due to this proposed delay.

MECA’s industry assessment, which is corroborated by others,<sup>15</sup> concluded that a GPF will cost approximately \$50-\$300 per vehicle, depending on engine displacement. In a recent update of GPF costs, ICCT has found that costs have come down by about 20% since their 2023 report as a result of manufacturing optimization and industry learning. For engine displacements ranging from 1.5L to 7.0 L, uncoated GPF direct manufacturing costs range from \$72 to \$187 while catalyzed GPF costs are estimated as \$65 to \$152 based on saving due to smaller TWC.<sup>16</sup> Our members have already been working with their OEM customers to integrate this technology onto vehicles ahead of the 2027 and 2028 implementation dates of the Tier 4 standards finalized in 2024. EPA’s own analysis corroborates MECA’s cost estimate for GPF technology.

As noted above in the discussion on technological feasibility of GPFs, there are already nearly 100 vehicle models certified with a GPF for MY 2026. It is not clear how EPA’s analysis considers potential cost savings for these vehicles given automakers would incur a cost to remove GPFs from these vehicles rather than create savings. Furthermore, nearly 40 additional models have been planned with GPFs for MY 2027, with designs and supply chains set well in advance of vehicle production. Again, automakers would incur a cost to make changes to these designs so close to release rather than any savings estimated in EPA’s cost analysis. EPA should consider these points in reanalyzing costs and benefits for this proposal and release the results for public comment prior to finalizing this proposal.

MECA’s industry assessment of the costs to reduce a Bin 30 vehicle to a Bin 15 vehicle by making slight evolutionary upgrades to the three-way catalytic converter is approximately \$50-\$100. This cost range is also validated by EPA’s analysis in this rulemaking. However, it should be noted that the automakers have several available tools

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<sup>15</sup> <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1019VPM.pdf>; <https://theicct.org/wp-content/uploads/2023/11/ID-48-%E2%80%93-U.S.-GPF-fact-sheet-letter-70112-v3.pdf>

<sup>16</sup> <https://theicct.org/icct-comments-on-epa-proposed-revision-tier-4-criteria-pollutant-standards-part-1-amendments-to-phase-in-schedule-for-light-duty-and-medium-duty-vehicles/>

to cost effectively reduce NMOG+NO<sub>x</sub> from vehicles. For MY 2027 vehicles, the fleet average declines from 30 to 25. As already noted in our comments, hundreds of vehicle models are certified to Bin 30 with significant margins of 30-60%. Some automakers have certified MY 2027 vehicles to Bin 25 without any additional technology. EPA should include this compliance option in its cost analysis and share the results for comment prior to finalizing this proposal.

Besides upgrades to catalyst and substrate technologies that comprise a three-way catalytic converter, OEMs can reduce their NMOG+NO<sub>x</sub> emissions through improved calibration, thermal management and aftertreatment architecture design and canning. These are often considered during typical vehicle refresh and redesign cycles when many other elements of the vehicle, including comfort and performance attributes, are enhanced. Because the OEM spends engineering resources to improve many aspects of a vehicle during a typical refresh or redesign cycle, the cost of reducing emissions by the 20% needed to move from Bin 30 to Bin 25 would not be additive but rather included in the already scheduled vehicle refresh/redesign. EPA should model this typical business practice in its cost analysis and share this analysis for comment prior to finalizing this proposal.

In addition, many of the automakers have significant credit balances that could be used for MY 2027 and MY 2028 vehicles, which again would require no additional technology on vehicles for compliance with the NMOG+NO<sub>x</sub> fleet average. Environment and Climate Change Canada releases an annual report<sup>17</sup> that provides the progress towards meeting the NMOG+NO<sub>x</sub> fleet average for each automaker, including current credit balances. As noted in this report, the sales fleet of vehicles in Canada is representative of vehicles sold in the U.S. Furthermore, EPA has access to each automaker's progress towards the NMOG+NO<sub>x</sub> fleet average as well as their credit balances. This information should be considered in the cost analysis for achieving the MY 2027 and MY 2028 Tier 4 standards, and EPA should share this for comment prior to finalizing this proposal.

#### **Tier 4 MY 2027 and 2028 Criteria Pollutant Standards are Achievable Regardless of BEV Sales (C-9)**

MECA supports feasible criteria pollutant standards that provide continued progress for technological innovation. We have previously commented that we understand the Agency's position that MY 2027 and later GHG standards for both light- and medium-duty vehicles would require ambitious levels of EV sales. We have previously commented that these would be challenging for engine and vehicle OEMs given the current level of consumer demand for EVs, which has dropped to less than 6%<sup>18</sup> for light-duty vehicles. At the same time, hybrid vehicle sales have surged from 2% in 2020 to 13% of all light-duty sales in 2025. The lack of demand for EVs can be attributed, in part, to higher EV purchase costs compared to ICE and hybrid vehicles of the same class and the

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<sup>17</sup> <https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/publications/air-pollutant-performance-model-year-2024.html>

<sup>18</sup> <https://www.eia.gov/todayinenergy/detail.php?id=67144>

lack of robust charging infrastructure. These sales trends should have no impact on the ability of OEMs to comply with the vehicle emission standards set to phase in next year. The record supports that the criteria pollutant standards in model year 2027 and 2028 are achievable without relying on EVs, and those model years have already been designed and sourced. Furthermore, vehicles that weigh over 6000 lbs., potentially representing some of the more challenging applications, are not required to comply until 2030. Therefore, we believe that there is no need to delay implementation of the 2027-2028 requirements, and we urge EPA to continue to leave these standards in place as it reviews the latest information for the Step 2 Tier 4 proposal.

### **Fleet Averaging and the Addition of New Tier 4 Bins Provide Certification Flexibility to Automakers (C-2, C-3)**

The EPA requested comment (C-3) on “the use of the ABT program for NMOG+NOX emissions in MYs 2027 and 2028...” MECA supports continuation of fleet averaging for NMOG+NOx standards, including the ABT program. Fleet averaging has been used for NOx since Tier 2 began phasing in with MY 2004 and NMOG+NOx since Tier 3 began phasing in with MY 2017. This program combined with ABT provides automakers with compliance flexibility and has been supported by the auto industry for over 20 years. Averaging allows vehicles that emit less than their targets to offset those that emit more. MECA encourages EPA to retain a fleet average compliance method for NMOG+NOx rather than single vehicle standards. The fleet averaging system provides a less expensive and easier way for an automaker to comply with its fleet-average standard by reducing more emissions from cleaner vehicles or those undergoing engine redesign and delaying more challenging models to when they are scheduled for an engine refresh or new model introduction. ABT has existed as a compliance method since the 1980s and has been popular because it allows automakers to reduce emissions where and when it is most cost effective.

The Agency has also requested comment (C-2) on “if the Agency should add to the Tier 3 program the additional NMOG+NOx Bins in Tier 4 program for MYs 2027 and 2028.” EPA added that “doing so could provide additional flexibility to vehicle manufacturers for demonstrating compliance with the NMOG+NOx fleet average standard. First and foremost, MECA supports retention of the MY 2027-2028 Tier 4 standards with no delay. We acknowledge that the addition of Bins in Tier 4 does provide further flexibility to OEMs.

For MY 2027, MECA supports new Tier 4 federal certification bin options because these provide added flexibility for OEMs to review current vehicle model margins to each bin and more nimbly average their sales fleets to achieve fleet average NMOG+NOx standards. As noted in the discussion of costs above, we believe several vehicle models certified with high margin to current bins can be immediately certified to the next lower Tier 4 bin without any change in technology.

## CONCLUSION

MECA urges EPA not to delay implementation of the Tier 4 MY 2027-2028 criteria pollutant standards beginning as finalized in 2024. The existing phase-in schedule already provides substantial compliance flexibility, while the record demonstrates that both the PM and NMOG+NO<sub>x</sub> standards are technologically feasible using commercially available, globally deployed emission control technologies.

Suppliers have made significant investments in research, engineering, tooling, manufacturing capacity, and supply chain preparation in reliance on the finalized Tier 4 standards. Reversing course at this stage would strand billions of dollars of investment, reduce revenue for U.S. clean mobility manufacturers, and threaten tens of thousands of high-skilled American jobs. Regulatory stability is essential for continued innovation, domestic manufacturing investment, and maintaining U.S. leadership in advanced emission control technologies. The adverse economic impacts of the Step 1 proposal to delay the standards would not achieve manufacturer flexibility, increase vehicle choice nor reduce the cost of vehicles to consumers because the vehicles for MY's 2027 and 2028 have already been designed and sourced and 2027 is beginning production.

The evidence presented in these comments shows that the MY 2027 and 2028 PM standards can be achieved through the deployment of GPFs and advanced fuel injection systems that are already widely used in Europe, China, and India and are increasingly being deployed on vehicles certified for sale in the United States. Similarly, the MY 2027-2028 NMOG+NO<sub>x</sub> fleet average standards can be met through an evolution of existing engine calibration, thermal management, catalyst, substrate, and hybrid technologies without relying on increased electric vehicle sales.

MECA also supports continuation of the fleet averaging and ABT program, as well as retention of the new Tier 4 certification bin structure, because these provisions provide automakers with important compliance flexibility while preserving the environmental benefits of the program.

For these reasons, MECA respectfully requests that EPA finalize this rule without delaying the Tier 4 criteria pollutant standards for MY 2027 and 2028 and continue implementing the technology-neutral, performance-based framework adopted in 2024. Doing so will deliver meaningful reductions in NO<sub>x</sub>, VOC, and PM emissions, improve public health, support American manufacturing and innovation, and provide the regulatory certainty necessary for continued investment in clean mobility technologies.

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## Appendix

As discussed in the body of our comments, there are hundreds of Tier 3 vehicles that benefit from a variety of technology pathways to certify at 30 mg/mile. MECA examined the technologies on the over 80 vehicle models that emit less than 10 mg/mile and could certify to BIN20 and reduce the fleet average emissions for meeting MY2027 (25 mg/mile) and 2028 (23 mg/mile) limits. Below is a non-exhaustive list of the technologies deployed on the cleanest light and medium duty passenger cars and truck. The built-in phase-in schedule would allow OEMs to bring in these technologies into the remainder of the fleet during the regular powertrain redesign cycle.

### Strategies to Meet Tier 4 Criteria Pollutant Standards

#### *Engine Mapping and Calibration*

One of the most cost-effective strategies to optimize tailpipe emissions is engine calibration. OEMs work with their emission control technology suppliers to calibrate the engine for the best operation that takes advantage of the catalyst and filter designed for the engine. MECA members work with the OEM calibration engineers to design aftertreatment systems for each engine family. This can be a time-consuming process that if not needed to meet lower fleet average targets, is often short cut or overlooked. This explains why similar vehicle types made by different manufacturers can have vastly different certification levels, by a factor of two or three.

To comply with lower NMOG+NO<sub>x</sub> and PM emissions standards over certification cycles such as the FTP, US06, SC03, and LA92, manufacturers will employ improved engine maps and calibration strategies of existing engines and emission control related systems. Other design changes to system architecture, such as placement or insulation can be used to manage engine-out emissions and exhaust flows, reduce catalyst light-off times, increase exhaust temperatures during periods of low-load or idle and reduce hot running temperatures to protect engine and emission control components.

#### *Advanced Ceramic Honeycomb Substrates*

Several emission control choices can be made to improve and optimize emission control performance. For gasoline engines, the technology base of advanced three-way catalysts deposited on high cell density (as high as 1200 cells/in<sup>2</sup>), thin-walled substrates (approaching 0.05mm) have evolved dramatically for light- and medium-duty chassis certified vehicles to comply with Tier 3/LEV 3 standards. Recent advances have yielded high porosity, low thermal mass substrates with narrow pore size distributions, which

enable high emission reduction efficiency with less precious metal loading<sup>19,20</sup>. Catalyst manufacturers have optimized catalyst coating techniques based on layered or zoned architectures to strategically deposit precious metals on these substrates in ways that optimize their performance and cost. These advanced catalysts are then packaged using specially designed matting materials and passive thermal management strategies which can be used to meet lowest Bin emissions.

In support of the Tier 3 light-duty regulation<sup>21</sup>, EPA tested a 2011 LDT4 pick-up truck with a 5.3L V8 engine that included a MECA supplied aftertreatment system. The aftertreatment package consisted of advanced catalyst coating on 900 cpsi substrates in the close-coupled location as well as underfloor catalysts and was aged to 150,000 miles. The system was combined with cylinder deactivation and achieved an FTP NMHC+NOx level of 18 mg/mile. A 2026 MY version of that same pick-up truck is reporting certification levels of 12 mg/mile deploying only 750 cpsi substrates and is a testament to the innovation at suppliers and OEMs to meet standards without increasing costs.

### *Gasoline Particulate Filter Technologies to Meet Tier 4 PM Standards*

Gasoline particulate filters (GPFs) are exhaust aftertreatment devices designed to reduce fine particulate matter emitted by gasoline engines, particularly those using gasoline direct injection (GDI). Like their diesel counterparts (DPFs), GPFs employ a ceramic wall-flow honeycomb structure—typically made of cordierite—forcing exhaust gases through porous channel walls where particles are trapped and stored. These systems are optimized to capture very small particles (PM<sub>2.5</sub> and below), which are prevalent in the exhaust of gasoline-fueled engines and in particular, engines utilizing direct fuel injection (GDI) exhaust due to incomplete fuel atomization and combustion.

In real-world operation, modern GPF-equipped vehicles demonstrate very high control of particulate emissions, often reducing PM to well below regulatory limits across a wide range of driving conditions. Filtration efficiencies exceeding 90–95% are typical, and efficiency can even increase over time as an ash layer develops in the filter. For gasoline engines, GPFs typically operate under passive regeneration due to their characteristically higher exhaust temperatures compared to diesel engines with only very occasional active measures initiated via engine control when necessary.

The current state of the art in GPF technology focuses on improving filtration efficiency, durability, and system integration while minimizing backpressure and fuel consumption penalties. Advanced designs incorporate higher-porosity ceramic substrates,

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<sup>19</sup> T. Asako, D. Saito, T. Hirao and E. Popp, "Achieving SULEV30 Regulation Requirement with Three-Way Catalyst on High-Porosity Substrate while Reducing Platinum Group Metal Loading (SAE 2022-01-0543)," in SAE WCX, Detroit, MI, 2022.

<sup>20</sup> J. Warkins, T. Tao, M. Shen and S. Lyu, "Application of Low-Mass Corning FLORA Substrates for Cold-Start Emissions Reduction to Meet Upcoming LEV III SULEV30 Regulation Requirement (SAE 2020-01-0652)," in SAE WCX, Detroit, MI, 2020.

<sup>21</sup> U.S. EPA, "EPA," March 2013. [Online]. Available: <https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-and-related-materials-control-air-pollution>.

optimized microstructures, and catalyzed coatings that combine particulate filtration with additional emissions control functions. Emerging “next-generation” filters use hierarchical pore architectures and proprietary processing methods to capture smaller particles (down to ~10 nm) while maintaining low pressure drop, being driven by future regulations such as Euro 7<sup>22,23</sup>. Overall GPFs are now considered a mature and essential technology for meeting current and near-term gasoline particulate emissions standards.

### *Advanced Fuel Injection Systems for Particulate Control*

Turbocharging is a key enabler for the implementation of higher-pressure fuel injection systems employing direct fuel injection (DFI). Combinations of DFI and port fuel injection (PFI) also support higher compression ratios providing improved efficiency, engine power and reduced emissions under both warm and cold ambient conditions. The combination of DFI and PFI offers optimized fueling under the full range of engine operation.

In North America, most fuel injection systems still operate under 200 or 250 bar pressures with a transition to 350 bar underway. However, in Asian and European markets 500 bar direct injection systems are receiving growing interest from OEMs. The implementation of 500 bar direct fuel injection has been found to reduce particulate matter (PM) and particle number (PN) levels being driven by tighter Euro 7 PN standards. In the US market, the availability of 500 bar DFI systems offers another technology pathway for meeting the 0.5 g/mile PM standard with minimal incremental costs to account for improved materials of construction<sup>24</sup>

### *Evolution in Exhaust Architectures*

Close-coupled catalyst exhaust architectures (with or without a secondary underfloor converter) have been used on light-duty vehicles starting with Tier 2 LDV standards and are an effective strategy for reducing catalyst light-off times during cold-start or low-load operation. Early close-coupled architecture, still being used on many vehicles today, consisted of a first converter just outside the engine compartment in the firewall position. Larger displacement engines would use a second converter in the underfloor position to capture the last remaining pollutants that may have slipped by the close-coupled converters. MECA’s survey of architectures on the cleanest Bin 30 and all Bin 20 certified vehicles shows some clear changes in how OEMs manage the catalyst temperature for cold start that encompasses over 80% of the cycle emissions. The cleanest vehicles being sold today find the first converter positioned inside the engine compartment and mounted on the side of the engine block to transfer engine heat to the light-off catalyst. This is often mounted directly to the turbo exit on boosted engines. On larger

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<sup>22</sup> <https://www.corning.com/worldwide/en/products/environmental-technologies/products/ceramic-particulate-filters/corning-dura-trap-gc-filters.html>

<sup>23</sup> <https://saemobilus.sae.org/papers/next-generations-gasoline-particulate-filters-catalyzed-applications-2024-01-2384>

<sup>24</sup> Gomot et al., “500 BAR Gasoline Direct Injection (GDI) System From Development to Serial Production”, Aachen Colloquium – Sustainable Mobility 2024, October 8th, 2024.

engines, the second converter is often positioned just outside the firewall where the close-coupled catalyst used to be in older designs.

### *Cylinder Deactivation and Variable Valve Actuation*

Cylinder deactivation (CDA) is an established technology on light-duty gasoline cars and trucks, with the primary objective of reducing fuel consumption. This technology combines hardware and software computing power to seamlessly, in effect, “shut down” some of an engine’s cylinders, based on the power demand, and keep the effective cylinder load in an efficient portion of the engine map without burning more fuel. Based on decades of experience with CDA on gasoline passenger cars and trucks, CDA is now being adapted for diesel engines. On a diesel engine, CDA is programmed to operate differently than on gasoline engines, with the goal of the diesel engine running hotter in low-load situations by having the pistons that are firing do more work. This programming is particularly important for vehicles that spend a lot of time in creep and idle operation modes. During low-load operation, CDA has resulted in exhaust temperatures increasing by 50°C to 100°C when it is most needed to maintain peak engine efficiency and effective diesel engine exhaust emissions control. In some demonstrations, CDA has been combined with a 48-V mild hybrid motor with launch and sailing capability to extend the range of CDA operation over the engine map, and this may deliver multiplicative fuel savings from these synergistic technologies<sup>25</sup>.

### *Modern Turbochargers*

Modern turbochargers enable engines to be downsized, resulting in fuel savings without sacrificing power and/or performance. Today’s turbochargers have a variety of available design options enabling improved fuel economy by improving thermal management capability, such as: i) state of the art aerodynamics, ii) electrically-actuated wastegates that allow exhaust gases to by-pass the turbocharger to increase the temperature in the aftertreatment, and iii) advanced ball bearings to improve transient boost response. More advanced turbochargers are designed with a variable nozzle that adjusts with exhaust flow to provide more control of intake pressure and optimization of the air-to-fuel ratio for improved performance (e.g., improved torque at lower speeds) and fuel economy. These variable geometry turbochargers (VGT), also known as variable nozzle turbines (VNT) and variable turbine geometry (VTG), also enable fuel efficiency through improved thermal management capability to enhance aftertreatment light-off. Continuous improvement in turbocharger technology is making it possible to run leaner combustion (high air/fuel ratios), which increases efficiency. This improvement allows for very low particulate generation and even lower engine-out NOx.

### *Mild Hybridization (MHEVs) and 48 Volt System Technologies*

48-volt systems can be found on many light-duty vehicle models (primarily from Europe) from Mercedes, Audi, VW, Renault and PSA. In the U.S., Stellantis is offering a 48-

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<sup>25</sup> [https://www.meca.org/wp-content/uploads/resources/MECA\\_2027\\_Low\\_NOx\\_White\\_Paper\\_FINAL.pdf](https://www.meca.org/wp-content/uploads/resources/MECA_2027_Low_NOx_White_Paper_FINAL.pdf)

volt system on the RAM 1500 pick-up and the Jeep Wrangler under the eTorque™ trademark. 48-volt mild hybrid electrical systems and components are making their way onto an increasing number of vehicles including commercial diesel vehicles as they reduce starter size and wire gauge requirements, offering cost and weight savings which increase with increasing vehicle size.

Like the passenger car fleet, OEMs are considering replacing traditionally mechanically-driven components with electric versions to gain efficiency on an increasing range of light- and medium-duty vehicles. Running accessories off 48-volt electricity rather than 12-volts is more efficient due to reduced electrical losses and because components that draw more power, such as pumps and fans, have increased efficiency when operating at higher voltages. The types of components that may be electrified include electric turbos, electronic EGR pumps, AC compressors, electrically heated catalysts, electric cooling fans, oil pumps and coolant pumps, among others.

Mild hybridization covers a range of configurations, but a promising one includes an electric motor/generator, regenerative braking, electric boost and advanced batteries. In this way, 48-volt mild hybridization is complementary technology to cylinder deactivation and start-stop capability, allowing the combination of multiple technologies on a vehicle to yield synergistic benefits.

In lighter medium-duty applications, advanced start-stop systems have been developed that use an induction motor in a 48-volt belt-driven starter-generator (BSG). When the engine is running it acts as a generator charging a separate battery. When the engine needs to be started, the motor then applies its torque via the accessory belt and cranks the engine instead of using the starter motor. The separate battery can also be recharged via a regenerative braking system. In addition to the start-stop function, a BSG system can enhance fuel economy even during highway driving by cutting off the fuel supply when cruising or decelerating. Such systems can also be designed to deliver a short power boost to the drivetrain. This boost is typically 10 to 20 kW and is limited by the capacity of the 48-V battery and accessory belt linking the motor to the crankshaft. New designs are linking the BSG directly to the crankshaft and allowing additional power boost of up to 30 kW to be delivered, giving greater benefits to light and medium commercial vehicles<sup>26</sup>.

#### *Full / Strong Hybridization (HEVs)*

A full hybrid can enable electrification of many of the components described above for mild hybrid vehicles, but the higher voltages allow for more parts to be electrified and to a higher degree of efficiency. Full hybrids which implement larger electric motors and batteries also support greater acceleration capability, regenerative braking power recovery and fully electric operation over short distances. Full hybrid vehicles offer the

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<sup>26</sup> [https://www.meca.org/wp-content/uploads/resources/MECA\\_2027\\_Low\\_NOx\\_White\\_Paper\\_FINAL.pdf](https://www.meca.org/wp-content/uploads/resources/MECA_2027_Low_NOx_White_Paper_FINAL.pdf)

greatest benefit over urban driving conditions where they can take advantage of efficiency gains due to variable lower vehicle speeds and regenerative braking<sup>27</sup>.

The Honda Insight and Toyota Prius were the first full hybrid vehicles offered for sale in the U.S. in MY1999 and MY2000 respectively. After 25 years, full hybrids are now a common product offering on small and larger light-duty cars, crossovers, SUVs and pick-ups from manufacturers such as Toyota, Honda, Ford, Hyundai, Kia, Mazda and Subaru. In 2025, full hybrid vehicle sales industry wide represented 16% of all new U.S. vehicle sales with Toyota sales approaching 50%<sup>28</sup>. With respect to pick-ups, the hybrid versions of the Toyota Tacoma, Tundra, Ford F150 and Maverick represented 11.1%, 20.7%, 10.8% and 52% of sales respectively<sup>29,30</sup>.

Full hybrids (commonly parallel hybrids) offer several opportunities to reduce NMOG+NOx as well as PM emissions as described by Toyota engineers<sup>31</sup>. During engine start, the high voltage electric motor allows the engine to be spun up to target speed, with valve actuation pumping air within the cylinder to generate heat. This can be followed by the start of ignition followed finally by the injection of fuel to initiate combustion. Such a motored engine start reduces NMOG+NOx and PM emissions. Upon cold-start, parallel hybrids can employ a rapid heat-up strategy, operating in a lower emissions generator mode, where the engine is decoupled from the transient drive cycle. During this warm-up period, aggressive cold-start strategies such as aggressive use of Atkinson cycle combustion, retarded ignition, richer air-fuel ratio, exhaust throttling or secondary air injection can be used for active thermal management. Transient operation is blended in as catalyst light-off temperature is attained. Once the catalyst and coolant reach target operating temperatures and battery state of charge is replenished, engine control can transition to normal hybrid cycling. In addition, due to the presence of an existing high voltage system architecture, hybrids are well-suited to the addition of electric heating elements to further reduce the time to catalyst light-off. In addition, hybrids can employ advanced predictive model-based control of engine-electric motor coordination to reduce the magnitude of engine transient operation, engine-only operation and maximize electric only drive operation. By employing such techniques, Toyota engineers were able to demonstrate FTP NMOG+NOx emissions of 3 mg/mile.

### *Advanced Extended Range Electric Vehicles (EREVs)*

With respect to passenger and larger “non-passenger vehicles”, there is renewed interest in serial hybrid technologies with no engine-to-wheel connection – a hybrid powertrain more commonly known as extended range electric vehicles (EREVs). Of special note, the 2027 Nissan Rogue will offer an EREV variant<sup>32</sup> (known as e-Power™) and EREV

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<sup>27</sup> CARB, "Draft Technology Assessment: Heavy-Duty Hybrid Vehicles," 2015.

<sup>28</sup> <https://www.nada.org/nada/market-beat>.

<sup>29</sup> <https://www.fromtheroad.ford.com/us/en/articles/2026/ford-2025-full-year-us-sales-results>

<sup>30</sup> <https://s3.amazonaws.com/toyota-cms-media/toyota-pdfs/US%20December%202025%20FINAL.pdf>

<sup>31</sup> SAE 2019-01-2217, "ICE Vehicle Challenge Toward Zero Emissions: Future Technology Harmonization in Electrified Powertrain System".

<sup>32</sup> <https://www.caranddriver.com/news/a69635288/2027-nissan-rogue-e-power-hybrid-preview/>

technologies are anticipated to be utilized on larger passenger as well as light and medium pick-up duty trucks<sup>33,34</sup> where they can offer greater towing capacities.

Integrated hybrid electric drivetrain systems, consisting of a fully qualified transmission, motor and power electronics controller, are now also commercially available for medium-duty vehicles<sup>35</sup>. With the ability to meet high torque requirements, these systems will enable hybridization of a broad range of medium duty vehicles.

### *Plug-in Hybrids (PHEVs)*

Plug-in hybrids (PHEVs) can be practical for light and medium- duty vehicles that do not travel long distances or operate for long periods of time without returning to the owner's home or to a central fleet location for overnight recharging. PHEVs can also provide a usable daily driving range for many owners charging from conventional 110V wall outlets when the vehicles are not in use.

An increasing number of PHEVs now offer all-electric ranges in excess of 40 miles including the BMW X5, Mercedes GLC350e, GLE450e, S580e, and AMG E53, Toyota Prius and RAV4, and Volvo S60 and T60.

It is worth highlighting that both HEVs and PHEVs can deliver significant emission reductions and fuel economy benefits compared to their conventional vehicle counterparts by employing relatively low-capacity batteries.

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<sup>33</sup> <https://www.stellantisfleet.com/news-and-events/stellantis-news/range-extended-ram-1500-ramcharger-to-lead-brands-electrification-push.html>

<sup>34</sup> <https://fordauthority.com/2025/02/ford-lineup-including-super-duty-to-get-erev-variants-report/>

<sup>35</sup> <https://harbingermotors.com/newsroom/harbinger-unveils-first-of-its-kind-plug-in-hybrid-vehicle-for-medium-duty-fleets/>