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What EPA's new multi-pollutant emissions proposal means for PM emissions and GPFs

Vehicle particulate matter (PM) emissions are a major environmental health hazard; more stringent PM emissions limits are critical to protect public health. Under the U.S. Environmental Protection Agency's (EPA) current PM standards, real-world PM emissions *increased* for model years 2015–2020.[1] To reduce these emissions, EPA has proposed new Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. The proposed regulation would go beyond existing standards by setting the PM limit at 0.5 mg/mile on both the Federal Test Procedure (FTP) and US06 test cycles with the addition of the cold temperature FTP test cycle.[2]

EPA's current PM standards are 3 mg/mi for the FTP test cycle and 6 mg/mi for the US06 test cycle.[3] On a mass basis, these standards are comparable to current particle mass limits in the European Union (EU) and in China.[4] However, the U.S. lacks the particle number limit present in the standards for both the EU and China. The combination of particle mass and number limits in the EU and China effectively regulates both fine and ultrafine particulates.[5] Due to these tighter PM limits, gasoline particulate filters (GPFs) have become increasingly widespread among new vehicles in Europe and China.[6] In the U.S., new vehicles can meet EPA's particle mass standards on average without GPFs.[7] In fact, average certification PM emissions data, recent EPA testing described in its proposed rule, and the small size of gasoline particulates from

1 Michelle Meyer, Tanzila Khan, Tim Dallmann, and Zifei Yang, *Particulate Matter Emissions from U.S. Gasoline Light-Duty Vehicles and Trucks: TRUE Initiative U.S. Remote Sensing Database Case Study.* (Washington, D.C.: International Council on Clean Transportation, 2023), https://theicct.org/publication/true-pm-emissions-jun23/.

2 "Proposed Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles," U.S. Environmental Protection Agency, 2023, https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-multi-pollutant-emissions-standards-model.

3 "US: Light-Duty: Emissions," TransportPolicy.net, 2023, https://www.transportpolicy.net/standard/us-light-duty-emissions/

4 "EU: Light-Duty: Emissions," TransportPolicy.net, 2023, https://www.transportpolicy.net/standard/eu-light-duty-emissions/; "China: Light-Duty: Emissions," TransportPolicy.net, 2023, https://www.transportpolicy.net/standard/china-light-duty-emissions/.

5 Meyer, Khan, Dallmann, and Yang, *Particulate Matter Emissions from U.S. Gasoline Light-Duty Vehicles and Trucks*.

6 "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles: Draft Regulatory Impact Analysis," U.S. Environmental Protection Agency, 2023, https://www.epa.gov/system/files/documents/2023-04/420d23003.pdf.

7 Meyer, Khan, Dallmann, and Yang, *Particulate Matter Emissions from U.S. Gasoline Light-Duty Vehicles and Trucks*.

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direct injection engines suggest that even the proposed PM limit of 0.5 mg/mi may be met without GPFs. However, due to the requirement of meeting the standard over the cold temperature FTP test (-7°C/20°F), GPFs are likely to be the most cost-effective solution to meet the proposed standard, catching the U.S. up with Europe and China.

The ICCT updated its analysis of the cost of GPFs based on a review of the most recent literature and conversations with MECA.[8] We find that long-term GPF costs in 2023 are similar to the ICCT's GPF cost estimate from more than a decade ago, due to counterbalancing effects of manufacturer learning and inflation.[9] Table 1 compares the long-term direct cost estimates from 2011 (adjusted to 2023 dollars), today's update, and EPA's proposal (adjusted to 2023 dollars). Since the table shows costs of stand-alone GPFs, these costs are incremental to existing aftertreatment systems.

Table 1. Comparison of long-term direct manufacturing cost estimates for stand-alone, bare/uncoated gasoline particulate filters.

Source	Original Dollar Basis (2023 inflator)	Engine Displacement, Liters			Swept Volume Ratio
		1.5	3.0	7.0	
ICCT, 2011	2010 (1.41)	$80	$114	$203	0.55
EPA Proposal	2021 (1.12)	$68	$92	$155	0.55
ICCT, 2023	2023 (1.00)	$87	$135	$261	1.2

Table 1 compares the cost estimates for "bare" or "uncoated" GPFs. This type of filter is used by EPA to estimate GPF costs. The primary difference between EPA's cost estimate and the ICCT's current estimate is the use of higher swept volume ratio (SVR) (the ratio of the volume of the filter to the engine displacement). Current bare filter SVRs are typically between 1.0–1.4.

Most European and Chinese GPF implementations in 2023 are stand-alone and used for filtration purposes only. However, some applications use a catalyzed, or coated, GPF, that replaces all or a portion of a three-way catalyst (TWC) brick. Due to these two configurations, the ICCT updated the detailed cost breakdown of both bare and coated GPFs. Table 2 and Table 3 provide the incremental cost of GPFs over unfiltered TWCs. For bare GPFs, the incremental cost is the entire cost of adding a GPF. For coated GPFs, incremental costs are slightly lower than the full cost of the GPF, as a portion of the TWC is removed and replaced with the catalyzed GPF. Comparing the two tables, the coated GPF shows slightly lower costs than the bare GPF (due to the deletion of some TWC costs).[10] Overall, today's direct costs range between about $95–$325. At this level of cost, the GPF represents 1% or less of the price paid by consumers. Future learned direct costs are expected to be about $75–$260.[11]

8 MECA Clean Mobility, 2021, https://www.meca.org/.

9 Ray Minjares and Francisco Posada Sanchez, *Estimated Cost of Gasoline Particulate Filters*. (Washington, D.C.: International Council on Clean Transportation, 2011), https://theicct.org/publication/estimated-cost-of-gasoline-particulate-filters/.

10 Athanasios Mamakos et al., "Cost Effectiveness of Particulate Filter Installation on Direct Injection Gasoline Vehicles," *Atmospheric Environment* 77 (2013): 16–23, https://doi.org/10.1016/j.atmosenv.2013.04.063.

11 *Learning* refers to the reduction in cost over time due to increased production volume and manufacturer innovations. Manufacturers can reduce costs through raw material savings, manufacturing optimization, improving product performance, and even volume pricing. In this analysis, a learning rate of 20% is used, consistent with prior analyses by both EPA and the ICCT.

Table 2. Cost breakdown of a bare stand-alone GPF incremental to TWC (2023 dollars).

Engine Displacement, Liters	1.5	3.0	7.0
GPF volume, "CV" (SVR=1.2), Liters	1.80	3.60	8.40
Substrate - Wall flow, cordierite – ($21*CV)	$38	$76	$176
Filter can housing ($11*CV)	$20	$40	$92
Accessories & mounting hardware	$10	$10	$10
Differential pressure sensor	$28	$28	$28
Total hardware cost	$96	$153	$307
Labor & machinery cost w/ overhead	$10	$10	$10
Warranty costs (3% claim rate)	$3	$5	$10
Total incremental direct manufacturing cost	$109	$168	$326
Long-term production volume discounted cost (-20%)	$87	$135	$261

The cost of a bare GPF has been updated with an average SVR of 1.2 (as confirmed by MECA), substrate cost of $21/L (information provided by substrate suppliers to EPA), and recent filter housing average cost of $11/L (MECA range $9–$13/L). Accessories and sensor costs were confirmed to be unchanged from the prior analysis. Labor and machinery costs are taken from the prior analysis, updated to 2023 dollars. A warranty claim rate of 3%—also used by EPA—is taken from the prior analysis. In keeping with general industry trends, we apply a 20% discount to estimate long-term, learned direct costs (as in the prior analysis).

Table 3. Cost breakdown of TWC-integrated, coated GPF incremental to TWC (2023 dollars).

Engine Displacement, Liters	1.5	3.0	7.0
GPF volume, "CV" (SVR=0.8), Liters	1.20	2.40	5.60
Pd, 0.14 g/liter x CV x $50/g (incremental)	$8	$17	$39
Rh, 0.01 g/liter x CV x $132/g (incremental)	$2	$4	$9
Total incremental PGM cost	$10	$20	$47
Substrate - Wall flow, cordierite – ($14*CV) (incremental)	$17	$34	$78
Washcoat ($9*CV)	$11	$22	$50
Total incremental PGMs + substrate+ washcoat cost	$38	$76	$176
Filter can Housing ($5*CV) (incremental)	$6	$12	$28
Accessories	$10	$10	$10
Differential pressure sensor	$28	$28	$28
Total incremental hardware cost	$82	$126	$242
Labor & machinery cost w/ overhead	$10	$10	$10
Warranty costs (3% claim rate)	$3	$4	$8
Total incremental direct manufacturing cost	$94	$140	$260
Long-term production volume discounted cost (-20%)	$76	$112	$208

The incremental cost of a catalyzed GPF replacing a TWC includes an approximately 20% increase in PGM loading relative to the outgoing TWC. This incremental cost is shown in Table 3, identified by the parenthetical "incremental." The relative fractions of palladium and rhodium are assumed to be the same as that of the outgoing TWC, and are taken from EPA's assumed catalyst loading for TWC in its proposal.[12] One-year average PGM prices are from Johnson Matthey.[13] The cost for the GPF substrate and housing average, respectively, $14/L and $5/L more than that for the replaced TWC. Overhead, warranty, and long-term costs are calculated in the same manner as the bare GPF.

This fact sheet finds that GPF incremental direct costs represent less than 1% of vehicle price. In contrast to these findings, the Alliance for Automotive Innovation and several automakers claim that the direct and indirect costs of widespread GPF implementation at the pace proposed by EPA are unreasonable.[14] Because of their low cost and widespread implementation in Europe and China, it is unlikely that applying GPFs to U.S. vehicles in 2027 at the earliest will incur substantial additional costs. By EPA's own modeling of the market impacts of the proposal, virtually no gasoline-fueled light-duty vehicles will need GPFs in 2027 to comply with the proposed standard. By 2028, around three-fifths of gasoline *cars* and no gasoline *trucks* will need GPFs to comply. Only by 2030 will all new gasoline light-duty vehicles need GPFs to comply with the proposed PM standard.[15] Thus, automakers have 7 years before all their new U.S. gasoline vehicles may need GPFs, which is more than 15 years of experience implementing GPFs since the first implementation of Euro 6 in September 2014.

Cold testing and low PM mass measurements are also unlikely to cause substantial automaker expense, while providing assurance that emissions are controlled under the most challenging conditions. Automakers already perform cold tests for carbon monoxide and non-methane hydrocarbons, and cold PM testing means collecting particulates at the same time. In its proposal, EPA demonstrated the feasibility and reliability of sub-0.5 mg PM measurement and continues to conduct confirmatory testing. Lastly, costs associated with research and development, engineering and calibration, re-tooling and testing, are generally spread across hundreds of thousands or millions of vehicles. Prior ICCT work evaluating previous U.S. pollutant standards found these costs amount to around 10% or less of total costs.[16]

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12 See table 2-28 in "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles: Draft Regulatory Impact Analysis," U.S. Environmental Protection Agency.

13 "PGM management," Johnson Matthey, 2023, https://matthey.com/products-and-markets/pgms-and-circularity/pgm-management/.

14 Comment submitted by the Alliance for Automotive Innovation (Comment ID: EPA-HQ-OAR-2022-0829-0466) on the proposed "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles," U.S. Environmental Protection Agency, 2023, https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0829-0466.

15 The proposed PM standard is based on Gross Vehicle Weight Rating (GVWR). Its phase-in requires that 40% of vehicles with GVWR under 6,000 lbs (i.e., most sedans, crossovers, and many SUVs) meet the standard in 2027, 80% in 2028, and 100% in 2029. Light duty vehicles over 6,000 lbs GVWR (i.e., most pickups and some SUVs) do not need to meet the standard until 2030, at which point 100% of the fleet must be compliant. (See the "Default compliance scenario" in Table 39 of the Proposed Rule, "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles," *Federal Register* 88, no. 87 (May 5, 2023): 29184, https://www.govinfo.gov/content/pkg/FR-2023-05-05/pdf/2023-07974.pdf). EPA models the 2027 fleet of sedans, crossovers, and small SUVs to be 41% BEV in 2027, thereby automatically complying with the 40% phase-in target without any need for GPFs. This fleet in 2028 is projected to be 48% BEVs, thus only 32 percentage points of the remaining 52% of the fleet is needed to meet the 80% threshold, which is roughly 61% of these gasoline-fueled vehicles. Annual BEV market shares of each vehicle segment are extracted from the outputs of EPA's OMEGA model; see "Optimization Model for reducing Emissions of Greenhouse Gases from Automobiles (OMEGA)," U.S. Environmental Protection Agency, 2023, https://www.epa.gov/regulations-emissions-vehicles-and-engines/optimization-model-reducing-emissions-greenhouse-gases#omega-2.1.

16 Francisco Posada Sanchez, Anup Bandivadekar, and John German. *Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles*. (Washington, D.C.: International Council on Clean Transportation, 2012), https://theicct.org/publication/estimated-cost-of-emission-reduction-technologies-for-ldvs/.

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