THE REAL URBAN EMISSIONS INITIATIVE

CASE STUDY

OCTOBER 2024

Real-world NO_x emissions from diesel pickup trucks in the United States: A 2023 update

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INTRODUCTION

Emissions from diesel vehicles are a major contributor to harmful air pollution. Tailpipe emissions of nitrogen oxides (NO_x) are associated with adverse health impacts, including asthma and respiratory illnesses, and can lead to premature death.[1] Pickup trucks are one major source of NO_x emissions: In the United States, more than 5 million passenger and light-duty commercial diesel trucks collectively emitted over 140,000 tons of NO_x in 2020.[2]

Although vehicle emissions have substantially declined in recent years due to increasingly stringent emission standards, data from roadside remote sensing of motor vehicles have shown that real-world emissions from diesel vehicles often exceed regulatory limits.[3] This may have several causes. One is deterioration, the increase in emissions as vehicles age and emission control systems become less effective. Other causes are individual vehicle malfunctions, tampering with emission control systems, or the use of an auxiliary emission control device (AECD). The use of an AECD—a design feature that senses temperature, vehicle speed, engine revolutions per minute (RPM), and other factors to alter the operation of or deactivate the emission control system—can lead to emissions that are below the limit during official testing but much higher during real-world driving operation. When disclosed and approved by authorities, AECDs are legal; undisclosed, unapproved AECDs are known as "defeat devices."[4]

TRUE's first analysis of U.S. real-world emissions data, published in 2020, compiled approximately 60 million emission records from more than 100,000 vehicles to offer insights into several vehicle groups, including diesel pickup trucks.[5] The report identified high-emitting vehicle groups and examined trends in emissions by driving and ambient conditions; it found high rates of deterioration and high emissions at low ambient temperatures from certain pickup truck models.

This case study analyzes updated data to explore the real-world NO_x emissions from diesel pickup

1 U.S. Environmental Protection Agency, "Learn About Impacts of Diesel Exhaust and the Diesel Emissions Reduction Act (DERA)," last modified June 26, 2024, https://www.epa.gov/dera/learn-about-impacts-diesel-exhaust-and-diesel-emissions-reduction-act-dera.

2 "2020 National Emissions Inventory (NEI) Data," U.S. Environmental Protection Agency, accessed September 5, 2024, https://awsedap.epa.gov/public/single/?appid=20230c40-026d-494e-903f-3f112761a208&sheet=5d3fdda7-14bc-4284-a9bb-cfd856b9348d&opt=ctxmenu,currsel.

3 A comparison of real-world NO_x emissions with emission limits is not to determine vehicle compliance; instead, authorities can use real-world emissions information to target market surveillance and further investigate compliance. For our prior analysis of the United States, see TRUE Initiative, *Remote Sensing of Heavy-Duty Vehicle Emissions in the United States* (2020), https://www.trueinitiative.org/media/791469/us-hdv-emissions.pdf.

4 Declared AECDs may be permitted to protect against damage, but only if there are no reasonable means using currently available technology to protect the engine. See Rachel Muncrief, John German, and Joe Schultz, *Defeat Devices Under the U.S. and EU Passenger Vehicle Emissions Testing Regulations* (International Council on Clean Transportation, 2016), https://theicct.org/publication/defeat-devices-under-the-u-s-and-eu-passenger-vehicle-emissions-testing-regulations/.

5 Yoann Bernard et al., *Development and Application of a United States Real-World Vehicle Emissions Database* (TRUE Initiative, 2020), https://www.trueinitiative.org/publications/reports/development-and-application-of-a-us-real-world-vehicle-emissions-database.

trucks in the United States. We use remote sensing data collected as recently as 2023 to assess the emissions behavior of the four most popular heavy-duty diesel pickup truck models and how their real-world NO_x emissions compare with emission limits. We also examine trends by driving and ambient conditions to provide additional insight into the real-world performance of the four models. The results indicate that the emissions control system of the measured Ford F-250/F-350s is not effectively controlling real-world NO_x emissions, leading to high excess emissions; the scale of this pattern suggests that further investigation is warranted.[6]

DATA OVERVIEW

We focus on diesel pickup trucks categorized as Class 2b and Class 3 heavy-duty vehicles (HDVs) with 6.4–6.7L engines.[7] This group includes the Ram 2500 and 3500 models, which were the subject of a $1.6 billion settlement between engine manufacturer Cummins and the U.S. Department of Justice and the state of California.[8] The other three most common pickup truck models in the dataset are the Chevrolet Silverado, GMC Sierra, and Ford F-250/F-350. These four models make up over 93% of total Class 2b and Class 3 diesel vehicle remote sensing measurements, with diesel vans accounting for most of the balance. This analysis focuses on trucks of model year (MY) 2010 and later because they are certified to the latest emission standards.

The 2020 TRUE analysis of this group of vehicles included data collected from 2010 to 2018; this analysis uses data collected from 2015 to 2023.[9] The data were collected by the Virginia Department of Environmental Quality and the Colorado Department of Public Health and Environment. Most measurements (92%) are from the Colorado data, which also include the most recent data (up to 2023). The Virginia data contain measurements from 2015 to 2021 and are included in the analysis to expand the geographic coverage and range of ambient measurement conditions examined.

To align this study with previous TRUE analyses, we filtered measurements based on the following criteria:

- Vehicle specific power (VSP) > -5 kW/t[10]
- Speed > 1 mph
- Nitrogen oxide (NO): -6 to 600 g/kg CO_2

After filtering the measurements, the dataset included over 360,000 remote sensing measurements collected in Colorado and Virginia. Table 1 shows the total number of measurements and unique trucks for each of the four truck models. Each model was measured at least 70,000 times, and results for each model are based on measurements of at least 10,000 unique trucks. Although the Ford F-250/F-350 has a higher share of measurements taken in Virginia compared with the other three models, the differences in ambient and driving conditions between the four models are negligible (see Appendix).

6 Excess emissions are defined as emissions during real-world operation above the limits defined in regulatory standards. Some level of excess emissions can be expected due to differences between real-world driving conditions and certification testing conditions; however, high excess emissions may warrant investigation.

7 Class 2b and Class 3 heavy-duty vehicles are vehicles with gross vehicle weight ratings of 8,501–14,000 lb.

8 U.S. Justice Department, "United States and California Announce Diesel Engine Manufacturer Cummins Inc. Agrees to Pay a Record $1.675 Billion Civil Penalty in Vehicle Test Cheating Settlement," press release, January 10, 2024, https://www.justice.gov/opa/pr/united-states-and-california-announce-diesel-engine-manufacturer-cummins-inc-agrees-pay.

9 Data collected prior to 2015 are excluded due to the change in remote sensing instrumentation from the RSD 4600 to the RSD 5000 in 2015. We include only measurements taken with the RSD 5000 for consistency across the two datasets.

10 VSP is a surrogate for engine load that is calculated using speed, acceleration, and road slope. See Yoann Bernard et al., *Determination of Real-World Emissions from Passenger Vehicles Using Remote Sensing Data* (TRUE Initiative, 2018), https://www.trueinitiative.org/publications/reports/determination-of-real-world-emissions-from-passenger-vehicles-using-remote-sensing-data.

Table 1. Summary of remote sensing measurements and unique trucks by model

	Measurements			Unique trucks		
Truck model	Number of measurements	Colorado (%)	Virginia (%)	Number of unique trucks	Colorado (%)	Virginia (%)
Chevrolet Silverado	71,279	93%	7%	10,531	86%	14%
Ford F-250/F-350	111,262	86%	14%	21,090	80%	20%
GMC Sierra	70,488	95%	5%	10,196	91%	9%
Ram 2500/3500	115,760	94%	6%	21,683	90%	10%

We estimated NO_x emissions in this study because the remote sensing data include measurements of NO, not nitrogen dioxide (NO_2) or total NO_x. This was necessary to compare the measured emissions with the regulatory emissions limit, which is set in terms of NO_x. Previous real-world HDV emission studies showed an NO_2/NO_x ratio of 0.19 for trucks of MY 2009 and later.[11] Therefore, we divided the NO measurements by 0.81 to estimate total NO_x.

Several other assumptions were used to compare measured emissions (in g/kg fuel) with emission limits. The trucks of MY 2010–2015 were all certified to the heavy-duty emissions limit, which is in units of grams per brake-horsepower hour. Due to an update of light-duty emission standards, starting with MY 2016, the trucks were certified to the light-duty emissions limit, which is in units of milligrams per mile (see Table 2).[12] To compare the measured emissions with the heavy-duty emissions limit, we assumed 0.15 kg fuel consumed per brake-horsepower hour.[13] For comparison with the light-duty emission standard, we calculated the distance-specific emission factors using average fuel economy by truck model and model year.[14]

TRENDS BY MODEL YEAR

Figure 1 shows the average fuel-specific NO_x emissions by truck model. All models showed trends of declining emissions over time with newer model years. Among all MY 2011 and later trucks, the Chevrolet Silverado and GMC Sierra showed the lowest emissions out of the four models. The Ford F-250/F-350s show the highest emissions for all MY 2013–2019 vehicles. For MY 2017 vehicles, for example, Ford trucks showed over 2 times higher NO_x emissions than Ram trucks and over 4 times higher NO_x emissions than GMC and Chevrolet trucks.

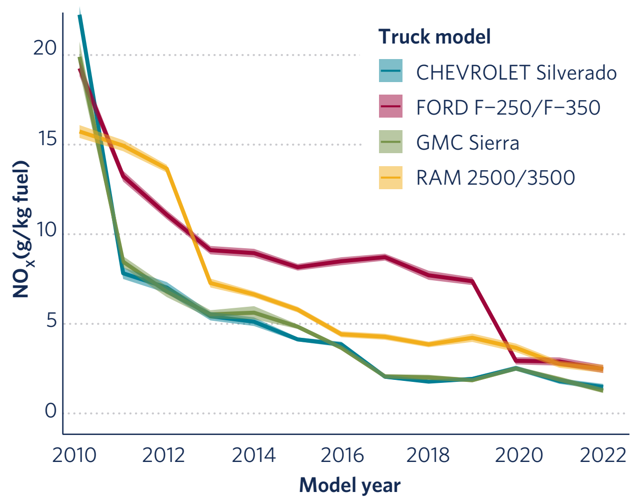

Figure 1. Fuel-specific NO_x emissions trends by vehicle model. The shaded region represents the 95% confidence interval.

COMPARISON WITH EMISSIONS LIMIT

As mentioned above, Class 2b and Class 3 trucks of MY 2010–2022 were certified to various emission standards. Table 2 shows how each model was certified by model year. All MY 2010–2015 vehicles were certified to the HDV emission standard. By MY 2016–2018, depending on the model, the trucks were certified to the Tier 3 light-duty standards.

11 TRUE Initiative, *Remote Sensing of Heavy-duty Vehicle Emissions in the United States.*

12 A provision in the Tier 3 light-duty emission standard, introduced starting with MY 2017 vehicles, allowed Class 2b and Class 3 vehicles to be certified to the light-duty standard.

13 Daniel A. Burgard et al., "Remote Sensing of In-Use Heavy-Duty Diesel Trucks," *Environmental Science & Technology* 40, no. 22 (November 2006): 6938–42, https://doi.org/10.1021/es060989a.

14 "Owner Reported MPG," Consumer Reports, accessed April 1, 2024, https://www.consumerreports.org/cars/.

Table 2. Certification by model and model year

<table>
<tr><th>Model year</th><th>Chevrolet Silverado and GMC Sierra</th><th>Ford F-250/F-350</th><th>Ram 2500/3500</th></tr>
<tr><td>2010</td><td>HDV (transition)</td><td>HDV (transition)</td><td>HDV (2010)</td></tr>
<tr><td>2011-2015</td><td>HDV (2010)</td><td>HDV (2010)</td><td>HDV (2010)</td></tr>
<tr><td>2016</td><td>HDV (2010)</td><td rowspan="4">Tier 3 bin 340 and bin 570 (interim)</td><td>HDV (2010)</td></tr>
<tr><td>2017</td><td rowspan="3">Tier 3 bin 250 and bin 400</td><td>HDV (2010)</td></tr>
<tr><td>2018</td><td>Tier 3 bin 250 and bin 400</td></tr>
<tr><td>2019</td><td>Tier 3 bin 250 and bin 270</td></tr>
<tr><td>2020–2022</td><td>Tier 3 bin 200 and bin 270</td><td>Tier 3 bin 200 and bin 270</td><td>Tier 3 bin 200 and bin 270</td></tr>
</table>

Figure 2 shows the NO_x emission trends by model year for only the vehicles certified to the HDV emission standard and compares them with the emissions limit. Similar to the findings of the 2020 TRUE report, the trucks showed real-world emissions well above the HDV emissions limit, particularly in the first few years after the new standard was introduced.[15] Excluding MY 2010 vehicles, which were certified to the interim standard, the Ford trucks showed emissions 6–10 times higher than the limit.

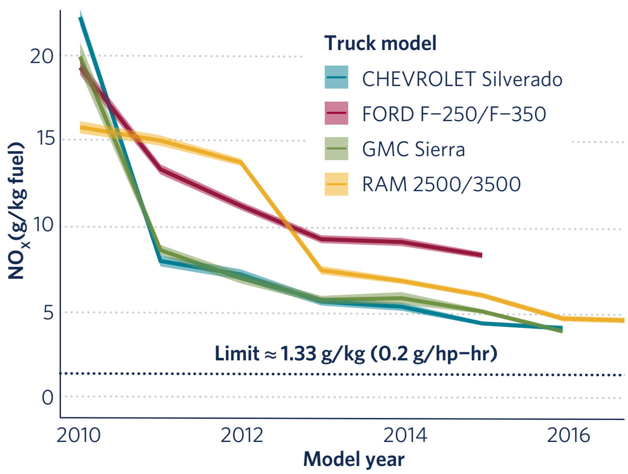

Figure 2. Fuel-specific NO_x emissions trends by vehicle model compared with the heavy-duty emissions limit approximated in grams per kilogram of fuel. The shaded region represents the 95% confidence interval.

Figure 3 displays the distance-specific emissions for trucks certified to the light-duty emission standard compared with the emissions limit. The Tier 3 NO_x emission limit is shown as a range because the limits vary by bin.[16] As in Figure 2, the Ford F-250/F-350s showed emissions well above the limit through MY 2019. While the Chevrolet Silverado and GMC Sierra showed NO_x emissions around the range of the Tier 3 limit, the pre-MY 2020 Ford F-250/F-350 presented emissions 3 or 4 times the upper range of the limit. Indeed, the MY 2018 and 2019 Ford trucks had approximately 2 times higher emissions than the next highest emitter, the Ram 2500/3500. Unlike the other three models, MY 2016–2019 Ford trucks, certified to interim bins, were not required to certify to the Supplemental Federal Test Procedures (SFTP).[17] MY 2020 Ford trucks, which were certified to the SFTP, showed a substantial decrease in emissions that brought them in line with the other three models.

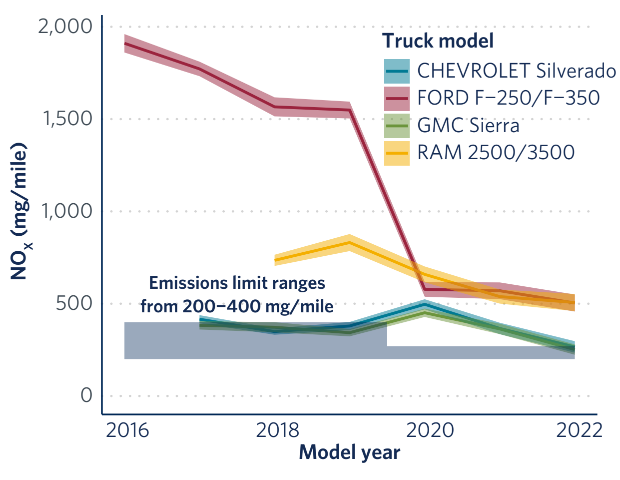

Figure 3. Distance-specific NO_x emissions trends by vehicle model compared with the Tier 3 light-duty emissions Federal Test Procedure limit. The shaded regions around the lines represent the 95% confidence interval and the shaded gray region represents the range of emissions limit.

15 TRUE Initiative, *Remote Sensing of Heavy-duty Vehicle Emissions in the United States.*

16 Most Tier 3 emission limits are defined for total NO_x and non-methane organic gases (NMOG); the exception is the interim NO_x limits to which MY 2016–2019 Ford trucks were certified.

17 "US: Light-Duty: Emissions," TransportPolicy.net, accessed October 2, 2024, https://www.transportpolicy.net/standard/us-light-duty-emissions/.

DETERIORATION TRENDS

The fact that the remote sensing data were collected over an 8-year span allowed for an examination of deterioration, or the increase in emissions as vehicles age. Figure 4 shows the trends of average NO_x emissions over time for each model year from 2010 to 2020. Overall, this figure shows approximately linear increases in NO_x emissions as vehicles age.

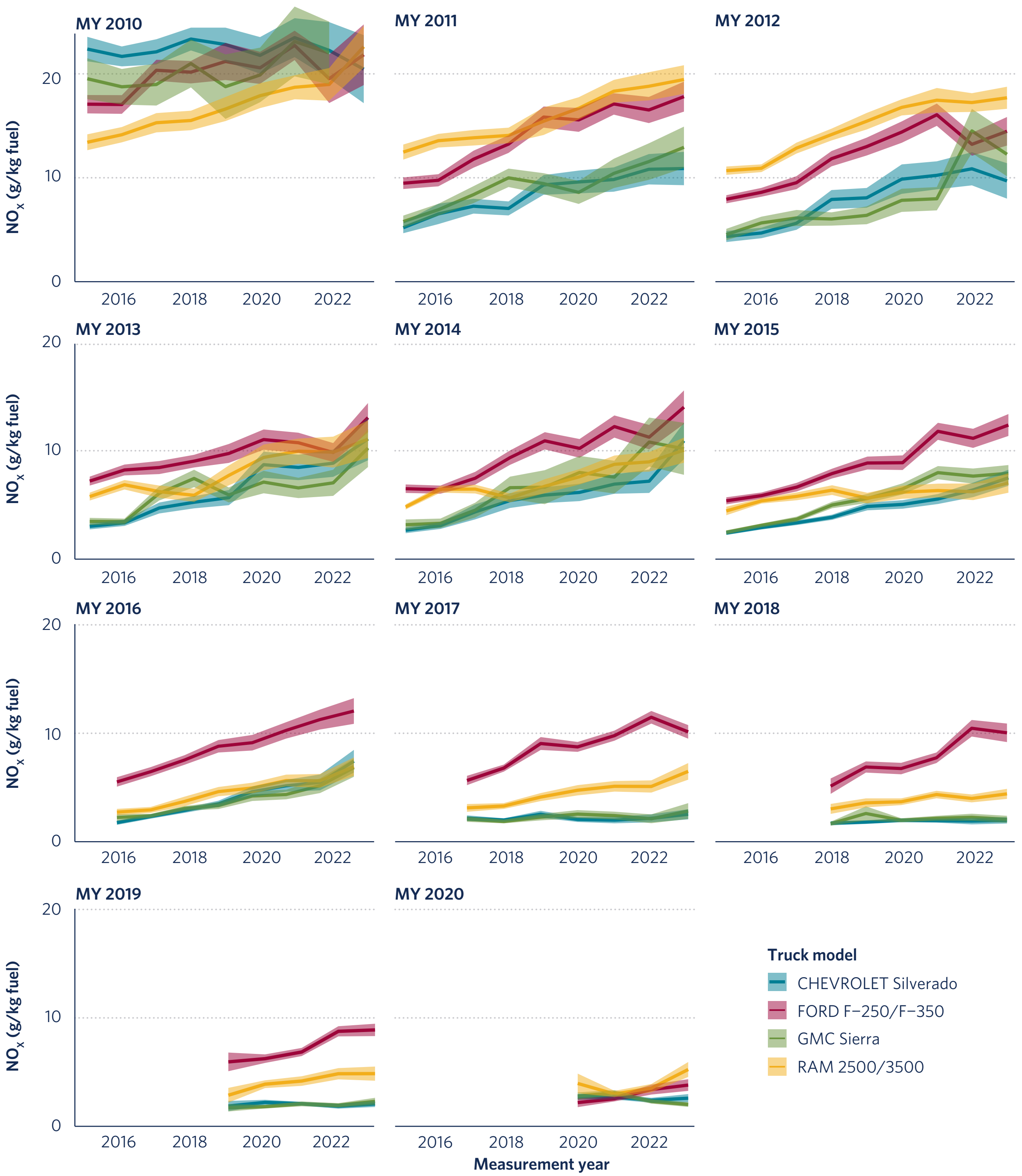

Figure 4. Average fuel-specific NO_x emissions by model year and measurement year. The shaded region represents the 95% confidence interval.

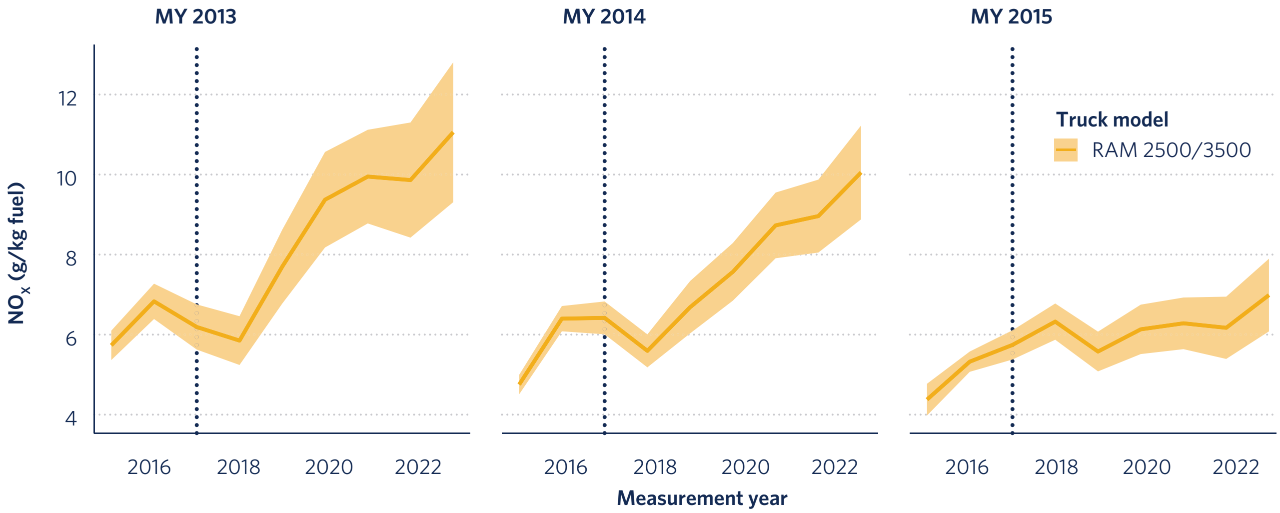

Figure 5. Average fuel-specific NO_x emissions by model year and measurement year to demonstrate the impact of the Ram truck recall. The shaded region represents the 95% confidence interval and the dotted line marks 2017, when recalls began.

While rates of deterioration were relatively similar across all four models for MY 2010–2016, distinct trends were observed for MY 2017–2019. The Chevrolet Silverado and GMC Sierra of MY 2017–2019 showed very small increases in NO_x emissions from their first year of measurement to the most recent year. Indeed, that the 95% confidence intervals for these vehicles overlap for all measurement years means there is no significant increase in NO_x emissions across the 5–7 years of measurement. Design changes implemented in MY 2017, the first year that Chevrolet and GMC trucks were certified to the light-duty standard, could be contributing to reduced deterioration. This differs substantially from the MY 2017–2019 Ford and Ram trucks, which showed significant increases in NO_x emissions over time. The Ram trucks, which use the Cummins engine that was subject to the U.S. Justice Department action, showed approximately 50%–110% increases in NO_x emissions between the first measurement year and the latest, or increases of 1.5–3.5 g/kg.

Even more substantial increases were observed for MY 2017 and 2018 Ford trucks. NO_x emissions approximately doubled from the first year of measurement to the latest, increasing by roughly 5 g/kg. In the latest year of measurement, NO_x emissions from these trucks were over 5 times higher than the light-duty emissions limit. Although this difference between the Ford and Chevrolet/GMC trucks can be partially explained by certifications to different bins under Tier 3 (Table 2), as detailed in the following sections, evidence suggests that other factors may be contributing to high emissions for MY 2017 and 2018 Ford trucks.

Another trend illustrated in Figure 4 is that MY 2016–2019 Ford trucks showed substantially higher emissions than the other three models starting at year zero (the leftmost point on each plot).[18] While this suggests that emission control systems employed by MY 2016–2019 Ford trucks are not effectively controlling real-world emissions even shortly after the time of sale, higher deterioration rates also contribute to elevated emissions.

The deterioration trends also provide insight into the impact of recalls. Starting in 2017, MY 2013–2015 Ram 2500/3500 trucks were recalled due to degradation of the selective catalytic reduction (SCR) system, which controls NO_x emissions.[19] A small but noticeable decrease in emissions between measurement years 2017 and 2018 is observed for MY 2013 and 2014 Ram trucks (Figure 5). For MY 2015 Ram trucks, there is a decrease between measurement years 2018 and 2019. Thus, the recalls were likely successful in reducing real-world NO_x emissions, though the decrease in emissions was not sustained.

18 Ford trucks of these model years are the least fuel-efficient out of the four models, which would lead to an even larger difference in distance-specific emissions.

19 California Air Resources Board, "Truck & Bus Cummins Recall," accessed August 7, 2024, https://ww2.arb.ca.gov/our-work/programs/truckstop-resources/regulation-overviews/truck-bus-cummins-recall.

EMISSIONS BY ENGINE LOAD

Vehicles undergo certification testing that covers a defined range of driving and ambient conditions that is narrower than the full set of conditions experienced in real-world driving. This section explores the real-world emission trends by VSP, a proxy for engine load, and ambient temperature for each of the vehicle models.

Using the updated remote sensing data, we first examine NO_x by VSP in Figure 6, which shows the average NO_x emissions for bins of 5 kW/t for each vehicle model. Both the Ram and Ford trucks showed emissions that were significantly higher at the 95% confidence interval at 20–25 kW/t compared with 15–20 kW/t. This was particularly pronounced for Ford trucks, which showed an increase of approximately 1.5 g/kg (or 15%) at the 20 kW/t threshold. NO_x emissions continued to rise with increasing VSP for the Ford trucks, such that average emissions for the 35–40 kW/t speed bin were nearly 80% higher than emissions at 10–15 kW/t. The Chevrolet and GMC trucks showed some increase in emissions at higher VSPs, but the increase is much smaller than for Ford and Ram trucks.

The maximum VSP in one of the standard light-duty test cycles in the United States, the Federal Test Procedure, is 23 kW/t.[20] The relatively smaller increases in NO_x emissions among Chevrolet and GMC trucks at engine loads above this threshold suggest that technologies exist that do not result in the magnitude of increases observed among the Ford and Ram trucks.

Ram trucks of all model years showed higher emissions at VSPs above 20 kW/t compared with below 20 kW/t, but the gap narrowed with newer vehicles (Figure 7). The Ford, Chevrolet, and GMC trucks showed higher emissions at lower VSPs for MY 2010, likely linked to their certification to the interim HDV standard (Table 2). For MY 2011–2019, Ford trucks showed

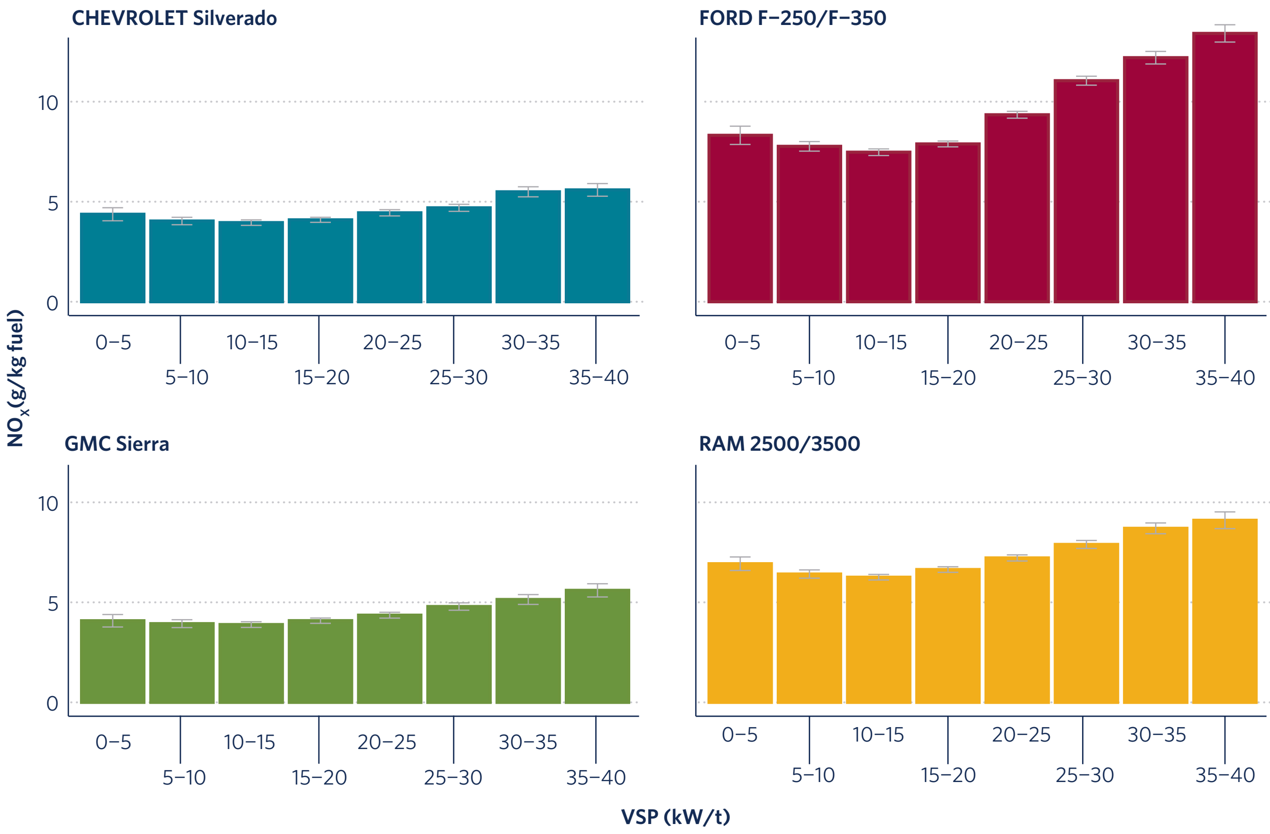

Figure 6. Average fuel-specific NO_x emissions by VSP for each vehicle model. Error bars represent the 95% confidence interval.

20 José L. Jiménez et al., "Vehicle Specific Power: A Useful Parameter for Remote Sensing and Emission Studies" (presentation, 9th CRC On-Road Vehicle Emissions Workshop, San Diego, CA, April 21, 1999), https://cires1.colorado.edu/jimenez/Papers/Jimenez_VSP_9thCRC_99_final.pdf.

substantially higher emissions at higher VSPs. Average NO_x emissions above 20 kW/t were 3.2–5 g/kg higher than average emissions below 20 kW/t, a much larger difference than observed for any other truck model.

EMISSIONS BY AMBIENT TEMPERATURE

The 2020 TRUE analysis of data collected up to 2018 found that MY 2010–2015 Ford F-250/F-350s showed temperature dependencies and emitted nearly 2 times higher NO at low temperatures than at high temperatures.[21] This trend was not observed for other vehicle models.

While the Chevrolet, GMC, and Ram trucks showed relatively minor differences in emissions across different temperatures, the Ford truck presented much higher emissions at low temperatures (Figure 8). An increase that is significant at the 95% confidence level was observed for measurements at 40–50 °F compared with those at 50–60 °F. Emissions continued to increase with declines in temperature, and at 30–40 °F, average emissions were roughly 2 times higher than emissions at the highest temperatures. Emissions

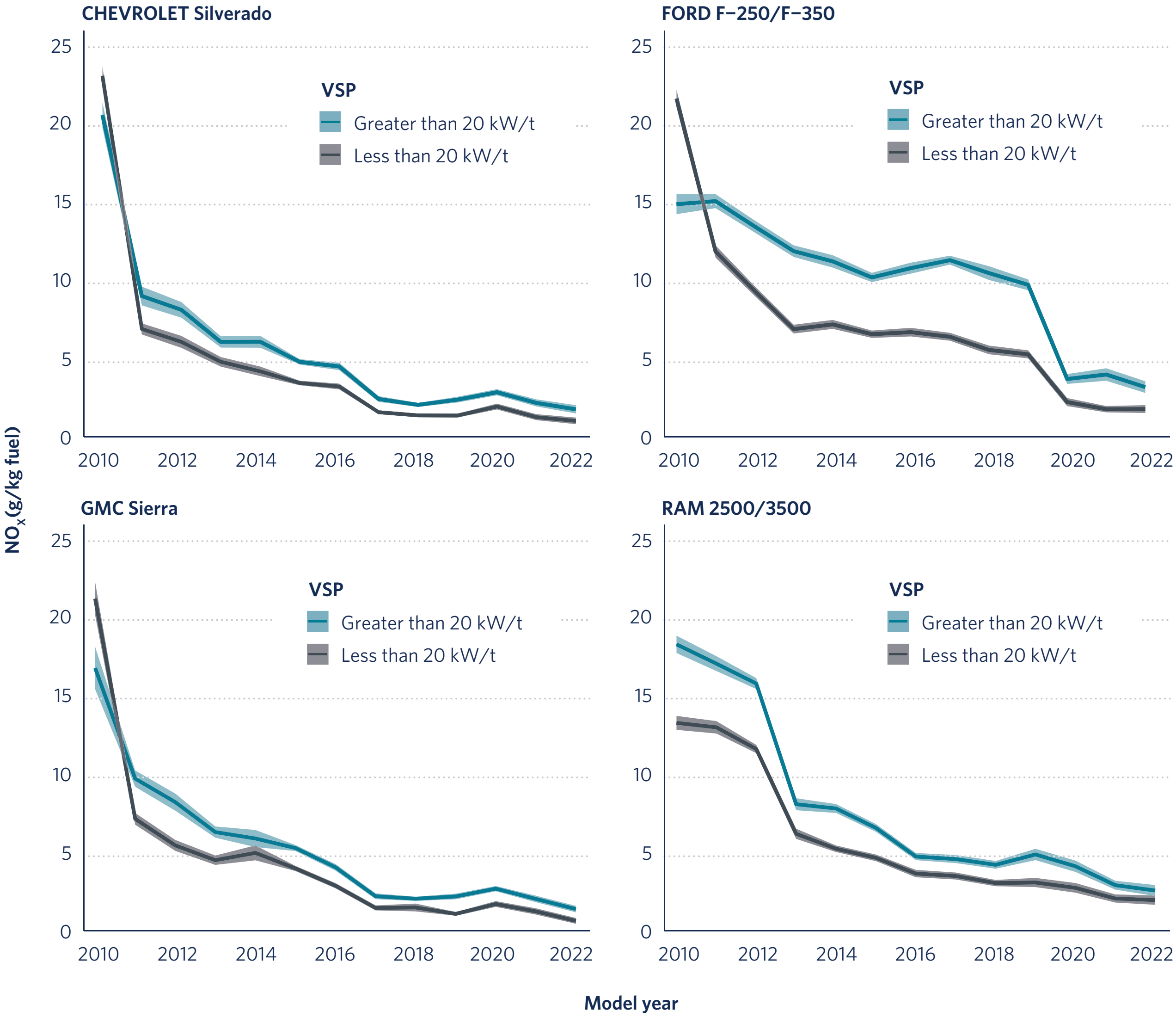

Figure 7. Fuel-specific NO_x emissions by model year and vehicle model for different levels of VSP.

21 Bernard et al., *Development and Application of a United States Real-World Vehicle Emissions Database.*

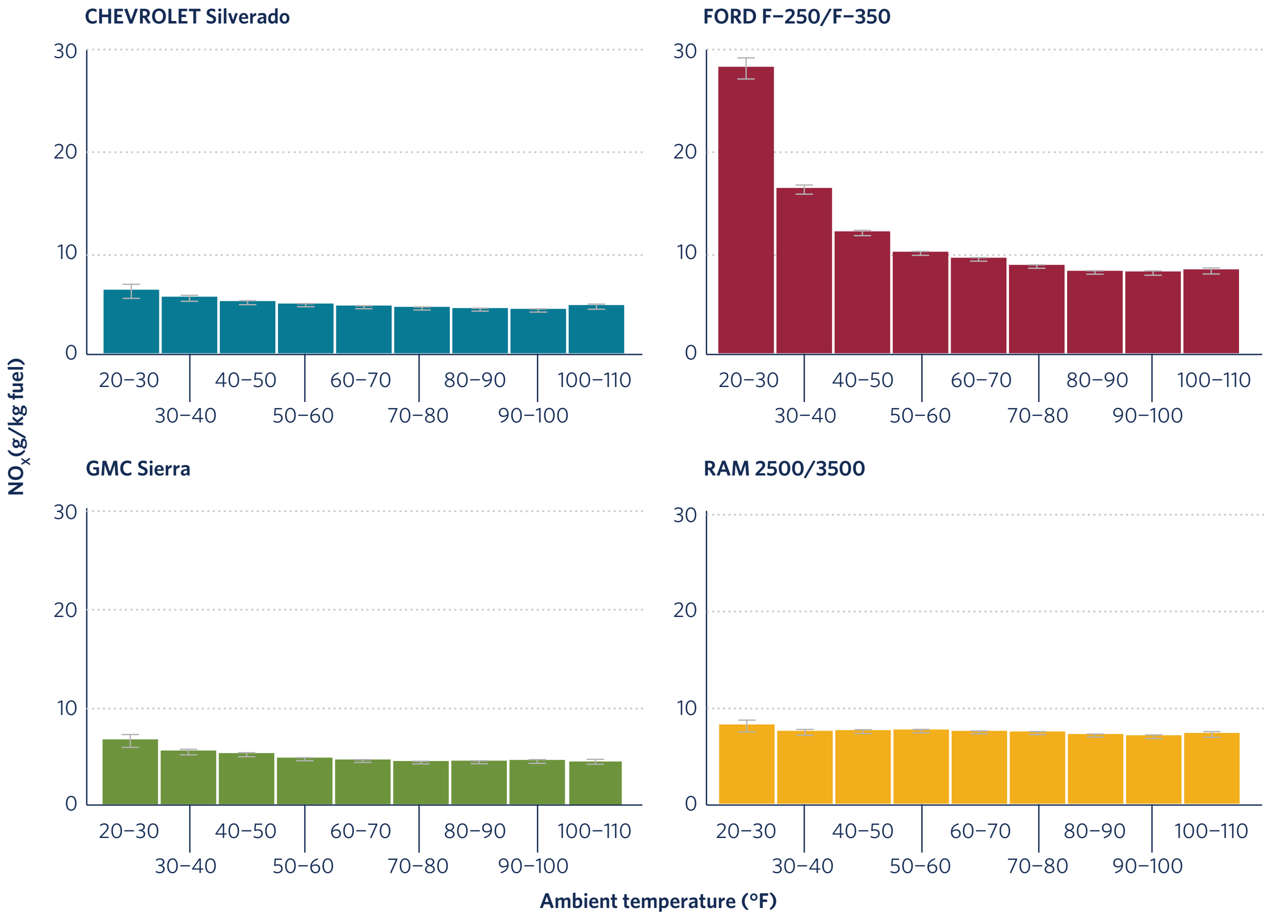

Figure 8. Average NO_x emissions by ambient temperature for each vehicle model. Error bars represent the 95% confidence interval.

at 20–30 °F were particularly high: almost 12 g/kg higher than emissions at 30–40 °F and over 3.5 times higher than emissions at the highest temperatures. The remote sensing data thus provide evidence that the NO_x emission control systems used in Ford trucks are less effective at low temperatures.

Only the Ford trucks showed a large difference when comparing emissions at ambient temperatures above and below 50 °F (Figure 9). This gap was pronounced for MY 2010–2019 vehicles: NO_x emissions were approximately 16% higher at temperatures below 50 °F for MY 2010 vehicles, widening to between 50% and 98% higher for MY 2011–2019 vehicles. The difference nearly disappears starting with MY 2020.

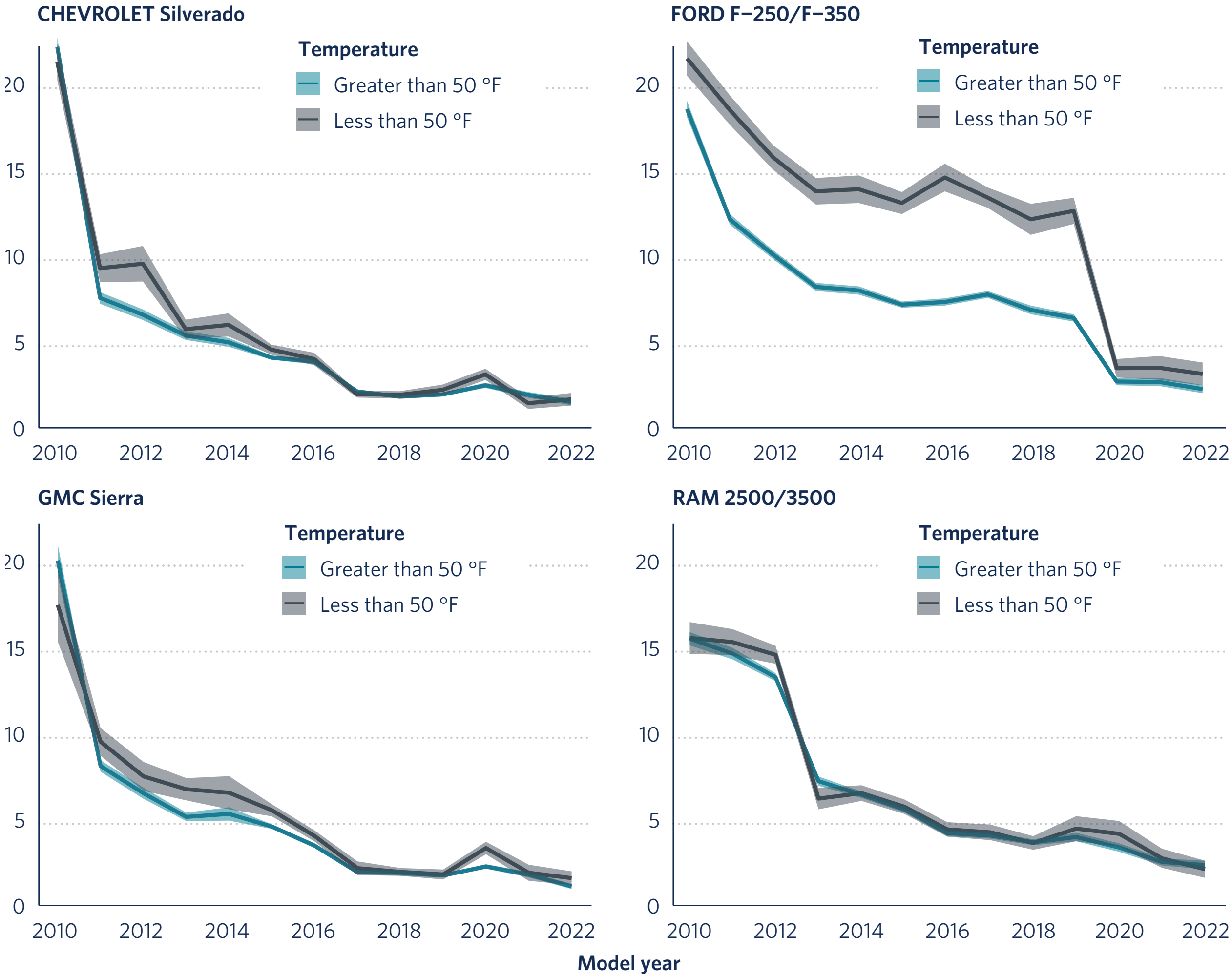

Figure 9. Fuel-specific NO_x emissions by model year and vehicle model for different ambient temperatures.

We discern no obvious technical explanation for the high NO_x emissions at low temperatures observed in the Ford trucks, and the other three truck models show little variation in NO_x by temperature. Further investigation of the Ford truck emission control system as it relates to ambient temperature would help to better understand the causes of high excess NO_x emissions.

ESTIMATION OF EXCESS EMISSIONS FROM FORD TRUCKS

In this section, we estimate both the number of Ford vehicles showing high NO_x emissions and the magnitude of excess NO_x emissions. We used average vehicle mileage and emission factors to estimate the approximate emissions in one year of operation and thereby contextualize the scale of excess NO_x emissions from the Ford F-250/F-350. This is intended as an approximate estimate, as we did not consider other factors such as vehicle retirement and changes in vehicle mileage by vehicle age.

Similar methods were used in a 2016 study that calculated the excess NO_x emissions attributable to light-duty diesel Volkswagen cars with defeat devices, the subject of the "Dieselgate" scandal.[22] Three main components go into the estimation: the number of vehicles, average annual vehicle miles traveled, and excess NO_x per distance traveled. Multiplying these three numbers gives an estimate of annual excess NO_x emissions, as shown in the equation below.

22 Lifang Hou et al., "Public Health Impact and Economic Costs of Volkswagen's Lack of Compliance with the United States' Emission Standards," *Int. J. Environ. Res. Public Health* (September 8, 2016), https://doi.org/10.3390/ijerph13090891.

$$\textit{Excess } NO_X = (\textit{number of vehicles}) \times (\textit{annual mileage per vehicle}) \times (\textit{excess } NO_X \textit{ in mg/mile})$$

We estimated the number of affected vehicles using two methods. First, we paired information from the Cummins settlement with the number of unique vehicles measured by remote sensing. According to the settlement, 630,000 Ram trucks of MY 2013–2019 were impacted. This model year group accounted for 74% of the unique trucks of MY 2010–2019 in our remote sensing data; we thus scaled up the number reported in the settlement to arrive at an estimate of approximately 850,000 Ram 2500/3500 models of MY 2010–2019. The numbers of unique Ford F-250/F-350 and Ram 2500/3500 models of MY 2010–2019 measured using remote sensing were nearly identical, within 0.2% of each another. Thus, our estimate derived from remote sensing measurements was 850,000 Ford F-250/F-350s of MY 2010–2019.

We derived the second estimate using sales data. Sales data are typically reported for the entire F-series, which includes the most popular model, the F-150, and the F-250, F-350, and F-450. Approximately 7,140,000 Ford F-series trucks were sold from 2009 to 2018.[23] We multiplied this number by the approximate share of F-250s and F-350s among the F-series. The sales data show that from the second quarter of 2023 to the second quarter of 2024, Ford Super Duty diesel vehicles—which include F-250s, F-350s, and F-450s—made up 18.7% of total F-series sales. We assumed this share to be roughly representative of the share for MY 2010–2019 F-series sales. From this, we obtained an estimate of 1,340,000 Ford Super Duty diesel vehicles of MY 2010–2019. Given that this estimate includes Ford F-450s, we used this as an upper bound estimate of the number of F-250s and F-350s sold.

Next, we used numbers from the Federal Highway Administration on the annual vehicle distance traveled per vehicle.[24] We used data from 2018, the average measurement year of all remote sensing data, to derive an estimate of approximately 11,500 miles per vehicle per year for light-duty vehicles with a long wheelbase, the category that most closely aligns with the Ford F-250/F-350.

Finally, we estimated the excess NO_X emissions using average real-world emissions measurements. We calculated a range of excess emission factors using the two methods summarized in Table 3. A lower bound estimate of excess emissions was developed by comparing the real-world emissions from the Ford vehicles with those of the GMC Sierra and Chevrolet Silverado and was calculated by taking the average of all remote sensing measurements for each model for MY 2010–2019. The GMC and Chevrolet trucks showed real-world emissions above the certification limits for almost all model years, but they showed lower emissions than the Ford and Ram trucks. Additionally, the GMC and Chevrolet emissions were less sensitive to ambient temperature and VSP than the Ford trucks' excess emissions. Therefore, we used the GMC and Chevrolet emission factors as a reference for expected baseline emissions for the lower bound. We calculated the upper bound estimate by using the lowest possible emissions limit under Tier 3 as the reference for the expected baseline.

Table 3. Lower and upper bound estimate of distance-specific excess emission factors for Ford trucks

	Ford emission factor	**Reference emission factor**	**Ford excess emission factor** (Ford minus reference emission factor)
Lower bound estimate	2,070 mg/mile	970 mg/mile[a]	**1,100 mg/mile**
Upper bound estimate		200 mg/mile[b]	**1,870 mg/mile**

[a] The average distance-specific emissions from the GMC Sierra and Chevrolet Silverado, according to remote sensing measurements
[b] The lowest NO_X emissions limit under Tier 3 certifications

Using these values, we found that the diesel Ford F-250/F-350 pickup trucks contribute 10,800–28,800 metric tons of excess NO_X emissions in 1 year of operation. For comparison, the aforementioned 2016 study found that Volkswagen diesel passenger cars emitted 3,414–14,796 metric tons of excess NO_X

23 We used 2009–2018 calendar year sales to estimate the number of MY 2010–2019 vehicles, as vehicles of MY 2010 were sold starting in January 2009. "Ford F-Series U.S. Sales Data & Charts," Good Car Bad Car, accessed September 4, 2024, https://www.goodcarbadcar.net/ford-f-series-sales-figures/.

24 "Table VM-1, Annual Vehicle Distance Traveled in Miles and Related Data – 2018," U.S. Federal Highway Administration, accessed September 5, 2024, https://www.fhwa.dot.gov/policyinformation/statistics/2018/vm1.cfm.

emissions in 1 year of operation (Figure 10).[25] This finding, that Ford diesel pickup trucks contribute similar or even higher levels of excess emissions than Volkswagen diesel passenger cars, aligns with a previous global study's findings that heavy-duty diesel vehicles are a larger contributor of excess NO_x emissions than light-duty diesel vehicles.[26] Addressing the high NO_x emissions from Ford F-250/F-350s could thus have a large impact on reducing real-world NO_x emissions.

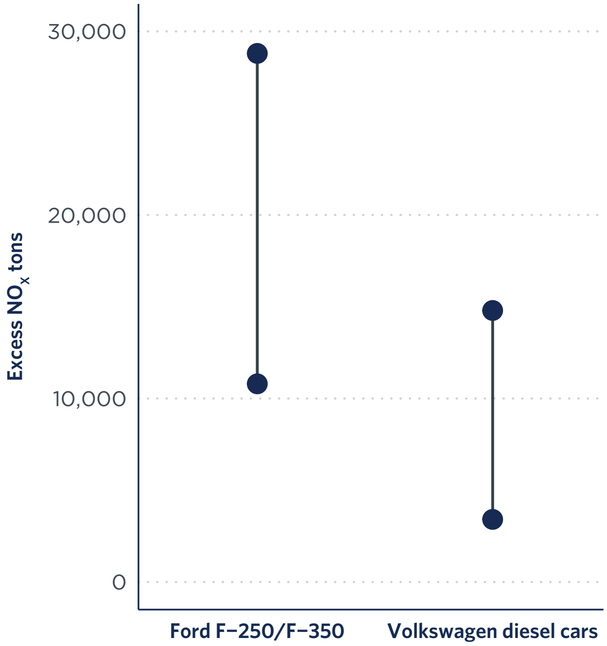

Figure 10. Comparison of excess NO_x between Ford pickup trucks and "Dieselgate" Volkswagen cars.

CONCLUSION

Real-world vehicle emissions data provide strong support for market surveillance activities. This study presented an updated analysis of real-world NO_x trends from diesel pickup trucks in the United States using remote sensing data collected as recently as 2023. The assessed data included the MY 2013–2019 Ram 2500/3500 diesel trucks, which were the subject of a recent federal action related to their emissions control system.

We found that the Ford F-250/F-350s showed higher emissions than the Ram trucks for MY 2013–2019. For MY 2010–2015 Ford trucks, which were certified to the heavy-duty emission standard, real-world NO_x emissions were estimated at 6–10 times over the limit. Trends by measurement year showed evidence of high emissions before vehicles experienced deterioration, which suggests that even shortly after the time of sale, real-world NO_x levels were not well controlled under specific driving and ambient conditions.

Both the Ford and Ram trucks showed higher emissions at VSPs above 20 kW/t, and the difference was more substantial for Ford trucks. Additionally, Ford truck emissions at temperatures below 50 °F were much higher than at higher temperatures. At the lowest temperatures examined in the analysis, 20–30 °F, emissions were more than 3.5 times higher than emissions at the highest temperatures.

This analysis indicates that the emissions control of the measured Ford F-250/F-350s does not effectively control real-world NO_x emissions and results in high excess pollution. We estimate that there are 850,000–1,340,000 Ford F-250/F-350s of MY 2010–2019 that contribute approximately 10,800–28,800 metric tons of excess NO_x emissions in 1 year of operation. This amount is similar to or even higher than the excess NO_x from Volkswagen's diesel passenger cars found to contain defeat devices.[27] This scale of excess NO_x suggests that further investigation is warranted. These vehicles will continue to be on the road for years to come, and action to address the high NO_x emissions can substantially reduce emissions and associated air pollution for the remainder of the vehicles' operation.

25 Lifang Hou et al., "Public Health Impact and Economic Costs."

26 Susan C. Anenberg et al., "Impacts and Mitigation of Excess Diesel-Related NO_x Emissions in 11 Major Vehicle Markets," *Nature* 545, no. 7655 (May 25, 2017): 467–71, https://doi.org/10.1038/nature22086.

27 Hou et al., "Public Health Impact and Economic Costs."

APPENDIX

Table A1. Average driving and ambient conditions by vehicle model

Vehicle model	Average ambient temperature (°F)	Average speed (mph)	Average acceleration (mph/s)	Average VSP (kW/t)
Chevrolet Silverado	72.2	40.8	1.38	20.1
Ford F-250/F-350	72.9	40.0	1.31	19.5
GMC Sierra	72.3	41.1	1.38	20.1
Ram 2500/3500	72.8	41.2	1.40	20.4

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TO FIND OUT MORE

For details on the TRUE U.S. remote sensing database and related questions, contact **Michelle Meyer, m.meyer@theicct.org**.

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