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Benefits of adopting California medium- and heavy-duty vehicle regulations in New York State

Authors: Ray Minjares (ICCT), Jeff Houk (Sonoma Technology, Inc.), and Joey Juang (Sonoma Technology, Inc.)

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Medium- and heavy-duty vehicles make a significant contribution to emissions of greenhouse gases and ambient air pollution in the state of New York. This paper estimates the benefits of implementing California regulations on medium- and heavy-duty vehicles, including the Heavy-Duty Omnibus regulation, the Advanced Clean Trucks regulation, and the California Phase 2 Greenhouse Gas regulation.

As of 2017, mobile emission sources, especially diesel-powered trucks, buses, cars, trains, and boats, produce nearly two-thirds of NOx emissions in New York State. The New York Metropolitan Area is not in attainment of the 2008 and 2015 National Ambient Air Quality Standards for ozone, and the state has pressed the U.S. Environmental Protection Agency (EPA) to strengthen NOx emission limits on new heavy-duty vehicles.[1] Low-NOx trucks can support state efforts to achieve conformity with air quality standards and address disparities in air pollution exposure, particularly in communities of color and in low-income communities.

New York State officials are also pursuing more ambitious climate policy. Under the Climate Leadership and Community Protection Act of 2019, New York State will limit greenhouse gas emissions to 40% below 1990 levels by 2030 and 85% by 2050. In pursuit of greenhouse gas emission reductions in the medium- and heavy-duty vehicle sector, Governor Andrew Cuomo signed the Multi-State Zero Emission Medium- and Heavy-Duty Vehicle Memorandum of Understanding on July 14, 2020, adopting the goal of making 30% sales of new medium- and heavy-duty vehicles zero-emission no later than 2030, and 100% no later than 2050.[2] On April 21, 2021, Governor Cuomo joined the

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1 New York Department of Environmental Conservation, *New York State's Beneficiary Mitigation Plan*, (September 5, 2018), https://www.dec.ny.gov/docs/air_pdf/vwcleantransportplan19.pdf.

2 "Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding," 2020, https://www.nescaum.org/documents/multistate-truck-zev-governors-mou-20200714.pdf.

Governors of 11 other states asking President Biden to set standards that ensure that all sales of medium- and heavy-duty vehicles are zero-emission by 2045.

Section 177 of the Clean Air Act permits New York State to adopt California new motor vehicle regulations.[3] On June 25, 2020, the California Air Resources Board (ARB) adopted the Advanced Clean Trucks Regulation to require the sale of zero-emission trucks.[4] Applicable manufacturers who certify Class 2b-8 chassis or complete vehicles with combustion engines will be required to sell an increasing percentage of zero-emission vehicles and chassis. Under the regulation, by model year (MY) 2035, zero-emission sales will be required to equal 55% of Class 2b-3 truck sales, 75% of Class 4-8 straight truck sales, and 40% of tractor truck sales.[5] On August 27, 2020, the ARB adopted new rules to limit nitrogen oxides from new engines to levels 90% below current limits under federal standards, among other changes, in order to reduce real-world NOx emissions from medium- and heavy-duty trucks.[6] California also continues to voluntarily certify greenhouse gas emission standards for tractor-trailers, as part of its Phase 2 greenhouse gas emission standards for heavy-duty vehicles. This paper estimates the emissions benefits in New York State from the implementation of these three rules beginning with requirements that apply in model year 2025.

Methods

The ICCT contracted Sonoma Technology, Inc. (STI) to project baseline and new policy scenarios in New York State from calendar year 2020 to 2050. STI used the latest version of the MOtor Vehicle Emission Simulator, MOVES3, as the basis for vehicle activity, vehicle population, and vehicle emissions projections of the baseline fleet.[7]

STI ran MOVES3 at the County Scale utilizing default model data and input data specific to New York taken from the 2017 National Emissions Inventory (NEI).[8] Based on New York State Department of Transportation regional definitions, STI identified 11 representative counties out of 62 total counties in New York State to model (see Table A6 in the Appendix) and utilized MOVES3 default data and New York's NEI 2017 data for each representative county and target year. The final sources of MOVES3 input data are summarized in Table 1.

3 New motor vehicle emission standards in nonattainment areas 42 U.S.C. § 7507 (1990).

4 "California takes bold step to reduce truck pollution," California Air Resources Board, June 25, 2020, https://ww2.arb.ca.gov/news/california-takes-bold-step-reduce-truck-pollution.

5 Advanced Clean Trucks Fact Sheet, California Air Resources Board, June 25, 2020, https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet.

6 "Heavy-Duty Engine and Vehicle Omnibus Regulation and Associated Amendments," California Air Resources Board, updated May 5, 2021, https://ww2.arb.ca.gov/rulemaking/2020/hdomnibuslownox.

7 U.S. Environmental Protection Agency, MOtor Vehicle Emission Simulator (MOVES) [version 3], https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.

8 2017 National Emissions Inventory (NEI) Data, accessed May 28, 2021, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data.

Table 1. Sources of MOVES3 input data for New York State.

MOVES3 county-scale input	NY data source
VMT, vehicle population	NEI 2017, grown to future years using MOVES default growth rates
Fuel supply, fuel usage fractions, inspection and maintenance program parameters, VMT month, day, hour fractions	MOVES3 defaults
Road type VMT distribution, vehicle age distribution	NEI 2017 data for corresponding representative county
Vehicle technology distribution, speed distribution	NEI 2017 data for corresponding representative county
Meteorology, retrofit program data	MOVES3 defaults

STI output vehicle miles traveled and vehicle population by regulatory class, together with NO_x, CH_4, VOC, CO, CO_2, SO_2, PM, and energy by regulatory class, for statewide emission estimations in 2020, 2030, and 2050. State-level results were aggregated from MOVES3 county-scale outputs for the 11 representative counties using an R script. As a quality assurance check, NO_x emissions for all 11 representative counties and state NOx emissions were compared against NEI 2017 data and EPA estimates for 2016, 2023, and 2028.[9] State-wide emissions were compared to default-scale MOVES3 runs for New York State.

STI generated estimates for 2025, 2035, 2040, and 2045 by running MOVES3 at the default scale for the state of New York. These results were used to calculate the trend in emissions over that period by pollutant and vehicle type. Finally, this trend was applied to the county-scale results for 2020, 2030, and 2050 to develop emissions estimates for these intermediate years. In all other calendar years for which no additional MOVES modeling was conducted, annual emissions estimates are interpolated.

STI applied a post-processing framework to estimate the potential change in New York State emissions resulting from the adoption of two California regulations: the Advanced Clean Trucks regulation and the Heavy-Duty Omnibus regulation. STI also adjusted NY State business-as-usual emissions to account for litigation that has prevented EPA from implementing greenhouse gas emission standards for trailers. Table 2 describes these adjustments.

9 EPA-developed emissions modeling platform with 2016 as the base year. The year 2023 and year 2028 inventories were projected by EPA from the 2016 inventory in support of the Revised Cross State Air Pollution Rule Update for the 2008 Ozone National Ambient Air Quality Standards. https://www.epa.gov/sites/production/files/2020-11/documents/2016v1_emismod_tsd_508.pdf.

Table 2. Post-processing adjustments to MOVES3 outputs

Regulation	Post-processing steps	EPA regulatory classes affected	Pollutants affected
Business-as-usual	Adjustments to remove the benefit of the trailer component of the US EPA HDV Phase 2 GHG rule captured in baseline emission projections	46, 47	CO_2 (emissions increase)
Advanced Clean Trucks (ACT)	Adjustment to reflect phased introduction of zero-emission HDVs into the fleet following the 2020 Advanced Clean Trucks Rule adopted in California; Application of GREET emission factors to calculate well-to-tank change in emissions following 2040 net-zero carbon power grid trajectory	41, 42, 46, 47	All (emissions decrease)
Heavy-Duty Omnibus	Adjustment to reflect ARB's Heavy-Duty Omnibus regulation and to extend the rule to New York State urban transit buses	42, 46, 47, 48	NO_x (emissions decrease)

Business-as-usual scenario

The business-as-usual (BAU) scenario assumes no new policy is adopted from calendar year 2020. Since the tractor-trailer provisions of the US EPA HDV Phase 2 GHG rule have not been implemented, pending the outcome of litigation in federal court, we assume that this component of the rule will not be implemented under a business-as-usual scenario.

MOVES3 incorporates the full implementation of the HDV GHG Phase II standard. This assumption requires an adjustment to MOVES3 default outputs across all calendar years. The primary basis for this post-processing adjustment is an estimate of the emissions reductions attributable to the trailer component of the HDV Phase 2 GHG rule. STI developed adjustment factors based on ICCT estimates of the percentage of tractor-trailer VMT subject to the regulation, the estimated percentage reductions from the regulation, and the baseline fuel consumption from tractor-trailers (See Figure 1).

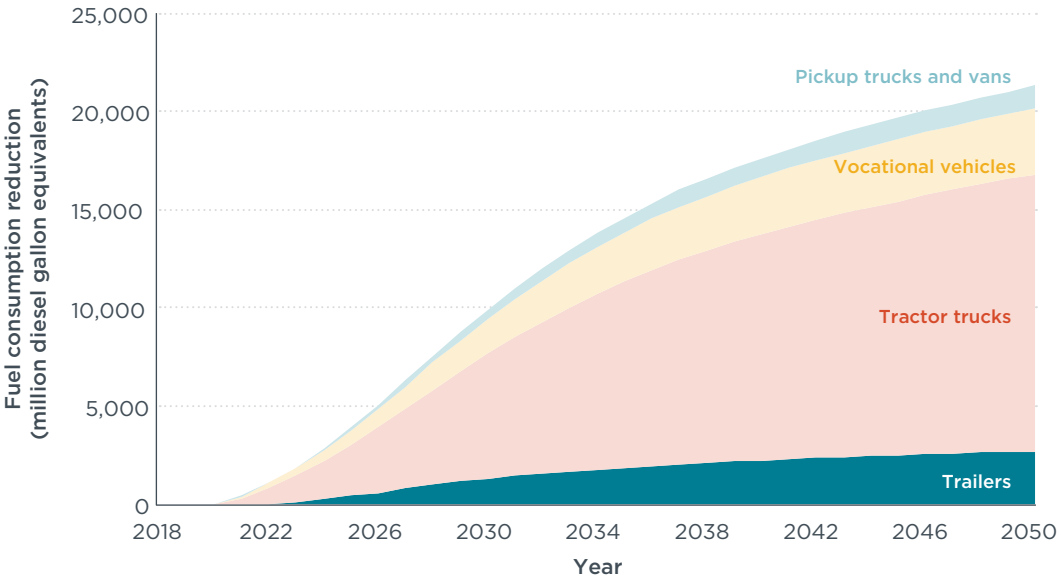

Figure 1. Projected fuel consumption reduction with full national implementation of the HDV Phase II GHG rule from 2020 to 2050.

STI mapped short-haul and long-haul tractor-trailer emissions estimates to MOVES3 regulatory classes, which are detailed in Table 3. Tractor-trailers ("combination vehicles" in MOVES terminology) exist in MOVES3 regulatory classes 46 and 47, but single-unit

vehicles exist in these weight classes as well. STI ran MOVES3 at the default scale to develop national vehicle population estimates by vehicle sourcetype and regulatory class, then used these data to determine the fractions of regulatory classes 46 and 47 comprised of combination vehicles. These fractions, together with ICCT fuel use and reduction estimates, were combined to calculate the emissions increase for classes 46 and 47 attributable to not implementing the trailer requirements of the HDV Phase 2 GHG rule.

Table 3. EPA regulatory classes

EPA regulatory class codes	Description
41	Class 2b and 3 Trucks (8,500 lbs < GVWR <= 14,000 lbs)
42	Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs)
46	Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs)
47	Class 8a and 8b Trucks (GVWR > 33,000 lbs)
48	Urban Transit Buses (as defined at CFR Sec 86.091_2)

Advanced Clean Trucks scenario

We evaluate a scenario in which New York State adopts the California Advanced Clean Trucks (ACT) regulation, beginning with model year 2025 sales requirements.

The ACT requires manufacturers to sell a minimum percentage of zero-emission trucks across all weight classes, beginning with model year 2024 and extending to model year 2035. The most recent version of MOVES3 cannot model zero-emission trucks and buses, so STI developed post-processing adjustments of MOVES3 outputs to simulate the penetration of zero-emission vehicles across this fleet.

STI utilized a variety of sources to develop post-processing adjustment factors. The primary resource was *Attachment D: Emissions Inventory Methods and Results for the Proposed Advanced Clean Trucks Regulation Proposed Modifications*, which reflects the latest publicly available benefits estimates prepared by ARB staff for the proposed rule.[10] STI also consulted directly with ARB staff who developed the rulemaking and who provided additional documentation to answer questions about benefits methodology[11]

We applied to New York State the ARB staff estimates for California zero-emission truck regulated phase-in percentages by model year, the expected fractions of new vehicles sold in-state versus purchased out-of-state, and the migration of vehicles out of state over time. ARB staff do not count the benefits of large fractions of ZEVs originally sold in California that ultimately migrate out of state. Between 85% and 91% of registered Class 4-8 vocational vehicles and Class 7-8 tractors are first sold in California. At nine years of age, 67%–75% of vocational vehicles registered in-state were first sold in California, but just 34%–48% of tractors. This methodology leads to a conservative accounting, whereby ARB does not assign to California the spillover benefits that accrue to other states that receive its zero-emission trucks. We apply this same accounting method to New York State.

10 California Air Resources Board, "Attachment D: Emissions Inventory Methods and Results for the Proposed Advanced Clean Trucks Regulation," (2019), Proposed Modifications https://ww3.arb.ca.gov/regact/2019/act2019/30dayattd.pdf.

11 "CARB 2020b.xlsx," provided by Paul Arneja via email on February 24, 2021.

A conservative judgment also applies to the accounting of benefits of sales requirements concurrent with Phase 2 greenhouse gas emission standards for engines and vehicles. Since the sale of zero-emission trucks can be counted towards meeting greenhouse gas standards, ARB staff sought to avoid double-counting the benefits of this compliance pathway under the ACT. As a consequence, ARB staff do not attribute to the ACT any marginal increase in zero-emission vehicle population or marginal decrease in greenhouse gas emissions until calendar year 2027. We apply this same accounting method to New York State.

The projections for California of zero-emission truck sales by vehicle type, model year, and calendar year were provided by ARB staff. Since the basis of benefits modeling in California rulemakings is the Emission Factor (EMFAC) model and not MOVES, STI mapped EMFAC vehicle types to MOVES3 model vehicle types by regulatory class, then calculated zero-emission truck stock percentages by regulatory class. These fractions were then applied directly to MOVES3 emissions outputs by regulatory class for each calendar year. We assume, as ARB staff have done, that electric and conventional trucks drive the same distance each day. ARB staff assume that brake-wear emissions from electric trucks are 50% lower than brake-wear from conventional trucks, due to the benefits of regenerative braking in electric drive vehicles. STI applied this assumption to the MOVES3 output for brake-wear particulate emissions from electric vehicles. STI did not apply any adjustment to particulate matter tire-wear emissions. In summary: if a given regulatory class consisted of 10% zero-emission vehicles in a given calendar year, STI reduced in that calendar year all exhaust emissions for that class by 10%, reduced brake-wear emissions by 5%, and did not adjust tire-wear emissions.

The ACT does not require the sale of zero-emission urban transit buses, which is already required under the separate Innovative Clean Transit Regulation adopted by the ARB in 2018. While the benefits of transit bus electrification are not included here, NY MTA has adopted the goal to electrify 5,800 transit buses by 2040 and Governor Cuomo intends to fully electrify approximately 1,300 transit buses operated by five other transit authorities by 2035.[12]

Heavy-Duty Omnibus scenario

We evaluate a scenario in which New York State implements the California Heavy-Duty Omnibus regulation beginning with model year 2025.

The Heavy-Duty Omnibus regulation establishes new requirements on heavy-duty vehicles and engines primarily to reduce real-world emissions of NOx, although new backstop limits on PM emissions are also included. The regulation includes NOx engine standards requiring 75% lower emissions from model year 2024 engines and 90% lower emissions from model year 2027 engines, as well as new warranty, durability, and useful life requirements, among other provisions.

As part of their rulemaking process, ARB staff developed an emissions inventory document summarizing the NO_x emissions impacts of the Heavy-Duty Omnibus Regulation.[13] The PM emission benefits of the regulation were not evaluated by ARB

12 "NY Governor Announces Initiatives to Electrify Transit Buses," *T&D World*, January 5, 2021, https://www.tdworld.com/electrification/article/21151516/ny-governor-announces-initiatives-to-electrify-transit-buses and Clayton Guse, "MTA plans to only buy electric buses come 2028 as officials map greener future for NYC Transit," *New York Daily News*, April 25, 2021, https://www.nydailynews.com/new-york/ny-mta-electric-buses-biden-emissions-plan-20210425-dhmcbiltcra2pmvo2pneqkrtn4-story.html.

13 California Air Resources Board, "Appendix D: Emissions Inventory Methods and Results for the Proposed Amendments," (2020), https://ww3.arb.ca.gov/regact/2020/hdomnibuslownox/appd.pdf.

staff; our analysis also does not consider PM emissions. Tables 6 and 7 of ARB's emissions inventory report provide baseline and reduced emission estimates for two scenarios: (1) NOx reductions with implementation of the ACT, and (2) NOx reductions without implementation of the ACT. Staff at the ARB incorporated assumptions about the share of vehicles in the fleet from those first sold in-state and first sold out-of-state.

The Heavy-Duty Omnibus inventory does not include any estimated benefits for urban transit buses. In the State of California these buses are regulated by the Innovative Clean Transit rule that requires the use of certified low-NOx engines. We assume New York State will not adopt the Innovative Clean Transit Rule, and so the heavy-duty omnibus scenario presented here incorporates reductions applied to urban transit buses.

The emission estimates by ARB staff are not provided by vehicle type, so STI applied reported fleet-wide reductions equally across all affected vehicle types, under the assumption that the general mix of heavy-duty vehicle classes would be similar in California and New York State.

Heavy-Duty Vehicle Greenhouse Gas Phase 2 Trailer scenario

We evaluate a scenario in which New York State adopts the California Phase 2 greenhouse gas emission standards in order to realize the benefits of tractor-trailer standards.

The ARB approved its first tractor-trailer greenhouse gas regulation in 2008. These standards reduce greenhouse gas emissions by improving aerodynamic performance of tractor-trailers and reducing rolling resistance. In 2019, ARB staff worked together with EPA and National Highway Traffic Safety Administration staff to develop a Phase 2 package of greenhouse gas emission standards for heavy-duty engines, vehicles, and trailers that are aligned in structure, timing and stringency.

The EPA intended to implement trailer standards beginning in model year 2018. However, on October 27, 2017, the US Court of Appeals for the District Court of Colombia granted a stay of EPA tractor-trailer standards, precluding EPA from enforcing them. While California's authority to regulate trailers is not contested, ARB nevertheless announced its decision on December 3, 2019, to voluntarily suspend enforcement of its own model year 2020 and 2021 tractor-trailer standards and to provide six months written notice before resuming enforcement of the standards. However, ARB continues to administer the trailer regulation on a voluntary basis, including certification of 2020 and subsequent model year trailer standards.

In order to realize the benefits of trailer standards, New York State has the option of adopting California Greenhouse Gas Phase 2 standards. We assume implementation in New York State begins with model year 2025 standards, that California will choose to enforce standards in that model year, and that benefits are first generated in calendar year 2025. Emissions pre-2025 are equal to the business-as-usual scenario in which trailer standards are not implemented. Since California standards are aligned in structure, timing, and stringency with federal standards, we make no post-processing adjustments to MOVES3 emission outputs in order to estimate annual emissions changes generated by the trailer standards.

Well-to-tank emissions

STI estimated the change in electrical grid emissions in response to projected energy demand from growth in the electric vehicle fleet. STI extracted grid electricity emissions factors (in units of tons of grams of emissions per million BTUs of electricity) from the

Department of Energy's GREET model.[14] These rates are provided for different regions of the country, and STI applied the rates applicable to New York.

STI utilized projections of state-wide renewable energy generation published in the 2020 New York State Pathway Analysis, which assumes full grid decarbonization by 2040 (Table 4).[15] STI used these projections to calculate the relative fraction of grid electricity that would be zero-emission in each calendar year, and then applied these fractions to baseline GREET factors for 2020 to project upstream emissions rates in future years.

Table 4. New York State projected annual fuel mix (GWh), 2020–2050.

Energy Source	2020	2025	2030	2035	2040	2045	2050
Nuclear	42,815	26,451	26,451	26,451	26,451	26,451	16,835
Coal	-	-	-	-	-	-	-
Gas and fuel oil	71,192	65,559	35,902	30,786	-	-	-
Gas with carbon capture and storage	-	-	-	-	-	506	4,201
Renewable natural gas/H_2	-	-	-	-	150	961	1,839
Biomass	2,729	2,729	2,729	2,729	2,729	2,337	1,596
In-state hydro	25,947	25,895	29,783	29,960	28,389	28,519	28,564
Hydro imports (Existing)	10,362	10,362	10,362	10,362	10,362	10,362	10,362
Hydro imports (New)	-	-	7,008	7,008	14,016	14,016	14,016
Wind	4,980	8,530	13,208	15,989	35,183	39,914	39,369
Offshore wind	-	7,506	25,853	37,528	40,779	45,103	63,932
Solar	4,267	11,573	17,458	20,096	50,052	69,558	78,864
Battery storage	2	22	(1,021)	(1,233)	(283)	(647)	(784)
Pumped storage	(140)	(22)	(69)	(16)	(320)	(512)	(574)
Imports[a]	4,530	4,140	2,598	4,664	13,920	14,671	15,484
Exports	(9,886)	(15,144)	(18,582)	(8,153)	(13,920)	(14,671)	(15,484)
Load	156,799	147,602	151,678	176,171	207,506	236,568	258,220
Renewable energy fraction	31%	45%	70%	70%	87%	88%	92%
Zero-emission fraction	58%	63%	87%	85%	100%	100%	100%

[a] Hydro Imports from Canada are included in the generation mix table and are therefore not included in the Imports row.

As part of its MOVES3 modeling, STI generated estimates of total energy consumption by vehicle class, in units of million BTUs. STI used zero-emission vehicle fleet fractions calculated for the ACT program to determine what portion of that total energy consumption was attributable to dedicated electric vehicles. The product of ZEV fleet energy demand and projected grid emission factors produced absolute grid emission projections. We do not consider any other upstream grid emissions scenario in this paper.

14 Argonne National Laboratory, Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET), https://greet.es.anl.gov/.

15 Energy+Environmental Economics, *Pathways to Deep Decarbonization in New York State*, (June 24, 2020), https://climate.ny.gov/-/media/CLCPA/Files/2020-06-24-NYS-Decarbonization-Pathways-Report.pdf.

Output Spreadsheet

STI incorporated all post-processing factors into an excel spreadsheet available online.[16] The spreadsheet includes a summary results worksheet, individual worksheets with results for several scenarios, the original MOVES3 output, and post-processing adjustments. The spreadsheet is designed so that the MOVES3 output by calendar year, regulatory class, and pollutant can be copied into the spreadsheet to generate new emission projections with identical post-processing factors.

Results

The projected estimates of emissions benefits in New York State under each policy scenario are presented below. Detailed information on vehicle growth and emissions per year can be found in the Appendix.

We project the population of trucks in New York State to grow from approximately 630,900 vehicles in 2020 to 894,300 vehicles by 2050 (Figure 2). The largest rate of growth will occur in the Class 6-8b weight class, equal to 69% above 2020 levels over the thirty-year period. The smallest growth will be in the gliders category. By 2050, Class 2b-3 vehicles will account for 49% of the total fleet, a decline from 57% in 2020.

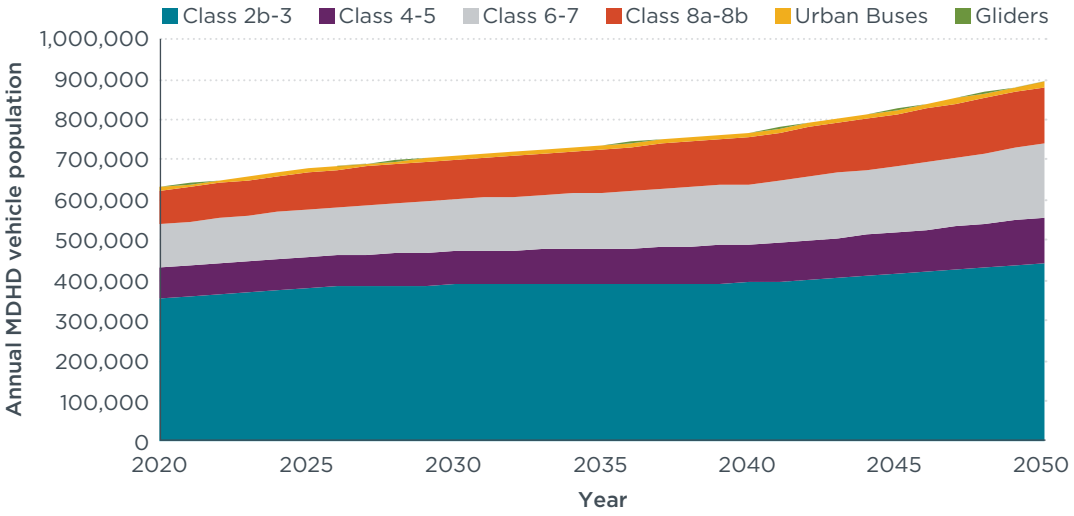

Figure 2. Annual medium- and heavy-duty vehicle population by regulatory class, 2020–2050.

Fleet-wide tank-to-wheel NOx emissions are projected to decline under all scenarios between 2020 and 2050 (Figure 3). Under a business-as-usual scenario, we project fleet-wide NOx emissions will decline 23% from 40,400 tons per year in 2020 to 31,200 tons per year in 2050. By 2035, NOx emissions will have fallen 40% below 2020 levels due to fleet turnover and replacement with the latest generation of emission control systems, including selective catalytic reduction, introduced with US 2010 engines. However, emissions will rise 28% above 2035 levels by 2050 with growth in vehicle population, vehicle miles traveled, and deteriorating per-vehicle emission rates. The introduction of ACT zero-emission sales requirements would reduce fleet-wide NOx emissions to 31% below 2020 levels by 2050, and the Heavy-Duty Omnibus standards introduced in MY 2025 would reduce fleet-wide NOx emissions to 43% below 2020

16 Available at https://theicct.org/publications/nys-hdv-regulation-benefits-may2021.

levels by 2050. The combination of ACT and Heavy-Duty Omnibus standards would deliver the greatest NOx benefits, equal to 46% below 2020 levels in 2050.

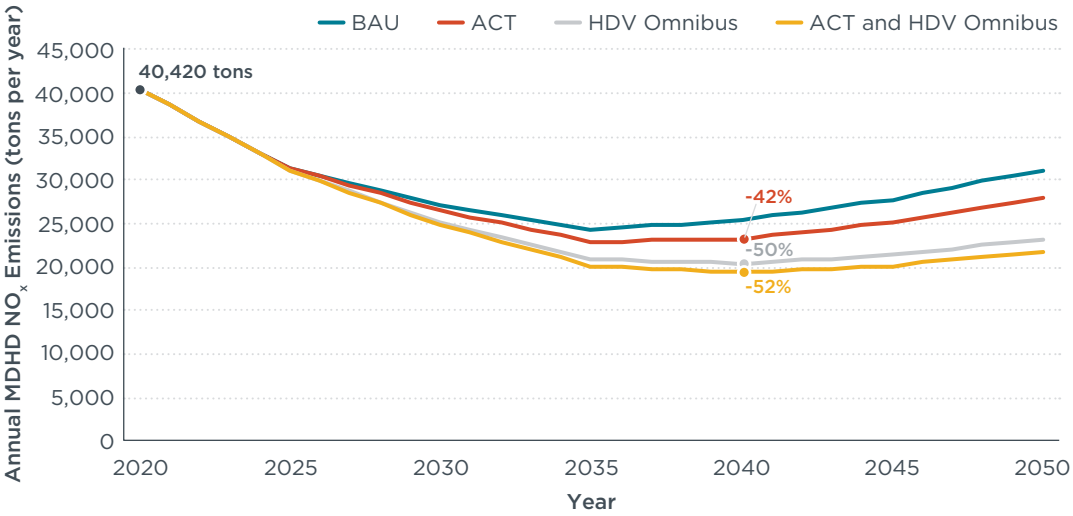

Figure 3. Medium- and heavy-duty vehicle tank-to-wheel NOx emissions by scenario (short tons per year), 2020–2050.

Fleet-wide tank-to-wheel PM2.5 emissions are also projected to decline under all scenarios (Figure 4). The latest generation of emission controls for PM, the most important being the diesel particular filter, was first introduced with model year 2007 engines. Under a business-as-usual scenario, fleet-wide PM2.5 emissions from medium- and heavy-duty vehicles will decline 55%, from 1,150 tons per year in 2020 to 520 tons per year in 2050, as fleet turnover replaces pre-2007 engines with newer engines fitted with diesel particulate filters. By comparison, implementation of ACT zero-emission sales requirements beginning in MY 2025 would reduce fleet-wide PM2.5 emissions to 59% below 2020 levels by 2050.

With ACT adoption we project New York state fleet-wide reductions between 2020-2040 of 62% and 42% of PM2.5 and NOx emissions, respectively. By comparison, ARB staff estimate in California the PM2.5 and NOx emissions benefits of ACT requirements in the Class 4-8 vocational truck category will generate reductions of 43% and 48%, respectively.

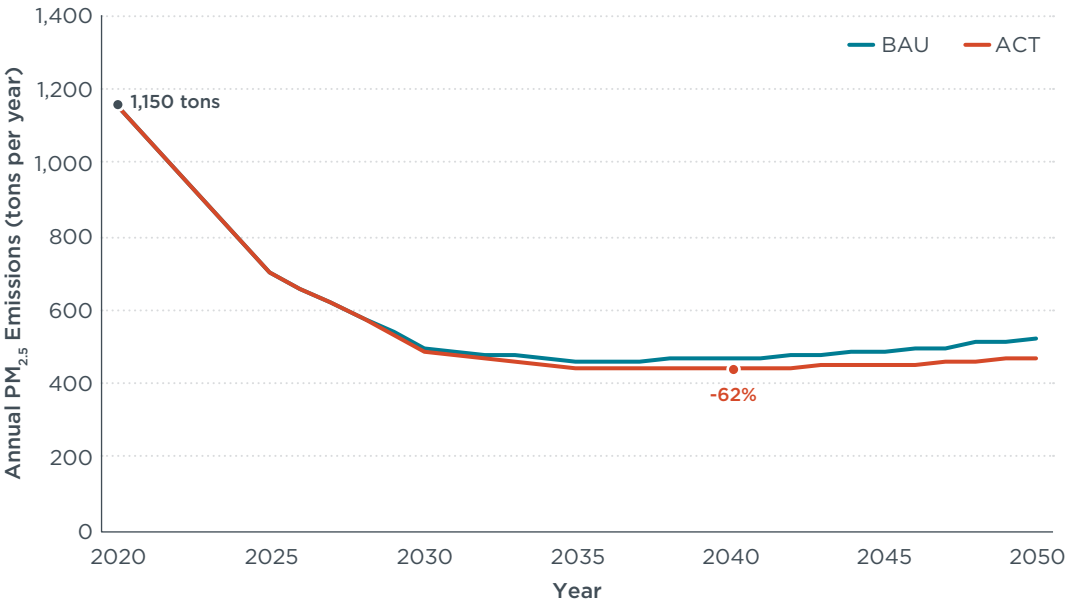

Figure 4. Medium- and heavy-duty vehicle tank-to-wheel PM2.5 emissions by scenario (short tons per year), 2020–2050.

In contrast to business-as-usual trends for PM2.5 and NOx emissions, we project well-to-wheel carbon dioxide-equivalent emissions will grow 21% above 2020 levels to 22.79 million metric tonnes per year in 2050 (Figure 5). The adoption of California Phase 2 Greenhouse Gas Emission Standards for heavy-duty vehicles and the enforcement of its trailer standards beginning with MY 2025 would limit this emissions growth to 17% above 2020 levels in 2050. By comparison, implementation of the ACT would reduce well-to-wheel greenhouse gas emissions to 2% below 2020 levels in 2050. And the combination of ACT and Phase 2 trailer standards enforcement would result in 2050 emissions 6% below 2020 levels.

Growth in vehicle activity and growth in the population of vehicles with internal combustion engines post-2040 explains in-part why the ACT does not put emissions of NOx, PM, or carbon dioxide-equivalent emissions on a permanently downward trend. Nearly three quarters of the vehicle population may continue to be ICE vehicles in 2050. Actions that shift out-of-state vehicles operating in New York towards cleaner engines, such as neighboring states adopting ACT, Heavy-Duty Omnibus, or similar federal requirements, would generate additional benefits. Other relevant actions include complementary policies such as zero-emission fleet purchase requirements designed to accelerate the replacement of vehicles with more efficient electric drive engines utilizing zero-emission electricity.

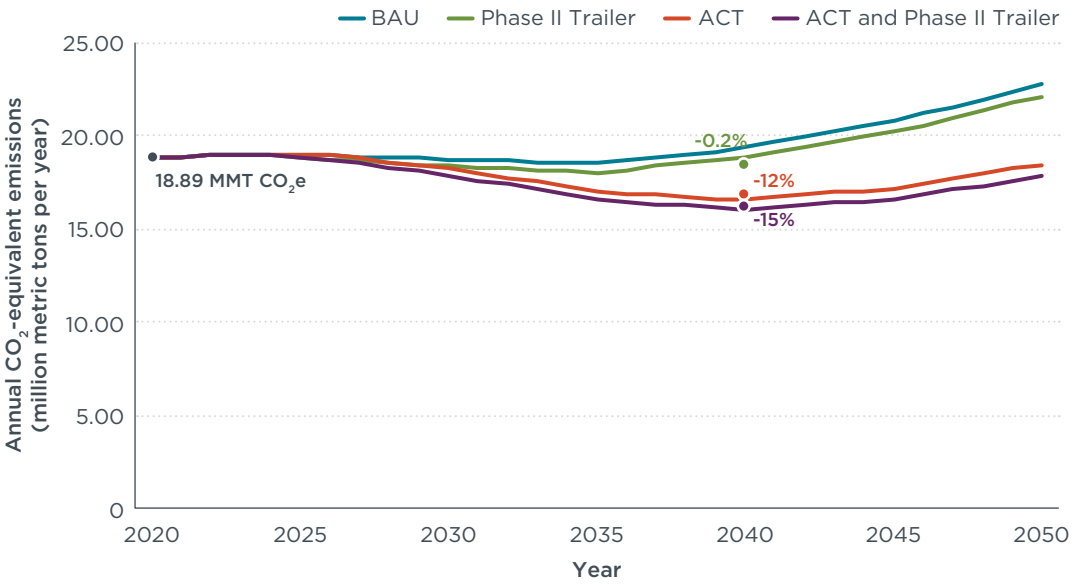

Figure 5. Medium- and heavy-duty vehicle well-to-wheel CO_2-equivalent emissions by scenario (million metric tonnes per year), 2020–2050.

Implementation of the ACT regulation would lead to growth in the population of zero-emission medium- and heavy-duty trucks in New York State (Figure 6). By 2030, we project an additional 25,200 new zero-emission trucks will have been sold over the course of the rule. By 2040, this fleet would grow to nearly 146,400 vehicles and, by 2050, the fleet would reach 228,300 vehicles. In that final year, 61% of the zero-emission truck fleet would be in the Class 2b-3 category, which comprises the largest single segment of the existing fleet, and 3% would be in the Class 8a-8b tractor category.

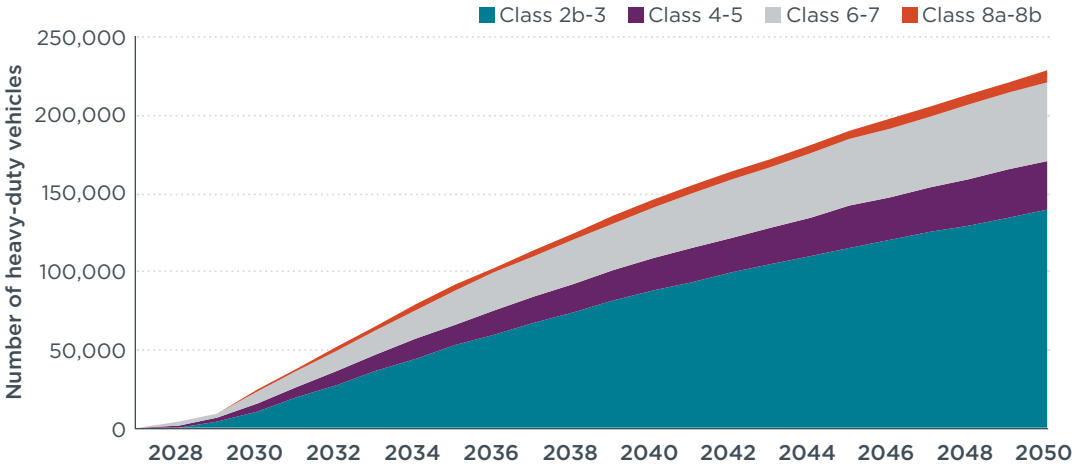

Figure 6. Cumulative medium- and heavy-duty zero-emission sales under the ACT Scenario, 2020–2050.

Conclusions

Over the next thirty years, the population of medium- and heavy-duty vehicles will grow by 40% in New York State. Over this time, state officials must attain 2008 and 2015 National Ambient Air Quality standards for ozone and reduce state-wide greenhouse gas emissions to 85% below 1990 levels. This paper evaluates the benefits to New York State of adopting three California regulations designed to reduce criteria pollutant and greenhouse gas emissions from the medium- and heavy-duty vehicle fleet. These regulations are the Advanced Clean Trucks rule, the Heavy-Duty Omnibus rule, and the California Phase II greenhouse gas rule.

Without any new policy, we estimate that fleet-wide emissions of nitrogen oxides and fine particulate matter will decline 40% and 60%, respectively, from 2020 to 2035. This trend is the consequence of the oldest and highest emitting vehicles in the fleet being replaced over time with newer vehicles designed to meet model year 2010 national tailpipe emission standards that require advanced emission control technologies like selective catalytic reduction and diesel particulate filters. But, from 2035 to 2050, NOx and PM emissions will grow 28% and 13%, respectively, as a result of a growing vehicle population and the absence of further emission reductions from the phase-in of model year 2010 emission control technologies.

The Advanced Clean Trucks rule and the Heavy-Duty Omnibus rule will reduce NOx and PM emissions further. By accelerating the deployment of zero-emission trucks and low-NOx heavy-duty engines, the combined adoption of these rules would generate 8% lower cumulative NOx emissions compared to the business-as-usual case from 2020 to 2040. Annual NOx emissions in 2050 would be 46% below 2020 levels, twice the reduction expected under the business-as-usual scenario. The Advanced Clean Trucks rule would generate cumulative PM reductions about 2% lower than the business-as-usual scenario from 2020 to 2040 and 59% lower emissions in 2050 relative to 2020 levels.

Well-to-wheel emissions of greenhouse gas emissions follow a less pronounced decline in near-term emissions followed by larger growth over the long-term. Without any new policy, we project 2% lower emissions in 2035 relative to 2020 levels following the phase-in of more efficient engines and vehicles with federal Phase 1 and 2 heavy-duty greenhouse gas emission standards and no implementation of trailer greenhouse gas standards. But, from 2035, we project growth in annual emissions, reaching 21% above 2020 levels in 2050, as the activity of trucks with internal combustion engines powered by fossil fuels grows and as the most efficient Phase 2 compliant engines and vehicles saturate the market.

The relative greenhouse gas emission benefits of the Advanced Clean Trucks rule, magnified by a zero-emission electric grid in 2040 and complemented by full implementation of trailer greenhouse gas standards, are significant. Cumulative avoided emissions are 17.91 million metric tons from 2020 to 2040, about 5% below business-as-usual. We project emissions in 2050 to be 6% lower than 2020 levels, reversing the double-digit increase expected without new policy.

Table 5. Projected emission benefits in New York State of adopting California medium- and heavy-duty vehicle regulations.

Avoided medium- and heavy-duty emissions in New York State, 2020-2040			
	NO_x (short tons)	$PM_{2.5}$ (short tons)	WTW CO_2e (million metric tonnes)
ACT	(16,210)	(230)	(17.91)
HDV Omnibus	(42,620)	-	-
Phase II Trailer Stds	-	-	(6.31)
Full Harmonization	(50,750)	(230)	(24.22)

Avoided medium- and heavy-duty emissions in New York State, 2020-2050			
	NO_x (short tons)	$PM_{2.5}$ (short tons)	WTW CO_2e (million metric tonnes)
ACT	(43,590)	(640)	(54.34)
HDV Omnibus	(108,660)	-	-
Phase II Trailer Stds	-	-	(12.29)
Full Harmonization	(128,730)	(640)	(66.63)

Appendix

The tables below list detailed information on medium- and heavy-duty vehicle growth and emissions reductions per year for each regulatory scenario.

Table A1. Annual medium- and heavy-duty vehicle population by vehicle regulatory class, 2020–2050.

	Class 2b-3	Class 4-5	Class 6-7	Class 8a-8b	Urban Buses	Gliders	Total
2020	356,970	73,060	108,640	83,710	7,700	770	**630,850**
2021	362,120	73,940	110,590	85,140	7,860	800	**640,450**
2022	367,260	74,810	112,540	86,560	8,020	820	**650,010**
2023	372,410	75,690	114,480	87,990	8,180	850	**659,600**
2024	377,550	76,560	116,430	89,410	8,340	870	**669,160**
2025	382,700	77,440	118,380	90,840	8,500	900	**678,760**
2026	384,050	78,270	120,740	92,450	8,650	910	**685,070**
2027	385,400	79,100	123,090	94,060	8,810	930	**691,390**
2028	386,750	79,930	125,450	95,680	8,960	940	**697,710**
2029	388,100	80,760	127,800	97,290	9,120	960	**704,030**
2030	389,450	81,590	130,160	98,900	9,270	970	**710,340**
2031	389,930	82,670	132,100	100,630	9,390	970	**715,690**
2032	390,420	83,750	134,040	102,350	9,520	970	**721,050**
2033	390,900	84,840	135,990	104,080	9,640	980	**726,430**
2034	391,390	85,920	137,930	105,800	9,770	980	**731,790**
2035	391,870	87,000	139,870	107,530	9,890	980	**737,140**
2036	392,220	88,560	142,170	109,420	10,040	980	**743,390**
2037	392,560	90,110	144,460	111,310	10,180	970	**749,590**
2038	392,910	91,670	146,760	113,210	10,330	970	**755,850**
2039	393,250	93,220	149,050	115,100	10,470	960	**762,050**
2040	393,600	94,780	151,350	116,990	10,620	960	**768,300**
2041	397,790	96,450	154,460	119,470	10,800	960	**779,930**
2042	401,980	98,110	157,560	121,960	10,970	950	**791,530**
2043	406,180	99,780	160,670	124,440	11,150	950	**803,170**
2044	410,370	101,440	163,770	126,930	11,320	940	**814,770**
2045	414,560	103,110	166,880	129,410	11,500	940	**826,400**
2046	420,170	105,170	170,170	131,850	11,680	930	**839,970**
2047	425,790	107,220	173,460	134,300	11,870	920	**853,560**
2048	431,400	109,280	176,750	136,740	12,050	910	**867,130**
2049	437,020	111,330	180,040	139,190	12,240	900	**880,720**
2050	442,630	113,390	183,330	141,630	12,420	890	**894,290**

Table A2. Tank-to-wheel NO_x emissions by scenario (short tons per year), 2020–2050.

	BAU	ACT	HDV Omnibus	ACT and HDV Omnibus
2020	40,420	40,420	40,420	40,420
2021	38,610	38,610	38,610	38,610
2022	36,790	36,790	36,790	36,790
2023	34,980	34,980	34,980	34,980
2024	33,160	33,160	33,160	33,160
2025	31,350	31,350	31,080	31,080
2026	30,510	30,510	29,890	29,890
2027	29,660	29,520	28,700	28,630
2028	28,820	28,530	27,520	27,360
2029	27,970	27,530	26,330	26,100
2030	27,130	26,540	25,140	24,830
2031	26,570	25,800	24,300	23,900
2032	26,010	25,070	23,460	22,970
2033	25,440	24,330	22,610	22,030
2034	24,880	23,600	21,770	21,100
2035	24,320	22,860	20,930	20,170
2036	24,530	22,940	20,820	20,020
2037	24,740	23,030	20,720	19,870
2038	24,950	23,110	20,610	19,720
2039	25,160	23,200	20,510	19,570
2040	25,370	23,280	20,400	19,420
2041	25,850	23,640	20,590	19,570
2042	26,340	24,010	20,780	19,720
2043	26,820	24,370	20,960	19,860
2044	27,310	24,740	21,150	20,010
2045	27,790	25,100	21,340	20,160
2046	28,470	25,660	21,720	20,500
2047	29,140	26,230	22,090	20,840
2048	29,820	26,790	22,470	21,180
2049	30,490	27,360	22,840	21,520
2050	31,170	27,920	23,220	21,860
Total	**894,570**	**850,980**	**785,910**	**765,840**

Notes: BAU refers to the business-as-usual scenario in which Phase II trailer standards are not implemented. ACT refers to the Advanced Clean Trucks scenario. HDV Omnibus refers to the Heavy-Duty Omnibus scenario. No scenario includes NYC MTA transit bus electrification goals (100% by 2040) or statewide transit bus electrification goals (25% by 2025 and 100% by 2035).

Table A3. Tank-to-wheel $PM_{2.5}$ emissions by scenario (short tons per year), 2020–2050.

	BAU	ACT
2020	1,150	1,150
2021	1,060	1,060
2022	970	970
2023	880	880
2024	790	790
2025	700	700
2026	660	660
2027	620	620
2028	580	580
2029	540	530
2030	500	490
2031	490	480
2032	480	470
2033	480	460
2034	470	450
2035	460	440
2036	460	440
2037	460	440
2038	470	440
2039	470	440
2040	470	440
2041	470	440
2042	480	440
2043	480	450
2044	490	450
2045	490	450
2046	500	450
2047	500	460
2048	510	460
2049	510	470
2050	520	470
Total	**18,110**	**17,470**

Notes: BAU refers to the business-as-usual scenario and ACT refers to the Advanced Clean Trucks scenario. No scenario includes NYC MTA transit bus electrification goals (100% by 2040) or State-of-the-State transit bus electrification goals applicable to 5 transit authorities (25% by 2025 and 100% by 2035).

Table A4. Well-to-wheel CO_2-equivalent emissions by scenario (million metric tonnes per year), 2020–2050.

	BAU	Phase II Trailer	ACT	ACT and Phase II Trailer
2020	18.89	18.89	18.89	18.89
2021	18.92	18.92	18.92	18.92
2022	18.95	18.95	18.95	18.95
2023	18.98	18.98	18.98	18.98
2024	19.01	19.01	19.01	19.01
2025	19.03	18.85	19.03	18.85
2026	18.98	18.76	18.98	18.76
2027	18.93	18.67	18.81	18.55
2028	18.88	18.58	18.64	18.34
2029	18.82	18.49	18.47	18.13
2030	18.77	18.39	18.30	17.93
2031	18.72	18.33	18.05	17.66
2032	18.67	18.26	17.80	17.39
2033	18.63	18.20	17.55	17.12
2034	18.58	18.13	17.29	16.85
2035	18.53	18.07	17.04	16.58
2036	18.70	18.22	16.95	16.48
2037	18.87	18.38	16.86	16.37
2038	19.04	18.54	16.77	16.27
2039	19.21	18.69	16.67	16.16
2040	19.37	18.85	16.58	16.05
2041	19.66	19.12	16.71	16.17
2042	19.95	19.39	16.84	16.28
2043	20.23	19.67	16.96	16.40
2044	20.52	19.94	17.09	16.51
2045	20.80	20.21	17.22	16.63
2046	21.20	20.60	17.47	16.87
2047	21.60	20.98	17.73	17.11
2048	22.00	21.37	17.98	17.35
2049	22.40	21.75	18.23	17.59
2050	22.79	22.13	18.49	17.83
Total	**607.60**	**595.31**	**553.26**	**540.96**

Notes: BAU refers to the business-as-usual scenario in which Phase II trailer standards are not implemented. Phase II Trailer refers to business-as-usual with Phase II trailer standards implemented from model year 2025. ACT refers to the Advanced Clean Trucks scenario. Upstream emissions include 100% zero-emission electric grid by 2040. No scenario includes NYC MTA transit bus electrification goals (100% by 2040) or statewide transit bus electrification goals (25% by 2025 and 100% by 2035). GWP-100 values are taken from the 2014 IPCC Fourth Assessment Report, (2014), https://www.ipcc.ch/report/ar4/syr. For methane the GWP100 used here is 25 and for nitrous oxide the value is 298.

Table A5. Medium- and heavy-duty zero-emission vehicle population growth attributed to the ACT by vehicle regulatory class, 2020–2050.

	Class 2b-3	Class 4-5	Class 6-7	Class 8a-8b	Total
2027	-	250	400	100	**750**
2028	880	1,350	2,120	430	**4,780**
2029	4,975	1,815	2,915	495	**10,200**
2030	10,830	4,980	7,950	1,420	**25,180**
2031	19,334	6,704	10,734	1,820	**38,592**
2032	27,838	8,428	13,518	2,220	**52,004**
2033	36,342	10,152	16,302	2,620	**65,416**
2034	44,846	11,876	19,086	3,020	**78,828**
2035	53,350	13,600	21,870	3,420	**92,240**
2036	60,384	14,978	24,040	3,660	**103,062**
2037	67,418	16,356	26,210	3,900	**113,884**
2038	74,452	17,734	28,380	4,140	**124,706**
2039	81,486	19,112	30,550	4,380	**135,528**
2040	88,520	20,490	32,720	4,620	**146,350**
2041	93,924	21,656	34,696	4,860	**155,136**
2042	99,328	22,822	36,672	5,100	**163,922**
2043	104,732	23,988	38,648	5,340	**172,708**
2044	110,136	25,154	40,624	5,580	**181,494**
2045	115,540	26,320	42,600	5,820	**190,280**
2046	120,414	27,288	44,156	6,026	**197,884**
2047	125,288	28,256	45,712	6,232	**205,488**
2048	130,162	29,224	47,268	6,438	**213,092**
2049	135,036	30,192	48,824	6,644	**220,696**
2050	139,910	31,160	50,380	6,850	**228,300**

Notes: ACT refers to the Advanced Clean Trucks scenario. Estimates are the product of total fleet population growth projected in New York State and zero-emission vehicle population shares developed by California Air Resources Board staff for the ACT. Estimates represent the additional ZEVs generated by the ACT and not the total population of ZEVs in the New York state fleet. ZEVs generated in compliance with initial ACT sales requirements are credited to the HDV GHG Phase II regulation and not the ACT until calendar year 2027. Transit buses are not regulated by the ACT and are not included here.

Table A6. New York State representative counties.

Name	County ID	NY DOT region	Representative county ID
Albany County	36001	1	36001
Allegany County	36003	6	36101
Bronx County	36005	11	36081
Broome County	36007	9	36007
Cattaraugus County	36009	5	36029
Cayuga County	36011	3	36067
Chautauqua County	36013	5	36029
Chemung County	36015	6	36101
Chenango County	36017	9	36007
Clinton County	36019	7	36089
Columbia County	36021	8	36119
Cortland County	36023	3	36067
Delaware County	36025	9	36007
Dutchess County	36027	8	36119
Erie County	36029	5	36029
Essex County	36031	1	36001
Franklin County	36033	7	36089
Fulton County	36035	2	36065
Genesee County	36037	4	36055
Greene County	36039	1	36001
Hamilton County	36041	2	36065
Herkimer County	36043	2	36065
Jefferson County	36045	7	36089
Kings County	36047	11	36081
Lewis County	36049	7	36089
Livingston County	36051	4	36055
Madison County	36053	2	36065
Monroe County	36055	4	36055
Montgomery County	36057	2	36065
Nassau County	36059	10	36103
New York County	36061	11	36081
Niagara County	36063	5	36029
Oneida County	36065	2	36065
Onondaga County	36067	3	36067
Ontario County	36069	4	36055
Orange County	36071	8	36119
Orleans County	36073	4	36055
Oswego County	36075	3	36067
Otsego County	36077	9	36007
Putnam County	36079	8	36119

Name	County ID	NY DOT region	Representative county ID
Queens County	36081	11	36081
Rensselaer County	36083	1	36001
Richmond County	36085	11	36081
Rockland County	36087	8	36119
St. Lawrence County	36089	7	36089
Saratoga County	36091	1	36001
Schenectady County	36093	1	36001
Schoharie County	36095	9	36007
Schuyler County	36097	6	36101
Seneca County	36099	3	36067
Steuben County	36101	6	36101
Suffolk County	36103	10	36103
Sullivan County	36105	9	36007
Tioga County	36107	9	36007
Tompkins County	36109	3	36067
Ulster County	36111	8	36119
Warren County	36113	1	36001
Washington County	36115	1	36001
Wayne County	36117	4	36055
Westchester County	36119	8	36119
Wyoming County	36121	4	36055
Yates County	36123	6	36101