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Technical Memo

To	Environmental Defense Fund
From	Ellen Robo, Dave Seamonds
Date	August 19, 2022
Subject	Investment Reduction Act Supplemental Assessment: *Analysis of Alternative Medium- and Heavy-Duty Zero-Emission Vehicle Business-As-Usual Scenarios*

ERM was retained by the Environmental Defense Fund (EDF) to update a previously performed assessment of projected business-as-usual medium- and heavy-duty[1] (M/HD) zero emission vehicle (ZEV) sales within the U.S. to incorporate the impacts of the Inflation Reduction Act (IRA). This memo describes the analytical methodologies used to update the baseline assessment as well as an overview of the revised results.

Summary

1) The grants and credits included in the IRA will help accelerate ZEV adoption by reducing the financial barriers of purchasing ZEVs. **In 2029, M/HD ZEV sales for the five scenarios in this analysis average 29 percent of total M/HDV sales.**

2) Compared to the previous analysis conducted before the adoption of the IRA, the M/HD ZEV sales projections for 2029 in this assessment are **46 percent higher when averaging across the five scenarios**.

3) When the IRA ZEV tax credit is incorporated, **purchase price parity for a wide range of M/HD ZEVs is reached at least 5 years and as much as 12 years earlier than would occur without the credit.**

4) Additionally, the IRA includes substantial funding for ZEV and ZEV-component domestic manufacturing, as well as charging infrastructure installations that **could further reduce the total cost of ownership of M/HD ZEVs**.

Analysis Background

As part of the comment process for the regulation proposed by the U.S. Environmental Protection Agency (EPA) on March 28, 2022, regarding new heavy-duty engine and vehicle standards,[2] ERM produced an analysis that projected a range of possible M/HD ZEV baseline adoption scenarios incorporating state policies, funding from the Infrastructure Investment and Jobs Act (IIJA), and market growth. Since that analysis was conducted, the IRA, which contains substantial funding for M/HD ZEVs, was signed into law. The IRA includes several mechanisms to incentivize the purchase of M/HD ZEVs, including grant programs as well as a ZEV tax credit program.

[1] The analysis includes M/HD vehicles greater than 14,000 lbs. gross vehicle weight (Class 4 to 8) but excludes long-haul combination trucks. See *ZEV Combination Trucks* for more information about why long-haul combination trucks were excluded. The appendix contains results for all Class 4-8 vehicles (including long-haul combination trucks).

[2] U.S. Environmental Protection Agency, Proposed Rule, "Control of Air Pollution From New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards," Federal Register 87, no. 59 (March 28, 2022): 17414-17888, https://www.govinfo.gov/content/pkg/FR-2022-03-28/pdf/2022-04934.pdf.

Medium- and Heavy-Duty Transportation-Related Components of the IRA

The Inflation Reduction Act of 2022 is a comprehensive law to aid in the reduction of inflation while investing in U.S. energy production and manufacturing, as well as help to reduce carbon emissions. The IRA includes significant investments in transportation, including several grant programs aimed at accelerating the sale of zero-emission vehicles (ZEVs), a direct ZEV credit program for M/HD ZEV purchases, and additional grants and credits for domestic ZEV manufacturing. These transportation-related programs will help reduce the incremental purchase price of vehicles, making it more economically viable for consumers and fleets to purchase ZEVs.

The following sections describe the components of the IRA that have been analyzed and ERM's underlying assumptions. It should be noted that ERM's assessment of the IRA assumes all ZEV purchases will be battery electric vehicles (BEVs) or fuel cell electric vehicles (FCEVs) and does not include the purchase of plug-in hybrid electric vehicles (PHEVs). Since PHEVs are eligible to receive tax credits from the ZEV credit program, the total number of zero-emission or near zero-emission M/HDVs may be larger than projected in this analysis.

Grant Programs

Table 1. IRA funding programs[3]

Program	Total Apportioned Funding	Eligible Vehicle Type	Assumed Percent of Total Funding for M/HD ZEV Purchases
Clean Heavy-Duty Vehicles	$1,000,000,000	Class 6 and 7 Vehicles	85%
Greenhouse Gas Reduction Fund	$27,970,000,000	All M/HD	5%
Diesel Emissions Reductions	$60,000,000	Single-Unit and Combination Trucks	75%
Funding to Reduce Air Pollution at Schools	$50,000,000	School Buses	50%
Funding to Reduce Air Pollution at Ports	$3,000,000,000	Combination Trucks	20%
Total IRA Funding Assumed for M/HD ZEV Purchases			**$2,830,100,000**

The IRA includes several grant programs that could be used to purchase M/HD ZEVs. The methodology employed to analyze the IRA programs is consistent with the methodology used in the original memo for

[3] The IRA includes provisions for United States Postal Service zero-emission delivery vehicles, which are considered M/HD vehicles; however, due to most of these vehicles being categorized as Class 2b or 3, this funding has not been included in our analysis. That said, the funds allocated for USPS are substantial and will help electrify vehicles within a sizeable federal fleet.

IIJA. See *Sales Impact of IIJA Funding* in the original analysis memo for additional information on the methodology.

Table 1 contains the specifics of each of the grant programs, the assumed vehicle types that could be purchased, and the percent of funding that might be used for MHD ZEVs. In total, ERM estimates that $2.8 billion could be allocated to M/HD ZEV purchases, which translates to the sales of an additional 74,200 vehicles between 2023 and 2031.

Since several of the programs indicate they will fund the vehicle incremental purchase price, as well as the price of charging equipment, ERM assumed this amount would be provided to grant recipients for all the programs. For purposes of this analysis, ERM derived the incremental price of a ZEV using the values in the California Air Resources Board's (CARB's) Advanced Clean Fleets (ACF) Regulation Standardized Regulatory Impact Assessment (SRIA) released in May 2022.[4] In the SRIA, CARB includes purchase price projections for different M/HDV types powered using diesel, gasoline, battery-electric, and fuel cell powertrains for the years 2024 to 2035. Using this data, an average bus, single-unit truck, and combination truck incremental ZEV price was calculated. The charger costs for BEVs were calculated using ICF and ICCT values.[5] Next, ERM allocated each funding program to individual states based on population.[6]

Some analyses have projected lower incremental prices compared to the values in the CARB SRIA, particularly for vehicle types well suited for electrification. If ZEV prices decrease faster than CARB projects, the theoretical number of ZEVs that will be funded by the IRA grant programs would increase. Using the projected ZEV prices from Roush,[7] the IRA grants could fund the purchase of 98,200 ZEVs between 2023 and 2031.

The percent of each grant program that will be used to fund purchases of ZEVs was estimated by ERM based on available grant materials and remains an area for uncertainty. It is possible that ERM's assessments are underestimating the funding that will be directed toward ZEV purchases given the substantial pool of funds available within these grant programs. In 2027, for each additional $100 million directed towards M/HD ZEVs, between 3,100 and 3,300 additional vehicles could be electrified.

[4] "Advanced Clean Fleets Regulation Standardized Regulatory Impact Assessment," State of California Air Resources Board, May 18, 2022.

[5] Michael Nicholas, *Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas* (The International Council on Clean Transportation, August 2019), https://theicct.org/wp-content/uploads/2021/06/ICCT_EV_Charging_Cost_20190813.pdf.

[6] US Census Bureau, "Annual Estimates of the Resident Population for the United States", 2020, https://www2.census.gov/programs-surveys/popest/tables/2010-2020/state/totals/nst-est2020.xlsx.

[7] Vishnu Nair et al., "Technical Review of: Medium and Heavy-Duty Electrification Costs MY 2027-2030" Roush Industries (February 2022). http://blogs.edf.org/climate411/files/2022/02/EDF-MDHD-Electrification-v1.6_20220209.pdf.

ZEV Tax Credit Program

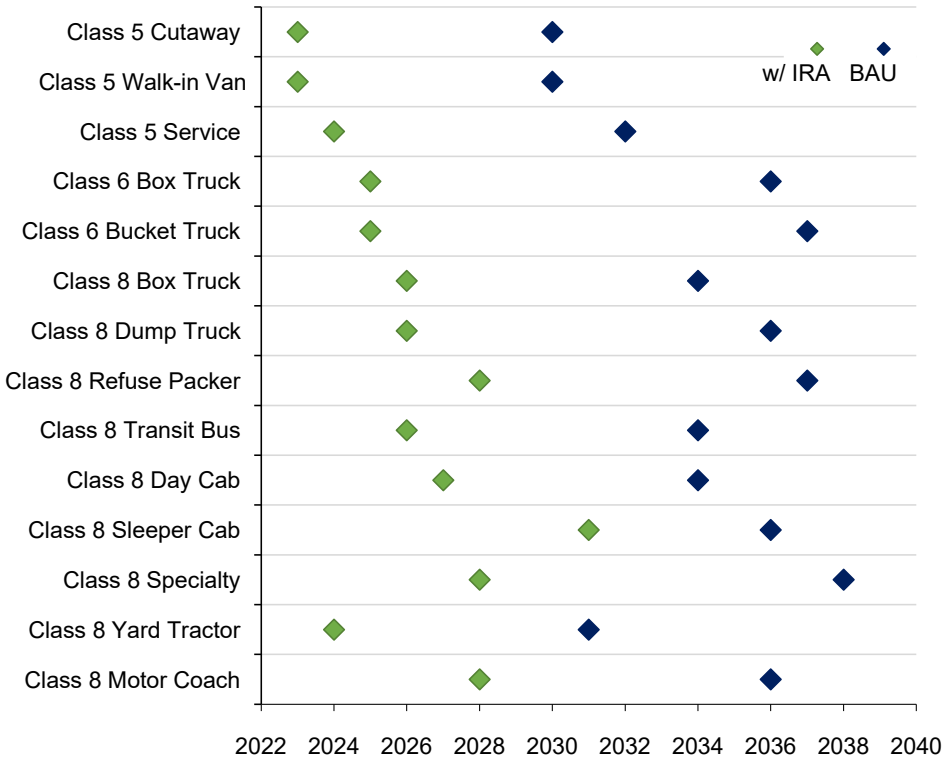
The IRA contains a section, "Credit for Qualified Commercial Clean Vehicles," which provides a tax credit for those who purchase qualified M/HDVs between 2023 and 2032. The credit amount is the smallest value of:

(1) 30 percent of the vehicle price;[8]

(2) The incremental cost of the vehicle; or

(3) $40,000.[9]

Figure 1. Year purchase price parity is achieved for a range of types of ZEVs compared to internal combustion vehicles for business-as-usual and with the IRA



The incremental and total ZEV purchase prices are required to determine the eligible ZEV credit amount. The CARB's ACF SRIA was used once again to calculate these two values. Since CARB's vehicle pricing estimates were only provided for 2024 through 2035, ERM extrapolated the vehicle prices for 2023 and from 2036 to 2040 utilizing the existing prices. Using this data, ERM calculated the year each vehicle type reaches purchase price parity compared with an equivalent diesel-powered vehicle under a business-as-usual (BAU) scenario. All vehicles reach price parity between 2030 and 2038. These years are shown in blue in Figure 1 above. With the ZEV credit applied to the purchase price, ERM recalculated the year purchase price parity is met, shown in green in Figure 1.

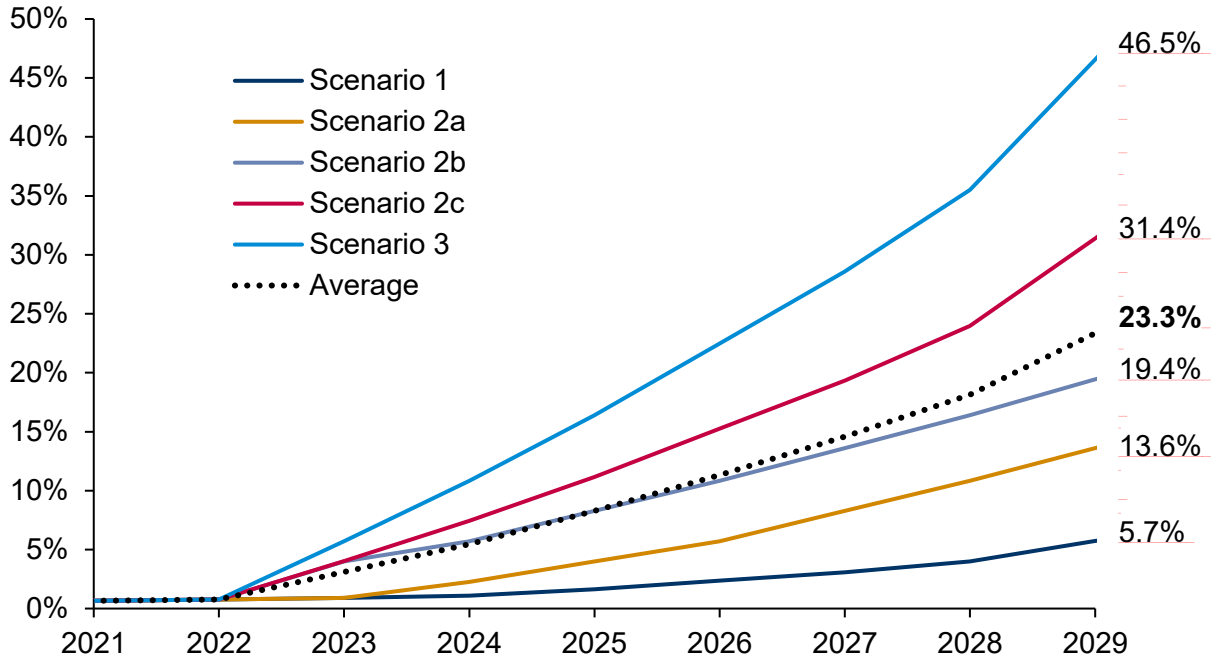
[8] The credit amount can only equal 15 percent of a clean vehicle that still contains a gasoline or diesel engine, such as a plug-in hybrid electric vehicle. This analysis assumes all ZEVs are either battery-electric or fuel cell vehicles.

[9] The upper limit of the credit is $7,500 for vehicles with a GVWR of less than 14,000 pounds but since this analysis only considers vehicles in Class 4 to 8, all vehicles have an upper limit of $40,000.

Using CARB's vehicle pricing estimates, IRA funding accelerates the year in which purchase price parity is reached, ranging from 5 years to as much as 12 years. With the ZEV credit, all vehicles reach purchase price parity by 2031, with 9 of the 14 vehicle categories reaching parity by 2027, and two reaching price parity by 2023.

Some studies have shown purchase price parity might be reached sooner than projected by CARB. Roush projected price parity would be reached no later than 2027 for some vehicle types well suited for electrification, including school buses, transit buses, Class 5 shuttle buses, Class 5 and 7 delivery vans, and Class 8 refuse trucks.[10] Four of these vehicle types would reach price parity by 2024. Even for vehicles well suited for electrification, the IRA speeds up when purchase price parity is met. With the ZEV credit, all the vehicles in the Roush study reach price parity in 2023 stimulating market growth for those vehicles.

Figure 2. Average Class 4-8 ZEV sales due to market growth updated to include impact of IRA ZEV credits



In the original analysis, ERM established a range of possible baseline M/HD ZEV market growth projections. Market growth is intended to account for sales due to increasing cost competitiveness of ZEVs, along with fleet commitments by corporations and public entities. See *Sales Impact of Market Growth* for more information about the original assessment. Since access to the ZEV credits for clean M/HDVs will speed up purchase price parity and make ZEVs cost competitive at the time of purchase, it can be expected that the market growth projections would also be accelerated. For this analysis, ERM has assumed the market growth projections will be accelerated by two years for Scenarios 2b, 2c, and 3. Since Scenarios 1 and 2a in the original analysis assumed very low levels of market growth and the sales were predominately driven by state adoption of the ACT, these trajectories were increased to account for the IRA. Similar to the market growth trajectories in the original analysis, Scenario 1 is assumed to be a

[10] Nair et al., "Technical Review"

third of the growth in the NREL analysis,[11] meaning it would take 3 times longer to reach each sales milestone projected by NREL, and the market growth for Scenario 2a is one-half NREL growth. It should be noted that Scenario 2a now has the same market growth Scenario 2b had in the original analysis. See Figure 2 for the updated market growth projections.

Because ZEVs provide significant fuel and maintenance savings compared to internal combustion engine (ICE) vehicles, even without subsidies, many categories of ZEVs are projected to be cost competitive when considering total cost of ownership (TCO) within the next five years. See *ZEV-ICE Cost Parity* in the original assessment for more details. With the additional reduction in purchase price due to the ZEV credit, the TCO of ZEVs will be markedly lower than that of ICE vehicles. Unlike diesel or gasoline M/HD vehicles, ZEV owners must consider the added upfront costs associated with charging or refueling infrastructure; however, the IRA includes credits for refueling infrastructure, helping to further reduce barriers of adoption. This is additional evidence that M/HD ZEV sales will increase substantially in the coming decade as they become the more economical choice for fleets.

Vehicle Manufacturing and Refueling Infrastructure Programs

The IRA additionally provides billions of dollars to accelerate clean vehicle manufacturing in the U.S. through tax credits for battery production and critical mineral mining, as well as loans and grants for domestic production of ZEVs.

Advanced Manufacturing Production Credit: This program provides between $10 and $45 per kilowatt-hour of battery storage produced in the U.S. as well as 10 percent of the costs of procuring critical minerals within the U.S.

Advanced Energy Project Credit: The IRA extends this program and increases the potential claims to $10 billion. It allows for up to a 30 percent tax credit on investments in a qualified energy project including ZEV vehicle, vehicle-component, and charging infrastructure manufacturing.

Advanced Technology Vehicle Manufacturing: Through 2028, $3 billion is available as direct loans for "reequipping, expanding, or establishing a manufacturing facility in the United States to produce…advanced technology vehicles".

Domestic Manufacturing Conversion Grants: With 50 percent cost sharing, $2 billion in grants are available for "domestic production of efficient hybrid, plug-in electric hybrid, plug-in electric drive, and hydrogen cell electric vehicles" through 2031.

Alternative Fuel Refueling Property Credit: The IRA extends and expands this program. Individuals can receive a 30 percent tax credit for "refueling property" (i.e., EV charging stations or fuel cell refill infrastructure) up to $1,000 and businesses can receive a 6 percent tax credit for refueling property up to $100,000.

Combined, these programs provide wide-ranging incentives to increase and speed up domestic ZEV production and refueling infrastructure installation. Manufacturing increased levels of ZEVs in the U.S. will be pivotal to ensuring that demand for vehicles funded by the IRA can be met. These programs could also have beneficial effects on vehicle TCO, aiding further market uptake. While not contemplated in this analysis, domestic manufacturers producing batteries could pass along a portion of the incentive realized to their customers, helping decrease the purchase price of ZEVs and improving the lifetime costs experienced by vehicle owners.

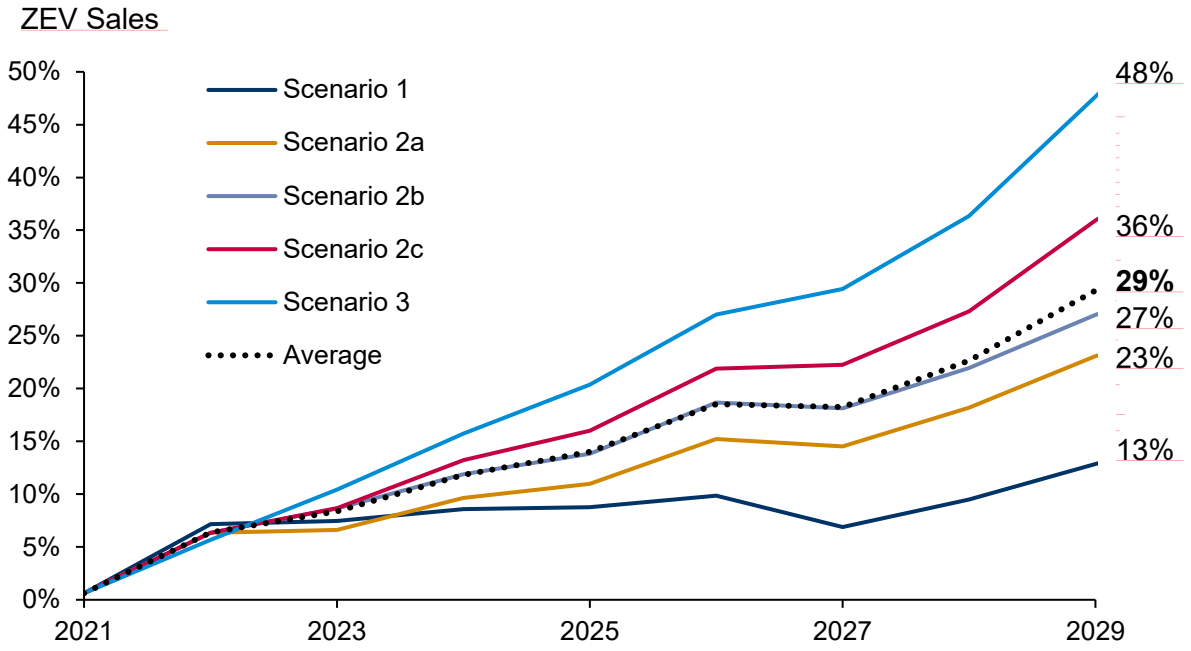
[11] Catherine Ledna et al., "Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis." NREL (March 2022). https://www.nrel.gov/docs/fy22osti/82081.pdf

The IRA includes provisions to boost both supply and demand of M/HD ZEVs in the U.S., thus increasing the likelihood of a higher trajectory of ZEV sales. These provisions will lower ZEV prices to be competitive with ICE vehicles while incentivizing manufacturers to produce ZEVs and ZEV components in the U.S. By taking a multifaceted approach to spurring ZEV adoption domestically, the IRA reduces the risk of excess supply or demand in the market.

Results

Under the five different scenarios, projected Class 4-8 ZEV sales, updated to include the impacts of the IRA, span a wide range, from 13 percent to 48 percent ZEV sales in 2029.[12] Figure 3 shows the trajectories of ZEV sales for the different scenarios.

Figure 3. M/HD ZEV sales under different scenarios updated to include the impacts of IRA



Note: the initial higher ZEV sales for Scenario 1 and lower ZEV sales for Scenario 3 is due to the assumptions made around IIJA and IRA funding. Since credits from M/HD ZEVs sold before ACT begins can be used once the state implements sales requirements, IIJA and IRA funded ZEVs in states with the ACT are not counted since they will not increase the total number of ZEVs sold in the U.S.

The average value of the five scenarios is plotted as a black dotted line on Figures 2, 3, and A1 in the appendix. While uncertainty remains around the exact M/HD ZEV sales trajectory through the end of the decade, the five scenarios in this analysis provide a reasonable range for possible eventualities. Scenario 1 represents the M/HD ZEV sales if no additional action is taken by states and market growth increases slightly in the next seven years; this means states and vehicle purchasers will have failed to take advantage of the possible ZEV credit opportunities provided by the IRA. Scenario 3 represents the sales with optimistic but reasonable additional state action and full utilization of ZEV funding programs. An average value of all five scenarios represents the most reasonable estimation of ZEV sales given the current level of information.

[12] The sales percentages for each scenario and each year are included in a table in the appendix.

Transit and School Bus Sales Projections

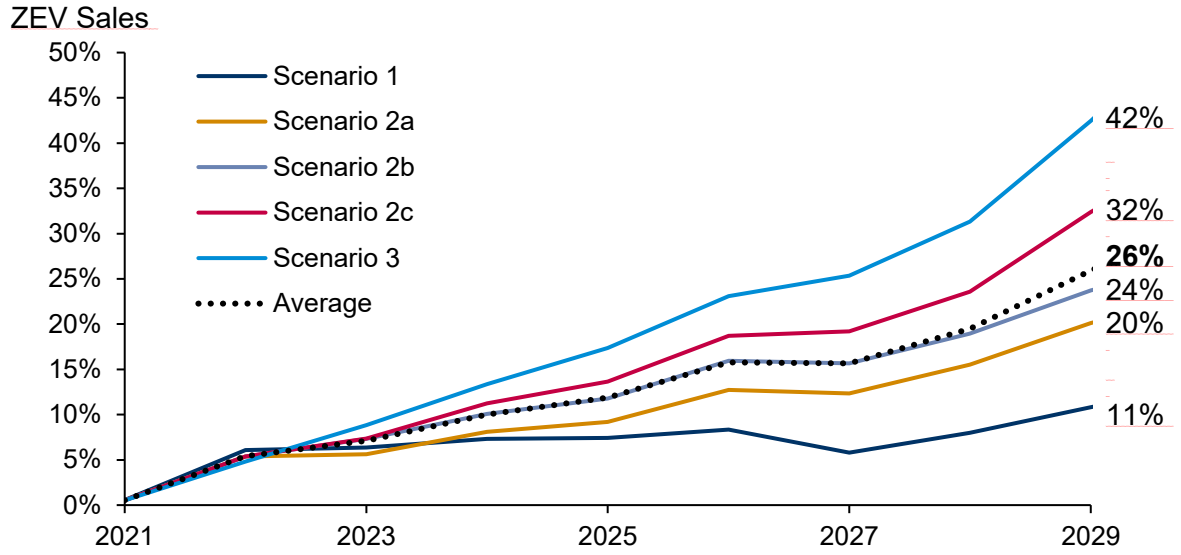
The IRA is anticipated to spur zero-emission bus (ZEB) adoption, both in the transit and school transport sectors. It contains programs such as the “Funding to Reduce Air Pollution at Schools” which identifies purchases of ZEBs as an eligible use of funding. In addition to the grant programs directed at ZEBs, the ZEV credit program accelerates purchase price parity making transitioning bus fleets to ZEBs more economically viable. By 2029, the analysis projects ZEB sales range from 15 to 48 percent with significant sales between 2022 and 2026 due to IIJA and IRA funding. It is likely that ZEB sales will continue to grow as manufacturers ramp up production to meet IIJA driven demand and the ZEV credit causes ZEBs to reach purchase price parity by 2027.

Appendix

Including Long-Haul Combination Trucks

Long-haul combination trucks (CTs) were not included in the above analysis. Given the challenges of transitioning long-haul CTs to ZEVs, they are expected to make up a smaller share of CT ZEV sales relative to short-haul CTs. However, to get a clearer sense of overall Class 4-8 ZEV sales, the analysis was also conducted including long-haul CTs. Figure A1 shows the ZEV sales for Class 4-8 vehicles including long-haul CTs.

Figure A1. M/HD ZEV sales under different scenarios including long-haul combination trucks



M/HD ZEV Sales by Scenario

Below are the ZEV sales in thousand vehicles and percent of total M/HD sales broken out by each factor examined in this analysis: state regulatory action, IIJA and IRA funding, and market growth.

Table A1. Scenario 1 results

	Scenario 1											
		M/HD ZEV Sales (Thousands)						Percent				
	M/HDV Annual Sales	State Reg. Action	IIJA	IRA	Market Growth	Total ZEV		State Reg. Action	IIJA	IRA	Market Growth	Total ZEV
2021	470.75	0.48			2.49	2.96		0.1%	0.0%	0.0%	0.5%	0.6%
2022	478.78	0.50	23.45	7.45	2.95	34.34		0.1%	4.9%	1.6%	0.6%	7.2%
2023	486.96	0.66	23.96	8.30	3.49	36.42		0.1%	4.9%	1.7%	0.7%	7.5%
2024	495.30	4.20	24.65	9.37	4.33	42.55		0.8%	5.0%	1.9%	0.9%	8.6%
2025	503.80	10.22	25.05	2.26	6.58	44.11		2.0%	5.0%	0.4%	1.3%	8.8%
2026	512.46	12.80	25.46	2.61	9.64	50.51		2.5%	5.0%	0.5%	1.9%	9.9%
2027	521.29	19.73		3.32	12.83	35.88		3.8%	0.0%	0.6%	2.5%	6.9%
2028	530.29	29.41		3.98	16.93	50.32		5.5%	0.0%	0.8%	3.2%	9.5%
2029	539.46	39.92		4.76	24.69	69.37		7.4%	0.0%	0.9%	4.6%	12.9%

Table A2. Scenario 2a results

	Scenario 2a										
	M/HDV Annual Sales	M/HD ZEV Sales (Thousands)					Percent				
		State Reg. Action	IIJA	IRA	Market Growth	Total ZEV	State Reg. Action	IIJA	IRA	Market Growth	Total ZEV
2021	470.75	0.67			2.24	2.92	0.1%	0.0%	0.0%	0.5%	0.6%
2022	478.78	0.70	20.45	6.51	2.66	30.32	0.1%	4.3%	1.4%	0.6%	6.3%
2023	486.96	0.87	20.90	7.25	3.15	32.18	0.2%	4.3%	1.5%	0.6%	6.6%
2024	495.30	10.02	21.50	8.19	8.06	47.77	2.0%	4.3%	1.7%	1.6%	9.6%
2025	503.80	17.05	21.85	1.98	14.52	55.40	3.4%	4.3%	0.4%	2.9%	11.0%
2026	512.46	32.26	22.21	2.29	21.19	77.95	6.3%	4.3%	0.4%	4.1%	15.2%
2027	521.29	41.54		2.91	31.22	75.66	8.0%	0.0%	0.6%	6.0%	14.5%
2028	530.29	51.36		3.49	41.58	96.43	9.7%	0.0%	0.7%	7.8%	18.2%
2029	539.46	67.10		4.17	53.16	124.44	12.4%	0.0%	0.8%	9.9%	23.1%

Table A3. Scenario 2b results

	Scenario 2b										
	M/HDV Annual Sales	M/HD ZEV Sales (Thousands)					Percent				
		State Reg. Action	IIJA	IRA	Market Growth	Total ZEV	State Reg. Action	IIJA	IRA	Market Growth	Total ZEV
2021	470.75	0.67			2.24	2.92	0.1%	0.0%	0.0%	0.5%	0.6%
2022	478.78	0.70	20.45	6.51	2.66	30.32	0.1%	4.3%	1.4%	0.6%	6.3%
2023	486.96	0.87	20.90	7.25	13.13	42.16	0.2%	4.3%	1.5%	2.7%	8.7%
2024	495.30	10.02	21.50	8.19	19.12	58.83	2.0%	4.3%	1.7%	3.9%	11.9%
2025	503.80	17.05	21.85	1.98	28.85	69.73	3.4%	4.3%	0.4%	5.7%	13.8%
2026	512.46	32.26	22.21	2.29	38.90	95.66	6.3%	4.3%	0.4%	7.6%	18.7%
2027	521.29	41.54		2.91	50.02	94.47	8.0%	0.0%	0.6%	9.6%	18.1%
2028	530.29	51.36		3.49	61.51	116.36	9.7%	0.0%	0.7%	11.6%	21.9%
2029	539.46	67.10		4.17	74.31	145.59	12.4%	0.0%	0.8%	13.8%	27.0%

Table A4. Scenario 2c results

	Scenario 2c										
	M/HDV Annual Sales	M/HD ZEV Sales (Thousands)					Percent				
		State Reg. Action	IIJA	IRA	Market Growth	Total ZEV	State Reg. Action	IIJA	IRA	Market Growth	Total ZEV
2021	470.75	0.48			2.24	2.92	0.1%	0.0%	0.0%	0.5%	0.6%
2022	478.78	0.50	23.45	6.51	2.66	30.32	0.1%	4.3%	1.4%	0.6%	6.3%
2023	486.96	0.66	23.96	7.25	13.26	42.29	0.2%	4.3%	1.5%	2.7%	8.7%
2024	495.30	4.20	24.65	8.19	25.86	65.57	2.0%	4.3%	1.7%	5.2%	13.2%
2025	503.80	10.22	25.05	1.98	39.83	80.71	3.4%	4.3%	0.4%	7.9%	16.0%
2026	512.46	12.80	25.46	2.29	55.44	112.20	6.3%	4.3%	0.4%	10.8%	21.9%
2027	521.29	19.73		2.91	71.58	116.02	8.0%	0.0%	0.6%	13.7%	22.3%
2028	530.29	29.41		3.49	90.08	144.92	9.7%	0.0%	0.7%	17.0%	27.3%
2029	539.46	39.92		4.17	122.54	193.81	12.4%	0.0%	0.8%	22.7%	35.9%

Table A5. Scenario 3 results

	Scenario 3										
		M/HD ZEV Sales (Thousands)					Percent				
	M/HDV Annual Sales	State Reg. Action	IIJA	IRA	Market Growth	Total ZEV	State Reg. Action	IIJA	IRA	Market Growth	Total ZEV
2021	470.75	0.48			2.03	2.86	0.2%	0.0%	0.0%	0.4%	1%
2022	478.78	0.50	23.45	5.75	2.41	27.22	0.2%	3.8%	1.2%	0.5%	6%
2023	486.96	0.66	23.96	6.40	24.76	50.81	0.2%	3.8%	1.3%	5.1%	10%
2024	495.30	4.20	24.65	7.22	41.34	77.91	2.1%	3.9%	1.5%	8.3%	16%
2025	503.80	10.22	25.05	1.75	64.26	102.70	3.4%	3.9%	0.3%	12.8%	20%
2026	512.46	12.80	25.46	2.02	80.41	138.47	7.1%	3.9%	0.4%	15.7%	27%
2027	521.29	19.73		2.57	103.11	153.42	9.2%	0.0%	0.5%	19.8%	29%
2028	530.29	29.41		3.08	129.11	192.77	11.4%	0.0%	0.6%	24.3%	36%
2029	539.46	39.92		3.68	174.00	257.11	14.7%	0.0%	0.7%	32.3%	48%