Impact of the Inflation Reduction Act of 2022 on Medium- and Heavy-Duty Electrification Costs for MYs 2024 and 2027

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Abbreviations and Acronyms

AC	Alternating Current
BEV	Battery Electric Vehicle
CTC	Cell-to-Chassis
CTP	Cell-to-Pack
DC	Direct Current
DCFC	Direct Current Fast Charging
DERA	Diesel Emissions Reduction Act
DOE	U.S. Department of Energy
EAM	Electrode Active Material
EDF	Environmental Defense Fund
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	Electric Vehicle
FCEV	Fuel cell electric vehicle
GHG	Greenhouse Gas
IRA	Inflation Reduction Act
ITC	Investment Tax Credit
kWh	Kilowatt-hour
LDV	Light-Duty Vehicle
MD/HD	Medium- and Heavy-Duty
MSRP	Manufacturer's Suggested Retail Price
OCED	Office of Clean Energy Demonstrations
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PTC	Production Tax Credit
TCO	Total Cost of Ownership
U.S.C.	United States Code

Executive Summary

Key Highlights

This study assesses and quantifies, where possible, the key impacts of the 2022 Inflation Reduction Act (IRA) on the cost of electrifying medium- and heavy-duty vehicles (MD/HDVs), using the costs from our previous study as a baseline [1]. As an extension to the previous report, we evaluate the impact of the IRA on the cost of electrifying MD/HDVs that have access to overnight recharging at a central location, including Class 8 transit buses, Class 7 school buses, Class 3–7 shuttles and delivery vehicles, and Class 8 refuse haulers. We quantify the impact of the IRA credits on the purchase price of battery electric vehicles (BEVs) for model years (MYs) 2024 and 2027, the total cost of ownership (TCO), and the resulting cumulative savings for MYs 2024 and 2027.

The key takeaways of the study are:

a) The IRA credits help absorb the higher upfront cost of BEVs and will accelerate the purchase parity of many MHD segments analyzed so that now all segments analyzed will meet purchase price parity with their diesel counterparts if purchased as early as MY 2024, assuming reasonable economies of scale for BEV production.

b) Our original cost projections showed that BEV operating costs are always lower than ICEV operating costs. The new IRA credits for BEVs and chargers will reduce the amount of time needed for BEVs to achieve TCO parity with ICEVs by an additional 1-2 years. Many segments analyzed will see TCO parity at the time of purchase as early as 2024.

c) The purchaser of a BEV in MY 2024 would save an estimated $17,000 on a Class 3 delivery van and $500,000 on an urban transit bus over the life of the BEV compared to a comparable diesel vehicle. If we assume that diesel fuel prices return to the prices occurring during the summer of 2022, the lifetime savings due to switching to a BEV would increase to $33,000 for a Class 3 delivery van and $700,000 for an urban transit bus.

d) The IRA also includes tax credits and other incentives for several aspects of battery production. These IRA provisions could lead to lower-priced batteries than we originally projected, or to batteries with competitive prices where much of the manufacturing occurred in the U.S. and North America.

Emissions from medium- and heavy-duty (MD/HD) diesel trucks, as well as buses of all classes, contribute to pollution that harms both human health and the environment. Medium- and heavy-duty vehicles (MD/HDVs) make up more than a quarter of transportation-produced greenhouse gas (GHG) emissions [2]. Diesel exhaust is a source of particulate emissions, nitrogen oxides (NOx), and other pollutants that have a detrimental effect on human health. Furthermore, greenhouse gas emissions contribute to climate change and are under regulatory scrutiny. The previous study from February 2022, *"Technical Review of Medium- and Heavy-Duty Electrification Costs for MY 2027–2030,"* which was prepared for the Environmental Defense Fund (EDF), analyzed the cost of electrifying several segments of the MD/HD market [1]. The analyzed MD/HDVs included delivery, box and stake trucks, and shuttle vehicles in classes 3–7, as well as class 8 transit and class 7 school buses. The battery-electric MD/HDVs in these segments have the advantage of overnight recharging at a central location, in contrast to the harmful emissions from their diesel counterparts.

This study projected the cost of electrification in three model years (MYs), 2021, 2024, and 2027 by estimating the direct manufacturing cost (DMC) of electric and diesel powertrains and working up to retail equivalent vehicle prices. Economies of scale in BEV manufacturing were assumed to exist. To these vehicle price equivalents were added fuel/energy and maintenance costs, and for BEVs, the cost of a charger, to project the lifetime costs of ownership (TCO) for both BEVs and diesel vehicles.

Key Assumptions and Methodology

The Inflation Reduction Act (IRA), signed into law on August 16, 2022, contains multiple provisions that are intended to combat climate change. It incentivizes investments that will strengthen American manufacturing and supply chains, create jobs, and lower costs for consumers. Specifically, it promotes the growth and adoption of clean transportation options such as zero-emission vehicles (ZEVs) and plug-in hybrid electric vehicles (PHEVs) to further mitigate emissions. It includes incentives, tax credits, and funding for various programs to fast-track the transition to clean energy by electrifying automobiles to address GHG emissions and air pollution and strengthen energy security. It is a game-changing move that will help accelerate the clean energy transition and increase the economic viability of electric vehicles (EVs) while creating a resilient, secure, and environmentally sustainable transportation sector.

The incentives contained in the IRA will catalyze the adoption of battery-electric MD/HDVs, advancing the benefits to prospective fleet owners in the near term. This study evaluated the impact of the IRA of 2022 on the electrification of medium- and heavy-duty market segments and looked at the impact of higher fuel prices. In addition, as in the previous study, we assume large economies of scale in BEV manufacturing and production.

This study assesses and quantifies where possible the key impacts of the IRA, both quantitatively where possible and qualitatively otherwise, on the cost of electrifying medium- and heavy-duty (MD/HD) vehicles in the reference case of our previous analysis of the incremental cost of electrifying selected HDVs. The reference case provides an estimate of the median prediction, or the most likely outcome, for all costs associated with the vehicle with a purchase timeframe of 2027 among the options considered. In addition, we examine the immediate impact of the IRA of 2022 on the purchase price, parity timeline, and cost of ownership of MY 2024 BEV. This evaluation provides a glimpse into the profound impact of IRA on the MD/HD segment in the immediate term for MY 2024 BEVs as well as in the medium term for MY 2027 BEVs, which was analyzed in the previous study. We only include the result of the TCO analysis for 2027 since there is hardly any difference between a TCO for a MY 2024 and a MY 2027 BEV. In this analysis, we have assumed the same operating expenses between the two MYs, with only the vehicle price varying between them.

Summary of IRA Credits Evaluated

The IRA contains many provisions which impact the production and use of heavy-duty BEVs. Here, we estimate the impact of two of the tax incentive provided on the cost of purchasing and operating BEVs quantitatively. These incentives are the tax credits of up to $7500-$40,000 provided to purchasers of heavy-duty BEVs and the 30% tax credit for BEV charging equipment in certain geographical areas. We also illustrate the potential impact of tax incentives applied to the production of battery packs and BEVs to either lower battery costs or enable more domestically-based supply chains.

Impact of Qualified Commercial Clean Vehicle Credit on Purchase Price Parity

The qualified commercial clean vehicle credit benefits the end consumer immensely by decreasing the purchase price of BEVs and bringing them on par with their ICEV counterparts. Overall, the results of this study demonstrate that after the application of commercial clean vehicle credits of up to $7,500 for vehicles with a gross vehicle weight rating (GVWR) of less than 14,000 lbs. (up to class 3) and $40,000 for others (classes 4 and above), all considered vehicle classes will achieve effective purchase price parity immediately in 2024. As shown in Figure 1, these credits accelerate the purchase parity of C8 Transit, C5 Shuttle, C3 Van, C5 Delivery, and C7 Delivery in the near term. Furthermore, these credits help absorb higher BEV prices without penalizing the end user.

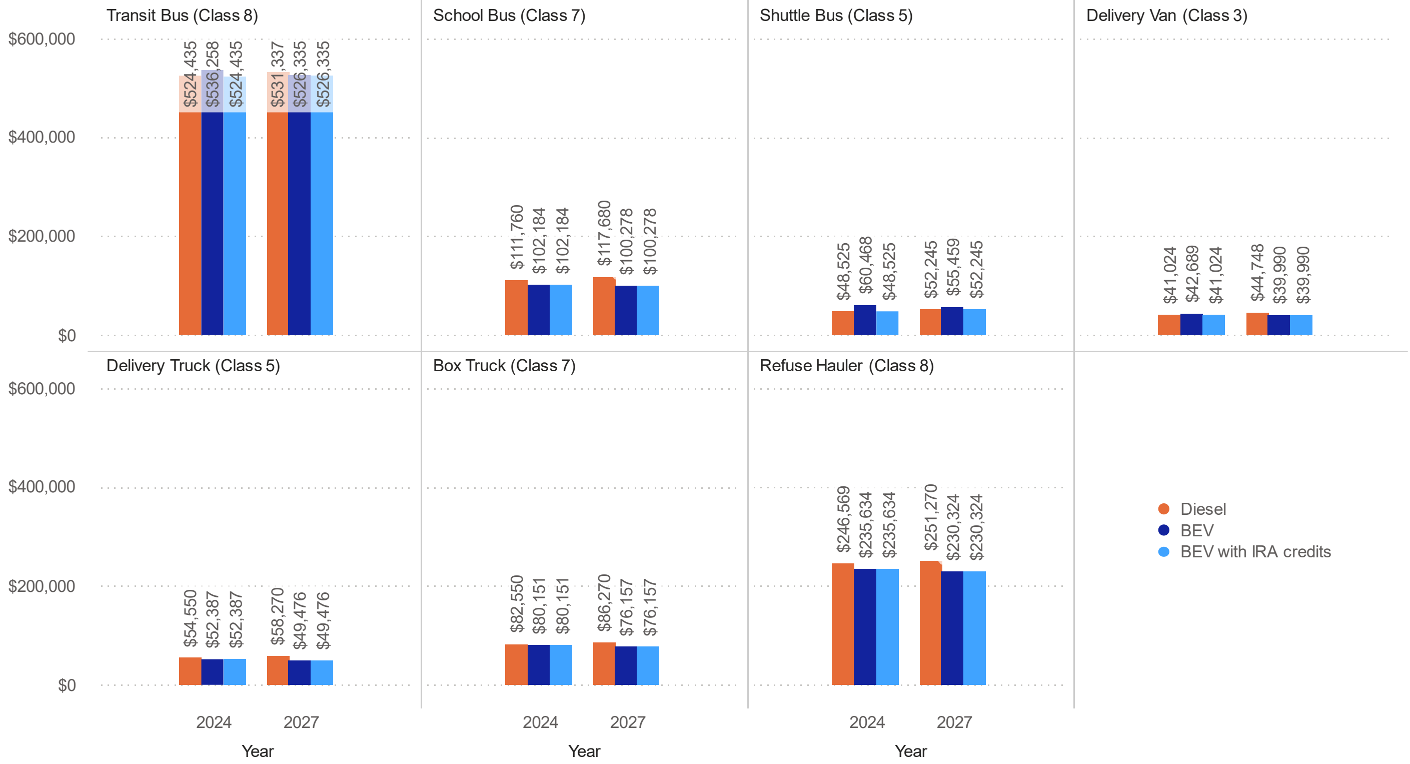


Figure 1: Impact of the IRA of 2022 Qualified Commercial Clean Vehicle Credits on MYs 2024 and 2027 BEV purchase prices.

Impact of Qualified Commercial Clean Vehicle and Alternative Fuel Refueling Property Credits Time to Reach TCO Parity

The previous study costed the charger equipment based on individual vehicle class's requirement and the projected case (scenario). The charging equipment differs for each class based on their sizing requirements. The charging scenario for the low-, reference-, and high-case were 6-hour depot charge, 4-hour depot charge, and DC fast charging, respectively. In the reference case, the charger size varies from 25 kW to 100 kW AC charger.

We applied qualified commercial clean vehicle credit and alternative fuel refueling property credit to vehicles from MYs 2024 and 2027 to assess the impact on TCO parity. We estimate that the charging unit-related savings can range from $1,064 for a 25 kW AC charger to $26,000 for a 300+ kW DC charger per vehicle. For a typical fleet owner, the combination of the matching sticker price and the charger equipment subsidy substantially reduces the TCO. However, it should be noted that the charging or refueling property would be eligible for credit only if it was installed in a low-income or rural census tract. Figure 2 shows the potential impact of the alternative fuel refueling property tax credit on BEV charger costs.

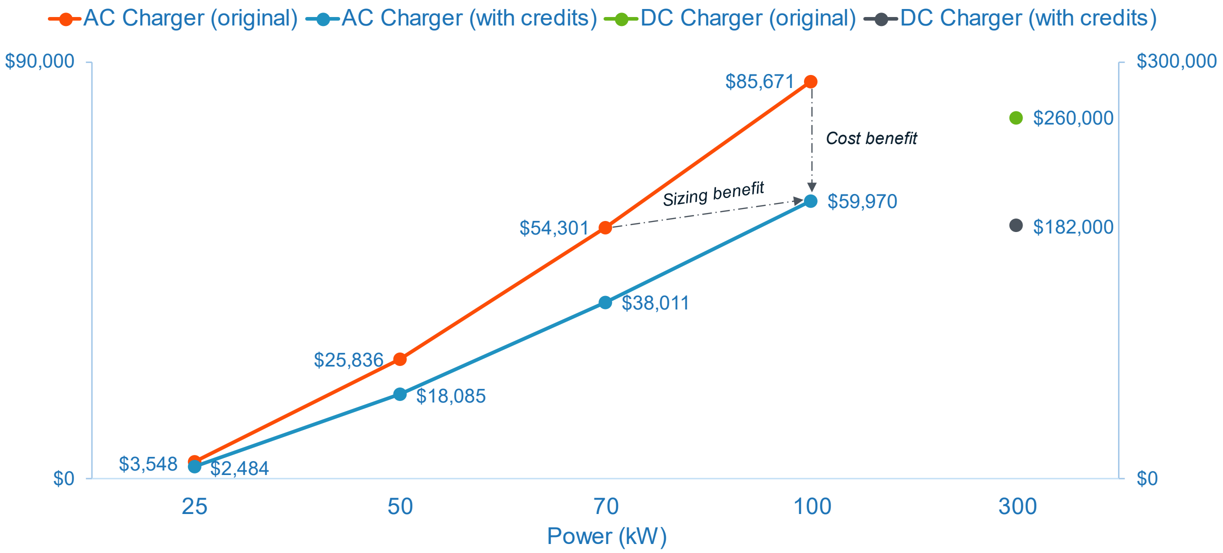


Figure 2: Alternative fuel refueling property credit applied to the charger equipment costs.

Table 1 shows the year TCO parity is reached in the baseline case without and with IRA credits when a BEV is purchased in the 2024 and 2027 timeframes, respectively. Due to the higher upfront purchase price of BEVs in 2024, it takes slightly longer to reach parity compared to a 2027 purchase timeframe.

Table 1: Year TCO parity is reached from 2024 and 2027 in the reference case without and with the application of IRA credits.

Vehicle Type	2024 Purchase Timeframe		2027 Purchase Timeframe	
	Without IRA	With IRA	Without IRA	With IRA
C8 Transit	2026	2025	2028	2028
C7 School	2024	2024	2027	2027
C5 Shuttle	2027	2025	2029	2028
C3 Delivery	2027	2026	2029	2028
C5 Delivery	2024	2024	2027	2027
C7 Delivery	2028	2027	2030	2029
C8 Refuse	2025	2024	2027	2027

With the application of IRA credits in the purchase year 2024, it can be observed that the time to reach parity advances by 1-2 years in non-immediate parity cases such as the class 8 transit bus, the class 5 shuttle bus, the class 3 delivery van, the class 7 delivery truck, and the class 8 refuse truck. A similar advancement in parity is observed with the application of IRA credits in the purchase year 2027 in classes such as the class 5 shuttle bus, the class 3 delivery van, and the class 7 delivery truck. The key takeaway is that with the benefit of IRA credits, the end consumer can avail of the financial benefits in the purchase timeframe of 2024 rather than waiting to purchase in 2027.

The original operating cost projections show that BEV operating costs are always lower than ICEV operating costs. The parity in vehicle prices and the subsidy for chargers mean that fewer years, if any, are needed for BEVs to achieve TCO parity with ICEVs. The increase in TCO savings is always a result of the purchase credits and charger credits. To compare the upfront cost reductions to the TCOs from the previous study, the TCO per mile for these vehicles with IRA credits is calculated. Since, for most fleets, the operating cost is a critical criterion to ascertain a vehicle’s economic viability, the IRA, on average, results in an additional 10% savings over a BEV without credits, which to begin with was originally, on average, 22% cheaper to own and operate over an equivalent diesel vehicle. The resultant net cumulative savings also increase substantially, ranging anywhere from $1,064 to $25,701 for a reference case BEV with IRA credits compared to a BEV without one. In the nearer term, MY 2024 BEV savings over an equivalent diesel will increase substantially.

Impact of Advanced Manufacturing Production Credits

To explore the benefit of tax credits in the form of purchase and advanced manufacturing production credits, a hypothetical exercise to assess the battery price ceiling in 2024 is also done in the study. Theoretically, the maximum battery price with the available tax incentives applied to batteries of different sizes across all vehicle classes is computed. On average, the maximum cost of a domestically manufactured battery pack could reach $418/kWh, about 363% more than the battery cost of $90/kWh projected in the previous study, and still achieve immediate purchase parity in 2024. The maximum battery cost differs based on the available price tolerance band of the vehicle under consideration. Nevertheless, it demonstrates the impact of credits on the battery pack cost buffer due to the volatile nature of battery prices and tight supply chains.

Impact of High Diesel Price

The ongoing geopolitical turmoil and volatile oil prices have penalized diesel vehicle owners heavily. Operating costs have significantly risen in recent months as a result of fuel price volatility, and this is expected to continue as global tensions contribute to fuel price volatility. Per the EIA, diesel reached its ever-highest price of $5.754 in June 2022 [3]. With the rising oil prices and uncertainty associated with future prices, we carried out a diesel price sensitivity analysis in a high diesel price scenario. In the original study, the diesel price used in the reference case was $3.25/gallon. For the sensitivity analysis, the diesel price of $5.18/gallon without taxes was considered an input, which is almost 59% higher than originally assumed. As shown in Figure 3, the average cumulative savings for a BEV with IRA credits effectively jumps to 35% over equivalent diesel vehicles, which is huge for any fleet owner.

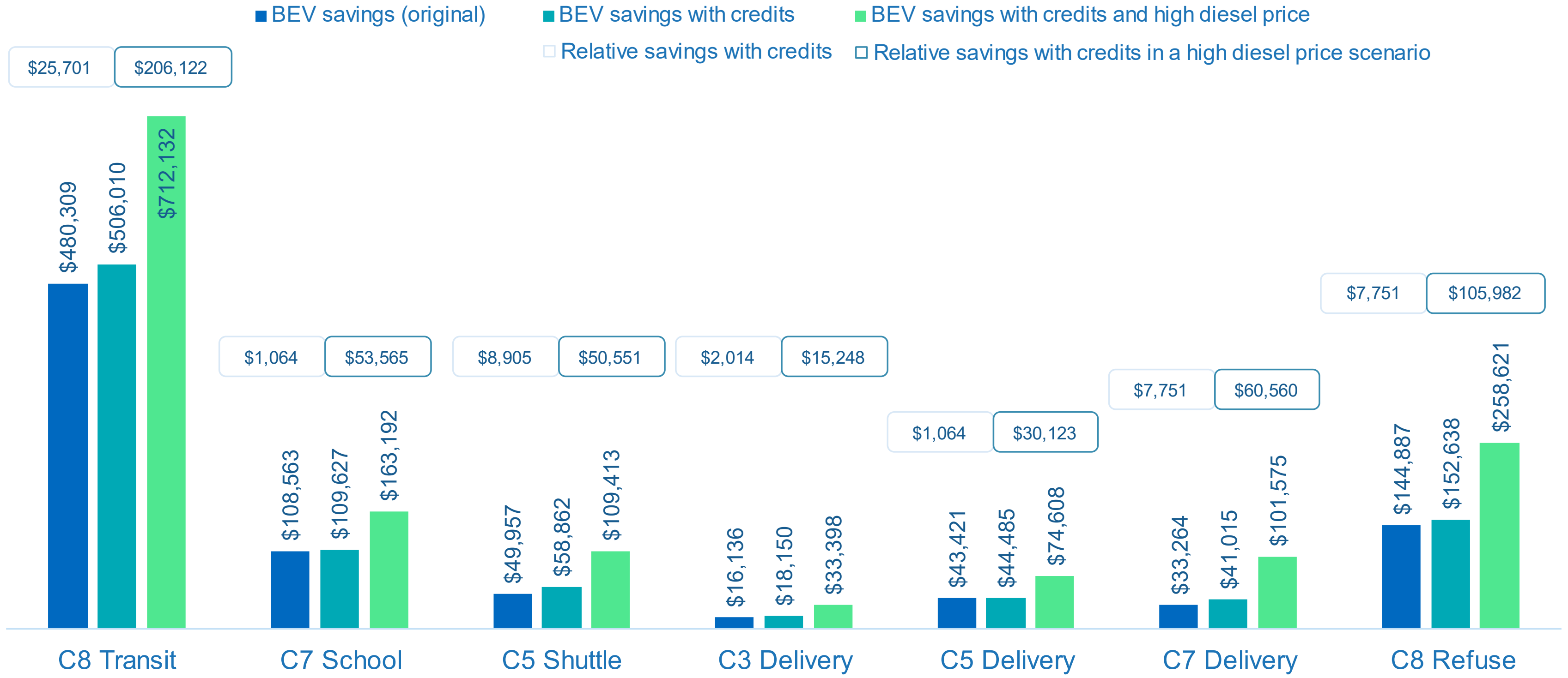


Figure 3: Comparison of cumulative net savings and additional net savings for a BEV, original, with credits, and credits in a high diesel price scenario observed in reference case in the 2027 purchase timeframe.

There are many external benefits to BEV adoption, including environmental benefits through the reduction of PM and NOx emissions as well as the reduction in noise in congested environments. IRA-based incentives, subsidies, and loans/grants can offset or outright reduce the costs of BEV adoption. These provisions only further drive investment in BEV adoption, increasing the overall market penetration and economies of scale for BEV components. These IRA provisions ensure that the U.S. reaps the full economic benefits while facilitating BEV deployment and protecting human health and the environment by transitioning away from ICEVs.

1. Introduction

According to the EPA, medium- and heavy-duty vehicles (MD/HDVs) account for less than 10% of the US vehicle fleet but 23% of greenhouse gas emissions. Since diesel engines power a large portion of MD/HDVs, they account for nearly 60% of total NOx and particulate emissions. Emissions from medium- and heavy-duty (MD/HD) diesel trucks, as well as buses of all classes, contribute to pollution that harms both human health and the environment. Diesel exhaust is a source of particulate emissions, nitrogen oxides (NOx), and other pollutants that have a detrimental effect on human health. Furthermore, greenhouse gas emissions contribute to climate change and are under regulatory scrutiny. The previous study from February 2022, "Technical Review of Medium- and Heavy-Duty Electrification Costs for MY 2027-2030," which was prepared for the Environmental Defense Fund (EDF), analyzed the cost of electrifying the MD/HD market [1]. The analyzed MD/HDVs included delivery, box and stake trucks, and shuttle vehicles in classes 3-7, as well as class 8 transit and class 7 school buses. The chosen battery-electric MD/HDVs, as listed in Table 2, have the advantage of overnight recharging at a central location in contrast to the harmful emissions from their diesel counterparts. Refer to Appendix 7.2 for mileage and lifespan assumed in the reference case.

Table 2: Representative vehicles from MD/HD segment with battery capacity considered in the previous study [1].

Market Segment	Weight Class	Battery Capacity (kWh)
Transit Bus	Class 8	400
School Bus	Class 7	60
Shuttle Bus	Class 3-5	200
Delivery and Service Van, Box, and Stake Truck	Class 3	100
Short Haul Delivery, Service, Box, and Stake Truck	Class 6-7	150
Short Haul Delivery and Service Van, Box Truck	Class 4-5	100
Refuse Hauler	Class 8	200

On August 16, 2022, the Inflation Reduction Act of 2022 (IRA) was signed into law. It contains multiple provisions regarding the adoption and deployment of clean transportation. The provisions in the act provide incentives, tax credits, and funding for various programs to electrify the transportation sector. This study analyzes the effect of these provisions in IRA on the MD/HD segment and attempts to quantify the credits on the purchase price of a BEV, charger unit cost, and the TCO of the vehicle. Furthermore, the qualitative impact of IRA provisions on the MD/HD ecosystem from upstream to downstream is looked at in detail. This study projects results with respect to the reference case of the incremental cost of electrification published in the original study [1]. The originally assessed incremental cost of electrification for MYs 2021, 2024, and 2027 has been used here as a baseline to analyze the impact of tax incentives contained in the IRA provisions. lists the representative MD/HDVs used in the previous study. TCO purchase price differences are based on incremental costs. The vehicle purchase and charging equipment credits have been addressed quantitatively, while the other aspects of the law have been addressed qualitatively.

This study does not factor in the geopolitical risks to the battery supply chain and the associated rising raw material costs. This study assumes that the long-term raw material supply grows simultaneously to meet the demand without any shortages.

2. Summary of IRA Credits Evaluated

The impact analysis of the IRA of 2022 has been broadly divided into two sections: quantitative (or direct) impact and qualitative (or indirect) impact. The quantitative impact applies the tax incentives towards the vehicle purchase price and the charging infrastructure to ascertain the cost-benefit to the end user. The qualitative assessment delves into the indirect impact of various funding and financing programs, grants, rebates, and emission reduction programs that stimulate and encourage the adoption of BEVs over comparable diesel vehicles in the MD/HD segment. The endeavor is to present the results generated from the theoretical application of all these provisions on the MD/HD segment and gauge its impact on electrifying MD/HD vehicles. There may be certain scenarios where the indirect impact on the drive to electrify MD/HD segment may be higher than estimated here.

The previous study estimated the purchase price and TCO of diesel vehicles and BEVs in 2021, 2024, and 2027 purchase timeframes. This study explores the impact of credits in the near-term scenario for 2024 and in the medium-term scenario on MY 2027 BEVs.

2.1 Quantitative Impact

To assess and quantify the direct impact on the MD/HD segment, vehicle purchase price credit and charging equipment credit are applied to the reference case of the incremental cost of electrification developed in the previous study.

2.1.1 Qualified Commercial Clean Vehicles – 26 U.S.C. §45W

This provision creates a new tax credit for qualified commercial electric vehicles placed into service by the taxpayer during the year. It adds a new section, 26 U.S.C. §45W which takes effect after December 31, 2022, and would not apply to vehicles acquired after December 31, 2032.

The credit would be the lesser of the:

a) 15% of the vehicle’s cost (30% for vehicles not powered by a gasoline or diesel internal combustion engine); or
b) Incremental (excess) cost of the vehicle relative to a comparable solely gasoline/diesel-powered vehicle.

The maximum credit limit is $7,500 for vehicles with a gross vehicle weight rating (GVWR) of less than 14,000 pounds, or $40,000 otherwise. Eligible vehicles are to be charged by an external source of electricity and must have a battery capacity of not less than:

a) 7 kWh in the case of vehicles with GVWR of less than 14,000 pounds i.e., light-duty vehicles (LDVs) and classes 2b and 3.
b) 15 kWh in the case of other classes i.e., class 4 and above.

The above clauses in the provisions are used to determine the applicable purchase price credits for each of the considered vehicle classes. These credits are then applied to 2024 and 2027 purchase timeframes.

2.1.2 Alternative Fuel Vehicle Refueling Property Credit – 26 U.S.C. §30C

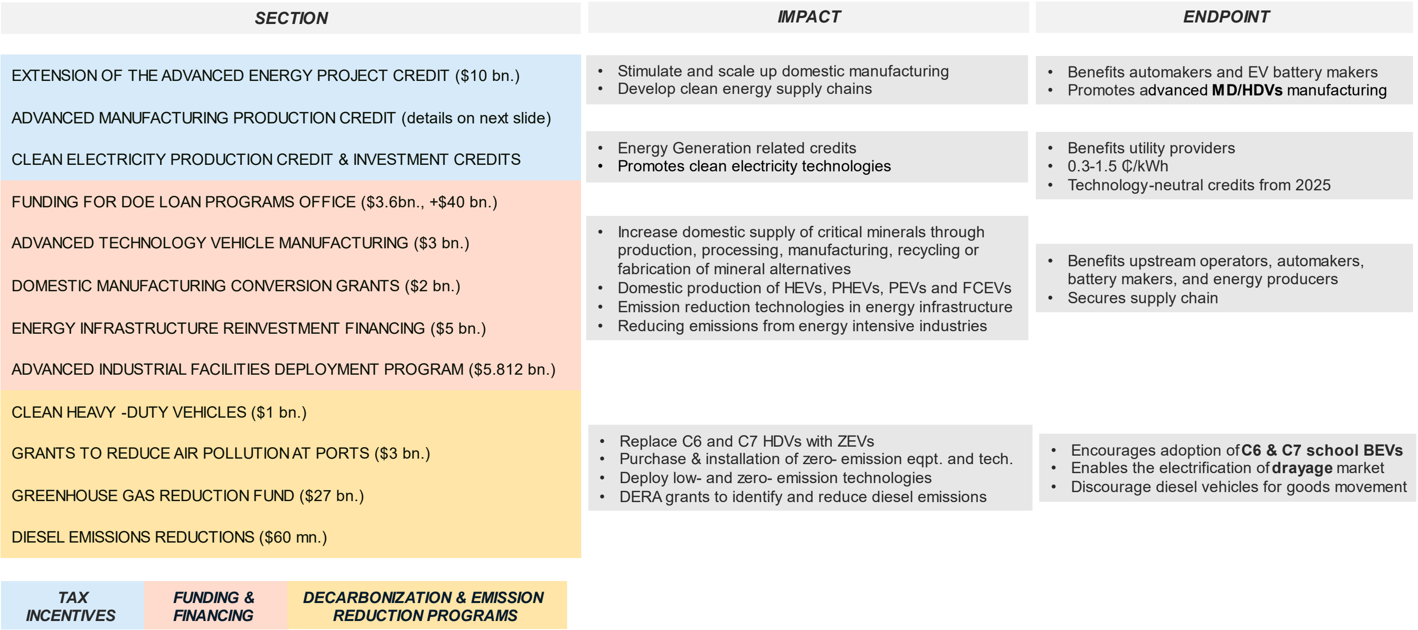
This provision extends and modifies the available credits in 26 U.S.C. §30C for alternative fuel vehicle refueling properties. A tax credit for the cost of any qualified alternative fuel vehicle refueling property installed by a business or at a taxpayer's principal residence was in existence until 2021 and has been extended by the IRA through the end of 2032. The credit is equal to 30% of refueling property costs, capped at $1,000 for residences (personal use property i.e., property not subject to depreciation). For business/investment use property (i.e., property subject to depreciation), the credit is extended at a rate of 6% (30% if prevailing wage and registered apprenticeship requirements are met) of the charger unit and installation cost and the credit is capped at $100,000. The credit expires on December 31, 2032, but starting in 2023, regarding either the residential and business credit, the charging or refueling property must be within a low-income or rural census tract.

According to the original study, BEV chargers would cost between $3,548 and $260,000, depending on the size and type of charger. A 6% credit rate would result in charger-related savings ranging from $213 to $15,600 (for a DCFC shared by three vehicles, or $5,200 per vehicle) for businesses that do not meet the wage and apprenticeship requirements. Furthermore, the charging or refueling property would be eligible for the tax credit only if installed in a low-income or rural census tract. This study assumes that the charger will be installed in a low-income or rural census tract and that prevailing wage and apprenticeship requirements will be met and will, thus be eligible for a 30% tax credit. Due to the wide variation in charger installation expenses across different regions, we have applied the credits only to the charger unit resulting in a conservative estimate. As a result, the credits range from $1,064 to $78,000 (for a DCFC shared by three vehicles, or $26,000 per vehicle).

2.2 Qualitative Impact

The qualitative impact on the MD/HD segments has been broadly divided into three sections such as tax incentives, loans, grants, and decarbonization, as shown in Figure

4. The provisions of the IRA of 2022 have been covered under each of these sections based on their indirect effect on electrifying the MD/HD segment.



SECTION	***IMPACT***	***ENDPOINT***
EXTENSION OF THE ADVANCED ENERGY PROJECT CREDIT ($10 bn.)	• Stimulate and scale up domestic manufacturing • Develop clean energy supply chains	• Benefits automakers and EV battery makers • Promotes advanced **MD/HDVs** manufacturing
ADVANCED MANUFACTURING PRODUCTION CREDIT (details on next slide)		
CLEAN ELECTRICITY PRODUCTION CREDIT & INVESTMENT CREDITS	• Energy Generation related credits • Promotes clean electricity technologies	• Benefits utility providers • 0.3-1.5 ₵/kWh • Technology-neutral credits from 2025
FUNDING FOR DOE LOAN PROGRAMS OFFICE ($3.6bn., +$40 bn.)		
ADVANCED TECHNOLOGY VEHICLE MANUFACTURING ($3 bn.)	• Increase domestic supply of critical minerals through production, processing, manufacturing, recycling or fabrication of mineral alternatives • Domestic production of HEVs, PHEVs, PEVs and FCEVs • Emission reduction technologies in energy infrastructure • Reducing emissions from energy intensive industries	• Benefits upstream operators, automakers, battery makers, and energy producers • Secures supply chain
DOMESTIC MANUFACTURING CONVERSION GRANTS ($2 bn.)		
ENERGY INFRASTRUCTURE REINVESTMENT FINANCING ($5 bn.)		
ADVANCED INDUSTRIAL FACILITIES DEPLOYMENT PROGRAM ($5.812 bn.)		
CLEAN HEAVY -DUTY VEHICLES ($1 bn.)	• Replace C6 and C7 HDVs with ZEVs • Purchase & installation of zero- emission eqpt. and tech. • Deploy low- and zero- emission technologies • DERA grants to identify and reduce diesel emissions	• Encourages adoption of **C6 & C7 school BEVs** • Enables the electrification of **drayage** market • Discourage diesel vehicles for goods movement
GRANTS TO REDUCE AIR POLLUTION AT PORTS ($3 bn.)		
GREENHOUSE GAS REDUCTION FUND ($27 bn.)		
DIESEL EMISSIONS REDUCTIONS ($60 mn.)		

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Figure 4: Summary of qualitative impact of the IRA on MD/HD segments

2.2.1 Tax Incentives

2.2.1.1 Extension of the Advanced Energy Project Credit – 26 U.S.C. §48C

This provision extends the 26 U.S.C. §48C advanced energy project credit. It provides additional allocations of the qualified advanced energy manufacturing tax credit, which is a 30% tax credit for investments in projects that reequip, expand, or establish certain energy manufacturing facilities. An additional $10 billion is earmarked to provide credits for advanced energy projects. The term “qualifying advanced energy project” includes one of the three following project types:

a) A project that re-equips, expands, or establishes an industrial or manufacturing facility for the production or recycling of one of the following nine property types:
   i) Property designed to be used to produce energy from the sun, water, wind, geothermal deposits, or other renewable resources.
   ii) Fuel cells, microturbines, or energy storage systems and components.
   iii) Electric grid modernization equipment or components.
   iv) Property designed to capture, remove, use, or sequester carbon oxide emissions.

    v) Equipment designed to refine, electrolyze, or blend any fuel, chemical, or renewable product or low-carbon and low-emission.
    vi) Property designed to produce energy conservation technologies (including residential, commercial, and industrial applications).
    vii) Light, medium, or heavy-duty electric or fuel cell vehicles, as well as technologies, components, or materials for such vehicles, and associated charging or refueling infrastructure.
    viii) Hybrid vehicles with a gross vehicle weight rating of not less than 14,000 lbs., as well as technologies, components, or materials for such vehicles.
    ix) Advanced energy property designed to reduce greenhouse gas emissions.
b) A project that re-equips an industrial or manufacturing facility with equipment designed to reduce greenhouse gas emissions by at least 20% through the installation of
    i) Low- or zero-carbon process heat systems,
    ii) Carbon capture, transport, utilization, and storage systems,
    iii) Energy efficiency and reduction in waste from industrial processes, or
    iv) Any other industrial technology designed to reduce greenhouse gas emissions.
c) A project that re-equips, expands, or establishes an industrial facility for the processing, refining, or recycling of critical materials (as defined in §7002(a) of the Energy Act of 2020 (30 USC §1606(a)).

Projects receive a base credit rate of 6% of the total cost or a bonus rate of 30% if the projects meet prevailing wage and registered apprenticeship requirements.

2.2.1.2 Advanced Manufacturing Production Credit – 26 U.S.C. §45X

This provision creates a new production tax credit, 26 U.S.C. §45X, that could be claimed for domestic battery production. The following credits apply to cell material or production:

a) A credit of 10% of the cost of production would also be available for the domestic production of critical minerals. Per the USGS, a “critical mineral” is a non-fuel mineral or mineral material essential to the economic or national security of the U.S. and which has a supply chain vulnerable to disruption. Critical minerals are also characterized as serving an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economy or national security. A list of critical minerals per 26 U.S.C. §45X can be found in Appendix 7.3 for reference.
b) For electrode active materials, the credit would be 10% of the production cost. The term “electrode active material” means cathode materials, anode materials, anode foils, and electrochemically active materials, including solvents, additives, and electrolyte salts that contribute to the electrochemical processes necessary for energy storage.

c) Battery cells could qualify for a credit of $35/kWh, and battery modules could qualify for a credit of $10/kWh. The term “battery cell” means an electrochemical cell—
    i) comprised of 1 or more positive electrodes and 1 or more negative electrodes,
    ii) with an energy density of not less than 100 Wh/liter, and
    iii) capable of storing at least 12 Wh of energy.

d) In the case of a battery module that does not use battery cells, they could qualify for a credit of $45/kWh. The term “battery module” means a module—
    i) (aa) in the case of a module using battery cells, with 2 or more battery cells which are configured electrically, in series or parallel, to create voltage or current, as appropriate, to specified end use, or (bb) with no battery cells, and
    ii) with an aggregate capacity of not less than 7 kWh (or, in the case of a module for a hydrogen fuel cell vehicle, not less than 1 kWh).

The sales of eligible components are considered only if their production is within the US or a US territory (including continental shelf areas). Full credits are provided for eligible components produced and sold before January 1, 2030. The credit would begin to phase out for eligible components sold at a fixed rate of 25% each year i.e., 75%, 50%, and 25% of the credits described above would be available in 2030, 2031, and 2032, respectively. No credit would be available for components sold after December 31, 2032. The phaseout does not apply to the production of critical minerals. Table 3 shows the applicability of credits specific to the battery-related components and materials.

Table 3: Advanced Manufacturing Production Credit applicable battery materials

Manufacturing production credit to batteries	***Credits remain same***								***Most credits phase-out***			
	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Electrode active materials	10%	10%	10%	10%	10%	10%	10%	10%	7.5%	5%	2.5%	-
Cells ($/kWh)	$35	$35	$35	$35	$35	$35	$35	$35	$26.3	$17.5	$8.8	-
Modules ($/kWh)	$10	$10	$10	$10	$10	$10	$10	$10	$7.5	$5	$2.5	-
Modules that don't use cells ($/kWh)	$45	$45	$45	$45	$45	$45	$45	$45	$33.8	$22.5	$11.3	-
Production of Critical Minerals *(Credits do not phase out)*	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%

Provision §45X contains some ambiguity regarding the following issues, which will be clarified through Treasury actions[1].

a) **Critical minerals**:

   i) Since critical minerals go through several transformation steps and the allocated capital is amortized over several years, determining the incurred costs in the production of critical minerals and electrode active materials is ambiguous. It is unclear if the definition of production costs includes overhead costs (such as the cost of consumables), upfront costs, and indirect production-related costs.

   ii) Moreover, it is unclear whether the requirement for sourcing, extraction, or processing of critical minerals from a non-foreign entity of concern is stipulated—that is, whether the critical mineral requirement in this section aligns with the definition in §30D.

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[1] This report was drafted in 2022 and early 2023 before the release of the prepublication draft Treasury guidance.

   iii) Furthermore, the provision does not state whether the critical minerals must be converted and purified into battery-grade material.
   iv) The eligibility of recycled critical minerals is unclear.

b) **Electrode active materials**: Whether other common battery materials or those under development, such as conductive additives (for example, carbon black), binder materials (fluoropolymers), ionically conductive separators, carbon nanotubes, pouches, cathode foils, solid electrolytes, tabs, tapes, adhesives and the raw materials used to make them, would be included in the definition of electrode active materials for credit eligibility.
c) **Module production tax credit**: If the battery pack is eligible for the module production tax credit in the absence of a module configuration in a cell-to-pack or cell-to-chassis configuration, or if combining multiple modules to form larger modules to form a pack would be considered individually for the credit.
d) Clauses such as “sale of components to a related and unrelated person” and “integrated, incorporated or assembled” obscure credit applicability.

2.2.1.3 Clean Electricity Production Credit and Investment Credit

These provisions bolster the energy generation sector by providing credits to clean energy producers, with a choice to avail of the credits either upfront to reduce their required investment or during production. The IRA extends, expands, and modifies the 26 U.S.C. §45 production tax credit (PTC) and the 26 U.S.C. §48 investment tax credit (ITC) through 2024. The producers can choose between a production tax credit (PTC) under section 45Y or an investment tax credit (ITC) under section 48D, which is provided based on the carbon emissions of the electricity generated – measured as grams of carbon dioxide equivalents (CO_2e) emitted per kWh generated. The provisions add a new §45Y known as the clean energy production credit and §48E known as the clean electricity investment credit. The provisions create an emissions-based incentive that would be neutral and flexible between clean electricity technologies. The credits would end after 2032 or when the emission targets are achieved i.e., when the electric power sector emits equal to or less than 25% of their 2022 levels, the incentives will be phased out over 3 years.

This could have a potential impact downstream on charging rates for businesses and public charging facilities by allowing the energy producers to absorb high investment and production costs.

2.2.2 Federal Funding and Financing Opportunities

2.2.2.1 Funding for the Department of Energy Loan Programs Office

The IRA provides $40 billion in additional commitment authority for eligible projects under Title XVII section 1703 through Sept. 30, 2026. This funding will be available for existing eligible projects and will expand the eligibility for projects that increase the domestic supply of critical minerals through the production, processing, manufacturing, recycling, or fabrication of mineral alternatives. Additionally, the provision will provide $3.6 billion in credit subsidy costs through September 30, 2026. It also establishes a time-limited (available through FY2026), $250 billion Title XVII loan guarantee commitment authority—Section 1706—for “Energy Infrastructure Reinvestment Financing”. This loan guarantee program includes fossil fuel energy infrastructure facilities, and electricity generation and transmission energy infrastructure encouraging them to reduce GHG emissions.

DOE would provide access to debt capital for large-scale energy projects that use innovative technology. Projects such as but not limited to energy infrastructure storage and modernization would benefit the producers and suppliers tied to the EV sector.

2.2.2.2 Advanced Technology Vehicle Manufacturing (ATVM)

The IRA of 2022 eliminated the loan program cap of $25 billion on the total amount of ATVM loans established under the Energy Independence and Security Act of 2007. The ATVM direct loan program finances U.S. auto manufacturing across the value chain as long as the projects meet stipulated criteria. This means that the program’s total loan capacity is no longer limited, as long as credit subsidies are available to offset the cost of those loans. The IRA provides $3 billion through September 30, 2028, to the Advanced Technology Vehicles Manufacturing (ATVM) Loan Program for re-equipping, expanding, or establishing a manufacturing facility in the United States to produce, or for engineering integration performed in the US of low- or zero-emission vehicles. According to DOE, eligible borrowers can be one of the following:

a) Manufacturers of advanced technology vehicles that achieve defined fuel economy targets. Eligible vehicles are light-duty vehicles that meet or exceed a 25% improvement in fuel efficiency beyond a MY 2005 baseline of comparably-sized vehicles; and/or ultra-efficient vehicles that achieve a fuel efficiency of 75 miles per gallon equivalent.
b) Manufacturers of components or materials that support eligible vehicles’ fuel economy performance. Examples of eligible components include:

  - i) Advanced engines & powertrain components including electrified powertrains, batteries, and electronics
  - ii) Materials for light-weighting such as aluminum, advanced steels, composites, and fuel-efficient tires
  - iii) Electric Vehicle Charging & Alternative Fuel Vehicle Fueling Infrastructure Components. For example, associated hardware and software for fuel cell hydrogen fueling stations
  - iv) May also be able to support projects that include the processing or manufacturing of critical minerals in support of eligible vehicles

According to 42 U.S.C. §17013(a)(1), the term "advanced technology vehicle" means—

- a) an ultra-efficient vehicle or a light-duty vehicle that meets—
  - i) the Bin 5 Tier II emission standard established in regulations issued by the Administrator of the Environmental Protection Agency under section 202(i) of the Clean Air Act (42 U.S.C. 7521(i)), or a lower-numbered Bin emission standard;
  - ii) any new emission standard in effect for fine particulate matter prescribed by the Administrator under that Act (42 U.S.C. 7401); and
  - iii) at least 125% of the average base year combined fuel economy for vehicles with substantially similar attributes.
- b) a medium-duty vehicle or a heavy-duty vehicle that exceeds 125% of the greenhouse gas emissions and fuel efficiency standards established by the final rule of the Environmental Protection Agency entitled "Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2" (81 Fed. Reg. 73478 (October 25, 2016));
- c) a train or locomotive;
- d) a maritime vessel;
- e) an aircraft; and
- f) hyperloop technology

To name a few, the ATVM loan program has benefitted automakers like Ford, Nissan, and Tesla. According to the U.S. DOE Loans Program Office, Ford received a direct loan of $5.9 billion, to retool their manufacturing facilities which aided the production of 13 separate models with electric, hybrid, or improved conventional powertrains and the introduction of a family of Ford EcoBoost™ engines; Nissan was awarded a loan of $1.45 billion to retool its plant to build BEVs and for a LIB manufacturing plant which aided the Nissan LEAF BEV; Tesla received $465 million loan to develop the Fremont manufacturing facility to produce the Model S. In July 2022, DOE issued a $102.1 million loan to Syrah Technologies LLC to expand its Syrah-Vidalia facility, which processes battery-grade natural graphite. Furthermore, in November 2022, DOE issued a direct loan of $2.5 billion to Ultium Cells, LLC to help finance the construction of new lithium-ion battery cell manufacturing facilities in Ohio, Tennessee, and Michigan. Ultium Cells is a joint venture between General Motors and LG Energy Solution which will manufacture nickel-cobalt-manganese-aluminum (NCMA) based large format, pouch-type cells for EVs.

Elimination of the loan program cap and the additional funding to ATVM could prove beneficial to various producers and manufacturers in the EV ecosystem, as essentially all EV technology would qualify for this credit. This $3 billion is expected to provide an additional ~$40 billion (under Title XVII) in loan authority, bringing the total estimated available loan authority under ATVM to ~$55.1 billion.

2.2.2.3 Domestic Manufacturing Conversion Grants

This provision appropriates $2 billion to remain available through September 30, 2031, as grants and loan guarantees under 42 U.S.C. §16062 to automobile manufacturers and suppliers and hybrid component manufacturers to encourage domestic production of efficient hybrid, plug-in electric hybrid (PHEV), plug-in electric drive (PEV), and hydrogen fuel cell electric vehicles (FCEV) stimulating the EV industry. Priority shall be given to the refurbishment or retooling of manufacturing facilities that have recently ceased operation or will cease operation in the near future.

2.2.2.4 Energy Infrastructure Reinvestment Financing

This provision appropriates $5 billion through September 30, 2026, to be leveraged for up to $250 billion in loan guarantees. Energy Infrastructure Reinvestment (EIR) will guarantee loans to projects that retool, repower, repurpose, or replace energy infrastructure that has ceased operations, or enable operating energy infrastructure to avoid, reduce, utilize, or sequester air pollutants or anthropogenic emissions of greenhouse gases. Potential projects could include repurposing shuttered fossil energy facilities for clean energy production, retooling infrastructure from power plants that have ceased operations for new clean energy uses, or updating operating energy infrastructure with emissions control technologies, including carbon capture, utilization, and storage (CCUS). It adds section 1706 to 42 U.S.C. §16516. As defined in the bill, energy infrastructure would include:

a) Electricity generation and transmission, or
b) Production, processing, and delivery of fossil fuels, petroleum-derived fuels, or petrochemical feedstocks

To qualify, projects would need to meet certain conditions laid out in the law.

2.2.2.5 Advanced Industrial Facilities Deployment Program

The IRA provides $5.812 billion under 42 U.S.C. §17113(c) through September 30, 2026, to create a new program within the Office of Clean Energy Demonstrations (OCED) to invest in projects aimed at reducing emissions from energy-intensive industries. It will provide financial assistance to projects for—

a) The purchase and installation, or implementation, of advanced industrial technology at an eligible facility;
b) Retrofits, upgrades to, or operational improvements at an eligible facility to install or implement advanced industrial technology; or
c) Engineering studies and other work needed to prepare an eligible facility for activities as described in paragraphs (a) or (b).

Iron and steel producers serving the automotive industry may benefit from this appropriation.

2.2.3 Decarbonization Funds

2.2.3.1 Clean Heavy-Duty Vehicles

The IRA provides $1 billion to the Environmental Protection Agency (EPA) to establish a program to make awards of grants and rebates to states, local governments, and nonprofit school transportation associations to replace Class 6 and Class 7 heavy-duty vehicles with zero-emission vehicles, and the necessary infrastructure and workforce development until September 30, 2031. The bill requires that 40% of funding ($400 million) be for communities located in nonattainment areas (i.e., areas with high levels of air pollution).

2.2.3.2 Grants to Reduce Air Pollution at Ports

The IRA provides $3 billion over the next 5 years to establish a program to award grants and rebates for the purchase and installation of zero-emission equipment and technology at ports. The bill allocates 25% of the funding ($750,000) for investments made at ports in nonattainment areas.

This would aid the electrification of cargo-fuel handling equipment like drayage trucks and reduce emissions at ports.

2.2.3.3 Greenhouse Gas Reduction Fund

The IRA will provide $7 billion to EPA for a new GHG Reduction Fund to make competitive grants to states, municipalities, tribal governments, and eligible recipients to provide financing and technical assistance to enable low-income and disadvantaged communities to deploy or benefit from zero-emission technologies, including distributed technologies on residential rooftops, and to carry out other GHG emission reduction activities; $11.97 billion for general assistance; $8 billion for low-income and disadvantaged communities; and $30 million for EPA administrative costs.

The program would also stimulate and promote the electrification of the medium-duty segment and discourage the use of diesel-powered vehicles.

2.2.3.4 Diesel Emissions Reductions

The IRA provides $60 million for Diesel Emissions Reduction Act (DERA) grants to the EPA to identify and reduce diesel emissions resulting from goods movements facilities (e.g., airports, railyards, and distribution centers), and vehicles servicing goods movement facilities, in low-income and disadvantaged communities to address the health impacts of emissions on those communities.

3. Results

3.1 Impact of Qualified Commercial Clean Vehicle Credit on Purchase Price

Table 4 lists the vehicles considered in the previous study for reference with the originally costed diesel vehicles and BEVs [1].

Table 4: MSRP of ICEVs and BEVs from the previous study [1]**.**

Vehicle Class	Diesel Vehicle Purchase Price		BEV Purchase Price without §45W credits	
	2024	2027	2024	2027
Transit Bus (Class 8)	$524,435	$531,337	$536,258	$526,335
School Bus (Class 7)	$111,760	$117,680	$102,184	$100,278
Shuttle Bus (Class 5)	$48,525	$52,245	$60,468	$55,459
Delivery Van (Class 3)	$41,024	$44,748	$42,689	$39,990
Delivery Truck (Class 5)	$54,550	$58,270	$52,387	$49,476
Box Truck (Class 7)	$82,550	$86,270	$80,151	$76,157
Refuse Hauler (Class 8)	$246,569	$251,270	$235,634	$230,324

The qualified commercial clean vehicle price credits, §45W, have been applied to each class of vehicle from the previous study to determine their purchase price in 2024 and 2027 with an equivalent diesel vehicle as the baseline. Table 5 lists the applicable purchase credits and the final price of BEVs after applying for those credits. Most of the Mys 2024 and 2027 do not qualify for purchase credits as the purchase price of BEV is at par or lower than the equivalent diesel vehicle.

Table 5: MSRP of BEVs with qualified commercial clean vehicle credits (§45W).

Vehicle Class	IRA §45W Credits		BEV MSRP with §45W Credits	
	2024	2027	2024	2027
Transit Bus (Class 8)	$11,823	No credit	$524,435	$526,335
School Bus (Class 7)	No credit	No credit	$102,184	$100,278
Shuttle Bus (Class 5)	$11,942	$3,214	$48,525	$52,245
Delivery Van (Class 3)	$1,664	No credit	$41,024	$39,990
Delivery Truck (Class 5)	No credit	No credit	$52,387	$49,476
Box Truck (Class 7)	No credit	No credit	$80,151	$76,157
Refuse Hauler (Class 8)	No credit	No credit	$235,634	$230,324

3.2 MSRP Ceiling of BEVs to Achieve Immediate Purchase Price Parity

As seen in the preceding sections, the application of credits results in BEVs achieving purchase price parity in the near term, in 2024, respectively. This is because our projected BEV costs in 2024 were within $40,000 of the diesel vehicle cost across all of the vehicle segments evaluated. This section attempts to establish a BEV MSRP ceiling where the available IRA vehicle tax credit still allows the buyer to pay no more for the vehicle than it would for a diesel. The MSRP ceiling is defined as the maximum selling price that the automakers set while allowing the end consumer to still avail of the maximum possible credit to maintain vehicle price parity from a buyer's perspective. The price tolerance band is defined as the maximum available credits or the difference between the BEV MSRP ceiling and an equivalent diesel vehicle price. Though it is not an IRA requirement, the availability of the price tolerance band provides flexibility to the automakers and/or cell makers to:

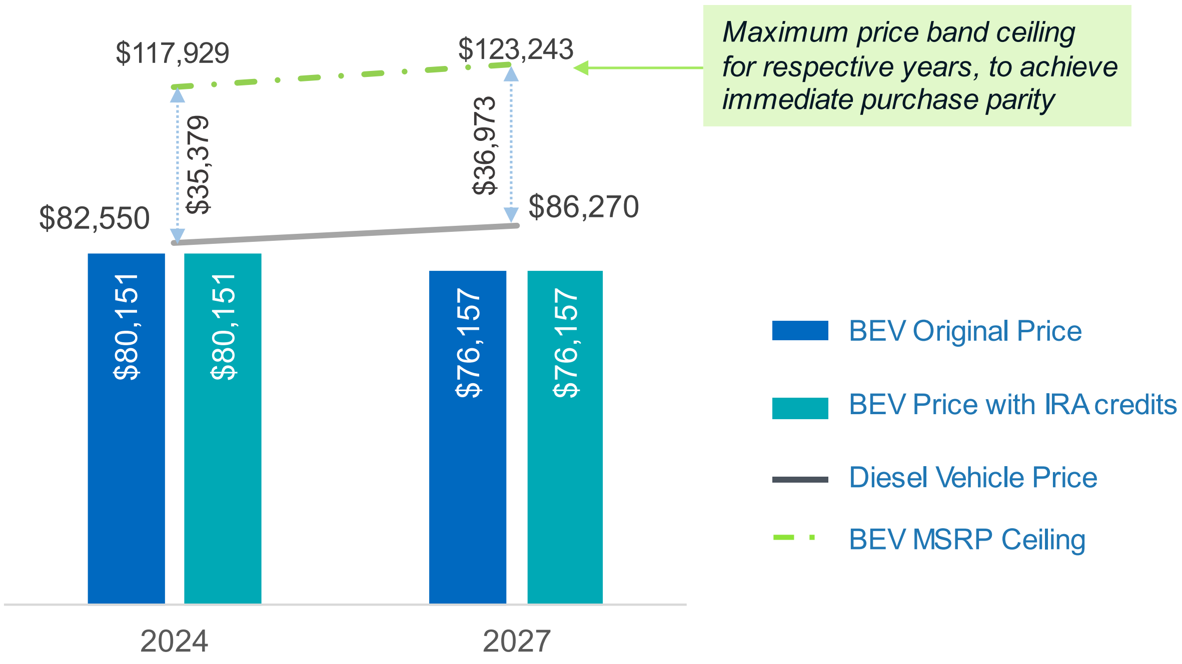
a) Increase battery size
b) Absorb battery price fluctuations
c) Develop a domestic supply chain
d) Compensate for less than full economies of scale in the early years of production

The following steps explain the methodology to compute the maximum MSRP of a BEV:

a) An optimum price point of a diesel vehicle is determined by using the equation, MIN(MIN(Incremental Cost, 30% of BEV price), $40,000). The optimum price point is defined as the price point where the applicable clauses determine the maximum available purchase credits change. The optimum price of a diesel vehicle is $93,333. Below $93,333, the maximum allowable credit is 30% of the BEV price. And above $93,333, the maximum credit is $40,000 (for class 4 and above vehicles) and $7,500 (up to class 3 vehicles) as excess cost of BEV over diesel i.e., ($\text{BEV}_{\text{MSRPmax}} = \text{Diesel}_{\text{MSRP}} + \$40{,}000$ or $7,500)

b) For class 4 and above vehicles, the equation to determine the maximum BEV price when a diesel vehicle is priced below $93,333 is, ($\text{BEV}_{\text{MSRPmax}} = \text{Diesel}_{\text{MSRP}} \div 0.7$).

A sample reference case of a class 7 delivery truck is illustrated in Figure 5 to demonstrate the BEV MSRP ceiling. The price tolerance band varies for the purchase years 2024 and 2027. In general, with the increase in diesel vehicle price, the BEV MSRP ceiling is raised. The maximum MSRP of a BEV with a diesel vehicle as the baseline is $117,929, and $123,243 in the years 2024, and 2027, respectively. However, the maximum available credit roughly remains the same in the considered cases ranging from $35,169 to $36,973.



Maximum price band ceiling for respective years, to achieve immediate purchase parity

Figure 5: MSRP ceiling of a class 7 delivery truck

Table 6 shows the maximum possible credit as a function of the diesel vehicle purchase price and the BEV MSRP ceiling for the considered vehicles.

Table 6: Availability of qualified commercial clean vehicle credit allows raising of the MSRP of BEVs while achieving immediate purchase parity.

Vehicle Class	Diesel Vehicle Purchase Price		Maximum Possible Credit (or Price Tolerance Band)		BEV MSRP Ceiling	
	2024	2027	2024	2027	2024	2027
C8 Transit	$524,435	$531,337	$40,000	$40,000	$564,435	$571,337
C7 School	$111,760	$117,680	$40,000	$40,000	$151,760	$157,680
C5 Shuttle	$48,525	$52,245	$20,797	$22,391	$69,322	$74,636
C3 Delivery	$41,024	$44,748	$7,500	$7,500	$48,524	$52,248
C5 Delivery	$54,550	$58,270	$23,379	$24,973	$77,929	$83,243
C7 Delivery	$82,550	$86,270	$35,379	$36,973	$117,929	$123,243
C8 Refuse	$246,569	$251,270	$40,000	$40,000	$286,569	$291,270

3.3 Charger Unit Credits

The previous study costed the charger equipment based on individual vehicle class's requirement and the projected case (scenario). The charging equipment differs for each class based on their sizing requirements, as shown in Table 7. The charging scenario for the low-, reference-, and high-case were 6-hour depot charge, 4-hour depot charge, and DC fast charging, respectively. The costing was done for both AC and DC chargers, with AC chargers varying in power based on the vehicle class under consideration. Appendix 7.2 lists the charger-related installation and equipment costs based on their sizing.

Table 7: Charger specifications used in the previous study [1]**.**

Vehicle Type	Low Case	Reference Case	High Case
C8 Transit	70 kW	100 kW	DCFC 300+ kW
C7 School	25 kW	25 kW	DCFC 300+ kW
C5 Shuttle	50 kW	50 kW	DCFC 300+ kW
C3 Delivery	25 kW	25 kW	DCFC 300+ kW
C5 Delivery	25 kW	25 kW	DCFC 300+ kW
C7 Delivery	25 kW	50 kW	DCFC 300+ kW
C8 Refuse	50 kW	50 kW	DCFC 300+ kW

Due to the wide variation in charger installation expenses across different regions, we have applied the credits only to the charger unit resulting in a conservative estimate. The 30% alternative fueling infrastructure credit is applied only to the charger unit and not its installation. A flat credit of 30% is applied to all the considered charging costs, assuming the end consumer would meet the prevailing wage and registered apprenticeship requirements, and the unit is placed in service within a low-income or rural census tract. As seen in Figure 6, the charger costs decrease considerably offering a sizing benefit and cost benefit to the end consumers. For example, from a sizing benefit perspective, a fleet owner who was previously considering a 70 kW AC depot charger, can now install a 100-kW depot charger for a similar price point. Alternatively, from a cost-benefit perspective, a fleet owner stands to save 30% if they decide to install the originally chosen 70 kW charger. While some charger units will not qualify for this credit due to the census tract limitations, we applied for the credit here because our analysis aims to evaluate the impacts of the IRA under favorable conditions.

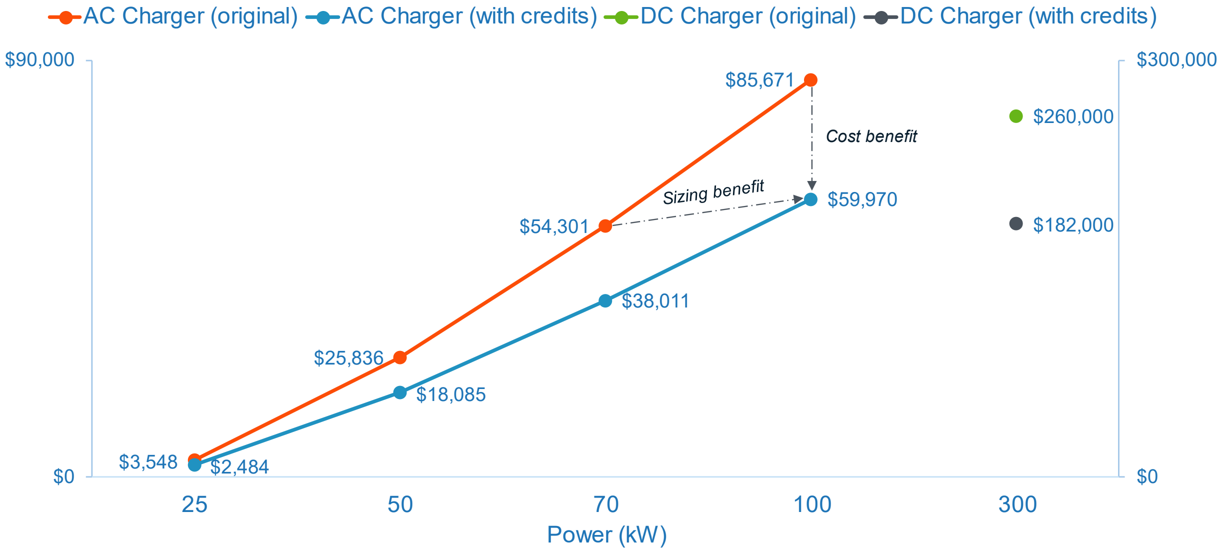


Figure 6: Alternative fuel refueling property credit applied to the charger equipment costs. DCFC station shared between 3 vehicles (assumed).

3.4 Total Cost of Ownership

The major benefit to a consumer after the application of IRA tax credits is seen upfront in the purchase price and the charge unit price. Over the MY 2027 BEV's lifetime, with the application of purchase and charger unit credits, the benefit in terms of TCO per mile is an average of 2% in the reference case when compared to the original without credits case. Nevertheless, the advantage is still prominent with an average savings of 24%

when compared to equivalent diesel vehicles in the 2027 purchase timeframe, as shown in Figure 7.

We only include the result of the TCO analysis for 2027, since there is hardly any difference between a TCO for a MY 2024 and a MY 2027 BEV. For analysis, we have assumed the same operating expenses between all the MYs with only the vehicle price varying between them. In the case of costlier BEVs, the IRA credits bring the BEV prices down at par with their ICEV counterparts across the board. Charger costs do not change but it is understood that with penetration of BEVs and production at economies of scale, the charger costs would decrease with time, thereby, accentuating the impact of IRA credits and the benefit to a consumer. Also, despite the assumed maintenance costs and low fuel prices remaining the same across all MYs, the IRA credits have a profound impact on BEV ownership. Currently, the only limitation is the economy of scale of BEV production which would take a few years for the automakers to ramp up and achieve. With the current high fuel prices compared to the assumed rates in the study and low M&R costs, a BEV is far more economical to own.

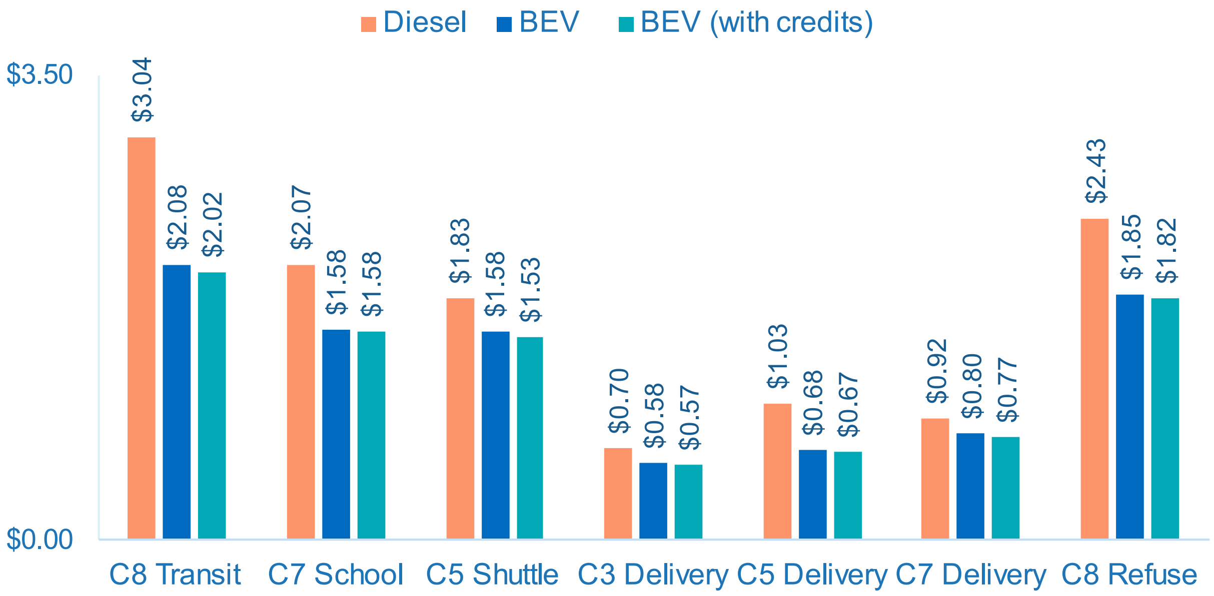


Figure 7: Comparison of Total Cost of Ownership (TCO) of MY 2027 MD/HDVs in the reference case without and with IRA credits.

3.5 Cumulative Net Savings

To quantify the benefit to end consumers in terms of relative savings against an equivalent diesel vehicle, net savings in purchase years 2024 and 2027, respectively, without and with the application of credits are computed, as depicted in Figure 8. An intra-year comparison indicates that with the application of credits, the relative net savings are greater if the BEV is purchased in 2024 compared to 2027 in the case of the class 8 transit bus, class 5 shuttle bus, and class 3 delivery van. However, the relative net savings remain the same in purchase years 2024 and 2027 for all other vehicle classes. This demonstrates that the end consumer does not have to defer the purchase of BEVs until 2027 if they can accrue the same or greater financial benefit when purchasing it in 2024. The IRA credits allow the end customer to offset the upfront capital cost of electrifying their fleet while making it cheaper than owning and operating an equivalent diesel vehicle over its period of ownership.

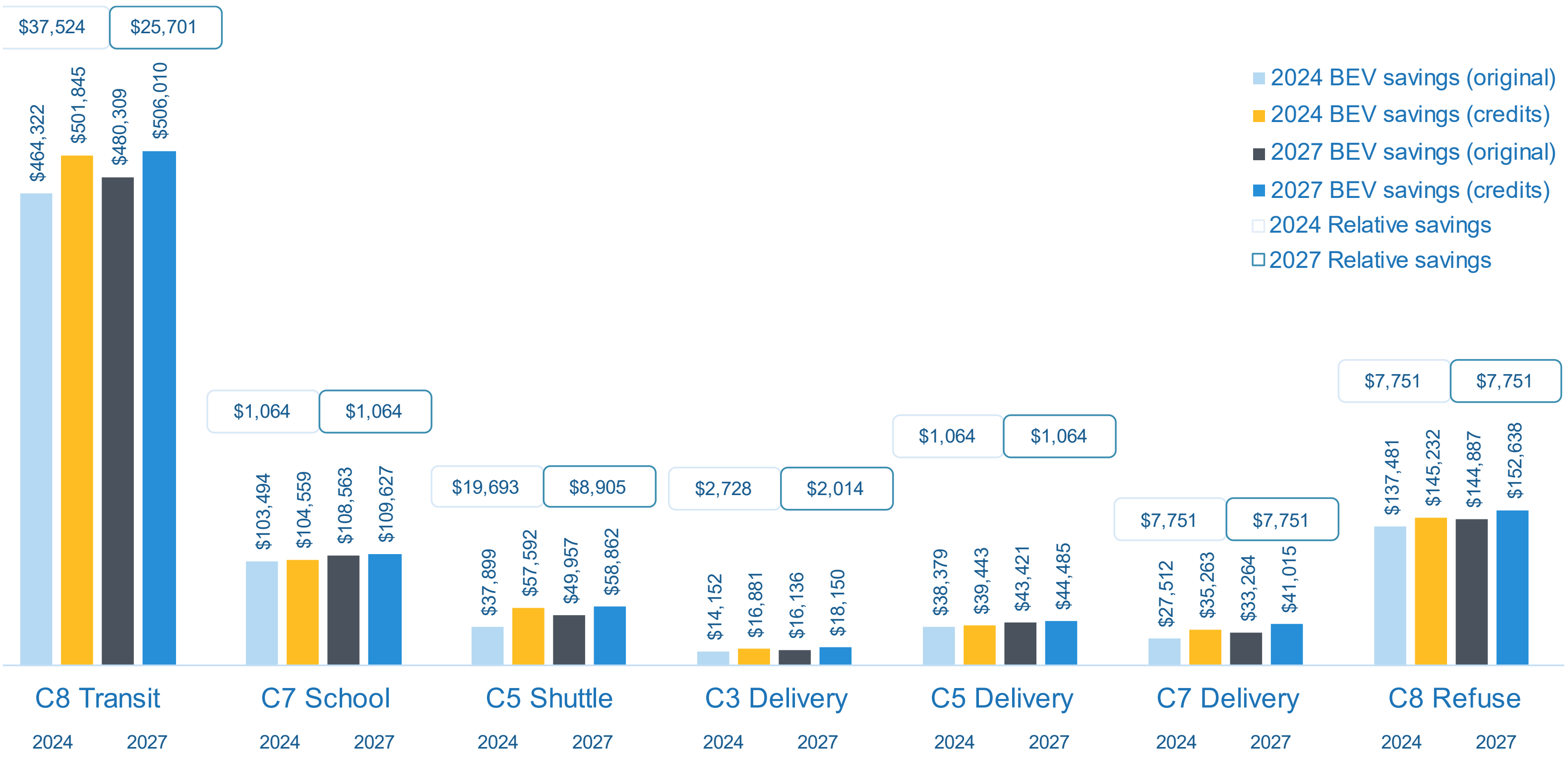


Figure 8: Cumulative savings of BEV over equivalent diesel vehicle for a reference case over its lifetime. The net savings in the purchase years of 2024 and 2027 with the application of IRA credits are computed, respectively, and indicated in the text above the columns.

3.6 Year of TCO Parity

Table 8 and Table 9 list the year parity is reached when a BEV is purchased in 2024 and 2027 timeframes, respectively. Due to the high upfront purchase price of BEVs in the 2024 purchase timeframe, in a few cases, it takes slightly longer to reach parity compared to a 2027 purchase timeframe. With the application of IRA credits in purchase years 2024, it can be observed that the time to reach parity advances by 1-2 years in non-immediate parity cases such as the class 8 transit bus, class 5 shuttle bus, class 3 delivery van, class 7 delivery truck, and class 8 refuse truck.

Table 8: Year TCO parity is reached for MY 2024 BEVs in the reference case without and with the application of IRA credits.

MY 2024 BEV	Without IRA Credits		With IRA Credits	
	Year	Time to Parity	Year	Time to Parity
C8 Transit	2026	2 years	2025	1 year
C7 School	2024	Immediate	2024	Immediate
C5 Shuttle	2027	3 years	2025	1 year
C3 Delivery	2027	3 years	2026	2 years
C5 Delivery	2024	Immediate	2024	Immediate
C7 Delivery	2028	4 years	2027	3 years
C8 Refuse	2025	1 year	2024	Immediate

A similar advancement in parity is observed with the application of IRA credits in the purchase year 2027, in classes such as class 5 shuttle bus, class 3 delivery van, and class 7 delivery truck, as shown in Table 9. The key takeaway is that largely owing to IRA credits, the end consumer can reap financial benefits in 2024 rather than 2027.

Table 9: Year TCO parity is reached for MY 2027 BEVs in the reference case without and with the application of IRA credits.

MY 2027 BEV	Without IRA Credits		With IRA Credits	
	Year	Time to Parity	Year	Time to Parity
C8 Transit	2028	1 year	2028	1 year
C7 School	2027	Immediate	2027	Immediate
C5 Shuttle	2029	2 years	2028	1 year
C3 Delivery	2029	2 years	2028	1 year
C5 Delivery	2027	Immediate	2027	Immediate
C7 Delivery	2030	3 years	2029	2 years
C8 Refuse	2027	Immediate	2027	Immediate

3.7 Hypothetical Application of Credits to Establish Battery Pack Cost Ceiling

To evaluate the impact of advanced manufacturing production credit in conjunction with a vehicle purchase price credit of $40,000, we conducted a hypothetical exercise of applying these credits to a class 8 transit bus in the purchase year 2024. We then calculated the maximum battery pack cost per kWh if it is manufactured in the U.S. while still achieving vehicle price parity. As is the case throughout this report, BEV production is assumed to occur at economies of scale. The process of applying for these credits on a per-pack basis is illustrated in Figure 9.

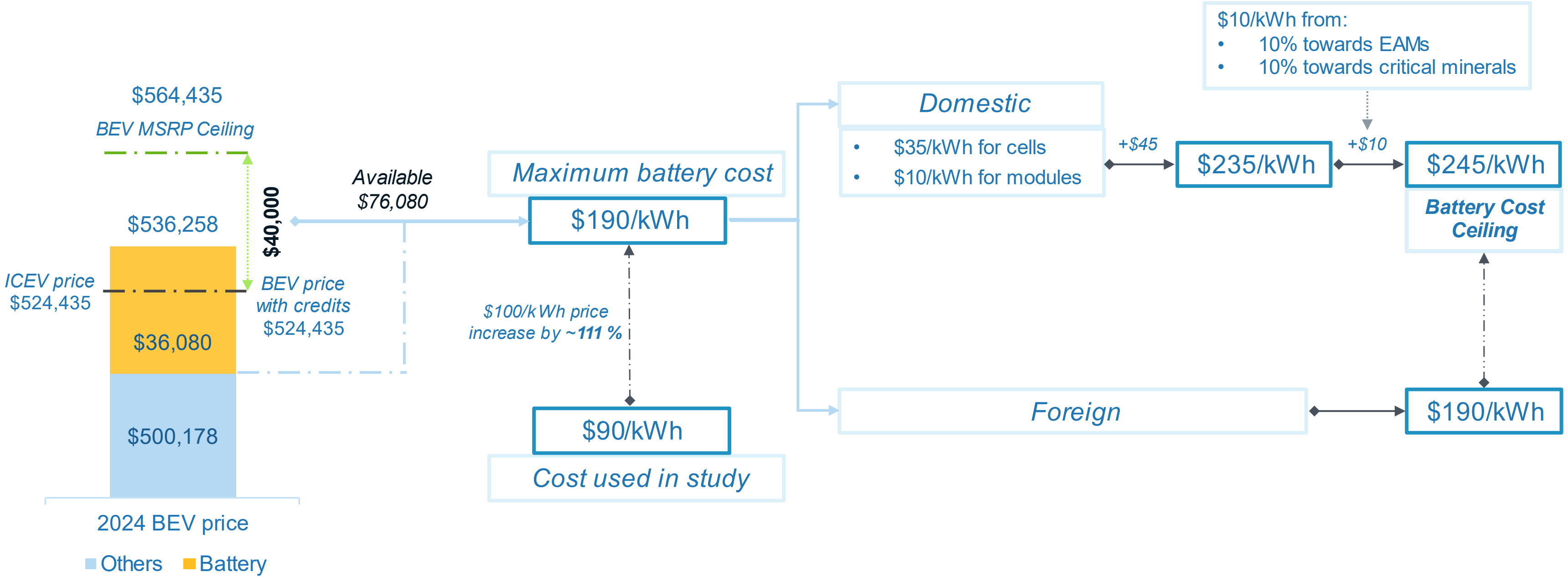


Figure 9: Hypothetical application of purchase and advanced manufacturing production credits to determine the maximum possible battery pack cost of a MY 2024 class 8 transit bus with a capacity of 400 kWh.

In the originally costed class 8 bus, the diesel bus cost $524,435, while the electric bus cost $536,258. In our assessment described above, the IRA tax credit would be $11,823, causing the price of the BEV to be the same as that of the diesel bus from the point of view of the buyer. The BEV transit bus is assumed to have a battery capacity of 400 kWh at a battery pack cost of $90/kWh in 2024. Thus, the battery constituted $36,080 of the vehicle price.

Under the IRA, the tax credit could be as high as $40,000 if the BEV bus cost $564,435. Assuming that the entire BEV price increase is due to increased battery costs, the cost of the 400 kWh battery could go up to $76,080, or $190/kWh. The purchasing credit provides a buffer of $100/kWh (~111%) on top of the original cost of $90/kWh.

If we assume that a manufacturer meets all the requirements for an advanced manufacturing production credit (§45X), the following credits apply:

a) $35/kWh for cells
b) $10/kWh for modules (assuming the manufacturer does not make cell-to-pack or cell-to-chassis configurations)
c) $10/kWh (assumed $/kWh) from 10% towards the production of electrode active materials and battery-associated critical minerals

With the stacking of these credits, the maximum pack cost of a domestically manufactured battery could be $245/kWh ($190/kWh after the vehicle tax credit, plus $55/kWh from the three battery production credits). This is about 172% more than the originally used pack cost of $90/kWh in the previous study. Of course, our original battery cost projection did not consider the sourcing of the battery materials nor the location of the battery and pack manufacturer.

In addition, for any taxable year, there is a qualifying advanced energy project credit (§48C) equal to 30% of the qualified investment in an eligible property:

a) which re-equips, expands, or establishes an industrial or manufacturing facility for the production or recycling of light-, medium-, or heavy-duty electric or fuel cell vehicles, as well as technologies, components, or materials for such vehicles, as well as associated charging or refueling infrastructure.
b) which re-equips, expands, or establishes an industrial facility for the processing, refining, or recycling of critical materials.

The advanced manufacturing production credit (§45X) cannot be claimed for components produced at a facility (or property) for which a credit was claimed under §48C (double dipping is not allowed). A wide range of projects are eligible for credits under §48C, but the following scenarios may shed more light on their potential impact on battery pack cost:

a) In cases where the automaker is essentially a vehicle integrator, i.e., sourcing a battery pack from a battery producer, then the tax incentives under §48C can be claimed by the automaker, while the credits under §45X can be claimed by the battery producer, allowing stacking of credits. Multiple automakers have joint ventures with battery producers, and most are anticipated to carry out the integration of batteries on a pack level in their BEVs. This allows them to claim the 30% tax incentive under §48C for an EV manufacturing facility; however, it is difficult to estimate the effect of §48C credits on the battery cost on a per kWh basis. Such incentives greatly benefit the EV value chain.
b) In cases where the automaker is vertically integrated, then they can claim the credits under §48C and §45X as long as the battery-related manufacturing activities and vehicle manufacturing or pack integration are done on separate properties. There's a whole gamut of activities in battery and BEV production and as long as "double benefit" is not claimed, the OEM would be able to use these credits to their advantage to produce cost-effective BEVs by lowering battery cost.

The battery value chain is incredibly complex with segmented supply chains involving numerous components and raw materials, spanning multiple vendors from various regions. This exercise attempts to demonstrate the cost buffer provided to various stakeholders in the battery ecosystem if the manufacturing is done completely in-house to be eligible for all the available credits. This is a simplified view of battery production, and numerous additional factors and elements influence the price of a battery. We recognize that we have made generous assumptions to arrive at the battery pack cost ceiling, and it is up to the automaker as to how they apportion the credits, such as §48C. Furthermore, since the 30% tax credit under §48C is for a manufacturing or industrial facility, the capital cost per unit of production and further down to the battery pack could be much lower than 30%. However, if the automakers were to use these credits towards arresting the battery price volatility by securing long-term strategic supply contracts, then it could directly impact the battery prices; however, we have not "stacked" it onto the battery cost in this analysis. Nevertheless, it is a first-order attempt to illustrate the potential "calming" effect that IRA credits could have on a potentially volatile battery supply chain.

Figure 10 shows the maximum cost a battery pack can reach in the case of other MD/HDVs with the application of purchase and advanced manufacturing production credits. The highest jump is seen in the case of a C7 school bus where the price can increase by $881 (i.e., 977%) while the lowest increase of $130 (i.e., 144%) is seen in the case of a C3 delivery van. The pack cost ceiling is dependent on the size of the battery and the availability of credits for the costed vehicles. On average, the battery pack cost could reach as high as $418/kWh i.e., a jump of 363%, and still achieve sticker price parity immediately upon purchase in 2024. This is purely a hypothetical exercise by applying all the credits towards battery pack cost and in no way a projection of battery pack cost. We recognize that the OEMs would prioritize profits while producing cost-effective BEVs and all these credits may not be passed on to benefit the end consumers.

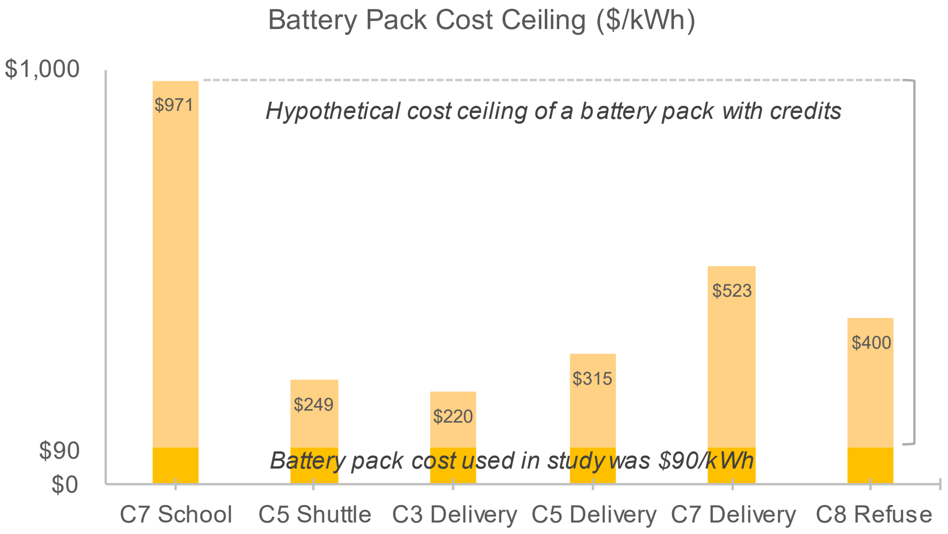
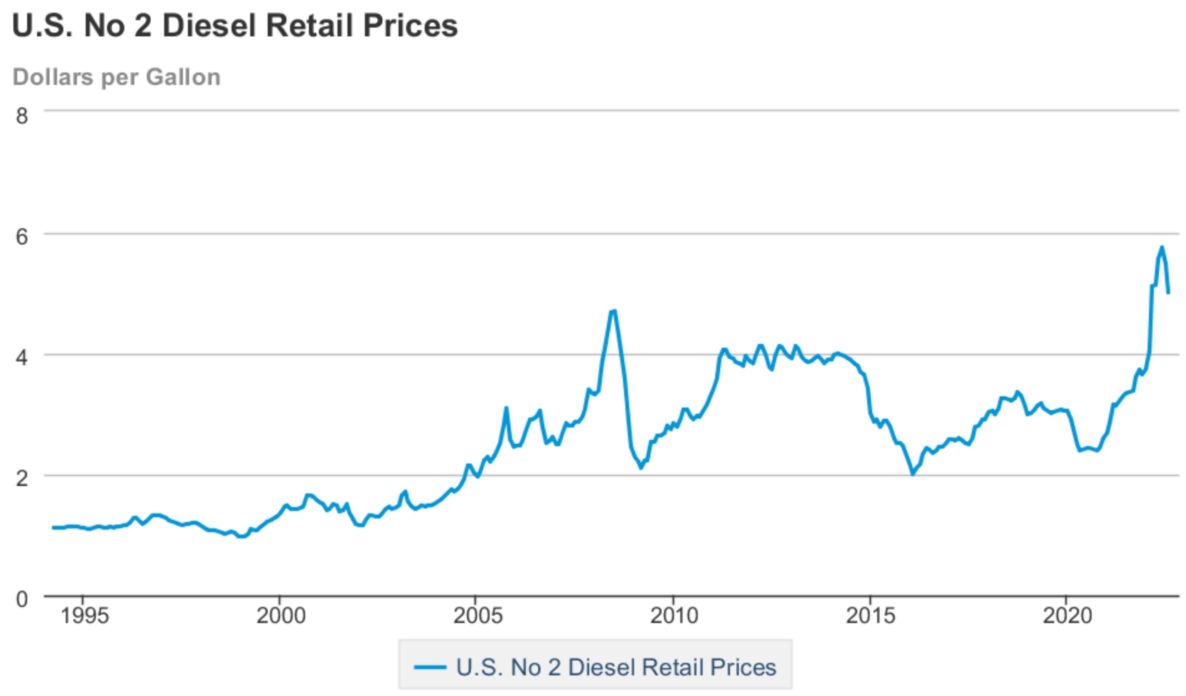


Figure 10: Hypothetical application of purchase and advanced manufacturing production credits to determine maximum battery pack cost for MD/HD vehicles.

4. Impact of High Diesel Price

With the rising gas prices and the volatile nature of oil, an exploratory exercise is conducted in this section to compare the additional net savings and TCO per mile of a diesel vehicle and BEVs without and with credits. In June 2022, diesel reached the ever-highest price of $5.754 per EIA [3] (refer to Appendix 7.1). We used $5.18 as diesel price without taxes as a sensitivity input to estimate its impact.



Source: U.S. Energy Information Administration

Figure 11: Historical U.S. Diesel Retail Price, EIA [3]

Figure 12 depicts the cumulative net savings and additional net savings for a BEV, original, with credits, and credits in a high diesel price scenario. The net savings go up considerably across all the classes in the high diesel price scenario with credits. This demonstrates that cumulative savings are a major factor that should be considered by fleet owners with a perspective on rising oil prices in the current world order.

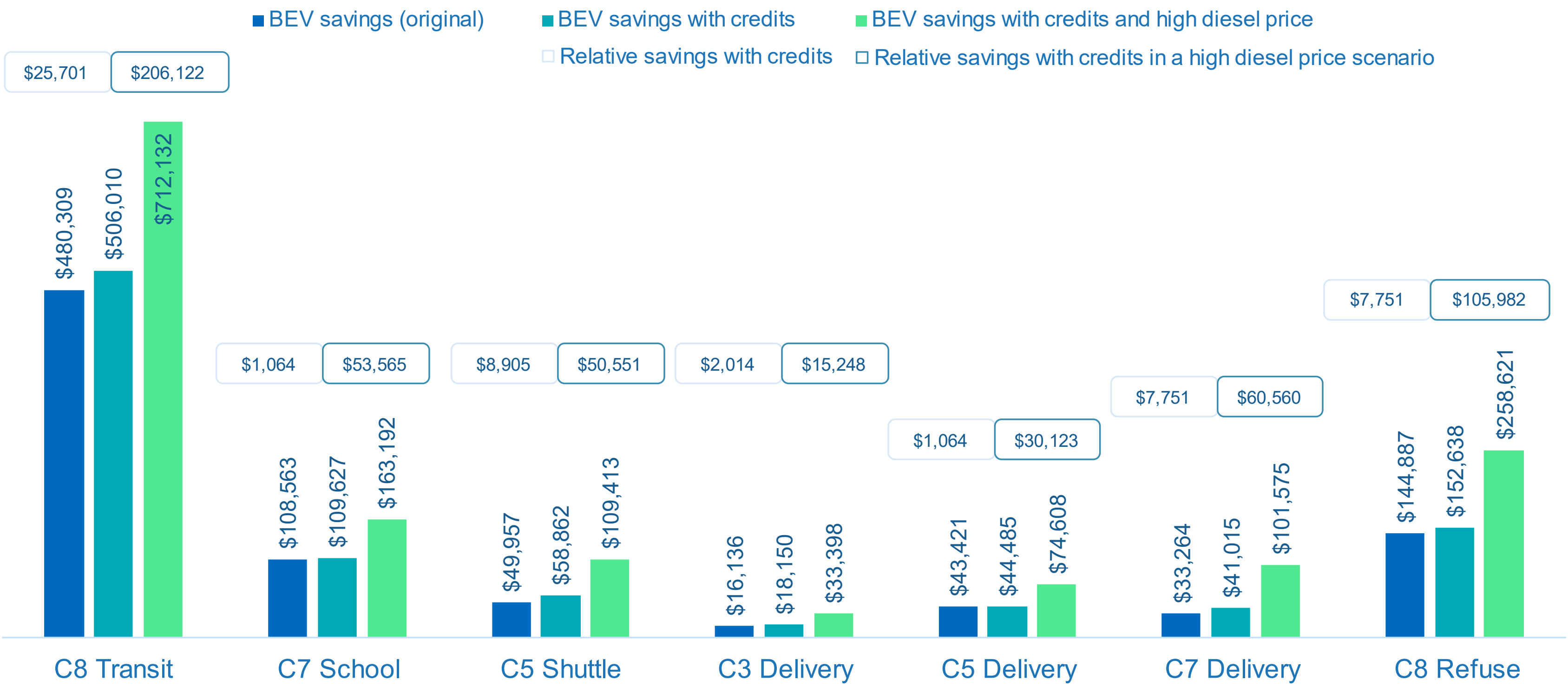


Figure 12: Comparison of cumulative net savings and additional net savings for a BEV, original, with credits, and credits in a high diesel price scenario observed in reference case in the 2027 purchase timeframe.

Figure 13 depicts the TCO per mile for a diesel vehicle and a BEV, without and with credits. With the rising oil prices and diesel vehicle prices due to meeting the regulatory requirements, the TCO of a BEV is much cheaper across all the classes despite the seemingly high upfront charger-related costs.

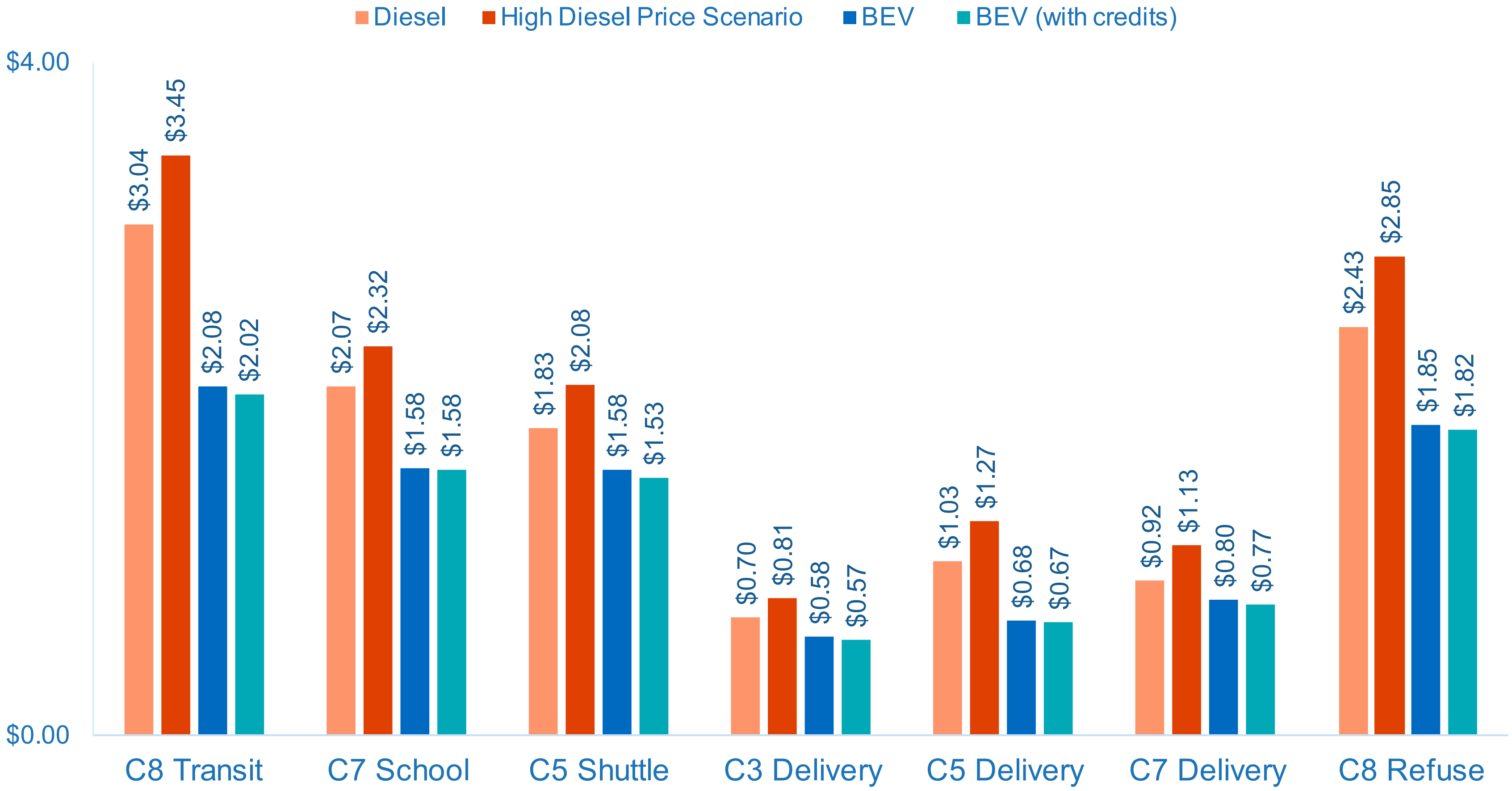


Figure 13: Comparison of the total cost of ownership (TCO) in $/mile in a high diesel price scenario in the reference case in the 2027 purchase timeframe.

5. Conclusion

The provisions in the IRA of 2022 on the electrification of the MD/HD segment would stimulate and promote the growth of BEVs. The provisions benefit the transportation-based ecosystem in a variety of ways, from upstream producers, midstream cell makers, and automakers to downstream end consumers who adopt BEVs in this segment. It incentivizes the entire value chain, attracting investments toward the transition to clean transportation. In general, the considered MD/HD vehicle classes would achieve immediate purchase parity in the near term (2024) on successful implementation of the provisions. The end user is not required to postpone electrifying their fleet until 2027 or later, as seen in the previous study.

The key takeaways of the study are:

a) The IRA of 2022's provisions regarding buying credits and charger equipment credits will directly affect the end user's savings. As the price of the battery pack falls, so does the net savings of a BEV with IRA credits over a BEV without one.

b) MY 2024 class 8 (C8) refuse haulers, C7 school buses and box trucks, C5 delivery trucks, and all other MY 2027 BEVs except the C5 shuttle bus, had already reached purchase parity with their diesel equivalents. The purchase parity of the MY 2024 C8 transit bus, C5 shuttle bus, and C3 delivery van, as well as the MY 2027 C5 shuttle bus, is accelerated by IRA credits to immediate. The credits shorten the time it takes to break even in situations where it wasn't already immediate by 1-2 years. In essence, fleet owners can take advantage of the credits as early as 2024 rather than delaying electrifying their fleets until 2027 and beyond.

c) Switching to BEVs would allow fleet owners to effectively reduce their TCO per mile by an average of 24%, which is almost a quarter of the cumulative costs incurred over a diesel vehicle’s lifetime.

d) The MSRP ceiling of a BEV can be higher by $7,500 in the case of a C3 delivery van and up to $40,000 for other classes, providing a cost buffer to the OEMs. This situation applies when the BEV purchase price is already close to the ICEV price without subsidy. In other words, instead of achieving parity, the subsidy allows for–a BEV with a larger battery, to absorb price fluctuations, and/or to invest in the regionalization of supply chains.

e) The charging equipment-related savings can vary from $1,064 for a 25 kW AC charger to $26,000 for a 300+ kW DC fast charger. The affordability and savings associated with the purchase price and charger equipment price improve significantly for a fleet owner.

f) With rising oil prices and uncertainty about future prices, the savings from BEVs with IRA credits ranging from 26% to 47% over equivalent diesel vehicles are significant for any fleet owner, as shown in the diesel price sensitivity analysis.

6. References

[1] V. Nair, S. Stone, and G. Rogers, “Technical Review of Medium and Heavy-Duty Electrification Costs for MY 2027- 2030,” 2022. [Online]. Available: https://blogs.edf.org/climate411/files/2022/02/EDF-MDHD-Electrification-v1.6_20220209.pdf

[2] U.S. Environmental Protection Agency, “Facts,” 2021. [Online]. Available: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[3] U.S. Energy Information Administration, “U.S. No 2 Diesel Retail Prices (Dollars per Gallon).” https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emd_epd2d_pte_nus_dpg&f=m (accessed Sep. 19, 2022).

7. Appendix

7.1 Diesel Retail Prices

The yellow-highlighted price in Table 10 was used for diesel price sensitivity analysis.

Table 10: U.S. No 2 Diesel Retail Prices (Dollars per Gallon), EIA [3]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994			NA	1.107	1.1	1.103	1.11	1.123	1.125	1.122	1.131	1.113
1995	1.098	1.088	1.088	1.104	1.126	1.12	1.1	1.105	1.119	1.115	1.12	1.13
1996	1.145	1.145	1.183	1.275	1.273	1.201	1.176	1.201	1.265	1.323	1.323	1.309
1997	1.291	1.28	1.229	1.212	1.196	1.173	1.151	1.165	1.16	1.183	1.192	1.166
1998	1.12	1.084	1.063	1.067	1.069	1.041	1.029	1.007	1.024	1.039	1.022	0.973
1999	0.967	0.959	0.997	1.079	1.073	1.074	1.122	1.172	1.215	1.228	1.263	1.292
2000	1.356	1.461	1.479	1.422	1.42	1.421	1.434	1.466	1.637	1.637	1.621	1.565
2001	1.524	1.492	1.399	1.422	1.496	1.482	1.375	1.39	1.495	1.348	1.259	1.167
2002	1.153	1.152	1.230	1.309	1.305	1.286	1.299	1.328	1.411	1.462	1.42	1.429
2003	1.488	1.654	1.708	1.533	1.451	1.424	1.435	1.487	1.467	1.481	1.482	1.49
2004	1.551	1.582	1.629	1.692	1.746	1.711	1.739	1.833	1.917	2.134	2.147	2.009
2005	1.959	2.027	2.214	2.292	2.199	2.29	2.373	2.5	2.819	3.095	2.573	2.443
2006	2.467	2.475	2.559	2.728	2.897	2.898	2.934	3.045	2.783	2.519	2.545	2.61
2007	2.485	2.488	2.667	2.834	2.796	2.808	2.868	2.869	2.953	3.075	3.396	3.341
2008	3.308	3.377	3.881	4.084	4.425	4.677	4.703	4.302	4.024	3.576	2.876	2.449
2009	2.292	2.195	2.092	2.22	2.227	2.529	2.54	2.634	2.626	2.672	2.792	2.745
2010	2.845	2.785	2.915	3.059	3.069	2.948	2.911	2.959	2.946	3.052	3.14	3.243
2011	3.388	3.584	3.905	4.064	4.047	3.933	3.905	3.86	3.837	3.798	3.962	3.861
2012	3.833	3.953	4.127	4.115	3.979	3.759	3.721	3.983	4.12	4.094	4	3.961
2013	3.909	4.111	4.068	3.93	3.87	3.849	3.866	3.905	3.961	3.885	3.839	3.882
2014	3.893	3.984	4.001	3.964	3.943	3.906	3.884	3.838	3.792	3.681	3.647	3.411
2015	2.997	2.858	2.897	2.782	2.888	2.873	2.788	2.595	2.505	2.519	2.467	2.31
2016	2.143	1.998	2.090	2.152	2.315	2.423	2.405	2.351	2.394	2.454	2.439	2.51
2017	2.58	2.568	2.554	2.583	2.56	2.511	2.496	2.595	2.785	2.794	2.909	2.909
2018	3.018	3.046	2.988	3.096	3.244	3.253	3.233	3.218	3.262	3.365	3.3	3.123
2019	2.98	2.997	3.076	3.121	3.161	3.089	3.045	3.005	3.016	3.053	3.069	3.055
2020	3.048	2.91	2.729	2.493	2.392	2.408	2.434	2.429	2.414	2.389	2.432	2.585
2021	2.681	2.847	3.152	3.13	3.217	3.287	3.339	3.35	3.384	3.612	3.727	3.641
2022	3.724	4.032	5.105	5.12	5.571	**5.754**	5.486					

7.2 Original Study Inputs

Table 11: Vehicle lifespans used in the TCO analysis for Reference Case

Vehicle Type	Mileage (or Vehicle Miles Traveled (VMT))	Years
Transit – Class 8	500,000	12
School Bus – Class 7	221,120	10
Shuttle – Class 5	200,000	7
Delivery Van – Class 3	136,785	11
Delivery – Class 5	124,350	10
Delivery – Class 7	285,710	10
Refuse – Class 8	250,000	10

Table 12: Charger infrastructure costs

Charger – 25 kW	$3,548.01
Installation – 25 kW	$3,626.05
Charger – 50 kW	$25,836.12
Installation – 50 kW	$14,005.09
Charger – 70 kW	$54,300.89
Installation – 70 kW	$21,938.63
Charger – 100 kW	$85,671.00
Installation – 100 kW	$34,232.60
Charger - DCFC 300+	$259,999.78
Installation - DCFC 300+	$132,707.14

7.3 List of Critical Minerals Eligible for IRA Credits Under §45X.

The term “applicable critical mineral” means any of the following:

a) Aluminum which is—
  i) converted from bauxite to a minimum purity of 99% alumina by mass, or
  ii) purified to a minimum purity of 99.9% aluminum by mass.
b) Antimony which is—
  i) converted to antimony trisulfide concentrate with a minimum purity of 90% antimony trisulfide by mass, or
  ii) purified to a minimum purity of 99.65% antimony by mass.
c) Barite which is barium sulfate purified to a minimum purity of 80% barite by mass.
d) Beryllium which is—
  i) converted to copper-beryllium master alloy, or
  ii) purified to a minimum purity of 99% beryllium by mass.
e) Cerium which is—
  i) converted to cerium oxide which is purified to a minimum purity of 99.9% cerium oxide by mass, or
  ii) purified to a minimum purity of 99% cerium by mass.
f) Cesium which is—
  i) converted to cesium formate or cesium carbonate, or
  ii) purified to a minimum purity of 99% cesium by mass.
g) Chromium which is—
  i) converted to ferrochromium consisting of not less than 60% chromium by mass, or
  ii) (purified to a minimum purity of 99% chromium by mass.
h) Cobalt which is—
  i) converted to cobalt sulfate, or
  ii) purified to a minimum purity of 99.6% cobalt by mass.
i) Dysprosium which is—
  i) converted to not less than 99% pure dysprosium iron alloy by mass, or
  ii) purified to a minimum purity of 99% dysprosium by mass.
j) Europium which is—
  i) converted to europium oxide which is purified to a minimum purity of 99.9% europium oxide by mass, or
  ii) purified to a minimum purity of 99% by mass.
k) Fluorspar which is—
  i) converted to fluorspar which is purified to a minimum purity of 97% calcium fluoride by mass, or
  ii) purified to a minimum purity of 99% fluorspar by mass.
l) Gadolinium which is—

  - i) converted to gadolinium oxide which is purified to a minimum purity of 99.9% gadolinium oxide by mass, or
  - ii) purified to a minimum purity of 99% gadolinium by mass.
- m) Germanium which is—
  - i) converted to germanium tetrachloride, or
  - ii) purified to a minimum purity of 99.99% germanium by mass.
- n) Graphite which is purified to a minimum purity of 99.9% graphitic carbon by mass.
- o) Indium which is—
  - i) converted to—
    - a. indium tin oxide, or
    - b. indium oxide which is purified to a minimum purity of 99.9% indium oxide by mass, or
  - ii) purified to a minimum purity of 99% indium by mass.
- p) Lithium which is—
  - i) converted to lithium carbonate or lithium hydroxide, or
  - ii) purified to a minimum purity of 99.9% lithium by mass.
- q) Manganese which is—
  - i) converted to manganese sulphate, or
  - ii) purified to a minimum purity of 99.7% manganese by mass.
- r) Neodymium which is—
  - i) converted to neodymium-praseodymium oxide which is purified to a minimum purity of 99% neodymium-praseodymium oxide by mass,
  - ii) converted to neodymium oxide which is purified to a minimum purity of 99.5% neodymium oxide by mass
  - iii) purified to a minimum purity of 99.9% neodymium by mass.
- s) Nickel which is—
  - i) converted to nickel sulphate, or
  - ii) purified to a minimum purity of 99% nickel by mass.
- t) Niobium which is—
  - i) converted to ferronibium, or
  - ii) purified to a minimum purity of 99% niobium by mass.
- u) Tellurium which is—
  - i) converted to cadmium telluride, or
  - ii) purified to a minimum purity of 99% tellurium by mass.
- v) Tin which is purified to low alpha emitting tin which—
  - i) has a purity of greater than 99.99% by mass, and
  - ii) possesses an alpha emission rate of not greater than 0.01 counts per hour per centimeter square.

w) Tungsten which is converted to ammonium paratungstate or ferrotungsten.
x) Vanadium which is converted to ferrovanadium or vanadium pentoxide.
y) Yttrium which is—
  i) converted to yttrium oxide which is purified to a minimum purity of 99.999% yttrium oxide by mass, or
  ii) purified to a minimum purity of 99.9% yttrium by mass.
z) Any of the following minerals provided that such mineral is purified to a minimum purity of 99% by mass:
  i) Arsenic.
  ii) Bismuth.
  iii) Erbium.
  iv) Gallium.
  v) Hafnium.
  vi) Holmium.
  vii) Iridium.
  viii) Lanthanum.
  ix) Lutetium.
  x) Magnesium.
  xi) Palladium.
  xii) Platinum.
  xiii) Praseodymium.
  xiv) Rhodium.
  xv) Rubidium.
  xvi) Ruthenium.
  xvii) Samarium.
  xviii) Scandium.
  xix) Tantalum.
  xx) Terbium.
  xxi) Thulium.
  xxii) Titanium.
  xxiii) Ytterbium.
  xxiv) Zinc.
  xxv) Zirconium.