THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

15 June 2023
U.S. Environmental Protection Agency
EPA Docket Center, Office of Air and Radiation Docket, Mail Code 28221T
1200 Pennsylvania Avenue, NW
Washington, DC 20460

DOCKET ID: EPA-HQ-OAR-2022-0985

RE: International Council on Clean Transportation (ICCT) comments on EPA proposed rule, titled "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3"

Dear Brian Nelson:

The International Council on Clean Transportation (ICCT) respectfully submits these comments in support of the finalization of a third phase of greenhouse gas emission standards for new heavy-duty highway vehicles proposed on 27 April 2023.

The ICCT was established in 2001 as an independent source of technical and policy expertise for motor vehicle regulators collectively working towards improving the environmental performance and energy efficiency of road, marine, and air transportation, in order to benefit public health and mitigate climate change. With dozens of international experts on staff and in partnership with current and former vehicle regulators, our work supports the development and implementation of advanced vehicle regulations in the world's largest markets, including the European Union, China, Canada, Mexico, India, Brazil, Indonesia, and others.

The ICCT welcomes the opportunity to provide comments on this proposal. We commend the agency for its continued efforts to promote a cleaner and more efficient vehicle fleet that can deliver near-term public health benefits, particularly in communities of concern, as well as greenhouse reductions needed at a pace consistent with the Paris Climate Accords. The comments below offer technical analysis of the proposal and specific recommendations for your consideration that would increase the greenhouse gas emission reductions achieved and accelerate the transition to zero-emission heavy-duty vehicles.

We would be glad to clarify or elaborate on any points made in our comments. Feel free to contact our Heavy-Duty Vehicles Program Director, Ray Minjares (ray@theicct.org) with any questions.

Sincerely,

Rachel Muncrief
Acting Executive Director
International Council on Clean Transportation

Executive summary

These comments provide data and technical analysis to support EPA in delivering greater absolute benefits from its proposal and ensuring these benefits reach more states. The comments address specific actions EPA can take to revise its forecast of zero-emission vehicle (ZEV) adoption to reflect more realistic and technically feasible assumptions of zero-emission vehicle and infrastructure deployment. These comments also provide information that demonstrates cost-effective improvements in internal combustion engine vehicle efficiency technologies whose deployment would increase the rule's benefits. Our analysis suggests the benefits of the proposed rule could more than double with appropriate changes in these areas.

Forecast of ZEV adoption

EPA proposes to define the stringency of its greenhouse gas standard based on a projection of future zero-emission vehicle sales. While the approach in principle is sound, our analysis has identified several improvements that, if corrected, would increase the potential benefits of this rule.

EPA has selected a model of technology adoption rates that we do not support. Central to the EPA approach is a market forecast of zero-emission vehicle (ZEV) adoption based on Equation 2-61 of the Draft Regulatory Impact Assessment. This model of ZEV technology adoption rates is taken from a proprietary study prepared by ACT Research. We find EPA's selection of the ACT Research study to be arbitrary. Furthermore, the selection of this study presents significant obstacles to public comment. The study is not available in the public docket and is not available from the EPA Reading Room. The study is available today for purchase at a cost of $25,000. This approach is not consistent with traditional standards of transparency that we think are necessary for the agency to defend and support its rulemakings.

To provide meaningful comment on this aspect of the rule, ICCT purchased the ACT Research report. Due to licensing limitations, we cannot comment on the specifics of the report. Based on our thorough review, we conclude that the report contains no empirical basis for equation 2-61 and cannot be used as the basis for the standards EPA proposes.

We consulted with several other research groups cited by EPA as the source of alternative technology adoption curves. We conclude and recommend that EPA adopt the TEMPO model, developed by the National Renewable Energy Laboratory (NREL), as the basis for projecting ZEV technology adoption rates. This model overcomes key deficiencies of the ACT Research-based curve by being based on validated empirical data, subject to peer-review, and freely available to the public.

Adoption of the TEMPO model would change the stringency of the proposed rule. All else being equal, we find replacing the EPA curve with a TEMPO-based curve would project a 37% ZEV market share in model year 2027 and a 60% market share in model year 2032. These estimates reflect the average share across all vehicle categories. We conclude that the selection of the TEMPO model, or a similarly robust and transparent model, is necessary for EPA to not only maintain traditional standards of transparency necessary to defend and support its rulemaking but to also utilize the best available data to project zero-emission vehicle sales. As a co-benefit, the rule will ensure greater benefits to public health and welfare.

Another element of the proposal that deserves reconsideration is the treatment of state zero-emission vehicle sales requirements in setting the stringency of the proposed standards. California and at least eight other states (Oregon, Washington, New York, New Jersey, Massachusetts, Vermont, Colorado, and Maryland) to-date have adopted the Advanced Clean Trucks (ACT) regulation, which sets minimum zero-emission truck sales requirements that exceed the ZEV technology adoption rate of the proposal. The stringency of the proposed standards does not take into consideration these higher state-mandated sales of zero-emission vehicles, but the proposal would nevertheless allow manufacturers to use these higher ZEV sales to demonstrate compliance. This compliance approach deviates from the approach taken in the Phase 2 standards.

Treating ZEV sales in manufacturer compliance determinations differently than for standard setting as EPA has proposed will result in adverse impacts. The higher ZEV sales in the nine states could be used by manufacturers to reduce the sales volume of ZEVs in the other states to a level far less than EPA's current market projection, potentially impeding investment in ZEV fleets and infrastructure in non-ACT states. Another result could be the higher ZEV sales in the nine states could allow manufacturers to certify and sell ICE vehicles with higher CO_2 emissions in the non-ACT states. Either outcome could result in fewer zero-emission vehicles and less efficient ICE vehicles deployed in non-ACT states, which would generate an inequitable distribution of benefits among states.

This inconsistency can be resolved in one of two ways. The first and simplest way is for EPA to retain the Phase 2 provision that would exclude vehicle sales in the ACT states when determining compliance with the EPA standards. The second way is for EPA, in determining the stringency of its greenhouse gas (GHG) standards, to proportionally weight the higher sales of ZEVs in the nine states with its revised market-based projection of sales in the other 41 states. As an example, we conclude that a national weighted average 2032 ZEV sales for Class 4–8 vehicles would be 33% using data given in Table 5 instead of 27% as projected in EPA's proposal. EPA would set a corresponding numerical lower average national GHG standard based on this weighted average. The adoption of one of these two approaches would ensure greater overall benefits and a greater distribution of benefits from the rule.

We support the agency's conclusions regarding infrastructure lead time for battery-powered vehicles. Our research shows a very strong business case exists for investment in charging infrastructure to enable these trucks, especially tractor-trucks that consume the most fuel. According to Atlas Public Policy, $20 billion in announced and awarded investments in publicly accessible charging infrastructure for all on-road vehicles have been made through 2023. As soon as 2027, battery-powered tractor-trucks will be cheaper to own and operate than diesel-powered trucks, according to our own published analysis. Billions of dollars are already being deployed to establish a multi-state network of electric truck charging depots and long-distance fast charging corridors. The strong business case for these investments is reflected in companies such as GreenLane, Terrawatt Infrastructure, Forum Mobility, WattEV, Voltera, Tesla, and many others.

The EPA rule would more closely reflect this business case with changes in its battery size assumptions. Excessively large battery sizes of over 1,000 kWh and up to 2,036 kWh for "vehicle ID 79" are driven by EPA's assumption that opportunity charging for long-distance truck applications will not exist. Opportunity charging can reduce the required battery mileage design point by more than 20% when assuming 350 kW charging capacity and by more than 40% when assuming 1 MW charging capacity. By assuming availability of opportunity charging, ICCT analysis demonstrates lower total-cost-of-ownership and higher forecasted adoption of battery-powered tractors in this decade relative to fuel cell powered tractors.

First, we suggest EPA size batteries based on daily energy needs, taking into account opportunity charging performed during a driver's mandatory break. Second, we suggest EPA assume per-vehicle charging capacity at publicly accessible charging stations is 350 kW today and will be 1 MW as of 2027. Finally, we suggest EPA assume a maximum battery size of 1 MWh due to payload and volume capacity constraints. Battery size assumptions are critical to the stringency of this proposal since they shape the retail price of battery-electric trucks, their fuel economy, technology payback period, technology adoption rate, the stringency of the proposal, and the benefits of the rule.

Improvements in ICE efficiency beyond Phase 2 requirements

EPA proposes Phase 3 greenhouse gas standards that do not reflect the adoption of new efficiency technologies for internal combustion engines and vehicles beyond those required to meet existing Phase 2 standards. EPA identified a range of technology packages with payback periods no greater than two-years when it finalized its Phase 2 standards in 2016. We find that manufacturers have been able to meet the standards without utilizing all technologies identified in the Phase 2 rule. Our research suggests that utilizing these and other technologies provide a potential additional improvement in ICE vehicle efficiency up to 23% in the high-roof sleeper cab vehicle category or up to 13% if we exclude engine efficiency improvements. Our research also suggests a potential ICE vehicle efficiency improvement of up to 31% for a diesel-fueled Class 6 multi-purpose vocational vehicle or up to a 20% improvement excluding engine efficiency gains. Certain strategies – including aerodynamic and tire efficiency improvements – are even more likely to be adopted because they can cost-effectively reduce the cost and increase the range of zero-emission vehicles. We conservatively estimate that incorporating such additional technologies in the stringency of the proposed rule – not including engine technology improvements – would generate an additional 537 million tonnes of cumulative CO_2 emissions avoided between 2020 and 2050.

We consider the market forecast of ZEV sales that informs this rule to be an upper limit on ZEV deployment in light of the fact EPA has not accounted for any deployment of vehicle efficiency technologies. For every 1% efficiency improvement due to technologies like aerodynamic drag reduction, for example, we estimate the projected ZEV sales share would decline by 0.8% for Class 8 high roof sleeper-cab tractors. EPA can provider greater certainty its ZEV market forecast will be met by adjusting the stringency of its rule to reflect cost-effective ICE efficiency improvements beyond those required to meet Phase 2 standards. Our analysis suggests that a more stringent standard is feasible based on the well-established technology potential we and the agency have previously identified.

An additional 1.8 Gt of avoided CO_2 through 2050 is technically feasible

In summary, EPA can make at least three major improvements to its proposal. First, the agency can revise its approach to projecting ZEV technology adoption, which our analysis suggests would increase the projected number of future ZEV sales. Second, the agency can exclude ZEV sales in ACT states when determining compliance with federal standards, or it can treat sales in a consistent manner in both setting the stringency of its emission standards and in determining manufacturer compliance. Finally, EPA can reflect additional ICE vehicle efficiency improvements beyond those required to comply with Phase 2 standards when finalizing the stringency of its standards.

Figure ES-1 illustrates the range of potential benefits from these three improvements. The EPA Proposal scenario represents the original EPA proposal. The EPA Proposal + Cost Effective ICE Improvement scenario represents the additional benefits if EPA were to assume deployment of additional ICE efficiency technology beyond Phase 2 requirements in its standard setting. The EPA Proposal + Cost Effective ICE Improvement + ICCT projected ZEV market growth including ACT state adoption scenario reflects the assumptions of the previous scenario and includes additional ZEV sales required in ACT states in addition to projected sales of ZEVs in non-ACT states, drawn from previous analysis of the effect of Inflation Reduction Act incentives on ZEV sales published by ICCT. (These projections are not taken from the TEMPO-based technology adoption curve, which we suggest be considered.) The National ACT + Cost Effective ICE Improvements + 100% ZEV sales in 2040 scenario reflects a schedule of ZEV sales equivalent to the requirements of the ACT at a national level and the scenario includes a 100% ZEV sales requirement in 2040. This last scenario is the only one shown that aligns with Paris climate goals and with U.S. support for the targets set under the Global Memorandum of Understanding endorsed by the White House in November 2022[1].

Our analysis suggests a pathway for EPA to potentially double the benefits of its original proposal – by about 1.8Gt through 2050. The proposal could deliver approximately 40% greater greenhouse gas reductions in 2050 by including additional cost-effective ICE vehicle efficiency technologies. And while we do not model the TEMPO-based technology adoption curve, we estimate based on previously published ICCT work that ZEV market uptake more closely aligned with projections from the TEMPO model could deliver greater benefits. This work illustrates the multiple pathways EPA has available to strengthen its proposal.

[1] https://www.energy.gov/articles/us-secretary-energy-advances-americas-commitment-reaching-net-zero-global-emissions-and

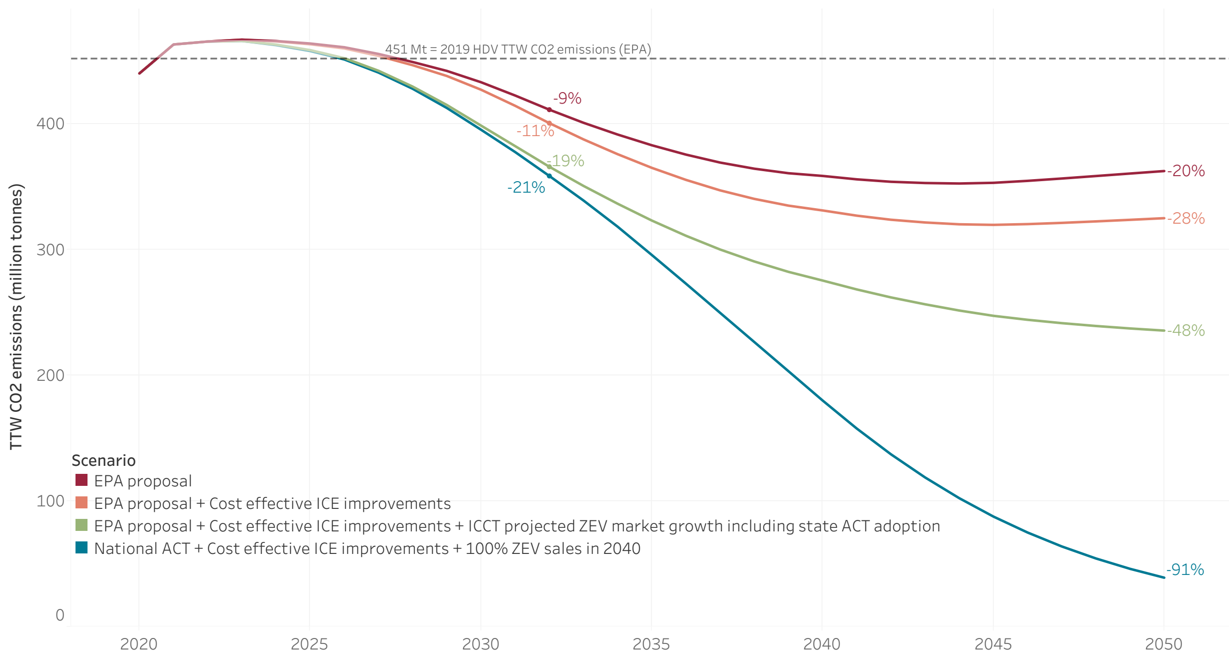

FIGURE ES-1. 2019-2050 ANNUAL TANK-TO-WHEEL (TTW) CO_2 EMISSION PATHWAYS FOR EACH SCENARIO

OTHER CONSIDERATIONS

ICCT supports the proposal to eliminate advanced technology credit multipliers. Historically, these multipliers were appropriate to provide manufacturers an incentive to invest in the research and development of battery electric and fuel-cell electric vehicles that had yet to be commercialized. Since the adoption of the Phase 2 standards, these technologies have entered the commercial market on a broad scale and, beginning in model year 2024, nine states will require manufacturers to sell them. We do not think multipliers have any further role to play in this rule.

ICCT supports the proposal to establish durability monitoring and warranty requirements for batteries. The battery is the most significant new cost component of a zero-emission vehicle. The used vehicle market will rely to a significant extent on access to objective information on the state of health of the battery to inform residual value calculations. Durability monitoring and warranty requirements will provide greater certainty to fleet customers that their batteries are reliable. These requirements will create a level playing field for the industry to meet minimum reporting and warranty expectations.

ICCT supports EPA's proposed revision of its regulations addressing preemption of state regulation of locomotives and new engines used in locomotives. The proposal allows California to proceed with innovative programs and regulatory policies to address emissions from in-use locomotives. The proposal would permit the state to move forward with a pending locomotive in-use regulation, which would increase the pace at which locomotive emissions are reduced and increase the opportunity to transition to zero-emission locomotives.

Technical summary

Assumptions regarding zero-emission vehicle technology and infrastructure

ZEV Technology Adoption Rate

This section responds to EPA's request for comment on their approach to selecting technology adoption rates for battery electric and fuel-cell electric vehicles based on payback period. While we support the approach in principle, we have identified changes to the approach that we think would strengthen the rule.

First, the EPA's approach to estimating technology adoption rates can be improved by reducing its reliance on a proprietary study. In section 2.7.9 of the Draft Regulatory Impact Assessment, EPA cites the ACT Research report *ChargeForward* published in December 2021(Mitchell, 2023). This report is the source of equation 2-61, which reflects a relationship between the payback period and the technology adoption rates given in Table 2-72, and which produces an adoption rate schedule for model years 2027 and 2032 in HD TRUCS given in Table 2-73. EPA cites other studies, including studies by CALSTART, NREL, and ICCT, but in our view chooses to arbitrarily rely exclusively on the ACT Research study to produce Table 2-73.

In light of the sensitivity of the EPA proposal to equation 2-61, ICCT sought to understand the empirical basis of this formula by securing a copy of the study. The ACT Research *ChargeForward* report is not licensed for publication and is not available in the public docket or in the EPA reading room (Mitchell, 2023). An ACT Research website lists the price of the full North America version of the report at $25,000.[2] This circumstance does not meet traditional standards of transparency and public access that have historically been necessary to justify EPA rulemakings.

In order to provide comment on the empirical basis and technical underpinning of Equation 2-61, ICCT purchased the report from ACT Research. In purchasing the report, ICCT accepted a licensing agreement that restricts its ability to distribute or reproduce the report or selected data outside of the organization under any circumstance. For the purposes of these comments, we are limiting ourselves to generalizations of what we find in the report in order to honor the licensing agreement with ACT Research.

We conclude that the ACT Research report provides no data or any other empirical basis to support Equation 2-61. The equation is contained in a total-cost-of-ownership model provided with the report. This equation generates a projected share of ZEV sales in each calendar year that is applied equally across twelve vehicle categories selected to represent class 4-8 vehicles. The report is 200 pages in length and contains a one-paragraph description of the equation. This paragraph contains no citations, data or analysis. The paragraph points to the experience of the authors as the source of the equation.

Considering how fundamental this equation is to the stringency of the rule, we find its justification to be wholly inadequate, out of step with traditional standards of scientific rigor, and not representative of the deep technical research and scientific knowledge we know is available to support this rule. We do not support this equation as the basis for defining technology adoption rates. We are very concerned about the viability of the rule without a change in approach.

Furthermore, EPA claims that the considered technology adoption curve follows an S-shape curve. While ICCT takes no issue with the shape of the curve, we disagree with the decision to convert a smooth s-curve into a step curve, where a discrete single value of adoption rate is assigned to a bin of payback periods. A step curve is not conceptually consistent with technology diffusion and should be revised. ICCT examined the impact of converting the s-curve into a step curve on the total ZEV adoption rate and found the s-curve

[2] https://www.actresearch.net/consulting/special-projects/commercial-vehicle-decarbonization-forecast-reports

shows a 7% higher total ZEV adoption rate by 2032. ICCT recommends using a smooth s-curve to represent technology adoption rates.

Moreover, EPA has modified the ACT research technology adoption curve to a seemingly arbitrary maximum adoption rate of 80%, a value below what we find in the ACT Research report. To justify this cap, EPA assumes that not all truck owners and fleets will have the financial and technical capacity to install and access chargers at their convenience. The proposal does not present an analysis of infrastructure needs to support this assumption. ICCT supports a 90% cap, which aligns with the assumption EPA makes that the energy storage system of the vehicle is sized to meet the 90th percentile of the truck's daily mileage. ICCT finds this assumption reasonable and a more appropriate basis for the cap. To support this point and respond to EPA's request for comment on infrastructure availability, we discuss trucks' infrastructure needs and the progress in fulfilling them in other sections of these comments.

Our view is the EPA rule can be strengthened through the adoption of an alternative technology adoption curve derived from empirical data, free to access, and open to public scrutiny. We propose EPA select a technology adoption curve which we refer to here as the TEMPO curve. The curve was derived by the Environmental Defense Fund (EDF) from the Transportation Energy & Mobility Pathway Options (TEMPO) Model (Muratori et al., 2021) and shared with the ICCT.[3] The curve is capped at 90%, in line with our recommendation. The EPA curve, TEMPO curve, and combined EPA and TEMPO curves are presented in Figure 2 and tabulated in the appendix in Table A. 1.

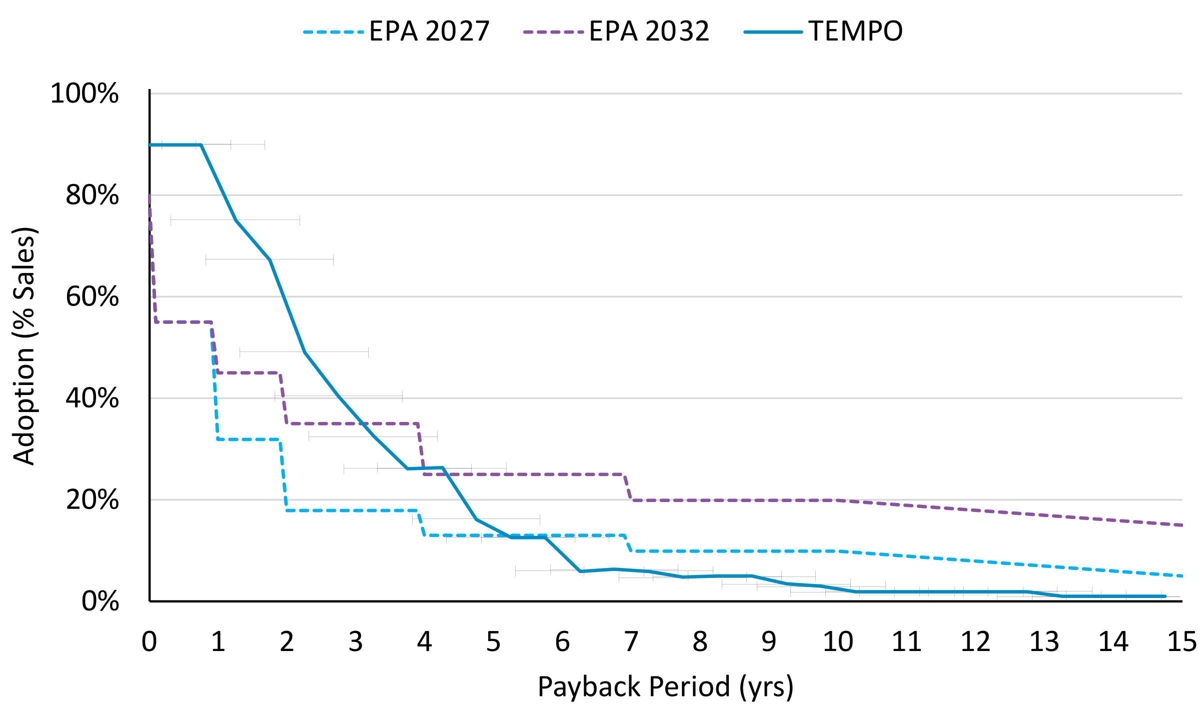

FIGURE 2. SUMMARY OF THE DIFFERENT TECHNOLOGY ADOPTION CURVES ICCT USED TO ESTIMATE THE TOTAL ZEV ADOPTION RATES.

EPA has applied a faster adoption rate in comparison to the ACT research rates for the high payback periods bins due to the impact of the proposed regulation. ICCT supports this assumption. The proposed TEMPO curve doesn't take into account the impact of the proposed regulation on technology adoption. We

[3] Please refer to comments submitted by the Environmental Defense Fund for a discussion of methods.

develop another variant of the TEMPO curve considering EPA's adoption rates for payback periods above 6 years in 2027, and above 4 years in 2032.

We then examined the impact of the three different technology adoption curves on the total ZEV adoption rates: (1) EPA rates schedule, (2) TEMPO curve, and (3) TEMPO curve modified to include the impact of the proposed regulation (TEMPO+EPA). The total ZEV adoption rates are presented in Figure 3 for different technology adoption curves. The total ZEV adoption rate in 2027 is more than doubled when using the TEMPO curve, reaching 37%. In 2032, the total ZEV adoption rate reaches 60% under the TEMPO s-curve versus 46% under EPA's curve. In addition, when considering the impact of the proposed regulation on the technology adoption for the TEMPO curve (TEMPO + EPA), higher adoption rates are obtained, reaching 66% in 2032.

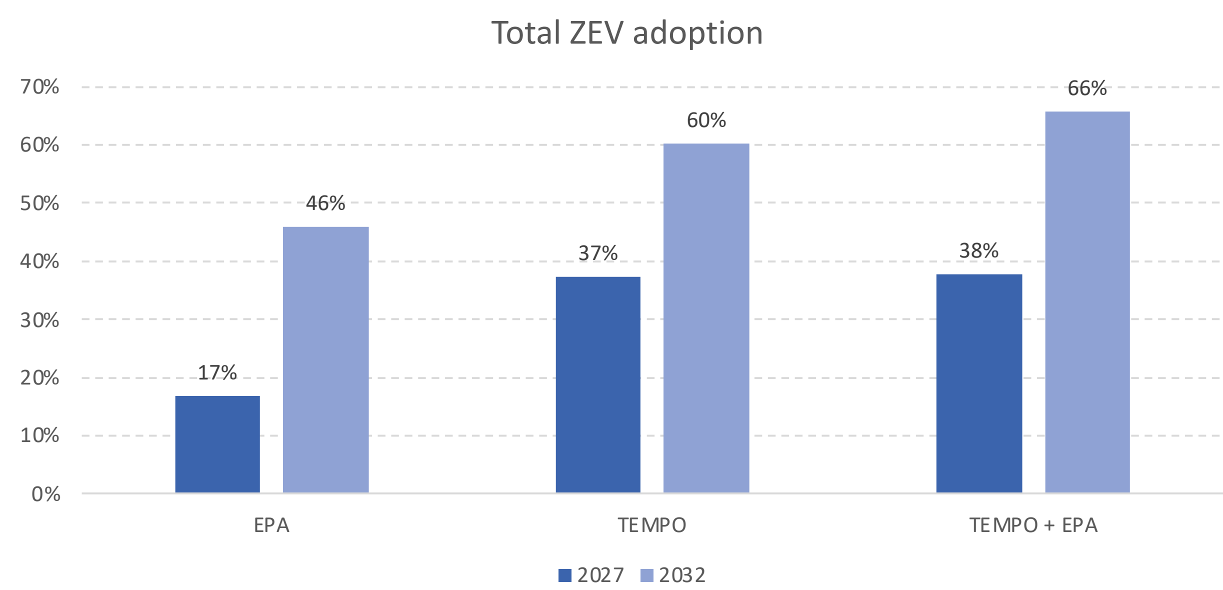

FIGURE 3. IMPACT OF DIFFERENT TECHNOLOGY ADOPTION CURVES ON THE TOTAL ZEV ADOPTION

Based on the analysis presented in this section, ICCT recommends that EPA consider different technology adoption rates than the ones presented in Table 2-73 in the draft regulatory impact analysis and consider technology adoption curves that are derived from empirical data and follow a smooth s-curve such as the ones proposed by ICCT in this section (TEMPO and TEMPO+EPA curves).

SENSITIVITY OF ZEV ADOPTION RATES OF VOCATIONAL VEHICLES TO LEVEL 2 CHARGING ASSUMPTIONS

EPA assumes that each Level 2 charging station (AC charging up to 19.2 kW in this context) will not be shared by more than one truck. EPA explicitly states that this is a conservative assumption. Level 2 charging is considered the main charging technology for step vans, box trucks, shuttle and school buses, and utility trucks. Given the long dwell times of these vehicles and their relatively smaller battery sizes, it is technically possible to share charging ports between at least two trucks, and fleets will take advantage of port sharing among several trucks to reduce their capital investment. ICCT modified this assumption in the HD TRUCS model to investigate the impact on the payback period and adoption rates. The total ZEV adoption rate of vocational vehicles increased by 6% in 2027 and 4% in 2032 under this new assumption.

PRIVATE SECTOR INVESTMENTS IN CHARGING INFRASTRUCTURE

This section responds to the EPA's request for comment on whether development in ZEV charging infrastructure will hinder the adoption of ZEVs and the ability to meet the proposed GHG standards. According to Atlas Public Policy, $20 billion in announced and awarded investments in publicly accessible charging infrastructure for all on-road vehicles have been made through 2023 (Gabriel, 2023). Vehicle manufacturers, charging-as-a-service companies, and utilities, together with public sector agencies, are together investing in this space. In support of the EPA's proposed standards, the ICCT has compiled below selected information on private and utility investments into charging infrastructure.

Truck manufacturers are among the leading investors in charging infrastructure. Daimler Trucks, together with NextEra Energy and Blackrock Renewable Power, announced a $650M joint venture in January 2022 to construct a nationwide network for powering battery electric and hydrogen fuel cell vehicles (Daimler Truck North America, 2022). Greenlane, the company established under this joint venture (Nextera Energy, 2023), will initially focus on battery electric trucks and will build a network of publicly accessible charging sites along critical freight routes on the west and east coasts of the U.S., and in Texas. Navistar plans to offer full infrastructure design and construction services for its customers. Navistar is partnering with Quanta Solutions, one of the largest electric grid infrastructure companies in North America, who will provide site selection, engineering, and construction services. (Navistar, 2023). Tesla, who delivered its first electric semi-trucks in December 2022, currently owns the nation's largest network of publicly accessible charging stations, albeit serving primarily passenger vehicles. Its existing V3 architecture uses 1MW power cabinets that support up to 250kW of charging per vehicle (Tesla, 2019). GM and Ford have announced plans to adopt Tesla's charging standard, giving their vehicles access to the Tesla Supercharger Network and benefitting trucks in the lighter weight classes (Shepardson & White, 2023). Ford already offers its Ford Pro depot charging service, which will build, operate, and maintain a charging depot for a fleet (*Depot-Charging-Brochure.Pdf*, n.d.). Based on publicly available information, we expect Tesla to release a V4 architecture with megawatt charging capability to support the Tesla Semi (Kane, 2022). Reports from the first Tesla Semi deployment in Modesto, CA suggest the capacity of installed dispensers is 750kW (Seabaugh, 2023). These investments and partnership illustrate the extent to which vehicle manufacturers are investing capital and establishing strategic partnerships to deliver the necessary charging infrastructure.

Charging-as-a-service companies finance, design, construct, operate, and maintain publicly accessible charging depots. Forum Mobility recently announced a $415 million investment, including funds from the Amazon Climate Pledge and commercial real estate company CBRE, to construct electric truck depot charging to support zero-emission port trucks (CBRE Investment Managament, 2023). Terawatt infrastructure has secured at least $1billion in investment capital to construct a multi-state charging network for medium- and heavy-duty vehicles, beginning with an 800-mile corridor that extends from the Port of Long Beach to El Paso at 150-mile intervals (*TeraWatt Developing I-10 Electric Corridor, the First Network of Electric Heavy-Duty Charging Centers*, 2022). The investments come from Vision Ridge Partners, Keyframe Capital, and Cyrus Capital (Terawatt Infrastructure, 2022). WattEV is constructing a 200-vehicle truck charging depot in Bakersfield, CA as part of a network of charging depots along the I-5 corridor in California (WattEV, 2021). The company recently opened the first of four charging depots in Southern California at the Port of Long Beach, capable of serving 26 trucks with CCS chargers capable of 360kW (*WattEV to Open Charging Depot at Port of Long Beach*, 2023) The power cabinets are rated at 1.2 MW and CEO Salim Youssefzadeh tells ICCT these will be converted to megawatt charging once a megawatt charging standard is finalized in 2025. Voltera Power, launched in 2022, builds, identifies and acquires real estate, procures power, designs and constructs charging facilities, and deploys operates and maintains charging infrastructure. The company draws experience from data center siting, design and construction through a partnership with EdgeConneX (EdgeconneX, 2022). And Amply Power, whose fleet solutions include charging equipment procurement, installation, operation, maintenance, and smart charging, will also provide mobile and non-permanent charging solutions to overcome temporary physical and operational constraints to accessing charging infrastructure ("Products and Services," n.d.).

Fleet owners and operators are also investing in charging infrastructure at their facilities. Schneider, which will have a fleet of 92 battery-electric class 8 tractors in operation by the end of this year, recently opened a 32-vehicle charging depot in South El Monte to support its fleet of Freightliner eCascadias operating in Southern California. The site includes 16 350 kW dual-corded dispensers (*Schneider Opens Large-Scale Zero Emission Electric Charging Depot in Southern California*, 2023). Sysco, who has announced plans to take delivery of up to 800 battery-electric tractors by 2026, is investing in charging infrastructure in their Riverside, CA facility (Daimler Truck North America, 2022b). And FedEx, who has purchased 150 electric delivery vehicles from BrightDrop, a subsidiary of GM, has invested in a network of 500 chargers in California with additional purchases planned (FedEx, 2022).

Recent announcements by major retailers demonstrate that significant investments in charging infrastructure are underway at their facilities. As part of its planned deployment of 100,000 electric delivery vehicles by 2030, Amazon has added thousands of charging stations at its delivery stations across the country and will continue to build out charging infrastructure (Amazon, 2022). Recognizing the need to make charging infrastructure smaller, cheaper, and more flexible, Amazon has invested in Resilient Power, who is developing solid state transformers that can significantly reduce the cost and space requirements of distribution infrastructure of high-capacity charging depots (St. John, 2021). IKEA, whose goal is to achieve zero-emission home deliveries by 2025, has partnered with Electrify America and Electrify Commercial to install delivery vehicle charging to 25 IKEA retail locations, including 225 chargers with up to 350kW capacity across locations in 18 states (Sickels, 2022). WalMart, whose goal is to achieve zero emissions across their global operations by 2040, has announced plans to construct its own fast charging network at thousands of WalMart and Sam's club locations where delivery vehicles will have the opportunity to charge (Kapadia, 2023).

Utilities are also making significant investments in charging infrastructure. In 2022, The California Public Utilities Commission approved $1 billion in transportation electrification infrastructure investments by utilities over the period 2025-2029, with 70 percent earmarked for medium- and heavy-duty charging infrastructure (California Public Utilities Commission, 2022). Up to $750 million has already been made available through the period 2020-2024 (California Public Utilities Commission,). The California Energy Commission has made an additional $1.7 billion available for medium-and heavy-duty infrastructure for the period 2022-2026 (California Energy Commission, 2022).

Based on this review, we find there is considerable ongoing activity and investment to address both present and future charging infrastructure demand. We support EPA's conclusion that charging infrastructure can be made available to nearly all trucks that need it in the next decade. We also take the view that the proposed rule further strengthens the market signal for private sector investment. In addition, we encourage EPA's active participation in infrastructure planning with federal, state, and tribal agency partners.

Scope of charging infrastructure needs

ICCT analysis supports the view taken in the 'Lead time assessment' of the proposal preamble that there is sufficient time for charging infrastructure to gradually increase over the remainder of this decade to levels that support the stringency of the proposed standards for the timeframe they would apply.

In May 2023, ICCT published an assessment of where, when, and how much charging infrastructure needs to be available to support the deployment of zero-emission class 4-8 vehicles in the contiguous United States (Ragon, Kelly, et al., 2023). We conclude that charging infrastructure needs this decade will be concentrated in a sub-set of states and counties where freight activity is concentrated. This pattern of infrastructure development limits the geographic scale of infrastructure needs during this period and reinforces the business opportunity in the most active freight zones.

The study finds total energy demand from all Class 4-8 vehicles will be approximately 139,865 MWh. This amount of energy is equivalent to around 1 percent of national electric retail sales in 2021, and we do not expect this share to significantly change in light of the ongoing electrification of other sectors. This relatively small share of national electricity demand suggests to us that the availability of new generating capacity will not be a significant constraint on electrification of this sector.

The overriding infrastructure needs of zero emission class 4-8 vehicles will be concentrated in a sub-set of U.S. states and major metro areas. This leads us to conclude that the nation's deployment of charging infrastructure will be constructed in stages and not all at once. (See Figure 4.) The study estimates that 49% of national charging needs in 2030 will exist in ten states led first by Texas and second by California. Texas and California alone will account for 19% of national charging needs in 2030. The study also finds that out of more than 3,079 counties, the top 1% will account for 15% of national charging needs. Among the top ten counties, four of these are located in Southern California (led by Los Angeles then by San Bernardino, San Diego, and Riverside counties) and three are in the Texas triangle (led by Harris and then Dallas and Bexar counties). Other prominent counties that make the top ten include Maricopa, AZ, Salta Lake, UT, and Cook, IL.

While these counties will experience the largest aggregate energy demand, it is also important for planning purposes to consider counties with the largest concentration of energy demand per unit area. From this perspective, nine of the top ten counties are located in the Northeast, including five counties in New York State (the Bronx, New York, Queens, Kings, and Richmond), Suffolk, MA, Philadelphia, PA, and Hudson, NJ. These projections suggest that the infrastructure does not need to be deployed everywhere all at once. A sub-set of states governing these counties and a sub-set of utilities serving them will be responsible for critical charging infrastructure delivery through 2030.

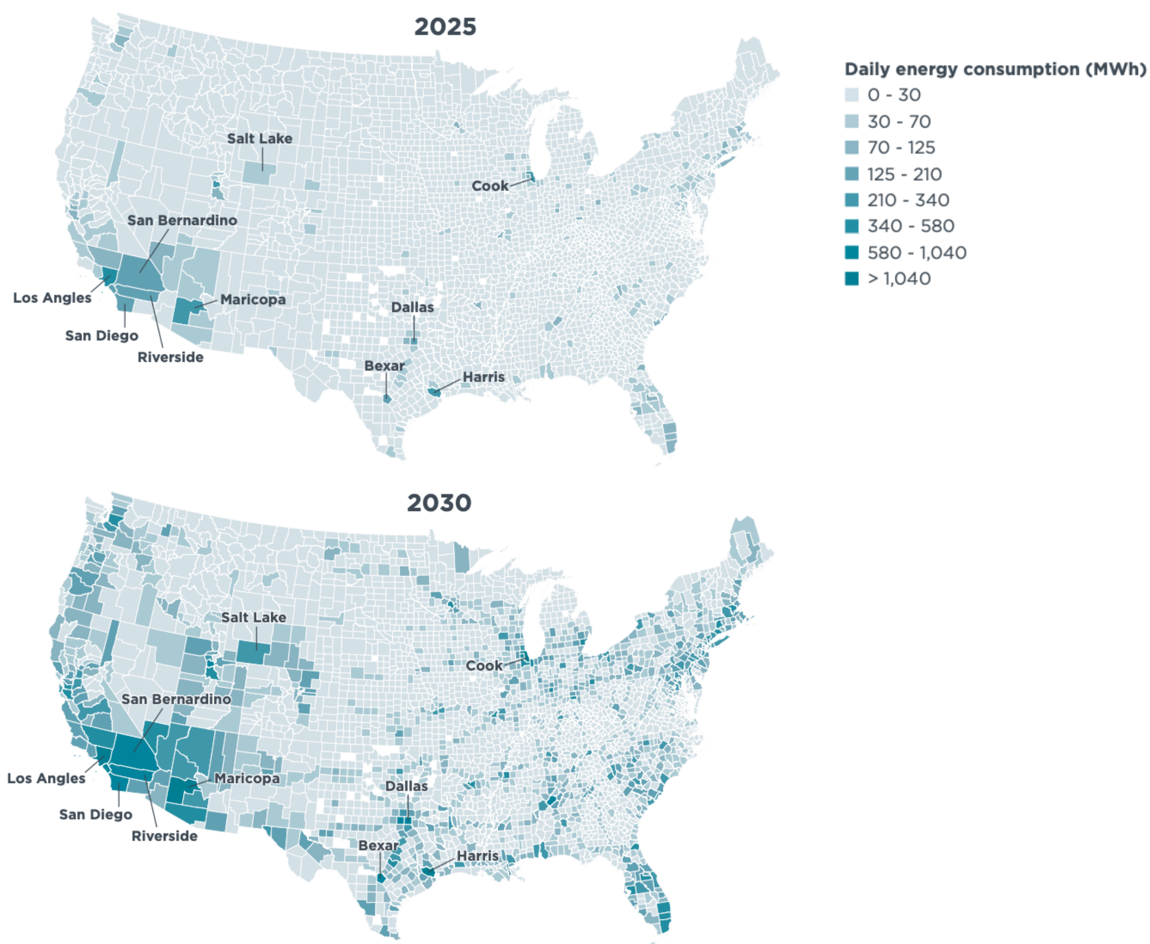

FIGURE 4. PROJECTED DAILY ENERGY NEEDS OF CLASS 4-8 ZERO-EMISSION TRUCKS, BY COUNTY, IN 2025 AND 2030

Utilities have many options to provide timely delivery of grid capacity to support these charging needs. ICCT has identified actions that (1) require no regulatory approval or pre-authorization (2) require regulator consent or notification, or (3) require regulatory approval or state legislation.

Utilities have the greatest flexibility to meet charging infrastructure needs in a timely fashion when actions can be taken without regulator notification or approval. These actions include short-term load rebalancing, the use of non-firm distribution capacity, the incorporation of smart charging into feeder ratings and load forecasting, the deployment of temporary distribution, generation and storage, and public-private partnerships that allow for third-party funding, design, and construction of infrastructure. This list is not comprehensive but demonstrates that options do exist for utilities to meet the most acute needs of fleets.

As the trend toward truck electrification grows, utilities will need to take actions to adapt to a new market environment in their service area. Any adaptation in programs and planning will require the notification, if not consent, of state regulatory agencies. For example, utility regulators can consent to periodic adjustments to transportation electrification programs to better respond to market trends. Utilities can also request consent to explicitly incorporate transportation electrification load forecasts into their distribution system planning and related investments. These modifications to existing programs and planning processes reflect the type of adaptation most utilities serving freight zones will need to perform.

Finally, utilities may need to take certain actions that increase their responsiveness to freight charging needs beyond what state utility regulation permits them to do. For example, authorization to pre-build distribution capacity infrastructure in 'no-regrets' freight zones will require either state legislation or explicit regulation where it does not already exist. Examples of such policies under development in California include SB410 passed by the California State Senate on 25 May 2023.(Powering Up Californians Act, n.d.) Another example includes the Zero-Emissions Freight Infrastructure Planning proposal made by the staff of the California Public Utilities Commission on 22 May 2023. (Gruendling, 2023.) Similar examples exist in New York State, including a new proceeding opened by the New York Public Service Commission to address barriers to Medium- and Heavy-Duty Charging Infrastructure.[4]

In response to EPA's request for comment on how to engage infrastructure stakeholders, we suggest EPA consider infrastructure needs tbroadly, starting from the transmission grid and downstream to the charger that connects to the vehicle. Many players exist in each segment of this chain.

Key stakeholders include electric utilities (IOU, POU, NRECA, EPRI), EVSE manufacturers, CharIN (MCS), CPO (Charge Point Operators/Network Service Providers), Bundled Service Providers (charging-as-a-service, trucking-as-a-service), public charging hub owner/operators (such as the Daimler/NextEra/Blackrock JV, WattEV, Terawatt, bp Pulse, etc), engineering/construction firms (Black & Veatch, Burns MacDonnell, Schneider Electric, etc), fleets (including NACFE) and depot owners. EPA can engage these stakeholders individually and facilitate dialogue across these groups to support the data collection, planning, and coordinated deployment to support the objectives of the greenhouse gas standards. A regular meeting, such as an annual summit, is one strategy EPA could use to gather information on challenges and solutions in the zero-emission vehicle transition.

While EPA does not have jurisdictional authority over electric utilities, interagency collaboration with the Department of Energy, Department of Transportation, and the Joint Office of Energy and Transportation would ensure EPA has a voice in federal infrastructure policy these other agencies may be responsible for developing.

BATTERY SIZING FOR TRACTOR-TRAILERS

Assumptions regarding truck battery size are critical as they strongly affect the retail price and fuel economy of battery electric trucks, significantly affecting the technology payback period and the

[4] https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=23-E-0070&CaseSearch=Search

corresponding technology adoption rate. In general, the sizing approach considered by EPA resulted in reasonable battery sizes for most truck classes. However, the approach considered by EPA for battery electric tractor-trailers sleeper cabs and day cabs (referring to vehicle ID 78, 79, 80, 82, 84) resulted in very large and unrealistic battery sizes, exceeding 1,000 kWh in some cases and reaching 2,036 kWh for "vehicle ID 79". This is driven by EPA's assumption of the absence of opportunity charging for long-distance truck applications.

Trucks operating in long-haul will have the opportunity to recharge at truck stop stations during a driver's mandatory break, resulting in a lower battery size without affecting the mission profile. Based on a recent ICCT publication, opportunity charging during the day can reduce the required battery mileage design point by more than 20% when using 350 kW charging technology and by more than 40% when using 1 MW charging technology (Basma et al., 2023). Based on independent discussions with leading truck OEMs, we conclude that trucks will likely be designed with battery sizes no greater than 1 to 1.2 MWh in energy capacity to minimize payload and packaging constraints. Futhermore, we conclude based on information provided via monthly megawatt multi-port charging meetings organized by Argonne National Laboratory since 2021 that the megawatt charging standard SAE J3271 capable of up to 3.5MW is on track to be finalized by 2025 (Bohn, 2023).

Based on our independent analysis, industry design decisions, and progress towards finalizing a megawatt charging standard, we recommend EPA revise its battery size assumptions for battery electric sleeper cabs and day cabs in the following manner:

- Size batteries according to the daily energy needs of the vehicle while assuming opportunity charging would occur during a driver's mandatory break.
- Consider the following charging rates for trucks at publicly accessible charging stations: 350 kW today and 1 MW as of 2027.
- Cap the battery size to 1 MWh due to payload and volume capacity constraints. When a larger battery is required, it can be assumed that the drivers stop more frequently for charging, which will increase labor costs. The increase in labor cost can be assumed to be proportional to additional needed charging time during the day outside the drivers' break time window.

With this sizing approach, we estimate that the battery size of a 500-mile sleeper cab is in the range of 900 kWh by 2027, as highlighted in Table A1 in Basma et al. (2023), and we recommend that EPA uses a similar approach to design the battery size of electric trucks.

In addition, EPA's battery sizing approach considers oversizing the battery by 20% to accommodate capacity fade over time. While battery capacity fade will certainly reduce a truck's driving mileage, it is unclear how EPA decided on the 20% figure given the very scarce battery aging data for heavy-duty vehicle applications. In addition, recent developments in battery technology are resulting in a significantly prolonged battery lifetime, reaching 1.5 million kilometers (ca. 932,000 miles) for long-distance trucking applications. We encourage EPA to adopt a capacity fade assumption based on publicly available information and in consultation with battery suppliers.

Energy consumption of tractor-trailers

EPA assumes there will be no improvement in the energy efficiency of zero-emission trucks over time. This is driven by EPA's assumption that there will be no efficiency improvements for ICE vehicles beyond Phase 2 requirements. Improvement in vehicle aerodynamics, tires, and lightweight chassis technologies can decrease truck energy consumption and result in smaller battery sizes. We think it would be appropriate for EPA to assume manufacturers will deploy vehicle efficiency technologies that reduce the direct manufacturing costs of the vehicle without sacrificing vehicle range. Based on ICCT's analysis, improvements in vehicle technologies can result in energy efficiencies as low as 2.29 kWh/mile by 2032 for battery electric tractor-trailer sleeper cabs reaching 2.12 kWh/mile once the technology reaches its full potential by 2035. (Basma et al., 2023)

Another important factor considered by EPA to estimate the vehicle energy needs, and therefore the battery size, is the auxiliary heating and cooling load. The heating and cooling load includes the driver's cabin and the battery thermal management system. To estimate the energy needed for heating and cooling, EPA uses publicly available data on the heating and cooling needs of a transit bus and then corrects this heating and cooling load to reflect a truck application considering the ratio between the truck cabin surface area and the reference bus surface area. This simplistic approach ignores the impact of surface type on the different heating transfer phenomena that take place between the vehicle cabin and the environment. For example, a significant portion of a transit bus body surface is glazed, which leads to a higher rate of heat transfer with the environment. In addition, the bus passengers are a significant additional heat source that would increase the cooling needs of the bus during hot days, which is not relevant for trucks. ICCT published an analysis in 2022 on the cooling and heating needs of trucks, focusing on long-haul trucks operating in Europe. (Basma & Rodríguez, 2022) Table 1 summarizes the heating and cooling load. ICCT recommends that EPA uses the presented data in Table 1 as the baseline data for the truck cooling and heating needs and adjusts the load accordingly for other truck segments given the ratio of the trucks' surface areas.

TABLE 1. SUMMARY OF TRUCK CABIN COOLING AND HEATING NEEDS IN DIFFERENT WEATHER CONDITIONS

Temperature	59 °F (15 °C)	19.4 °F (-7 °C)	95 °F (35 °C)
Cooling/heating load (kW)	0.08	1.94	0.79

SOURCE: BASED ON BASMA & RODRÍGUEZ, 2022

ICCT recommends updating the energy consumption figures for battery-electric tractor-trailer sleeper cabs, considering the vehicle technology improvement and more representative cooling and heating loads, which would result in a truck energy consumption in the range 2.29 kWh/mile by 2032. This energy consumption estimate is almost 18% lower than what EPA assumes.

TREATMENT OF ACT COMPLIANCE TOWARDS COMPLIANCE WITH PHASE 2

This section responds to EPA's request for comment on how to account for ZEV adoption rates that would arise from compliance with the California ACT program in setting the proposed Phase 2 GHG standards. We are concerned that EPA's decision to revise the definition of "U.S.-directed production volume" will allow manufacturers to comply with the proposed CO_2 standards through the sale of zero-emission trucks they are already required to sell under state law. This flexibility dilutes the stringency of the proposed standards, reinforces investments in fleet deployment and charging infrastructure in ACT states at the expense of non-ACT states, and limits the benefits of the rule in non-ACT states.

In our view the simplest solution would be to retain the existing definition of 'U.S.' directed production volumes that has been in effect since the adoption of the Phase 2 standards. This would ensure manufacturers are investing in more efficient and zero-emission vehicles in non-ACT states. This would also ensure utility companies and charging infrastructure providers are investing in non-ACT states. And this would provide greater certainty that the rule would deliver its intended benefits in non-ACT states.

If EPA chooses to adopt its proposed revision to the definition of "U.S. directed production volume," we suggest the agency determine the stringency of its standards based on a weighted average of ZEV sales required in ACT states and the additional forecasted ZEV sales in non-ACT states. In this way, EPA is aligning the stringency of its standards with the benefits of ZEV sales required under state laws, and it is reinforcing and securing the additional market potential for ZEV deployments in non-ACT states.

A hypothetical example of a sales-weighted average can be illustrated for Class 7-8 short haul tractors. The EPA proposal assumes a 35% ZEV sales share in MY 2032 in this segment. We assume nine states that have adopted the ACT account for 24% of national Class 7-8 short-haul tractor sales. We also assume the ACT requires 74% of MY 2032 sales of these vehicles to be zero-emission. The weighted national average ZEV sales share for Class 7-8 short-haul tractor trucks is 44.4%. This weighted average would be the basis for setting the stringency of the standard for this vehicle category.

Assumptions regarding the retail price of hydrogen

EPA references Argonne National Laboratory's BEAN model for a $4/kg hydrogen retail price in 2030 and references the DOE's Liftoff report for a $4-$5/kg hydrogen price in 2030, and stating both values incorporate IRA incentives from the Inflation Reduction Act in their prices (Islam et al., 2022; Murdoch et al., 2023). However, both citations source the hydrogen price from a cost parity analysis done by NREL published prior to the passage of the Inflation Reduction Act (Ledna et al., 2022). This NREL study analyzed the required retail hydrogen price for fuel-cell electric vehicles, including buses and long-distance trucks, to reach total cost of ownership parity with diesel comparators. The hydrogen price at which the vehicles reach cost parity, determined to be $4-$5/kg , was referenced as the "willingness to pay" fuel price in the DOE's Liftoff report. Therefore, the $4/kg hydrogen price used by EPA cannot reflect the real market. It is more appropriate to take a bottom-up approach to understand what fleet owners would pay at the hydrogen refueling station.

A bottom-up analysis would estimate all the potential costs along the hydrogen supply chain that would contribute to the final retail price. The main cost components are hydrogen production, hydrogen distribution, and hydrogen dispensing. EPA references three studies for the production cost of green hydrogen, including a past study from ICCT. Among the three studies cited, only the Rhodium Group's cost ($0.39/kg -$1.92/kg) considered the hydrogen production tax credit (PTC) under the Inflation Reduction Act. However, that report simply subtracted $3/kg (the maximum value of the hydrogen PTC) from its estimated green hydrogen production cost without PTC ($3.39-$4.92 /kg). This is not how the PTC works in the real world. To reflect the impact of the PTC accurately, it is necessary to apply a discounted cash flow (DCF) model that evaluates the annual incomes and expenses at a hydrogen production plant. This cash flow analysis would determine the amount of annual tax liability by the hydrogen producer with and without the PTC. Similarly, the DOE's Liftoff report provided a range for green hydrogen production cost of $1.5/kg - $3.4/kg without the PTC and a less than or equal to $0.4/kg cost with PTC, explaining that, "$0.40/kg is when the PTC is applied in a given year / point-in-time and clean hydrogen costs can go negative. However, if investors apply a discounted cash flow DCF) to calculate the value of the credit (10-years) over 25+ year asset life, the value of the credit will fall from $3/kg (point-in-time) to ~$1.4/kg (applying DCF on the value of the PTC)".

A more recent ICCT study estimated the retail green hydrogen price considering the PTC and using a DCF model (Slowik et al., 2023). This analysis follows the detailed provisions in the Inflation Reduction Act to best reflect the impact of the PTC. Specifically, the 10-year tax credit starts in 2023 and ends in 2030, meaning that only producers that started operating early in 2023 would receive the full 10-year credits while plants start in 2030 would only receive 2 years of PTC out of the plant's lifetime of 30 years. Besides the $3/kg clean hydrogen PTC, the $0.026/kWh PTC for renewable electricity is also included, since the two are allowed to be combined under the Act. In addition, the PTCs for clean hydrogen are refundable for the first five years of operation per "direct pay" provision under section 6417 of the Act. Further, tax "transferability" under section 6418 was also included, where both renewable electricity and clean hydrogen producers are eligible to sell their unused tax credits to a buyer who has the tax burden. The ICCT result shows that the PTCs would reduce the levelized production cost of green hydrogen by $2/kg for a plant start in 2023, decreasing to $0.3/kg for a plant start in 2030.

For hydrogen distribution and dispensing costs estimates of $1/kg-$2/kg EPA references two reports (Rustagi et al., 2018; Satyapal, 2022). However, the numbers cited are based on very optimistic scenarios with aggressive fuel-cell electric vehicle market uptake, high-volume hydrogen supply and refueling, and advanced research and development accomplishment. In contrast, the same DOE 2018 document that is referenced by EPA (Rustagi et al., 2018) projected distribution and dispensing cost of $4.2/kg-$4.9/kg in 2025, which is more realistic. The ICCT analysis of the Inflation Reduction Act assumed a $4.6/kg cost in 2030, decreasing to $2/kg in 2050, based on an Argonne National Laboratory study of prices in the United

States and an impact assessment of the Alternative Fuel Infrastructure Regulation in the EU (European Commission, 2021; Reddi et al., 2017).

Taking all of this into consideration, ICCT estimates about $9.5/kg retail fueling price in 2030, assuming green hydrogen and meeting the 700-bar pressure requirement and high hydrogen purity requirement by the FCEV. This estimate taken from Slowik et al., 2023 is significantly greater than the price used in the EPA rule.

Battery mineral availability

Our analysis shows that the minerals required to produce batteries at the volume required during the period of this rule can be sourced domestically and from close trade partners. Battery supply chain capacity is expected to reach 1 terawatt-hour (TWh) by 2030. The U.S. has ten times more lithium reserves than needed to meet the 2030 EV production goals in its light-duty vehicle proposal. Friendly nations like Australia, Argentina, and Chile combined have two hundred times that amount. Australia and Canada also have one hundred times the amount of nickel, and fifty times the amount of cobalt needed in 2030, while Brazil, France, Indonesia, and the Philippines together have double again that amount. We expect truck manufacturers to favor lithium iron phosphate batteries for their safety and durability, reducing the need for nickel and cobalt supply on the zero-emission transition in the trucking sector.

ICE efficiency technologies beyond those required under the Phase 2 program

Additional ICE tech packages can deliver payback within two years

This section is ICCT's response to EPA's request for comment on whether to include additional GHG-reducing technologies and/or higher levels of adoption rates of existing technologies in the proposed Phase 2 GHG standards. For the purposes of setting the stringency of the rule, EPA does not assume the adoption of new technologies to improve the efficiency of internal combustion engine (ICE) vehicles beyond those already being deployed to meet the Phase 2 standards. In our view, the proposal can deliver greater benefits with minimal cost by revising the stringency of the proposed standards to reflect the deployment of additional commercially available and cost-efficient technologies like those considered in the Phase 2 standard that manufacturers have not found necessary to deploy. The ICCT conservatively estimates that incorporating such additional technologies in the stringency of its rule – not including engine technology improvements – would generate an additional 537 million tonnes of cumulative CO_2 emissions avoided between 2020 and 2050.

Several technologies are available to improve ICE vehicle efficiency beyond what is required to meet existing Phase 2 greenhouse gas standards. In recently published research, ICCT identified significant efficiency improvement potential from a list of technologies with a two-year payback period across tractor and vocational regulatory categories (Buysse et al., 2021; Ragon, Buysse, et al., 2023). EPA considered some of these technologies in its Phase 2 rulemaking, but only a few were incorporated into the stringency of the Phase 2 rule. These technologies are available to further increase ICE vehicle efficiency and should be reflected in the stringency of the Phase 3 final standards.

Our research suggests a potential improvement in ICE vehicle efficiency of up to 23% in the high-roof sleeper cab vehicle category, reflecting both engine and non-engine improvements. Table 2 shows the efficiency improvement potential of each identified technology. The largest contributions are from engine improvements, followed by aerodynamics, tires, and predictive cruise control. Without engine improvements (e.g., hybridization, alternative fuel injection systems, etc.), a smaller efficiency improvement up to 13% can still be realized. These percentages assume no contribution from trailer technologies such as trailer tires, aerodynamics, or weight reduction.

Table 2. Two-year payback ICE vehicle technology potential for high-roof sleeper cab tractors beyond the technology packages assumed by EPA under the Phase 2 standard for model year 2027. Technologies are listed in order of cost-effectiveness.

ICE technology	Potential efficiency improvement beyond Phase 2 MY 2027*
Engine improvements only	
Engine efficiency	10.8%
Non-engine improvements	
Aerodynamic drag	6.6%
Advanced tires	5.0%
Intelligent controls	3.0%
Weight reduction	2.2%
Axle efficiency	1.6%
Reduced accessory load	1.1%

* Percentage values not additive to reflect vehicle-level efficiency improvements

Our research also suggests a potential ICE vehicle efficiency improvement of up to 31% exists for a diesel-fueled Class 6 multi-purpose vocational vehicle. Table 3 shows the efficiency improvement potential of each technology. The largest contributions are from engine improvements, followed by stop-start, weight reduction, and tires. Without improving engine technology, efficiency improvements of up to 20% can still be realized.

Table 3. Two-year payback ICE vehicle technology potential for Class 6–7 diesel-fueled multi-purpose vocational vehicle beyond the technology packages assumed by EPA under the Phase 2 standard for model year 2027. Technologies are listed in order of cost-effectiveness.

ICE technology	Potential efficiency improvement beyond Phase 2 MY 2027*
Engine improvements only	
Engine efficiency	11.6%
Non-engine improvements	
Stop-start	9.7%
Weight reduction	5.7% (1,250 lbs)
Advanced tires	3.8%
Axle efficiency	3.6%
Aerodynamic drag	2.7%
Reduced accessory load	1.7%

* Percentage values not additive to reflect vehicle-level efficiency improvements

We identified meaningful efficiency packages across a range of vehicle types. Across tractor regulatory categories, we identified 11%–13% in unrealized efficiency improvements, as well as 6% for heavy-haul tractors. Across vocational vehicle categories, we identified 15%–20% in unrealized efficiency improvements. Original equipment manufacturers (OEMs) like Navistar and Volvo Trucks currently offer ICE products with technology options similar to the ones listed (*Advances In International® LT® Series And RH™ Series Drive Improved Fuel Efficiency And Uptime*, 2019; *Volvo Trucks Makes Latest-Generation D13 Turbo Compound Engine Standard in All VNL 740, 760 and 860 Models*, 2020). The benefits of the rule would be greater by encouraging the industry-wide adoption of these technologies.

EPA uses projected ZEV adoption as the sole determinant when setting the MY 2028 – MY 2032 GHG standards and neglected cost-effective ICE vehicle technology efficiency improvements. EPA can revise the stringency of its standards to reflect industry-wide ICE vehicle efficiency improvements that are additional to ZEV adoption alone. This would enable unrealized ICE efficiency improvements to be incorporated into the final stringency, while retaining OEMs' flexibility in achieving compliance. Table 4 gives suggested stringency levels based on ICE vehicle efficiency improvements for EPA to consider. These efficiency potential projections are described in more detail in Ragon et al. (2023). The use of these technology improvements can only strengthen the EPA proposal if they are treated as additional technologies – not complementary technologies – to the deployment of zero-emission vehicles. We encourage EPA to treat them as such in order to maximize the cost-effective reduction of greenhouse gas emissions achieved from the rule.

TABLE 4. ICE TECHNOLOGY POTENTIAL FOR HEAVY-DUTY VEHICLES BY REGULATORY CATEGORY WITHOUT ENGINE IMPROVEMENTS.

Class	Type	2027 EPA regulatory standard		ICCT post-2027 potential realized by 2032		Post 2027 efficiency improvement potential	
Tractor trucks		gCO_2/ton-mile		gCO_2/ton-mile		% efficiency improvement	
Class 7 tractor	Low roof	96.2		81.3		12%	
	Mid roof	103.4		88.2		11%	
	High roof	100.0		85.8		13%	
Class 8 tractor (day cab)	Low roof	73.4		63.0		11%	
	Mid roof	78.0		67.4		11%	
	High roof	75.7		66.0		12%	
Class 8 tractor (sleeper cab)	Low roof	64.1		54.5		12%	
	Mid roof	69.6		59.8		11%	
	High roof	64.3		55.8		13%	
Heavy-haul tractor		48.3		47.0		6%	
Vocational vehicles		gCO_2/ton-mile		gCO_2/ton-mile		% efficiency improvement	
		Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
Light heavy-duty	Urban	367	413	318	356	15%	15%
	Multi-purpose	330	372	283	314	16%	15%
	Regional	291	319	241	255	16%	17%
Medium heavy-duty	Urban	258	297	216	251	15%	15%
	Multi-purpose	235	268	194	220	17%	17%
	Regional	218	247	173	192	20%	20%
Heavy heavy-duty	Urban	269	297	226	251	12%	15%
	Multi-purpose	230	268	199	220	14%	17%
	Regional	189	247	160	192	16%	20%

Beyond the technology improvements outlined in Table 2 and Table 3, OEMs are demonstrating additional technology packages to improve ICE efficiency in vehicle prototypes. The U.S. Department of Energy's SuperTruck Program acts as a testbed for innovative technology packages to improve the freight efficiency of tractor trailers. Launched in 2010, the first phase of the program aimed to develop and demonstrate long-haul tractor trucks that achieve 50% improvement in overall freight efficiency. By 2016, all SuperTruck I participant OEMs reported efficiency improvements ranging from 80% to 116%. (*Adoption of New Fuel Efficient Technologies from SuperTruck*, 2016). Through the program, the OEMs developed and validated technologies like improved aerodynamics, low rolling resistance tires, and engine downsizing, and deployed them in their commercial products (Park, 2022).

All the major tractor-trailer OEMs (Peterbilt/Cummins, Daimler, Navistar, Paccar, and Volvo) are participating in the second phase of the program, SuperTruck II (Bashir, 2022; Bond & Li, 2022; Dickson & Mielke, 2022; Meijer, 2022; Zukouski, 2022). The second phase doubles the vehicle freight efficiency improvement target to 100% compared with a 2009 baseline and emphasizes cost-effective technologies. All participating OEMs are reporting the development of final trucks that exceed 125% of efficiency improvements, and their designs incorporate 48V mild hybrid, electrification of auxiliary systems, improved aerodynamics, and enhanced waste heat recovery.

The EPA rule can go further than we have outlined here by making use of the significant research and investment the U.S. Department of Energy is making in truck efficiency. The DOE SuperTruck program continues to deliver cutting edge innovations in partnership with private industry. The failure to incorporate commercially viable efficiency packages with short payback periods is a significant missed opportunity. We encourage EPA in preparing its final rule to consult with DOE and its industry partners to identify additional efficiency technologies we have not identified here. Their inclusion will further strengthen and increase the benefits of the proposed standards.

Benefits of a rule reflecting ICCT projections of technology feasibility, cost and compliance

The ICCT estimated the benefits of EPA's proposed ZEV uptake proposal and compared it against three more ambitious scenarios. In total, the four scenarios modeled were:

- **EPA proposal:** This assumes EPA's projected ZEV uptake for different classes of heavy-duty vehicles and no additional ICE technology improvement beyond the requirements to meet Phase 2 standards.
- **EPA proposal + Cost-effective ICE technology improvements:** This scenario combines EPA's projected ZEV uptake with ICE technology improvement outlined in Table 4 of this document.
- **EPA proposal + Cost-effective ICE technology improvements + ICCT projected ZEV market growth including state ACT adoption:** This scenario has more aggressive ZEV uptake until 2032 compared to EPA proposal in vehicle segments such as refuse trucks, Class 4-7 single unit short haul trucks, and Class 4-7 single unit long-haul trucks. This scenario considers market conditions in combination with state ACT rule adoption and federal subsidies under the Inflation Reduction Act (Slowik et al., 2023) This means that there is further increase in ZEV adoption beyond 2032, leading to 66% of the new HDV sales being ZEVs by 2045. The ICE technology improvements are carried over from the previous scenario.
- **National ACT aligned ZEV pathway + Cost effective ICE improvements +100% ZEV sales in 2040:** This scenario assumes every state adopts California's ACT, i.e. 100% new HDV sales being ZEVs by 2040 (Ragon, Buysse, et al., 2023). This scenario also aligns with the Global HDV MoU (Drive to Zero, 2021) that the United States is a signatory to. The ICE technology improvements are carried over from the previous scenario.

In 2032, the ZEV market growth scenario projects a 46% ZEV sales share of Class 4-8 HDVs, compared to 27% estimated by EPA's proposal. (See Table 5.) The National ACT scenario's ZEV sales share is almost double that of EPA's projection in 2032, at 53%.

Table 5. ZEV sales shares for class 4-8 HDVs in each scenario

Scenario	Vehicle	2027	2028	2029	2030	2031	2032	2035	2040	2045
EPA proposal	Buses	20%	25%	30%	35%	40%	50%	50%	50%	50%
	Rigid Trucks	8%	10%	12%	17%	24%	27%	29%	29%	29%
	Combination Short-haul Trucks	10%	12%	15%	20%	30%	35%	35%	35%	35%
	Combination Long-haul Trucks	0%	0%	0%	10%	20%	25%	25%	25%	25%
	Average for Class 4-8 HDVs	**7%**	**9%**	**11%**	**16%**	**23%**	**27%**	**28%**	**28%**	**28%**
EPA proposal + Cost effective ICE improvements + ICCT projected ZEV market growth including state ACT adoption	Buses	29%	31%	33%	37%	41%	50%	50%	51%	51%
	Rigid Trucks	31%	34%	43%	51%	54%	56%	63%	75%	87%
	Combination Short-haul Trucks	27%	38%	42%	44%	48%	49%	50%	53%	56%
	Combination Long-haul Trucks	4%	6%	10%	16%	20%	25%	25%	25%	25%
	Average for Class 4-8 HDVs	**23%**	**27%**	**33%**	**40%**	**43%**	**46%**	**50%**	**58%**	**66%**
National ACT + Cost effective ICE improvements + 100% ZEV sales in 2040	Buses	30%	32%	40%	49%	57%	67%	93%	100%	100%
	Rigid Trucks	31%	34%	43%	51%	55%	60%	75%	100%	100%
	Combination Short-haul Trucks	33%	42%	48%	52%	61%	74%	100%	100%	100%
	Combination Long-haul Trucks	4%	6%	10%	16%	20%	25%	49%	100%	100%
	Average for Class 4-8 HDVs	**24%**	**28%**	**35%**	**41%**	**47%**	**53%**	**73%**	**100%**	**100%**

ZEV sales share
0% – 100%

Source: ICCT analysis. Assumptions in ICCT projected ZEV market growth and in National ACT taken from Ragon, Buysse, et al., 2023. Cost-effective ICE improvements taken from Buysse et al., 2021.

EPA's proposal is estimated to reduce tank-to-wheel (TTW) CO_2 emissions 9% compared to 2019 levels by 2032 and 20% by 2050. EPA's proposal combined with cost effective ICE technology improvements results in an 11% TTW CO_2 emission reduction compared to 2019 by 2032 and a reduction of 28% by 2050. The EPA proposal and ICE improvements combined with additional ZEV market growth potential projected by ICCT in previously published work leads to a 19% TTW CO_2 emission reduction compared to 2019 by 2032 and a reduction of 48% by 2050. A final scenario aligned with a National ACT schedule would deliver a 21% TTW CO_2 emission reduction compared to 2019 by 2032. The addition of a 100% zero-emission sales milestone to this scenario by 2040 would deliver a reduction of 91% by 2050.

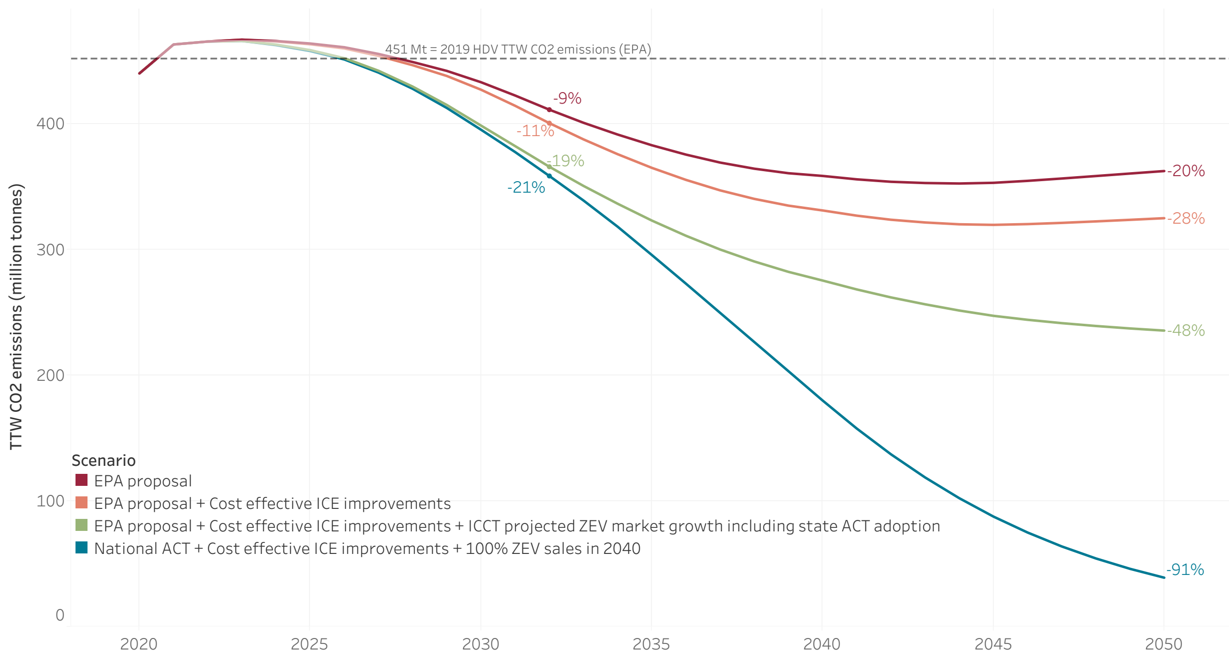

FIGURE 5. 2019-2050 ANNUAL TANK-TO-WHEEL (TTW) CO_2 EMISSION PATHWAYS FOR EACH SCENARIO

In terms of cumulative emissions reductions between 2023 and 2050 compared to the EPA proposal, the addition of cost-effective ICE technology improvements alone reduces cumulative TTW CO_2 emissions by 537 million tonnes. A scenario that includes these additional ICE efficiency improvements and additional ZEV sales in line with previously published ICCT projections would deliver a reduction of over 1.8 billion tonnes compared to the EPA proposal. And a scenario that reflects a National ACT schedule plus a 100% zero-emission sales milestone in 2040 would deliver a reduction of over 3.8 billion tonnes.

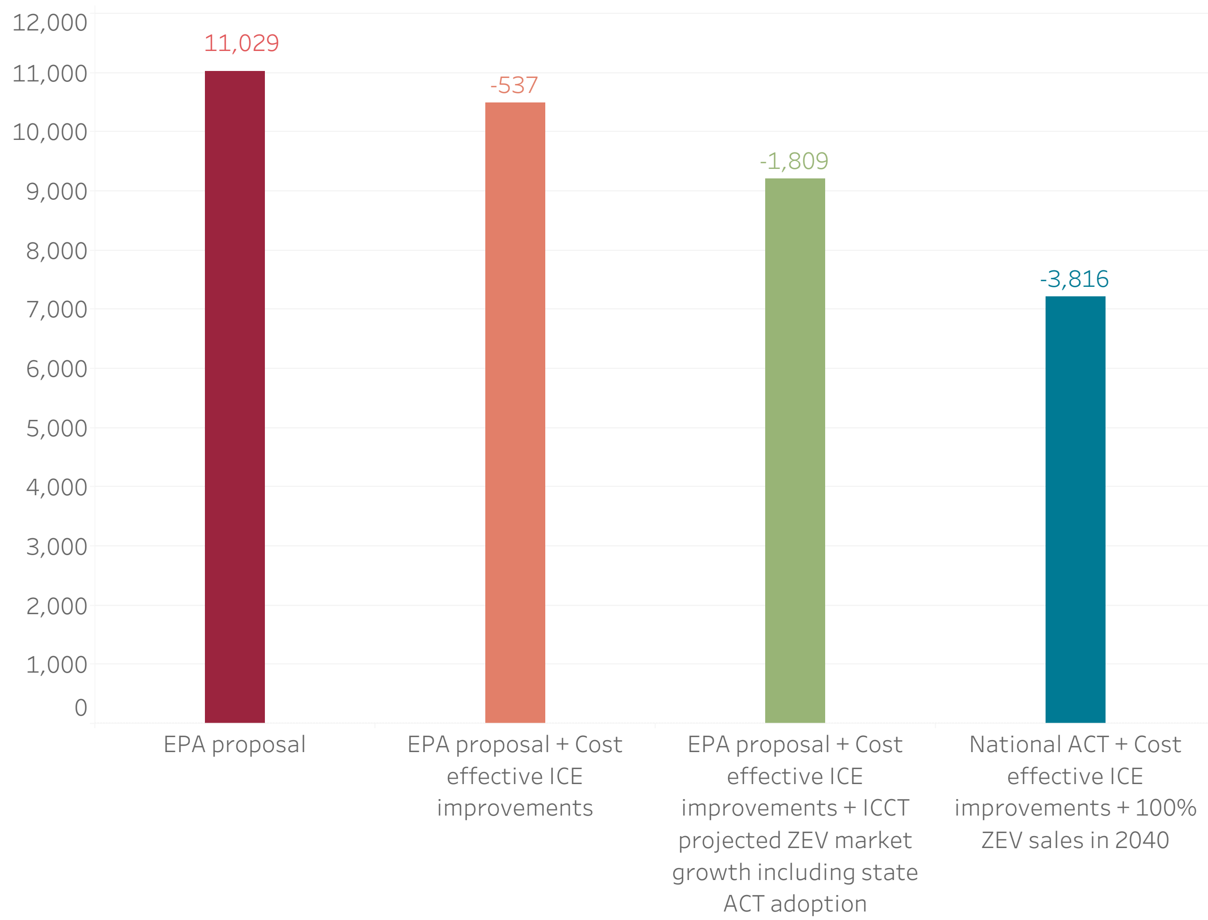

FIGURE 6. CUMULATIVE TANK-TO-WHEEL (TTW) CO_2 EMISSIONS (MILLION TONNES) FROM HEAVY-DUTY VEHICLES BETWEEN 2023 AND 2050

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Appendix

ICCT prepared the following table utilizing a technology adoption curve developed from 500 discrete data points drawn from the TEMPO model, an all-inclusive transportation demand model developed by the National Renewable Energy Laboratory (Muratori et al., 2021). The method of fitting a technology adoption function to these data points was developed by the Environmental Defense Fund and is described in their comments on the proposed rule.

Table A. 1 Technology adoption curves data

Payback	TEMPO	TEMPO +EPA 2027	TEMPO +EPA 2032
<1	90.00%	90.81%	90.81%
1.25	75.12%	75.12%	75.12%
1.75	67.35%	67.35%	67.35%
2.25	49.18%	49.18%	49.18%
2.75	40.45%	40.45%	40.45%
3.25	32.57%	32.57%	35.00%
3.75	26.29%	26.29%	35.00%
4.25	26.31%	26.31%	35.00%
4.75	16.23%	16.23%	35.00%
5.25	12.65%	12.65%	35.00%
5.75	12.71%	12.71%	35.00%
6.25	6.00%	10.00%	20.00%
6.75	6.34%	10.00%	20.00%
7.25	6.00%	10.00%	20.00%
7.75	4.79%	10.00%	20.00%
8.25	5.00%	10.00%	20.00%
8.75	5.00%	10.00%	20.00%
9.25	3.42%	10.00%	20.00%
9.75	3.00%	10.00%	20.00%
10.25	1.86%	5.00%	15.00%
10.75	2.00%	5.00%	15.00%
11.25	2.00%	5.00%	15.00%
11.75	2.00%	5.00%	15.00%
12.25	2.00%	5.00%	15.00%
12.75	2.00%	5.00%	15.00%
13.25	1.00%	5.00%	15.00%
13.75	1.00%	5.00%	15.00%
14.25	1.00%	5.00%	15.00%
14.75	1.00%	5.00%	15.00%
15	0.00%	0.00%	5.00%