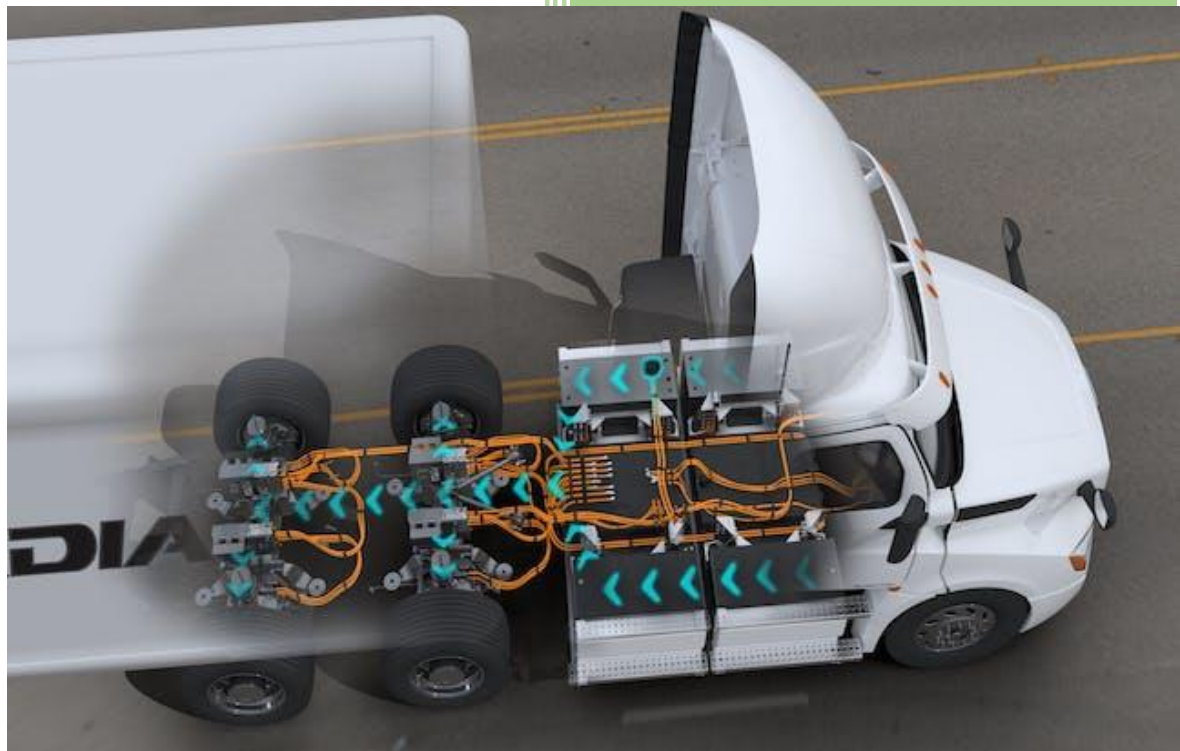


Used Truck Voucher Pilot
RFI Comment
Feb. 2025



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Contents

1. Cover Letter	2
2. Responses to Selected CARB's Questions	3
3. Policy Implications.....	8
4. Conclusions.....	10

Acronyms

Abbreviation	Term
AI	Artificial Intelligence
BET	Battery-Electric Truck
BEV	Battery-Electric Vehicle
ICEV	Internal Combustion Engine Truck
ICEV	Internal Combustion Engine Vehicle
IMPACT	Integrating Market Penetration and Cost Technologies
OEM	Original Equipment Manufacturer
PPT	Predictive Pretraining Transformer
RUL	Remaining Useful Lifetime
SOH	State of Health
ZET	Zero-Emission Truck
ZEV	Zero-Emission Vehicle

1. Cover Letter

Dear CARB Compliance Assistance and Outreach Branch,

We are writing to express our appreciation for the opportunity to provide input on the development of the Used Truck Voucher Pilot Concept as part of the Innovative Small E-Fleet Pilot Project (ISEF). As a research group in the Sustainable Freight Program at the University of California, Davis, Institute of Transportation Studies, our expertise lies in zero-emission vehicle (ZEV) technologies, vehicle electrification, and incentive-based policy analysis. Through past efforts, we have focused on market transformation strategies that ensure an equitable and effective transition to clean transportation solutions.

The transition to ZEVs in the used truck market presents unique challenges and opportunities, particularly for small fleets that may rely on financial incentives to adopt these technologies. My research team has developed the IMPACT (integrating market penetration and cost technologies), an integrated analytical framework that quantifies vehicle costs, market dynamics, and infrastructure constraints specific to the used ZEV sector. Additionally, we employ large-scale AI models (specialized predictive pretraining transformer networks) to assess battery health and lifetime prognostics, which provide critical insights into residual vehicle value and long-term operational feasibility. These tools enable us to offer data-driven recommendations on optimal incentive structures and program design considerations to ensure success in the secondary ZEV market.

We appreciate CARB's commitment to advancing clean transportation through targeted financial incentives and policy development. We welcome the opportunity to further collaborate on undertaking needed analysis and supporting developing and refining program strategies, and would be happy to provide additional insights or participate in stakeholder discussions.

Thank you for your time and consideration.

Sincerely,

Jingyuan Zhao, Anuj Dhole, Lewis M. Fulton

University of California, Davis Institute of Transportation Studies

2. Responses to Selected CARB's Questions

Q4. What should the incentive level be?

To design an effective incentive structure for the Used Truck Voucher Pilot Concept, the voucher amount must directly address the price gap between used ZEVs, such as BEVs, and their ICEV counterparts.

Prices of current zero-emission vehicles (ZEVs) can be two to three times that of a comparable internal combustion engine vehicle (ICEV). There is not enough clarity on the pricing strategy of the OEMs, and the contributing factors to this large price disparity. This is likely to contribute to a large uncertainty to ZEV prices in coming years. Large price disparity also means that early adopters are paying a premium for ZEVs and they would expect a predictable and viable value for their ZEVs when they sell them in secondhand market.

The current challenge is that there is a lack of information on how much these used ZEVs would be worth. It certainly will be a function of the age of the 2nd hand vehicle sold, and factors such as battery remaining life. But other market forces will be important as well. For example, there will likely be an expectation of a reduction in the prices of new ZEVs as OEMs achieve economies of scale, along with improved technologies in newer trucks. Used ZEVs would thus be expected to be priced appropriately to compete with new ZEVs that could be a better value proposition due to possible improvements in prices and technology.

Used trucks are usually preferred by small and medium fleets because of their affordable prices. Used ZEVs would thus be competing against used ICEVs. To make used ZEVs a natural choice, they must be priced aggressively to compete with used ICEVs. While a limited amount of premium could be acceptable owing to cheaper operations of ZEVs, a high premium for used ZEVs would make ZEVs unviable for small and medium fleets to finance.

Incentive design for used ZEVs is thus a very complex problem since early adopters would expect a fair depreciation rate for their investments, while this could make used ZEVs unaffordable for the target fleets. Two unknown parameters are critical in this context: (i) the resale value of the used ZEV that the primary buyer expects, and (ii) the price that the buyer is ready to pay.

The following strategies are recommended as key components of a comprehensive and balanced incentive system:

Due to a lack of information on the parameters described above, we propose a price discovery program in the initial years. In such a program, buyers and sellers can work together to negotiate selling prices and buying prices respectively, and the incentive can be applied to a part or whole difference between the seller's expectation and the buyer's willingness to pay for the used ZEV. Such a program can reveal the market sentiment and provide much needed information for

determining a market value of the used ZEVs. Institute for Transportation Studies at UC Davis will be happy to explore this in further detail with CARB.

After the prices are discovered, the incentive can be designed to address the price gap between used ZEVs, and comparable used ICEVs. For example, if a used conventional truck costs \$100,000 and a comparable used zero-emission truck costs \$200,000, an \$80,000 incentive could be offered to cover 80% of the premium required for a used ZEV assuming 20% of the premium can be recovered by the buyer through cheaper operations of the ZEV.

Incentive design strategy that leverages the price gap between ZEVs and ICEVs should have already factored in vehicle characteristics like the battery size, battery health, mileage and the weight class. Additionally, OEM certified ZEVs can instill buyer confidence (discussed further below). This incentive scheme will require periodic review and adjustments with considering ZEV market uncertainties.

Additional considerations:

A. Incentive Based on Price Gap

The primary objective of the voucher should be to reduce the upfront cost of ZEVs by covering a reasonable portion of the price gap between used BEVs and comparable ICEVs. This requires the availability of reliable transaction data, including vehicle characteristics and transaction prices, along with data-driven analysis and modeling to assess the impact of incentives on vehicle pricing and market dynamics.

- If the incentive is too high, it will impose an excessive financial burden on the program and may distort market pricing.
- If the incentive is too low, it will have minimal influence on the adoption of used ZEVs, failing to drive substantial market transformation.

A balanced approach, informed by data and empirical modeling, is essential to ensure that the program remains both cost-effective and impactful. Developing a reliable model may require several years of second-hand vehicle transaction data. In the meantime, starting with a conservative voucher value estimate and gradually increasing it to stimulate transactions may be a viable approach.

B. Sliding Scale Based on Vehicle Characteristics

Given the complexity of valuing BEVs compared to ICEVs, the incentive structure could incorporate vehicle-specific factors, including battery health, vehicle type, and intended use case.

(a) Battery State-of-Health

The incentive could be set more neutrally; however, in cases of significant aging or degradation, this approach would be less likely to incentivize sales. For BEVs with very short battery life, an additional or alternative voucher program may be necessary. This could include measures such as ensuring a warranty period of a couple of years, providing incentives for purchasing replacement battery systems in used trucks, or encouraging second-life applications—for instance, repurposing batteries for energy storage or promoting material recycling, both of which are important considerations.

We do note that battery health is a critical determinant of the performance, including driving range after a full charge, longevity, and market value of BEVs. Unlike ICEVs, where mileage and production year reliably indicate vehicle condition, BEVs require a more nuanced assessment due to battery degradation factors such as usage patterns, charging cycles, and thermal management.

Incentive Tiers Based on SOH

The battery SOH should serve as a primary criterion for determining incentive levels, for example:

- SOH above 90% → Highest incentives to encourage the adoption of well-preserved ZEVs.
- SOH 80–90% → Moderate incentives to reflect slightly reduced battery performance.
- SOH 70–80% → Reduced but still meaningful incentives to support continued use.
- SOH below 70% → Vehicles should undergo additional technical assessments to determine:
 - ✓ The remaining useful battery life.
 - ✓ The expected driving range under real-world conditions (e.g., seasonal variations).
 - ✓ Whether the vehicle remains suitable for commercial operations or should be repurposed for secondary applications (e.g., stationary energy storage).

For used BEVs lacking comprehensive historical operational records, alternative battery health assessments should be implemented:

- Charge-discharge cycle tests to estimate the remaining capacity after a full charge.
- Mileage and production date as secondary indicators, recognizing that both cycle life (mileage) and calendar life (age) impact battery longevity.

(b) Body Type and Use Case

Incentives should reflect the environmental and operational impact of different vehicle types:

- Larger trucks (e.g., Class 8) → Higher incentives, as they have a greater potential for CO₂ reduction and diesel displacement.
- Medium-duty trucks & delivery vans → Significant incentives, prioritizing deployment in urban areas where ZEV adoption can maximize air quality benefits.

C. Equity and Community-Focused Adjustments

To ensure that the Used Truck Voucher Pilot promotes social and environmental equity, additional targeted incentives should be provided for fleets operating in underserved communities and for small fleet operators who face financial and operational barriers in transitioning to ZEVs. Disadvantaged communities, which are disproportionately affected by air pollution, should be prioritized to maximize the program environmental and public health benefits. Similarly, small fleets, which often have limited access to capital and financing options, require additional support to make the adoption of ZEVs a viable and cost-effective choice.

D. Periodic Reviews and Adjustments

As ZEV technology advances and market conditions evolve, it is essential for the California Air Resources Board to conduct regular program reviews to ensure that incentives remain aligned with shifting economic and regulatory landscapes. Declining ZEV prices, driven by market growth and technological advancements, may reduce the financial gap between used internal combustion engine vehicles and used ZEVs, necessitating periodic adjustments to incentive structures. Additionally, fluctuations in the supply and demand of used ZEVs can influence market accessibility, requiring ongoing evaluation to prevent unintended distortions. Furthermore, new regulatory requirements and improvements in charging and refueling infrastructure may impact the feasibility and

attractiveness of used ZEVs, warranting adjustments to program parameters. By adopting a data-driven and adaptable approach, CARB can ensure that the voucher program remains effective, equitable, and responsive to market developments, maximizing its long-term impact on fleet electrification and emissions reduction.

Q5. What type of certification should a used vehicle have to ensure quality?

A robust certification program is essential to build trust in the used ZEV market. Buyers require assurance of vehicle reliability before making purchasing decisions. Certification should include:

- **OEM or Third-Party Certification:** Vehicles should undergo inspection by either the OEM or a CARB-approved third-party entity to verify that they meet safety and performance standards.
- **Battery SOH Certification:** Given that battery degradation is one of the most critical factors in used ZEV valuation, a standardized battery SOH report should be required. Trucks with at least 80% of original battery capacity should be prioritized for incentives.
- **Comprehensive Vehicle History Reports:** Certification should include maintenance records, accident history, and software updates to ensure that the vehicle has been properly maintained and is free of significant defects.

Integrating large-scale AI models for battery health diagnostics will further enhance the accuracy of these assessments, providing real-time insights into vehicle longevity. These certification requirements will boost buyer confidence, increase residual values, and ensure the long-term reliability of used ZEVs.

Q6. Should eligible vehicles be capped at a specific mileage or age?

Battery health in BETs is significantly more complex than in ICEVs. Unlike ICEVs, where mileage and age serve as relatively reliable indicators of vehicle condition, the aging process in BETs is influenced by multiple factors beyond simple wear and tear. Battery degradation is affected not only by mileage (cycle life) and age (calendar life) but also by operational conditions such as charging patterns, temperature exposure, and load profiles. Therefore, using a simple mileage or age cap as an eligibility criterion may not accurately reflect a true residual value and usability of the vehicle.

The Limitations of Mileage- or Age-Based Caps

A strict cap based only on mileage or age is not sufficient to assess the usability and market value of used BETs. The resale price and operational viability of a used BET are largely driven by battery SOH, which depends on:

- **Cycle life (mileage-driven aging)** → Frequent deep discharges and rapid charging can degrade battery capacity, even if mileage remains moderate.
- **Calendar life (time-dependent aging)** → Batteries naturally degrade due to chemical reactions, even if the vehicle is not heavily used.
- **Cell-to-cell and pack-to-pack variations** → Two trucks with identical mileage and age can have very different battery health due to manufacturing tolerances, operational conditions, and thermal management strategies. For example: Truck A: 5 years old, 200,000 miles, but well-maintained with controlled charging cycles and optimized thermal management → Battery SOH remains at 85%. Truck B: 5 years old, only 150,000 miles, but exposed to

frequent fast charging, extreme temperatures, and deep discharges → Battery SOH degraded to 70%.

Clearly, a simple mileage or age cap would misrepresent the real value and usability of these trucks. Thus, given the complexity of battery aging mechanisms, eligibility could be based primarily on battery SOH rather than rigid mileage or age limits. A tiered approach could be implemented based on the SOH of the battery systems. This data-driven approach ensures that only BETs with a meaningful remaining operational life receive incentives, preventing the misallocation of funds. By shifting from traditional ICEV-centric eligibility criteria to a battery-focused approach, CARB can ensure that the voucher program maximizes fleet efficiency, financial sustainability, and environmental benefits.

3. Policy Implications

The success of the Used Truck Voucher Pilot hinges on well-structured incentives, robust certification processes, infrastructure development, and long-term market sustainability. Based on advanced modeling and real-world fleet data analysis, the following recommendations and policy implications are outlined to ensure the effectiveness and longevity of the program.

4.1 Establishing an Optimal and Equitable Incentive Structure

To maximize adoption and ensure that incentives are both effective and fiscally sustainable, the program must be structured to address key market dynamics. Incentives should be allocated based on vehicle condition, adopting a tiered approach that offers higher financial support for vehicles with better battery health and lower mileage. Additionally, financial assistance should be designed to bridge the cost differential between used ZEVs and ICEVs, ensuring that used zero-emission trucks become a competitive alternative in the secondary market. Therefore, the program should offer incentives up to a reasonable percentage of the fair market value for low-mileage, high-battery-health ZEVs while implementing periodic reviews to assess the effectiveness of incentives based on real-world adoption rates and resale market trends.

4.2 Strengthening Vehicle Certification and Quality Assurance

Ensuring that used ZEVs meet reliability and performance standards is essential for fostering trust in the secondary market and encouraging widespread adoption. A well-structured program should mandate standardized certification, covering key aspects such as battery SOH, drivetrain integrity, and software system diagnostics to provide buyers with confidence in vehicle quality. Incorporating artificial intelligence-based predictive maintenance models can further enhance the assessment of battery longevity and reliability by leveraging historical performance data. Additionally, full transparency in vehicle history, including maintenance records, accident history, and component replacements, should be required to provide a clear picture of a vehicle condition. To implement these measures effectively, the program should require original equipment manufacturer or third-party battery SOH certification, ensuring a minimum capacity of 80 percent for incentive eligibility. Furthermore, establishing a comprehensive used ZEV registry will make vehicle history reports accessible to potential buyers, improving market transparency and supporting informed decision-making.

4.3 Ensuring Long-Term Market Sustainability

The long-term viability of the used ZEV market depends on maintaining residual value, establishing effective financing mechanisms, and developing repurposing strategies to maximize economic and environmental benefits. To support a sustainable transition, it is essential to monitor residual values to prevent excessive depreciation, which could discourage fleet investments in new ZEVs and slow market growth. Implementing fleet-wide electrification policies can help create a steady influx of high-quality used ZEVs into the secondary market, ensuring a reliable supply of well-maintained options for buyers. Additionally, developing robust battery repurposing and recycling programs will ensure that older ZEVs retain economic value even if they are no longer viable for trucking applications. To reinforce these efforts, a used ZEV buyback program should be established to

stabilize residual values and encourage long-term fleet turnover. Furthermore, funding battery second-life applications will contribute to sustainability beyond the vehicle operational lifespan, supporting broader energy storage and circular economy initiatives.

4. Conclusions

The Used Truck Voucher Pilot presents a transformative opportunity to expand the adoption of ZEVs among small fleet operators, thereby accelerating California transition to a cleaner and more sustainable transportation sector. By implementing a well-structured incentive program, ensuring rigorous certification processes, addressing infrastructure limitations, and fostering long-term market sustainability, CARB can effectively support the development of a viable secondary market for used ZEVs.

- **Data-Driven Incentive Strategies** – The program should be structured to bridge a specific portion of the cost gap between used ICEVs and ZEVs, ensuring affordability and accessibility for small fleets while preventing market distortions.
- **Vehicle Certification & Quality Assurance** – Implementing original equipment manufacturer and AI-driven battery health assessments will enhance market confidence and provide buyers with greater protection by ensuring the reliability and longevity of used ZEVs.
- **Infrastructure Accessibility & Investment** – Expanding charging networks and improving infrastructure accessibility will address operational concerns, making fleet electrification more feasible and convenient for small operators.
- **Sustainable Market Development** – Continuous monitoring of residual values, the development of financing mechanisms, and the promotion of battery repurposing strategies will support the long-term sustainability of the used ZEV market, ensuring that the program remains effective and financially viable over time.

Call to Action:

We encourage CARB to leverage this opportunity to create a structured, data-driven, and impactful voucher program that effectively supports small fleet operators in adopting used ZEVs. As experts in transportation electrification and policy analysis, we are eager to contribute further insights and collaborate in refining the pilot program.

We welcome further discussion on these recommendations and look forward to engaging with CARB and other stakeholders to ensure a successful implementation. Please feel free to reach out for additional collaboration opportunities or further research support.

Sincerely,

Jingyuan Zhao, Anuj Dhole, Lewis M. Fulton

University of California, Davis Institute of Transportation Studies