July 17, 2026

California Air Resources Board
1001 I Street
Sacramento, CA 95814

Re: Joint Comments – Incorporate 'virtual miles' into Drive Forward durability and warranty requirements to account for V2X wear on EV battery state of health

We, the undersigned organizations, strongly support the proliferation of bidirectional EVs. This technology holds immense promise to support California's clean energy and grid reliability and resiliency goals – the Energy Commission estimates vehicle-to-home adoption alone could reduce peak residential demand by up to 5 GW in 2030.[1] The state has an extensive framework of policies driving EVs to become bidirectional, including:

- Supplying 100 percent of its electricity from renewable and zero carbon resources by 2045.[2]
- Requiring the Public Utilities Commission to develop strategies and quantifiable metrics to maximize vehicle grid integration by 2030.[3]
- Adopting a goal to shift 7,000 MW of energy demand by 2030, of which approximately 600 MW comes from bidirectional EVs.[4]
- Allowing the California Energy Commission to require any vehicle to be bidirectional capable if it determines it benefits drivers and the grid.[5]

These policies strongly encourage EV batteries to be increasingly used not only for propulsion but also as stationary distributed energy resources – providing home backup power, solar self-consumption, peak-shaving, grid services, and emergency resilience. However, CARB's proposed EV battery durability and warranty requirements evaluate battery state of health (SOH) solely through vehicle age and odometer miles, even though odometer miles capture only propulsion-related battery cycling. As bidirectional use expands, a growing share of battery cycling will occur without vehicle motion, meaning CARB's durability and warranty frameworks will increasingly undercount total battery usage.

[1] California Energy Commission. *A Roadmap to Unlocking the Benefits of Bidirectional Charging*. March 2026. Page 1.
[2] Senate Bill 100 (de Leon, 2018). Public Utilities Code 454.53.
[3] Senate Bill 676 (Bradford, 2019). Public Utilities Code 740.16.
[4] California Energy Commission. *SB 846 Load-Shift Goal Report.* May 2023. Page 24.
[5] Senate Bill 59 (Skinner, 2024). Health and Safety Code 44269.

To provide market certainty and consumer protection, we encourage CARB to incorporate this additional battery usage through a metric called "virtual miles". Virtual miles convert the energy discharged for V2X[6] purposes into the equivalent number of miles the vehicle would have driven to use the same amount of battery energy. This allows CARB to continue to use its existing, consumer-friendly mileage-based durability and warranty thresholds while ensuring that all battery usage – not just driving – is counted.

Multidisciplinary Digital Publishing Institute published research on the impact of V2X cycling on battery durability concluding that V2X use activates the same degradation mechanisms as driving. The authors conclude:

> *"The ageing results demonstrate that temperature is the dominant factor accelerating the capacity fade across all tested storage and cycling conditions, especially when combined with high SOC storage or deep depth-of-discharge cycles. Diagnostic analysis revealed that the loss of lithium inventory (LLI) is the dominant ageing mechanism under both storage and V2G cycling, with minimal loss of active material. Importantly, shallow V2G cycling (30–50% SOC) was shown to induce comparable degradation to high* SOC (≥80% SOC) storage…"[7]

These findings demonstrate that 1) V2X cycling is not free battery usage – it causes measurable degradation; 2) V2X activates degradation mechanisms (loss of lithium inventory) that are also associated with conventional battery cycling during vehicle operation, and; 3) even shallow V2X cycling contributes to battery wear, comparable to high state of charge (SOC) storage, which is itself also a known stressor. Additional studies reinforce this conclusion: Wei et al. (2022) found that vehicle-to-grid cycling reduces calendar ageing at high SOC but still adds cyclic ageing proportional to energy throughput.[8] JRC TEMA modeling demonstrates that battery ageing is a function of SOC history, temperature history, and energy throughput, not odometer miles.[9]

Together, these studies validate that battery wear correlates strongly with energy throughput, regardless of whether the vehicle moves. Therefore, it's critical for CARB to account for V2X energy throughput through a well-defined metric to help consumers understand their battery SOH.

There is policy and market precedent for virtual mile accounting. UN GTR No. 22 explicitly recognizes V2X as a meaningful source of battery degradation: "there are six major vehicle operating parameters that affect in-vehicle battery durability, [including] other uses not reflected in calendar life or distance traveled, such as Vehicle to Grid (V2G)"[10]. Furthermore, UN GTR 22 outlines its intent to develop "a methodology to define Normal Usage Indices based on data read from vehicles"[11] and suggests a formula to calculate this degradation. Virtual miles are fully consistent with this requirement – they provide a usage index that captures battery cycling beyond odometer miles.

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[6] "Vehicle-to-Everything" or "V2X" means technologies that enable bidirectional interactions between an EV and external systems, including vehicle-to-home, vehicle-to-building, and vehicle-to-grid capabilities.

[7] Darikas, G. et al. (2026). *Experimental Investigation of the Impact of V2G Cycling on the Lifetime of Lithium-Ion Cells Based on Real-World Usage Data*. Batteries. 2026. https://www.mdpi.com/2313-0105/12/1/22.

[8] Wei, Y. et al. *A Comprehensive Study of Degradation Characteristics and Mechanisms of Commercial Li(NiMnCo)O_2 EV Batteries under Vehicle-To-Grid (V2G) Services*. Batteries. 2022. https://www.mdpi.com/2313-0105/8/10/188.

[9] Paffumi, E. *JRC Contribution to EVE IWG: In-Vehicle Battery Durability*. European Commission Joint Research Centre (JRC), TEMA platform presentation to UNECE GRPE/EVE Working Group. 2020.

[10] United Nations. *Addendum 22: United Nations Global Technical Regulation on In-vehicle Battery Durability for Electrified Vehicles*. March 9, 2022. Page 4.

[11] *Id.* Page 12.

Virtual miles can effectively use CARB's metric for evaluating battery durability (e.g. miles driven, certified vehicle range, and usable battery energy) as follows:

$$\text{Virtual Miles} = E_{V2X} \times \frac{R_{cert}}{UBE}$$

- E_{V2X} means cumulative V2X energy discharged (kWh)[12]
- R_{cert} means certified vehicle range (miles)
- UBE means usable battery energy (kWh)

For example, if a vehicle has a range of 300 miles and 75 kWh usable battery energy, the vehicle will travel 4 miles per kWh used. If the driver uses 10 kWh for V2X, then the battery experiences the same energy throughput as driving 40 miles, even though the odometer does not change.

Virtual mileage calculations are already standardized and available to both customers via dashboard displays and to technicians via typical scan tools. CARB using virtual mileage has the added benefit of aligning with global efforts to communicate this information in a consistent and transparent way to consumers.

Using virtual miles is consumer friendly. Consumers do not think in terms of kilowatt hours, full-equivalent cycles, or lithium inventory loss. They do think about how far their vehicle can drive, how many miles remain in the battery, and how many miles are left in their warranty. Using virtual miles preserves this familiar framework by expressing all battery usage in miles, avoiding the need to introduce new technical units or concepts. This metric can minimize the potential for consumers to be frustrated by a perceived bad EV owning experience, help avoid durability or warranty disputes by "unexpected" battery degradation, and eliminate ambiguous interpretations or processes to use "good engineering judgment"[13] that risk market uncertainty and could cool manufacturer investment in and development bidirectional capabilities.

Virtual miles make battery usage transparent, intuitive, and consistent with CARB's existing regulatory structure. Therefore, we encourage to amend its draft regulatory language as follows:

- Durability: 10 years or 150,000 miles, including virtual miles
- Warranty: 8 years or 100,000 miles, including virtual miles

As V2X capabilities become more common, incorporating virtual miles will help ensure that battery usage associated with bidirectional operation is reflected in a transparent, consistent, and consumer-friendly manner. We respectfully encourage CARB to consider this approach as it finalizes the Drive Forward durability and warranty requirements.

[12] E_{V2X} could be calculated using SAE J1979

[13] California Air Resources Board. Section 1962.7. In-Use Compliance, Corrective Action and Recall Protocols for 2026 and Subsequent Model Year Zero-Emission and Plug-in Hybrid Electric Passengers Cars and Light-Duty Trucks. Page 13.

Sincerely,

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