ENERGY INNOVATION
POLICY & TECHNOLOGY LLC

www.energyinnovation.org
98 Battery Street, Suite 202
San Francisco, CA 94111
policy@energyinnovation.org

California Air Resources Board
1001 I Street
Sacramento, California 95814

October 17, 2022

Dear California Air Resources Board staff and Board Members,

Thank you for the time, effort, and careful consideration you have devoted to this proceeding.

Energy Innovation Policy and Technology LLC® offers the following comments:

1. *The Advanced Clean Fleets rule advances the state of the art in policy design and is another instance of California leadership with spillover effects that will spur accelerated global climate action.*

2. *We support adoption of the staff proposal, while noting even stronger action is merited, considering the demonstrated climate, public health, and economic benefits.*

3. *Learning curve effects mean costs are likely to be lower and economic benefits greater than CARB estimates.*

4. *We recommend establishing a regular schedule for future policy updates considering rapidly evolving markets and technology.*

The remainder of this letter offers expanded discussion of these four points.

1. ANOTHER EXAMPLE OF CALIFORNIA'S CRUCIAL POLICY LEADERSHIP

California's Advanced Clean Fleets (ACF) policy[1] will be viewed as a bold new chapter in the state's policy leadership, contributing significantly to global decarbonization momentum and changing perceptions about what is achievable.

The work of Energy Innovation® is international in scope, and we have observed how California's climate and clean-energy leadership has spurred others to adopt stronger decarbonization policies. The international community views the state as an economic and technology powerhouse. With the fifth-largest economy in the world, California's commitments and successes have led to other major global economies increasing their ambition and setting carbon-neutrality goals.

The ACF policy also advances the state of the art in decarbonization policy design. The policy pioneers a new approach to support the demand side of market transformation, which is a necessary part of an effective market transformation strategy. California's Advanced Clean Trucks policy phases in a zero-

[1] We use "ACF policy" as an umbrella term for the several measures, i.e., the three measures specifically tailored for different types of fleets—high-priority and federal, drayage, state, and local government — as well as the state's supply-side standard, relevant to manufacturers, establishing a 2040 timeline for the transition to all zero-emission new commercial vehicle sales.

emission vehicle sales requirement for commercial vehicle manufacturers. Until now, vehicle purchase incentives have been the main instrument for encouraging clean vehicle purchases. The ACF policy supports consumer demand for clean commercial vehicles, while reducing reliance on publicly funded expenditures, freeing up government revenue for other investments.

2. EVEN STRONGER ACTION IS MERITED

While supporting the current proposal as the strongest deemed feasible, we recommend an even stronger policy in line with measures in the Accelerated Alternative defined in the August 2022 staff report.[i] Two key provisions we support are the lower threshold for the number of class 7-8 vehicles needed to qualify as a high-priority fleet Accelerated Alternative and achieving the transition to 100 percent ZEV sales in 2036.

Analysis by the consultancy ERM found that accelerating the timetable for completing the transition to only ZEV sales yields significant benefits. Considering impact through 2050, ERM found greater ZEV deployment led to additional emission reductions of 24 million metrics tons of carbon dioxide equivalent, 30,000 metric tons of nitrogen oxides, and 1,040 metric tons of small particulate matter (particles 2.5 microns or smaller).[ii] Considering related climate and public health benefits due to improved air quality, as well as lower overall economic costs from fuel and maintenance cost savings, this study estimated $9.9 billion in net benefits through 2050.[iii]

CARB's own analysis identifies immense social benefits resulting from the Accelerated Alternative's faster transition to ZEVs. The staff report shows the Accelerated Alternative delivers about $9.8 billion in additional net benefit (Table 81), very close to the level estimated by ERM's recent study.[iv] The staff report methodology treats reduced taxes and fee revenue as a cost, but we note complementary policy adjustments could offset impacts to government budgets, so actual benefits could be higher.

The Accelerated Alternative better aligns with recent recommendations based on updated modeling conducted by Energy Innovation® using the California Energy Policy Simulator (EPS), including completing the phase-out of new fossil truck sales in 2035.[2] Phasing in ZEV sales requirements is the single most powerful driver of decarbonization in the Deeper Decarbonization Scenario developed using the California EPS.[v]

The importance of the ACF policy for achieving goals vis-à-vis sustainable freight is also underlined by its similarity to the renewable portfolio standard requirement for electric utility providers. A renewable portfolio standard sets generation standards for requirements on electricity providers in the same way the ACF policy sets procurement standards for commercial trucking companies. California's renewable portfolio policy has been a crucial driver of electricity supply decarbonization. In fact, Energy Innovation® has found the renewable portfolio standard has driven more reductions in greenhouse gas emissions than any other policy in California's portfolio to date.[vi]

3. EXPECT GREATER ECONOMIC BENEFITS DUE TO LARGER LEARNING CURVE EFFECTS

Economic benefits are also likely to be greater than CARB estimates because learning curves for battery technologies should reduce the price differential between car and truck batteries more quickly than

[2] We observe that a coalition of stakeholders cites the California EPS in footnote 3, among their arguments for a stronger ACF policy in their letter, "The Case for Adopting a Stronger Advanced Clean Fleets Rule," https://www.arb.ca.gov/lists/com-attach/195-acf-comments-ws-USUHaVYyVFhSN1Q1.pdf.

modeled. The "learning curve" for a product refers to the pattern of regularly improving performance and declining costs commonly observed for new technologies.[3] [vii]

CARB's own regulatory analyses show electric batteries for commercial vehicles are closing the gap more quickly than the agency expected just two years ago. Analysis completed to support adoption of the Advanced Clean Trucks Rule in 2020 shows the real-world cost declines have proven to be faster than modeled. At the time of the Advanced Clean Trucks analysis, the agency's expectation was that all medium- and heavy-duty trucks would face a five-year lag in equalizing cost improvements achieved for EV battery packs for light-duty vehicles, as evident in "Figure IX-3: Battery Price History and Projections," on page IX-10 of the Initial Statement of Reasons.[viii] CARB's cost modeling in Appendix G for the ACF proceeding indicates that some battery pack prices for some EV trucks are now closer in cost to light-duty vehicles. Specifically, Figure 10 shows class 2b-3 vehicles lagging only two years behind light-duty EV battery packs, while maintaining the expectation of a five-year lag for class 4-8 vehicles.[ix]

This example of real-world innovation exceeding forecast levels in CARB's analysis is typical, not unusual. It can be challenging for energy analysts to keep up to date with accelerating market and technology change and learning curve research.

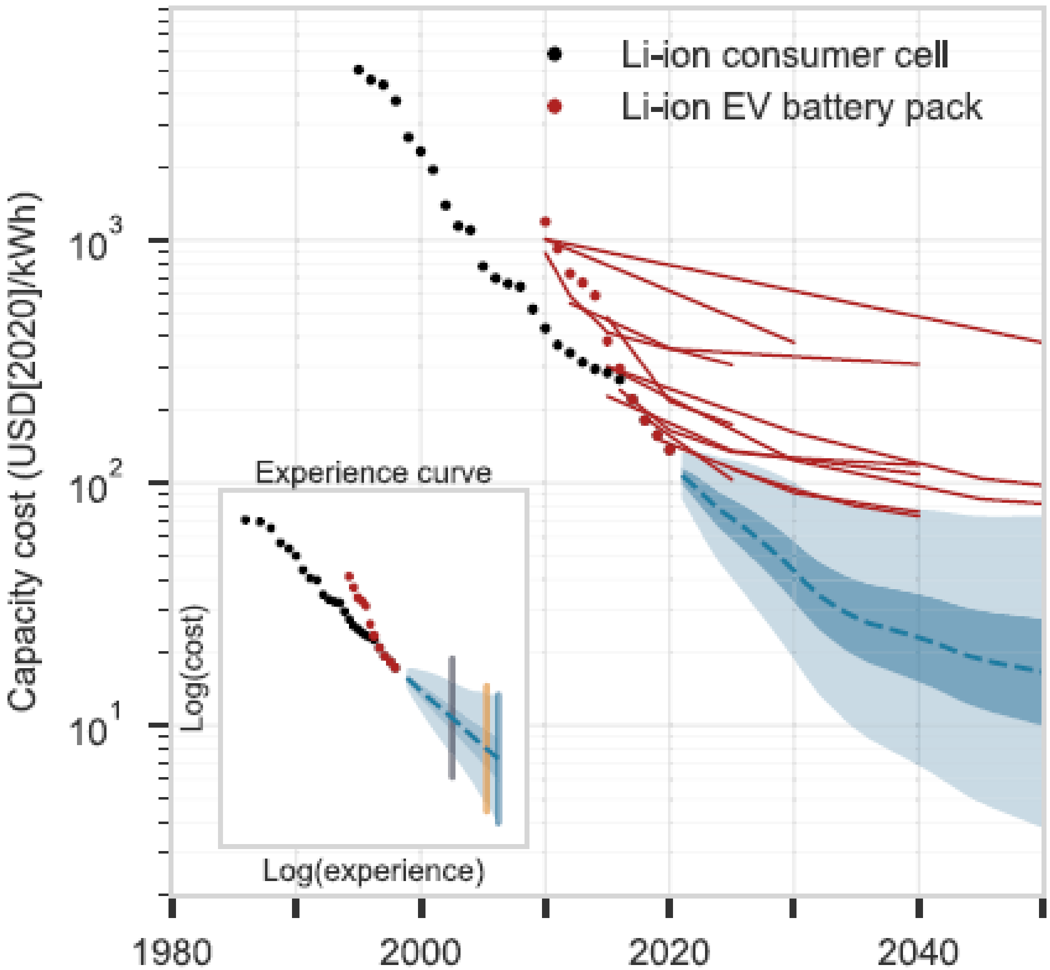
Energy and transportation modelers almost invariably have underestimated future technological progress and associated price benefits for EV batteries as they have for other key decarbonization technologies. Recent, peer-reviewed research by Way et al. shows the persistent underestimation of future innovation for solar photovoltaic panels, wind turbines, hydrogen-producing electrolyzers, and batteries.

Figure 1 reproduces the battery learning curve graph developed by Way et al., denoting historical prices for lithium-ion (Li-ion) consumer battery cell prices and Li-ion EV battery packs with black and red data points respectively, while red line segments trace historical forecasts for the most optimistic scenarios by leading energy-economy modelers such as the International Energy Agency.

This graphing of historical data alongside past forecasts of battery cell and EV battery pack prices reveals the persistent gap between actual and forecasted innovation for batteries.[x] We observe this by comparing the steeper trajectory of empirical price reductions to the shallower slope of past forecasts, showing the most optimistic projections for each past forecast. Even compared to these most optimistic projections, actual battery innovation and price improvements exceeded the forecasted pace of technological progress.

[3] Learning-by-doing leads to improvements in laboratories and pilot projects. When a product reaches commercial viability, increasing production yields economies of scale. For important recent work solidifying understanding of learning curves for decarbonization technologies, see Way et al., "Empirically Grounded Technology Forecasts and the Energy Transition," *Joule* 6, no. 9 (September 21, 2022), https://doi.org/10.1016/j.joule.2022.08.009.

Figure 1. Empirical data on battery cost show past forecasts underestimated future learning curve effects



Source: Way et al.[xi]

Figure 1 illustrates the distinct path for EV battery packs compared to generic consumer battery cell prices. As EV battery pack production has ramped up, the divergence between pack and cell prices has shrunk, highlighting the relevance of learning curves within specific market segments.[4]

The convergence of EV battery backs with consumer cell prices is important because, in cautioning against relying too much on learning curves, the staff report states: "The proposed regulation would affect a portion of California's medium- and heavy-duty trucking fleet, which is very small compared to the worldwide market for batteries in consumer electronics, light-duty vehicles, battery-storage, and other applications," (page 178, *Initial Statement of Reasons*).[xii] This focus on aggregate market size is misplaced, leading to an underappreciation of the potential learning curve benefits due to California's actions. The key parameter for determining expected learning curve effects is the magnitude of additional deployment

[4] The larger graph charts price over time, a more accessible perspective, but one that glosses over the fact that learning curves are a function of cumulative production. The smaller inset graph presents the data as is the convention in the scientific literature on learning curves, graphing the logarithm of price and cumulative production. Under such a log-log formulation, a constant learning curve effect as production results in a linear trendline.

compared to initial levels. From this perspective, it is evident that California's zero-emission commercial vehicle policies can make a material difference.

Annual truck sales in California are greater than the sum of all electric commercial vehicles on the road today, over 70,000 per year for class 2b and larger.[xiii] At the end of 2021, around 1,200 electric trucks were on the road in the United States, compared to around 2,300 in Europe and 20,000 in China.[xiv] With the proliferation of hundreds of electric truck offerings, sales are expected to ramp up quickly, but current deployment levels are the key determinant of expected learning curve effects.

Today, most EV truck batteries are produced in small batches. Growing demand will enable more dedicated factory production lines for truck battery packs, yielding important efficiencies and cost savings.

4. SET A SCHEDULE FOR REGULAR UPDATES AS A CORNERSTONE OF ADAPTIVE MANAGEMENT

We support adoption of the staff proposal, understanding that staff view it as the strongest possible currently. The staff report cites lack of certainty vis-à-vis the achievability of the Accelerated Alternative as the main reason for not selecting it. Policymakers face understandable challenges anticipating the maximum feasible rate of market transformation over decades. Staff are right to recognize the need to ensure policies boosting demand are calibrated to available supply, lest the higher demand unintentionally induce higher vehicle prices.

Given the rapid pace of economic and technological change, and in anticipation that future strengthening will be desirable, Energy Innovation® recommends establishing a schedule for future updates. Such a continuous improvement approach would be akin to the routine updating of the state's building energy code every three years.

Please do not hesitate to contact us for further information regarding any of these recommendations. Meanwhile, we will spread awareness of the ACF, its policy lessons, and the economic, public health, and equity benefits of rapid transportation decarbonization.

Our thanks to CARB for your work advancing this landmark policy and for considering our comments.

Sincerely,

Chris Busch, Ph.D.
Director, Transportation and Senior Economist
Energy Innovation Policy and Technology LLC®

---

[i] California Air Resources Board staff, "Staff Report: Initial Statement of Reasons," Public Hearing to Consider the Proposed Advanced Clean Cars II Regulations," April 12, 2022, https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/isor.pdf.

[ii] Ellen Robo, David Seamonds, and Amanda Freeman, "California Clean Trucks Program: An Analysis of the Impacts of Low NOx and Zero-Emission Trucks on the Environment, Public Health, Industry, and the Economy" (ERM Group, 2022), https://www.ucsusa.org/sites/default/files/2022-08/ca-clean-trucks-report.pdf.

[iii] Robo, Seamonds, and Freeman, "California Clean Trucks Program."

[iv] California Air Resources Board, "Advanced Clean Fleets Regulation: Standardized Regulatory Impact Assessment," May 18, 2022, https://dof.ca.gov/wp-content/uploads/Forecasting/Economics/Documents/ARB-ACF-SRIA_2022-05-18.pdf.
[v] Chris Busch et al., "California Energy Policy Simulator 3.3.1 Update: Earlier Action Delivers Social and Economic Benefits" (Energy Innovation: Policy and Technology, LLC, June 16, 2022), https://energyinnovation.org/wp-content/uploads/2022/06/California-Energy-Policy-Simulator-Insights.pdf.
[vi] Debra Kahn and Patterson Clark, "What You Need to Know about Cap-and-Trade in California," *Politico Pro*, October 8, 2020.
[vii] California Air Resources Board, "Advanced Clean Fleets Regulation: Standardized Regulatory Impact Assessment."
[viii] California Air Resources Board, "Staff Report: Initial Statement of Reasons," Public Hearing to Consider the Proposed Advanced Clean Trucks Regulation, October 22, 2019, https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/act2019/isor.pdf.
[ix] California Air Resources Board, "Appendix G. Total Cost of Ownership Discussion Document," Advanced Clean Fleets proceeding, August 30, 2022, https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/appg.pdf.
[x] Rupert Way et al., "Empirically Grounded Technology Forecasts and the Energy Transition," *Joule* 6, no. 9 (September 13, 2022): https://doi.org/10.1016/j.joule.2022.08.009.
[xi] Way et al., "Empirically Grounded Technology Forecasts and the Energy Transition."
[xii] California Air Resources Board staff, "Staff Report: Initial Statement of Reasons."
[xiii] California Air Resources Board staff, "Staff Report: Initial Statement of Reasons."
[xiv] Baha M. Al-Alawi and Owen MacDonnell, "Zeroing in on Zero Emission Trucks" (CALSTART, January 2022), https://calstart.org/wp-content/uploads/2022/02/ZIO-ZETs-Report_Updated-Final-II.pdf.