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Evaluating decarbonization pathways for medium- and heavy-duty vehicles

Additional submitted attachment is included below.

Electric Program Investment Charge 2026–2030 (EPIC 5) Research Concept Proposal Form

The California Energy Commission (CEC) is currently soliciting research concept ideas and other input for the Electric Program Investment Charge 2026–2030 (EPIC 5) Investment Plan. For those who would like to submit an idea for consideration, please complete this form and submit it to the CEC by **August 8, 2025**. More information about EPIC 5 is available below.

To submit the form, please visit the e-commenting link: https://efiling.energy.ca.gov/EComment/ECommentSelectProceeding.aspx and select the Docket **25-EPIC-01**. Enter your contact information and then use the "choose file" button at the bottom of the page to upload and submit the completed form. Thank you in advance for your input.

1. **Please provide the name, email, and phone number of the best person to contact should the CEC have additional questions regarding the research concept:**

   Nafisa Lohawala, nlohawala@rff.org (202) 328-5025

2. **Please provide the name of the contact person's organization or affiliation:**

   Resources for the Future

3. **Please provide a brief description of the proposed concept that you would like the CEC to consider as part of the EPIC 5 Investment Plan. What is the purpose of the concept, and what would it seek to do? Why are EPIC funds needed to support the concept?**

   The proposed concept aims to evaluate decarbonization pathways for medium- and heavy-duty vehicles (MHDVs), a critical sector for addressing both climate change and local air pollution. Despite policy efforts, adoption of non-diesel alternatives has been limited. Potential decarbonization options—including battery-electric and hydrogen fuel-cell vehicles, as well as the use of low-carbon fuels such as renewable diesel—differ widely in emissions profiles, fuel sourcing, and impacts on the electric grid.

This project would develop a model that compares these pathways, accounting not only for their technical characteristics but also for how fleet operators and vehicle manufacturers respond to policy incentives and constraints.

Below we describe the decisions that we will model based on observable data on this sector:

1. **Powertrain and Fuel Economy Decisions:** Manufacturers choose the powertrain (electric, diesel, hydrogen) and fuel economy of their trucks based on expected demand and marginal production costs. These decisions maximize expected profits while considering regulatory constraints, such as emissions standards. By modeling this, we can evaluate how policies influence manufacturers' decisions to introduce new products and adjust the attributes of existing models.

2. **Pricing Decisions:** Manufacturers competitively set prices for their portfolios based on production costs and anticipated fleet demand. The model allows for market power by the manufacturers, which provides an opportunity to assess how policies and incentives affect pricing strategies and markups.

3. **Fleet Purchasing Decisions:** Fleet owners decide which trucks to purchase and operate, based on factors such as upfront prices, operating costs, and truck attributes. Fleet owners also consider future utilization (as described below) and the availability of new and used trucks. This portion of the model captures how policies like the vehicle purchase subsidies or higher fuel prices influence fleet adoption of vehicles of different fuel types.

4. **Truck Utilization:** Fleet owners decide how intensively to utilize different trucks, balancing operational costs with demand for freight services. Factors like per-mile costs and maintenance expenses drive these decisions. By modeling truck utilization, we assess how various policies impact total miles driven and emissions in the trucking sector.

Such a framework is essential for understanding how different policy scenarios influence vehicle decarbonization pathways through their effect of investment and adoption decisions. Without it, existing models based on total cost of ownership or technology advancement would likely overestimate the speed at which fleets will shift to low-emission vehicles, while also incorrectly predicting policy effectiveness or cost. This work can thus help policymakers identify more cost-effective approaches to achieving their climate goals.

Funding is needed to support the development of this model, including data acquisition, modeling, and policy simulations. More specifically, EPIC funding is critical due to the lack of other funders in this space, especially when it comes to supporting modeling efforts. At Resources for the Future, we have developed research proposals to pursue this research agenda, but we have found that it is a difficult environment for funding long-term decarbonization research given the many competing priorities of foundations and the rejection of climate science in the federal government under the Trump administration. Additionally, EPIC funding is important for this project due to the relevance of this research for the state of California and because of the leadership role that California plays in vehicle decarbonization. California's leadership in the vehicle decarbonization space has and will continue to influence the United States and the international community in advancing this important work.

4. **In accordance with Senate Bill 96[i], please describe how the proposed concept will "lead to technological advancement and breakthroughs to overcome barriers that prevent the achievement of the state's statutory energy goals." For example, what technical and/or market barriers or customer pain points would the proposed concept address that would lead to increased adoption of clean energy technology or innovation? Where possible, please provide specific cost and performance targets that need to be met for increased industry and consumer acceptance. For scientific analysis and tools, provide more information on what data and information gaps the proposed concept would help fill, and which specific parties or end users would benefit from the results, and for what purpose(s)?**

One barrier to adoption of non-diesel technologies is the presence of soft transition costs that fleets face when switching technologies. These include operational adjustments and workforce retraining. Such costs are often difficult to observe and are not captured in engineering or total-cost-of-ownership models, but they can materially affect fleet decision-making.

A second barrier is market power among vehicle manufacturers, which can affect policy effectiveness—for example, by limiting the pass-through of subsidies. Evaluating policy effectiveness under these conditions requires a model that can capture strategic interactions between vehicle manufacturers—not just engineering feasibility or cost.

The proposed model would fill this gap. On the demand side, it will capture fleet owners' vehicle purchase decisions based on upfront costs (purchase price, infrastructure requirements), operating costs (fuel, maintenance), and vehicle attributes (range, payload capacity). It will also explicitly incorporate indirect costs associated with transitioning to non-diesel technologies, such as operational adjustments. We will leverage data on actual fleet-owner purchase decisions and prices to estimate the underlying preferences that produce observed outcomes. This will clarify why businesses have hesitated to buy electric MHDVs, beyond financial incentives, and provide more realistic predictions of how they would respond to different policies and market conditions.

On the supply side, we will model manufacturers' strategic pricing behavior using game-theoretic methods. This will allow us to account for market power and assess the potential for manufacturers to adjust pre-incentive prices or change vehicle offerings in response to policy interventions.

The model's outputs would support policymakers, regulators, and utilities in designing policies that better reflect real-world constraints. It will allow users to compare the effects of taxes, subsidies, LCFS credits, and other instruments on adoption of different technologies, use of biofuels, emissions reductions, and electricity demand. An extension of the model could estimate the resulting impact on electricity prices.

5. **Please describe the anticipated outcomes if this research concept is successful, either fully or partially. For example, to what extent would the research reduce technology or ratepayer costs and/or increase performance to improve the overall value proposition of the technology? What is the potential of the innovation at scale? How will the innovation lead to ratepayer benefits in alignment with EPIC's guiding principles to improve safety,[ii] reliability,[iii] affordability,[iv] environmental sustainability,[v] and equity?[vi]**

If successful, this research would provide policymakers with a tool to compare how different policies influence hydrogen, biofuel, and electric pathways for medium- and heavy-duty vehicle decarbonization, and to assess the implications of these policies for electricity demand.

By helping anticipate these effects, the model would support efforts to balance climate goals with grid capacity and ratepayer costs, improving the affordability, reliability, and environmental sustainability of the state's energy transition.

6. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed research concept.

   Quantitative metrics:

   - Model validation by:
     - Testing sales predictions against historical data excluded from model development.
     - Comparing model-recovered costs with engineering estimates.
     - Checking consistency of estimated parameters (e.g., demand elasticities) with established values in the literature.
   - Publication of at least one peer-reviewed article.
   - Number of stakeholder briefings on policy impacts.
   - Web traffic for working papers and related communication outputs to gauge circulation.

   Qualitative indicators:

   - Feedback from participants and discussants at relevant academic conferences.

   Policymaker and industry stakeholder assessments of the model's relevance.

7. **Please provide references to any information provided in the form that supports the research concept's merits. This can include references to cost targets, technical potential, market barriers, equity benefits, etc.**

Spiller et al. (2023) describe factors influencing the adoption of electric medium- and heavy-duty vehicles, including vehicle logistics and operations, manufacturing, infrastructure needs, and externalities. The report also discusses barriers to an equitable transition, such as uneven access to charging infrastructure and financial constraints faced by smaller fleets.

Nehrkorn et al. (2024) provide an overview of hydrogen fuel cell truck technology in the United States, including its current status, comparisons to diesel and battery-electric alternatives, deployment challenges, and relevant policy considerations.

The Governor's Executive Order N-79-20 requires that by 2035, all new cars and passenger trucks sold in California be zero-emission vehicles.

The Advanced Clean Fleets (ACF) Regulation, adopted by CARB in April 2023 and later withdrawn, would have required targeted fleets suited for electrification to phase in ZEV use and directed manufacturers to sell only ZEV trucks starting in the 2036 model year. The model would be able to evaluate policies such as the ACF.

Spiller, Beia, Nafisa Lohawala, and Emma DeAngeli. "Medium-and heavy-duty vehicle electrification: Challenges, policy solutions, and open research questions." *Resource for the Future, Washington DC, Tech. Rep.* (2023).

Nehrkorn, Katarina, Beia Spiller, and Alan Krupnick. "Exploring Hydrogen's Role in Heavy-Duty Trucking." *Resource for the Future, Washington DC, Tech. Rep.* (2024).

8. **The EPIC 5 Investment Plan must support at least one of five Strategic Goals:**[vii]
    a. **Transportation Electrification**
    b. **Distributed Energy Resource Integration**
    c. **Building Decarbonization**
    d. **Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas**
    e. **Climate Adaptation**

    Please describe in as much detail as possible how your proposed concept would support these goals.

This work would support both Strategic goals a. (Transportation Electrification) and d. (Achieving 100 percent net-zero carbon emissions and the coordinated role of gas). It would address the stated goal of transitioning all MHDVs (one of the hardest-to-decarbonize sectors in the economy) in California to ZEVs by 2045, and help identify pathways to doing so that minimize the cost on rate payers and maximize environmental benefits. This work would also address issues around green electrolytic hydrogen production used for decarbonizing the MHDV sector and its impacts on rate payers, particularly in comparison to battery electric truck adoption.

About EPIC

The CEC is one of four EPIC administrators, funding research, development, and demonstrations of clean energy technologies and approaches that will benefit electricity ratepayers of California's three largest investor-owned electric utilities.

EPIC is funded by California utility customers under the auspices of the California Public Utilities Commission.

To learn more about EPIC, visit: https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program

EPIC 5 documents and event notices will be posted to: https://www.energy.ca.gov/proceeding/electric-program-investment-charge-2026-2030-investment-plan-epic-5

Subscribe to the EPIC mailing list to stay informed about future opportunities to inform the development of EPIC 5: https://public.govdelivery.com/accounts/CNRA/signup/31897

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i See section (a) (1) of Public Resources Code 25711.5 at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25711.5.

ii EPIC innovations should improve the safety of operation of California's electric system in the face of climate change, wildfire, and emerging challenges.

iii EPIC innovations should increase the reliability of California's electric system while continuing to decarbonize California's electric power supply.

iv EPIC innovations should fund electric sector technologies and approaches that lower California electric rates and ratepayer costs and help enable the equitable adoption of clean energy technologies.

v EPIC innovations should continue to reduce greenhouse house gas emissions, criteria pollutant emissions, and the overall environmental impacts of California's electric system, including land and water use.

vi EPIC innovations should increasingly support, benefit, and engage disadvantaged vulnerable California communities (DVC). (D.20-08-046, Ordering Paragraph 1.) DVCs consist of communities in the 25 percent highest scoring census tracts according to the most recent version of the California Communities Environmental Health Screening Tool (CalEnviroScreen), as well as all California tribal lands, census tracts with median household incomes less than 60 percent of state median income, and census tracts that score in the highest 5 percent of Pollution Burden within CalEnviroScreen, but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data.

vii In 2024 the CPUC adopted five Strategic Goals to guide development of the EPIC 5 Investment Plan. A description of the goals can be seen in Appendix A of CPUC Decision 24-03-007 available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M527/K228/527228647.PDF