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Fuel Cell Systems as Generators

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:

   Dominik Haering, dhaering@uci.edu, 331-803-8670

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

   University of California, Irvine

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?

While renewable energy sources are rapidly expanding, certain applications still depend on fossil fuels. The current backup power market is largely dominated by diesel generators, with limited adoption of battery-powered systems. Although batteries are effective for specific short-duration use cases, they are not well-suited for sustained power delivery over multiple hours or days.

We propose hydrogen fuel cell-based generator systems, powered by liquid or gaseous hydrogen, which can be refueled quickly and operate continuously. Toyota is already advancing the development and commercialization of such systems; however, further research is needed to fully understand the capabilities and limitations of fuel cells in continuous 24/7 operation. This includes exploring how they can be integrated into distributed energy systems to reduce carbon emissions, support California’s 100% Net-Zero Carbon Emissions goal, and enhance public benefit by minimizing costly energy imports and stabilizing the grid with renewable hydrogen-based power.

EPIC funding is critical to de-risk this novel utility-scale application of hydrogen fuel cell generators and accelerate its path to commercial readiness. The project will generate publicly accessible data on performance, safety, and economic viability in real-world conditions, paving the way for broader adoption to strengthen California’s grid resilience and decarbonization efforts.

4. In accordance with Senate Bill 96, 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)?

While hydrogen fuel cells are gaining traction in automotive and heavy-duty trucking applications, their deployment for continuous, stationary power generation—such as utility-scale or distributed backup systems—presents a distinct and largely unaddressed set of technical and market challenges. Unlike intermittent or mobile use, continuous 24/7 operation places unique demands on fuel cell systems, particularly in terms of material durability, system reliability, and long-term economic viability. These challenges must be overcome to enable fuel cells to serve as a practical and sustainable replacement for fossil-fuel-based generators.

One of the primary barriers to adoption is the limited understanding of aging and degradation mechanisms in fuel cells subjected to uninterrupted operation. These degradation processes, especially at the electrode and membrane levels, can impact system longevity, efficiency, and maintenance requirements—factors that are critical for grid applications. Currently, there is a lack of publicly available long-duration performance data under real-world conditions, creating uncertainty for utilities, regulators, and technology adopters.

To address these gaps, we propose to establish a specialized testing facility capable of both short-stack and full-system testing. Short-stack configurations will allow for controlled experimentation with lower hydrogen consumption, enabling cost-effective, high-throughput analysis of component behavior, failure modes, and performance degradation over time. In addition, full-system testing will be conducted in a climate-controlled environment to simulate a range of real-world operational conditions. Temperature and environmental factors play a critical role in the performance and durability of fuel cell systems, and the ability to control these parameters is essential for generating reliable and reproducible data. This will ensure that insights gained reflect realistic field conditions, supporting technology validation and system optimization.

This project will generate publicly accessible, high-resolution data on the long-term performance, durability, safety, and cost-effectiveness of hydrogen fuel cell systems in continuous operation. These insights will be directly applicable to utilities evaluating alternatives to diesel generators, technology developers refining system design, and regulatory bodies establishing performance standards for clean backup and distributed power systems. Importantly, this work will also support economic assessments by identifying the conditions under which hydrogen fuel cells become cost-competitive—based on metrics such as dollars per kilowatt-hour, system lifespan, and refueling logistics.

By addressing key technical and informational barriers, this project will accelerate the commercialization and broader adoption of zero-emission hydrogen technologies. It directly supports California's statutory energy goals, including achieving 100% zero-carbon electricity, enhancing grid resilience, and reducing reliance on imported fossil fuels. EPIC funding is essential to de-risk this first-of-its-kind application and catalyze a transition to clean, continuous power systems rooted in renewable hydrogen.

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, reliability, affordability, environmental sustainability, and equity?

If successful, this research will significantly advance the technical and commercial readiness of hydrogen fuel cell systems for continuous power generation. It will reduce uncertainty around long-term performance and support cost-effective deployment by improving durability, extending system life, and providing real-world performance data essential for accurate cost modeling.

Through climate-controlled, 24/7 testing, the project will identify degradation mechanisms and demonstrate system reliability, helping lower total cost of ownership and enabling more informed investment decisions. These findings will support replacement of diesel generators with zero-emission hydrogen alternatives, reducing greenhouse gas emissions, air pollution, and noise—particularly in disadvantaged communities.

Ratepayer benefits include:

- Safety & Reliability: Quiet, stable operation with fewer moving parts improves system resilience.

- Affordability: Greater efficiency and durability will help reach cost parity with diesel, especially when accounting for fuel and emissions savings.
- Environmental Sustainability: Enables deep decarbonization, especially when powered by green hydrogen.
- Equity: Promotes cleaner energy infrastructure in communities disproportionately affected by diesel use.

Even partial success—such as identifying operational limits or demonstrating cost-effective performance under specific climate conditions—will inform pilot projects, policy development, and infrastructure planning, accelerating California's transition to clean, resilient energy systems.

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

The proposed research will be evaluated using a combination of quantitative and qualitative metrics to assess technical performance, cost-effectiveness, and alignment with EPIC's goals of safety, reliability, affordability, sustainability, and equity.

Quantitative Metrics:

- Durability & Lifespan: Total operational hours, performance degradation over time, and number of sustained start/stop cycles.
- Efficiency & Fuel Use: Electrical efficiency (%), hydrogen consumption (kg H_2/kWh), and degradation rates of key parameters.
- Cost: Estimated cost per kWh based on actual system performance and comparison to diesel generator benchmarks.
- Environmental Impact: GHG and local pollutant emissions avoided (e.g., CO_2, NO_x, PM).
- System Reliability: Uptime %, mean time between failures (MTBF), and maintenance intervals.
- Climate Tolerance: Performance across varying temperatures and humidity levels.

Qualitative Metrics:

- Integration Readiness: Compatibility with utility and microgrid systems; feedback from stakeholders.
- Regulatory Insight: Identification of market or policy barriers informed by operational data.
- Knowledge Sharing: Number of public reports, datasets, and stakeholder engagements.
- Equity & Community Benefit: Qualitative assessment of cleaner, quieter energy alternatives in disadvantaged communities.

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.

Technical Potential and Market Barriers:

- U.S. Department of Energy (DOE) Hydrogen and Fuel Cell Technologies Office, *Multi-Year Research, Development, and Demonstration Plan*, 2020. https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

  Details technical challenges related to long-duration operation of fuel cells and identifies performance targets for stationary applications.

- National Renewable Energy Laboratory (NREL), *Backup Power Cost of Ownership Analysis and Incumbent Technology Comparison*, 2021. https://www.nrel.gov/docs/fy21osti/77888.pdf

  Compares cost and performance of fuel cells versus diesel generators for backup power use.

Cost Targets and Commercial Viability:

- Hydrogen Council, *Hydrogen Insights 2023: Market and Cost Perspective*. https://hydrogencouncil.com/en/hydrogen-insights-2023/

  Provides cost projections for hydrogen production and fuel cell systems, including expected cost parity with diesel in specific markets by 2030.

- California Energy Commission (CEC), *Assembly Bill 8: 2022 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. https://www.energy.ca.gov/publications/2022/ab-8-2022-annual-evaluation-fuel-cell-electric-vehicle-deployment-and-hydrogen

  Outlines infrastructure readiness and market challenges for hydrogen fuel cell technologies in California.

  Equity and Environmental Benefits:

- California Air Resources Board (CARB), *Technology Assessment: Mobile Source Fuels – Fuel Cell Technology*, 2020. https://ww2.arb.ca.gov/resources/documents/technology-assessment-fuel-cell-electric-vehicles

  Evaluates air quality benefits of fuel cells and highlights their importance in reducing localized pollution in disadvantaged communities.

- California Office of Environmental Health Hazard Assessment (OEHHA), *CalEnviroScreen 4.0*, 2021. https://oehha.ca.gov/calenviroscreen

  Used to identify disadvantaged communities that stand to benefit from cleaner, quieter alternatives to diesel-based generators.

8. The EPIC 5 Investment Plan must support at least one of five Strategic Goals:
   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.

The proposed concept supports several key goals of the EPIC 5 Investment Plan, with primary alignment to:

(b) Distributed Energy Resource Integration

Hydrogen fuel cells can serve as clean, dispatchable DERs, ideal for backup power and grid support. This project will validate their performance and integration potential, enabling greater use of zero-emission resources in microgrids and critical infrastructure, especially in areas vulnerable to outages or Public Safety Power Shutoffs (PSPS).

(d) Achieving 100 Percent Net-Zero Carbon Emissions

By replacing diesel generators with fuel cells powered by renewable hydrogen, the project supports California's decarbonization targets. It helps define hydrogen's role in reducing fossil fuel reliance and transitioning to a zero-carbon energy system, particularly for hard-to-electrify applications.

(e) Climate Adaptation

Fuel cells offer reliable, grid-independent power during climate-driven events such as wildfires and heatwaves. This research will assess system performance across a range of environmental conditions, supporting deployment in climate-vulnerable communities and ensuring continuity of critical services.