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AI-Driven Probabilistic Forecasting to Manage Power System Risk During Extreme Weather Events

To improve Californiaâ€™s ability to anticipate and manage grid reliability and market stability challenges during extreme weather events such as heat waves and atmospheric river events by integrating cutting-edge AI-based probabilistic weather, load, renewable energy forecasting with grid and electricity market simulations. This approach would allow California to better forecast and mitigate the operational and economic impacts of extreme weather on a renewable-rich grid, ultimately supporting resilience, reliability, and cost stability in future energy systems.

Additional submitted attachment is included below.

CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

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:

   Nanpeng Yu, nyu@ece.ucr.edu, 951-827-3688

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

   University of California, Riverside

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?

   Concept Title: AI-Driven Probabilistic Forecasting to Manage Power System Risk During Extreme Weather Events.

   Purpose: To improve California's ability to anticipate and manage grid reliability and market stability challenges during extreme weather events such as heat waves and atmospheric river events by integrating cutting-edge AI-based probabilistic weather, load, renewable energy forecasting with grid and electricity market simulations.

   What is seek to do:

The proposed research would develop and apply a computationally efficient framework that:

- Uses advanced AI weather models to generate **ensemble, probabilistic forecasts** for key meteorological variables (temperature, precipitation, wind, humidity, solar irradiance).
- Translates these forecasts into **probabilistic projections** of electricity demand, renewable generation potential, operational risks, and market prices.
- Couples these projections with a **high-resolution power grid and market simulation engine** to evaluate operational risks and price volatility under a range of plausible weather scenarios.
- Quantifies **location-specific risk** for grid operations and electricity markets, enabling system operators, planners, and market participants to make more **risk-aware, proactive decisions**.

This approach would allow California to better forecast and mitigate the operational and economic impacts of extreme weather on a renewable-rich grid, ultimately supporting **resilience, reliability, and cost stability** in future energy systems.

Why are EPIC funds needed?

This concept addresses a **critical gap** in California's energy resilience toolkit—accurately forecasting and managing power grid reliability and market volatility during extreme weather in a high-renewables future. While individual components of the framework (AI weather models, demand forecasting, renewable performance simulation) exist in academic or early pilot stages, **no integrated, operationally ready system** currently supports California's grid operators and market participants with **real-time, probabilistic, multi-variable forecasts** under stressed conditions.

EPIC funds are essential because:

1. **Bridging the Research-to-Operations Gap** – Current academic work is promising but remains untested for **California-specific grid configurations, market rules, and climate extremes**. EPIC can fund the adaptation, validation, and scaling of these models for CAISO and statewide use.
2. **Public Benefit, Not Private Incentive** – The outputs (forecasts, models, risk metrics) would be **openly available** to support system operators, regulators, community choice aggregators, and DER providers—benefits that are too diffuse for private investors to justify funding.
3. **Extreme Weather Preparedness** – Climate projections indicate **more frequent, more intense extreme weather events**; EPIC investment

ensures California's forecasting capability evolves ahead of these threats, reducing outage risk, curbing price spikes, and protecting vulnerable populations.

4. **Alignment with EPIC Mission** – This research directly supports EPIC's mandate to fund innovations that **increase grid reliability, integrate renewables, reduce costs, and prepare for climate impacts**.

   Without EPIC funding, this work is unlikely to advance beyond fragmented pilots, leaving California's grid vulnerable to the growing uncertainty of climate-driven extreme events.

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)?

   California's statutory energy goals—including **100% clean electricity by 2045 (SB 100)**—depend on the ability to **reliably operate a renewable-dominated grid** under increasingly volatile climate conditions. Achieving this vision is constrained by the following technical barriers:

   a. **Inadequate Extreme-Weather Forecast Integration** – Current operational tools cannot rapidly generate and integrate *probabilistic, multi-variable forecasts* of weather, load, renewable output, and market conditions. This limits operators' ability to make risk-aware, preemptive decisions during events like heat waves.
   b. **Fragmented Modeling Ecosystem** – Weather forecasting, demand modeling, renewable performance simulation, and market operations are often developed in silos. Without integration, uncertainty compounding across domains is ignored, leading to unforeseen supply shortfalls or price spikes.
   c. **Computational Bottlenecks** – Traditional numerical weather prediction (NWP) can require hours of supercomputing time per forecast ensemble. This delay prevents rapid scenario analysis during fast-changing extreme events.

Breakthrough Enabled:
This concept's **AI-driven, ensemble-based forecasting** and **integrated power grid and market simulation** overcome these technical bottlenecks by delivering **statewide, probabilistic operational forecasts in minutes instead of hours**, enabling proactive resource scheduling, targeted demand response, and optimized renewable dispatch.

Cost and Performance Targets for Adoption
Forecast Latency: Deliver full probabilistic forecast ensembles (<2 minutes per run) vs. multi-hour NWP timelines—critical for real-time decision-making.
Avoided Outage Costs: Enable proactive interventions that prevent at least one major rotating outage event per decade—saving hundreds of millions in economic losses.

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]

Anticipated Outcomes and Benefits
If this research concept is **fully successful**, California will gain an **operationally ready, AI-driven probabilistic forecasting and power grid, market simulation platform** capable of delivering accurate, high-resolution forecasts of weather, load, renewable generation, system operation risks and market prices **within minutes** during extreme events.

1. Technology and Ratepayer Cost Reductions
Reduced Outage-Related Costs: By enabling proactive mitigation strategies (e.g., targeted demand response, distributed energy resource dispatch), the framework could prevent at least one major rotating outage per decade, avoiding hundreds of millions in economic losses.

2. Potential at Scale
California-Wide Deployment: The framework is designed for CAISO operations but can be scaled to investor owned utilities, community choice aggregators, and regional transmission operators.
Replicability Beyond California: Adaptable for other U.S. ISO/RTOs and global grids facing renewable integration and climate-driven volatility.

Market Transformation: Could become the standard operational forecasting tool for renewable-rich grids, accelerating clean energy adoption without compromising reliability.

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

   Forecasting accuracy, forecast latency, uncertainty resolution, avoided outage costs, emergency procurement reduction, event preparedness lead time.

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.

   Joseph Brown, Nanpeng Yu, Aowabin Rahman and Kostas Oikonomou, "Assessing Power System and Market Volatility During Heat Waves Using Probabilistic AI Forecasts: Insights from the WECC Region," 2025.

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.

Primary Strategic Goal Alignment
(e) Climate Adaptation – *Primary Support*

- **Extreme Weather Preparedness:** The framework directly addresses the operational and market uncertainty caused by climate-driven events such as prolonged heat waves and atmospheric river events, which are projected to increase in both frequency and intensity in California.
- **Resilience through Uncertainty Quantification:** By producing **location-specific probabilistic forecasts** of load, renewable generation, and market prices, the tool gives grid operators and market participants the ability to prepare for a range of plausible scenarios, not just a single-point forecast.

- **Rapid Forecasting for Emergency Response:** The AI-driven approach delivers forecasts in **under two minutes**, compared to hours for conventional numerical weather prediction, providing critical lead time to deploy demand response, mobilize distributed resources, and adjust market bids.
- **Equity in Adaptation:** Publicly accessible risk and forecast products will help disadvantaged communities and smaller market participants prepare for extreme events, reducing disproportionate impacts.

(d) Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas – *Secondary Support*

- **Higher Renewable Utilization:** By reducing operational uncertainty, the tool enables **more aggressive scheduling of solar and wind generation** during high-stress events, decreasing reliance on gas-fired peaker plants.
- **Pathway to Reduced Gas Dependence:** Improved forecast accuracy can enable a gradual phase-down of fossil backup by increasing operator confidence in renewable dispatch under volatile conditions.

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