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Module validation program for perovskite tandem PV

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:*
   Todd Krajewski, Todd.Krajewski@swiftsolar.com,

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

   Swift Solar Inc.

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?*

   We propose a module validation program for perovskite (incl. tandem) PV that: (1) designs and down-selects robust interconnects for perovskite architectures; (2) establishes and executes IEC-aligned testing & rating protocols adapted to perovskite materials; and (3) builds physics-based lifetime models calibrated by accelerated stress and outdoor exposure data representative of California climates. EPIC support is needed to produce reliability data, standards alignment, and bankability evidence that private funding under-invests in, thereby reducing risk and accelerating safe, affordable deployment for IOU ratepayers.

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)?*

   Barriers. i) Immature module-level reliability evidence under IEC 61215/61730 for perovskites; (ii) lack of perovskite-tailored reliability test protocols, lifetime models and standardized test protocols; (iii) limited bankability artifacts recognized by IEs; (iv) California stressors (wildfire smoke, high heat) under-represented in datasets.

   Advancements & targets
   - Interconnect reliability (R&D prototypes): fabricate ≥2 interconnect concepts; demonstrate ≤5% ΔPmax after TC200 (−40-+85 °C), ≤5% ΔPmax after DH1000 (85 °C/85% RH), and no safety nonconformities per IEC 61730-1 inspections.
   - Perovskite-adapted testing & rating: define a perovskite test matrix that augments IEC 61215-2 with ISOS-derived light/thermal/humidity sequences; include PID per IEC TS 62804-1 and DML per IEC TS 62782; target ≤5% ΔPmax on each leg and <10% lab-to-outdoor performance variance.
   - Lifetime & bankability modeling: calibrate a physics-based lifetime model so predictions are ±20% of observed degradation in outdoor exposure; compile a bankability requirement package for reliability aligned with independent-engineering expectations (PVEL/IE) and BNEF bankability factors.
   - Sampling/TRL: Use an IEC-typical small sample set (~10 modules) per sequence; document TRL 5→6 progression.

   End users & data gaps filled. Utilities, regulators, lenders/IEs, and project developers gain traceable reliability evidence and models required for due diligence and program planning.

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]

- Full success: Demonstrated IEC-aligned pass performance on R&D module prototypes (TC200, DH1000, PID, DML), a validated lifetime model, and a third-party-reviewable bankability packet for reliability (test data + methods + uncertainties) comparable in structure to PVEL/IE expectations—lowering perceived technology risk and clarifying LCOE pathways and accelerating DER/building adoption in CA.
- Partial success: If some sequences fall short, we still deliver failure-mode insights, revised materials/interconnect guidance, and open test datasets to accelerate subsequent iterations—valuable public goods consistent with EPIC's RD&D mandate.

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

1. Interconnect development
   - ≥2 concepts fabricated; ≤5% increase in series resistance (or ≤10 mΩ absolute) after TC200; no visual/safety failures per IEC 61730 inspections.
2. Testing & rating protocols
   - Publish perovskite IEC-style test matrix (includes UV, TC, HF, DH, PID, DML); test ≥10 modules/leg (IEC typical sample size); ≤5% ΔPmax after DH1000 and TC200; PID result meeting 62804-1 criteria; <10% lab-to-outdoor variance.
3. Field-relevant LCOE modeling & lifetime estimation
   - Lifetime model error ≤±20% vs. outdoor exposure; CA stressors parameterized (temperature/humidity/smoke AOD) and in included in the LCOE model; dataset released with metadata suitable for IE review.
4. Cross-cutting
   - TRL 5→6 transition documented; ≥3 external stakeholders (lab, developer, financier) provide written feedback; draft IE bankability brief produced.

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.
    - IEC 61215-1:2021 (design qualification/type approval overview and changes).
    - IEC 61730-1:2023 (module safety construction requirements).
    - IEC TS 62804-1 (2025) (PID test methods, updated edition).
    - IEC TS 62782 (2016) (dynamic mechanical load).
    - IEC TS 63209-1/-2 (extended-stress testing for modules/materials).
    - NREL consensus on perovskite stability (ISOS-based). Link
    - PVEL PV Module Reliability Scorecard 2024 (bankability-relevant tests & expectations). Link
    - NREL wildfire smoke & PV generation impacts (CA). Link
    - RETC PV Module Index 2025 (beyond-certification bankability testing approach). Link
    - DNV on solar due diligence / bankability (what IEs expect). Link
    - IEC 61215 small sample set (~10 modules) (NIST/NREL slide deck summarizing 61215). Link

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.

    - Distributed Energy Resource Integration & Building Decarbonization: Provides validated performance/rating methods and reliability evidence for distributed perovskite modules.
    - Achieving 100% Net-Zero: De-risks a high-efficiency PV pathway and clarifies lifetime/LCOE.
    - Climate Adaptation: Incorporates wildfire smoke/heat into testing and modeling to ensure resilience in California 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