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<th><strong>Docket Number:</strong></th>
<th>19-ERDD-01</th>
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<td><strong>Project Title:</strong></td>
<td>Research Idea Exchange</td>
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<td><strong>TN #:</strong></td>
<td>224675</td>
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<td><strong>Document Title:</strong></td>
<td>Presentation - Research Needs for Thin-Film Photovoltaic Technologies</td>
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<tr>
<td><strong>Description:</strong></td>
<td>Staff Presentation</td>
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<tr>
<td><strong>Filer:</strong></td>
<td>Silvia Palma-Rojas</td>
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<td><strong>Organization:</strong></td>
<td>California Energy Commission</td>
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<td>Commission Staff</td>
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<td><strong>Docketed Date:</strong></td>
<td>9/8/2018</td>
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Research Needs for Thin-film Photovoltaic Technologies

Rizaldo Aldas, PhD
Energy Research and Development Division

September 7, 2018
Sacramento, CA
Housekeeping

- Facilities
- Emergency Exit
- Sign-In Sheet
Workshop Objective

✓ Examine ways to advance the science and manufacturing of thin-film photovoltaic (PV) technologies and possibilities for reducing associated costs.

✓ Determine research needs that would enable improvements to materials science and manufacturing to create high value market applications for selected thin-film PV technologies.

✓ Obtain feedback from interested parties and experts on the objective, groups, metrics of our planned grant solicitation.
Agenda


9:40-10:00 AM: Presentation on DOE Solar Energy Technologies Office (SETO)’s Research and Development on PV Technology

10:00 – 11:30 AM: Panel Discussion on State of the Art and Research Needs for Conventional and Emerging Thin-film Photovoltaics

11:30-12:00 PM: Discussion and Public Comments
Enhanced Outreach & Engagement Opportunities

EPIC Innovation Showcase

- [http://innovation.energy.ca.gov](http://innovation.energy.ca.gov)

Social Media

- Blogs, tweets and video features of research projects

Extensive public workshops on research scope, technology advancements, and market opportunities

Participating in meetings and events with diverse organizations
Connecting With Us

Instagram

California Energy Commission Follow along as we advance energy policy, encourage energy efficiency, develop renewable energy & invest in energy & transportation innovation. @calenergy

calenergy 190 posts 663 followers 192 following

CA Energy Commission

The California Energy Commission is the state’s primary energy policy and planning agency.

Sacramento, CA

energy.ca.gov

Joined July 2010

Twitter

Tweets 7,729
Following 1,553
Followers 9,872
Likes 996

LinkedIn

California Energy Commission Networking Hub

Manager’s Choice

California Energy Commission Networking Hub

This Networking Hub is a user-driven group page the California Energy Commission has set up to help potential applicants connect, collaborate and partner on proposals for funding opportunities through the Electric Program Investment Charge, Alternative and Renewable Fuels and Vehicle Technologies Program, and Natural Gas RD&D Program. Posts and statements of qualifications on this group page are not endorsed or otherwise evaluated by the Energy Commission.

See the Group Rules for more information and the complete description of this group.
CREATE Solar

Silvia Palma-Rojas, PhD
Energy Research and Development Division

September 7, 2018
Sacramento, CA
Electric Program Investment Charge (EPIC)
The Science of Innovation

Create  Inspire  Collaborate
The Electric Program Investment Charge (EPIC) is funded by an electricity ratepayer surcharge established by the California Public Utilities Commission (CPUC) in 2011.

- Annual program funds total $162 million per year (adjusted for inflation) with 80% administered by the California Energy Commission.

The purpose of EPIC is to:

- Benefit the ratepayers of the three largest electric investor-owned utilities, Pacific Gas and Electric Co., San Diego Gas and Electric Co., and Southern California Edison
- Funds clean energy technology projects and Encourage technological advancement and breakthroughs.
EPIC Program released:

- 2012-2014: Triennial Investment Plan with 11 funding areas
- 2015-2017: Triennial Investment Plan with 11 funding areas

Funding initiatives on applied R&D for solar energy:

- Develop Innovative Tools and Strategies to Increase Predictability and Reliability of Wind and Solar Energy Generation.
Current Solar Portfolio

Air-driven tracking system

Self-Tracking Concentrator PV System

Manufacturing Approach for Perovskite Cells

Developing a Next Generation Manufacturing Tools

Improving Accuracy of Solar Forecasting

All terrain tracking system

Strategic Initiative 4.1.1 “Advance the Material Science, Manufacturing Process, and In-Situ Maintenance of Thin-film PV Technologies” identified the need to:

- Advance the material science associated with emerging thin-film PV technologies
- Develop novel encapsulating materials and techniques that will prevent module failures and pave the pathway for large-scale application.
- Identify innovative high value applications.
Cost Reductions, Advanced Technology for Solar Photovoltaics (CREATE Solar)

- Facilitate technological advancements in thin-film solar photovoltaic (PV) systems for distributed level applications.
- Enable scaling while addressing constraints in cell efficiency, supply chain, materials scarcity and toxicity.
- Create new market applications for thin-film PV technologies with unique properties to increase renewables penetration and to lower the levelized cost of energy (LCOE) at distributed level.
Policy Drives Thin-Film PV Innovation

- Increase RPS to 50% by 2030
- Reduce GHG to 40% below 1990 levels by 2030
- Title 24 requires residential solar PV systems in new construction starting in 2020.

- Double energy efficiency savings by 50%
- 12,000 MW of distributed generation by 2020
- Increase access to clean energy in disadvantaged communities
Cumulative installed capacity of distributed solar PV increased 360% from 2012-2017.

Behind-the-meter (BTM) PV shares approximately 51 percent of the total distributed generation sources, with an installed capacity nearly to 6,000 MW.

Wafer-based silicon solar PVs dominate the solar energy landscape with a market share of about 90 percent.

Thin-film PV technologies market share is growing, but currently it is about 10 percent.
Advantages

- Less material used, potential cost reduction.
- Potential for lower thermal budget, potential cost reduction
- Thin, light, flexible, transparent make thin-film technology suitable for building-integrated PV applications.
- Potential for roll-to-roll application due to its flexibility, which may reduce installation costs

Disadvantages

- Lower efficiency than c-Si, potentially larger module costs
- Potential for capital-intensive production equipment
- Use of scarce, toxic materials, degradation rates

https://www.pveducation.org/pvcdrom/absorption-coefficient
What is the goal of CREATE Solar?

- Fund applied research and development projects that catalyze achieved breakthroughs in materials science and manufacturing process.
- Fund Projects that go beyond the state-of-the-art PV technology to support the development of innovative market application at distributed level.
- Ensure market readiness and higher penetration of solar generation at distributed level.
Challenges faced by conventional thin-film PV technologies, including cadmium telluride (CdTe), copper indium gallium selenide (CIGS), Gallium Arsenide (GaAS).

Pilot Technology demonstration projects should reach at least a technology readiness level of TRL 6-7 at the end of the project.
Research Areas

1) Improvement of material properties to increase voltage, diode quality, and efficiency.

2) Development of novel cell architecture to improve cell performance and address the short lifetimes of photo-excited electrons in cells.

3) Advancement of high-quality interfaces for high performance solar cells with increased current, reproducibility and stability.

4) Development and demonstration of four-terminal tandem systems.

5) Advanced manufacturing processes to address challenges to produce high performance modules in large-scale manufacturing.
Challenges faced by emerging thin-film PV technologies that include perovskites, organic/polymer, III-V multi-junction solar cells, and quantum dots.

Technology development projects should reach at least a technology readiness level of TRL 4-5 at the end of the project.
Research Areas

1) Development of novel absorber, contact materials, and device architectures for increased lifetime and device performance.

2) Advancement of structural, compositional, and/or interface engineering to improve the perovskite solar cell operational stability and to reduce eco-toxicological problems.

3) Improvements in process/manufacturing.

4) Improvement of precision optics and solar tracking systems to enhance cost competitiveness of III-V multi-junction solar cells.
Technology Development projects should finish in this range:

- TRL 1: Basic scientific principles observed
- TRL 2: Technology concept or application formulated
- TRL 3: "Proof of Concept" established
- TRL 4: Basic prototype tested in lab
- TRL 5: Basic prototype tested in field

Technology Demonstration and Deployment projects should finish in this range:

- TRL 6: Subsystem model demonstrated in the field
- TRL 7: System model demonstrated in field
- TRL 8: System demonstrated as intended without significant design problems
- TRL 9: System proven through successful operation

Technology leaves the lab and system is as close to the operational version as possible.
### Metrics: Group I

<table>
<thead>
<tr>
<th>PV TECHNOLOGY</th>
<th>Module Efficiency</th>
<th>Cell Efficiency</th>
<th>LCOE</th>
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<tbody>
<tr>
<td>CdTe</td>
<td>&gt;19.1 %</td>
<td>&gt;22.6 %</td>
<td>≤$0.04/kWh</td>
</tr>
<tr>
<td>CIGS</td>
<td>&gt;19.7 %</td>
<td>&gt;23.1 %</td>
<td>≤$0.04/kWh</td>
</tr>
<tr>
<td>GaAs</td>
<td>&gt;25.9 %</td>
<td>&gt;34%</td>
<td>≤$0.04/kWh</td>
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Source: Confirmed single junction terrestrial cell and submodule efficiencies measured under the global AM1.5 spectrum (1000 W/m²) at 25°C (IEC 60904-3: 2008, ASTM G-173-03 global); Green et al. Progress in Photovoltaics, Res Appl. 26, p. 3-12, 2018.

[https://doi.org/10.1002/pip.2978](https://doi.org/10.1002/pip.2978) PV Technology Metrics


# Metrics: Group II

<table>
<thead>
<tr>
<th>PV TECHNOLOGY</th>
<th>Module Efficiency</th>
<th>Cell Efficiency</th>
<th>LCOE</th>
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<tbody>
<tr>
<td>Perovskite</td>
<td>&gt;16.4 %</td>
<td>&gt;23.5% or &gt;26%</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for tandem cells</td>
<td></td>
</tr>
<tr>
<td>Organic/Polymer</td>
<td>&gt;10.0 %</td>
<td>&gt;12.4%</td>
<td>N/A</td>
</tr>
<tr>
<td>Multi-junction (III-V)</td>
<td>&gt;40 %</td>
<td>≤$0.04/kWh</td>
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</table>

Life Cycle Performance

- Proposals under this solicitation must demonstrate how they will meet the efficiency and Sunshot’s LCOE targets shown in table 1.
- Project must include a life cycle assessment of such thin-film solar technology, showing how the technology will address the life cycle constraints, including but not limited to material supply, toxicity and recyclability.
Thank You!

Please submit your comments by September 14, 2018

Silvia Palma-Rojas, PhD
Energy Generation Research Office
Energy Research and Development Division
Email: silvia.palma-rojas@energy.ca.gov
Discussion Panel

Katharina Snyder, PhD
Energy Research and Development Division

September 7, 2018
Sacramento, CA
Panel Discussion on State of the Art and Research Needs for Conventional and Emerging Thin-film Photovoltaics

DR. ELI YABLONOVITCH, UNIVERSITY OF CALIFORNIA, BERKELEY
DR. MICHAEL MCGEHEE, UNIVERSITY OF COLORADO, BOULDER
DR. DAVID FENNING, UNIVERSITY OF CALIFORNIA, SAN DIEGO
DR. WEN MA, SUNPREME INC.
DR. CHENLEI WANG, SUNPREME INC.
DR. MICHAEL WOODHOUSE, NATIONAL RENEWABLE ENERGY LABORATORY
Question?
Comments?
Thank You!

Please submit your comments by September 14, 2018

Katharina Snyder, PhD
Energy Generation Research Office
Energy Research and Development Division
Email: katharina.snyder@energy.ca.gov