

# Technical Assistance Request for Highly Efficient and Low-cost Carbon-based Perovskite Solar Cells

## Project Overview:

In this project, we propose an upscale printable carbon-based planar perovskite solar cell techniques through flexible carbon electrode and perovskite interface engineering. Through this interface engineering strategy, we target to achieve 20% solar cell efficiency with desirable stability for more than 5 years and 18% mini-module efficiency (100 x100 mm<sup>2</sup>) using a blade coating approach with the sponsorship of this American-Made Solar Prize project.

## Goals and Objectives:

The **major goal** of this project is to demonstrate that the printable cost-effective carbon-based perovskite mini-module with high efficiency (>15% initially), low cost, and improved stability compared to the traditional noble metal electrode (e.g., gold and Silver)-based perovskite.

The **objectives** include:

Objective 1: Carbon interface modification for the n-i-p structured planar perovskite solar cells

Objective 2: Fabricated lab-scale small area carbon-based perovskite solar cells with efficiency 20% and stability >1000 hours.

Objective 3: Demonstrate a 10x10 cm<sup>2</sup> solar module with an efficiency of over 15%

## Technical Assistance Requested to Meet These Goals

### National Labs

Our team will collaborate with National Renewable Energy Laboratory (NREL), Sandia National Laboratory (SNL) and Oak Ridge National Laboratory (ORNL) to develop thin film solar cells.

- NREL has the required testing equipment for the large-scale perovskite solar cell fabrication, measurement and stability tests such as highly calibrated module analysis, accelerated outdoor testing, rigorous shading, hotspot testing, and electroluminescence. This would give Carbon Solar a unique opportunity to understand, test, and validate our solar module technology and contrast our technology to best differentiate the solar cell and solar module performance.

- NREL has the solar cell certification service to certificate our champion devices and minimodule. NREL also has the solar simulator, ambient conditions-based stability test, light soaking, max-power point tracking system, and specific carbon-based perovskite solar measurement protocol development that will benefit our team.
- NREL has the materials electronic and photonic properties characterization equipment, such as conductive Atomic Force Microscopy (cAFM), Kelvin probe force microscopy (KPFM), Photoluminescence (PL) and Time resolved PL (TRPL) to better understand the device performance and the materials electronic transport behavior.
- ORNL has the Center of Nanophase Materials Sciences (CNMS) for the nanoscale materials characterization, including the transmittance electron microscopy (TEM), and atom probe tomography (APT). Through the materials and interface characterization, we can better understand the material's structural and chemical defects and the interface quality to reveal the approach to control these defects and interface to achieve improved device performance.
- SNL has the photovoltaic module level test capability for the field test. We will collaborate with the PV team at the SNL to evaluate our minimodule field test to learn the stability performance. Also, SNL has access to environmental chambers for damp-heat testing at 85 °C and 85% humidity.

### **Industry partners**

Our team will also work with other perovskite solar cell companies to learn the manufacturing and license our technology. Particularly, we will build our supply chain to satisfy our large scale manufacturing needs. Collaboration with leading industrial manufacturers would aid us in scaling-up manufacturing and developing a successful business model. We can utilize these partnerships to get access to high throughput coaters to scale up the production, high-purity raw materials, and consumables such as aluminum and silver paste, and screen printing materials, we can also tap into their installation partners for real-world data on performance benefits for shading, hot spot generation, and power production, and connection with high volume perovskite solar module manufacturers such as First Solar, SwiftSolar, CubicPV, Energy Materials Corporation and partnerships with fellow American Made companies would be a valuable asset to help accelerate the development. We will also reach ADL Ventures to develop our business model and commercialization pathways.