Photovoltaic Mini-Module Soiling Stations

Cooperative Research and Development Final Report

CRADA Number: CRD-22-23086

NREL Technical Contact: Michael Deceglie

NREL is a national laboratory of the U.S. Department of Energy
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Technical Report
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Cooperative Research and Development Final Report

Report Date: June 27, 2025

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Swift Coat, Inc.

CRADA Number: CRD-22-23086

CRADA Title: Photovoltaic Mini-Module Soiling Stations

Responsible Technical Contact at NREL:

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Name and Email Address of POC at Company:

Peter Firth | peter@swiftcoat.com

Sponsoring DOE Program Office(s):

Office of Energy Efficiency and Renewable Energy (EERE), Solar Energy Technologies Office

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources Government In-Kind
Year 1	$50,000.00
TOTALS	$50,000.00

Executive Summary of CRADA Work:

NREL will construct two soiling stations, each having three photovoltaic modules: one with bare glass, one with a commercial antireflective coating representative of the present state of the art, and one with Swift Coat's *PHOTOCLEAN PV* antireflective and anti-soiling coating.

CRADA benefit to DOE, Participant, and U.S. Taxpayer:

- Assists laboratory in achieving programmatic scope.
- Uses the laboratory's core competencies.

Summary of Research Results:

Photovoltaic (PV) panels can become soiled due to a variety of environmental factors. This soiling reduces the amount of light reaching the cells and thus their energy output. The ratio of actual output of the soiled device that of a clean device is known as the soiling ratio. The daily change in soiling ratio is known as the soiling rate. To study soiling for different glass coatings. Two soiling stations were fabricated. The stations were designed to monitor the short-circuit current of PV cells encapsulated with glass featuring different coatings and measure the daily soiling ratio with a pair of reference cells, one of which is automatically brushed daily. This work meets the need to understand how the glass coatings perform in additional environments.

The stations are designed to quantify both the soiling ratio (the ratio between actual/expected photovoltaic panel power output) as well as differences in anti-soiling performance of different glass coatings. The design of the dirty/clean reference cell system is described by Toth et al.[1] The soiling ratio is calculated by calculating the average irradiance measured within one hour of solar noon by each of the reference cells and then taking the ratio of these daily near-noon averages. The soiling ratio time series for the station deployed in Georgia is shown in Figure 1. This figure shows that the soiling ratio at the site has not yet fallen below 0.99, indicating that peak daily soiling losses have been below 1%. The site was chosen because it is thought to be affected by pollen soiling. With continued monitoring over the course of at least a full year, we expect to be able to observe and quantify pollen soiling events.

TASK 1: Mini module fabrication

NREL shall fabricate six mini photovoltaic modules, each containing four full-size Si cells. The cells shall be individually electrically addressable. The modules shall be suitable for outdoor deployment with weatherproof electrical connections. Swift Coat shall supply at least 12 pieces of 15-inch x 15-inch front glass for these modules (this includes at least one backup piece for each module to be fabricated). NREL shall supply cells, ribbons, encapsulants, back sheets, connectors, junction boxes, and wires.

The modules were fabricated as agreed upon and incorporated into the stations described in Task 2.

TASK 2: Station fabrication

NREL shall fabricate two photovoltaic soiling stations. Each station shall be powered by a standard 120V AC connection. Each station will contain:

- Ambient temperature and humidity measurement
- Cell temperature measurement for each of 12 cells
- Cell current measurement for each of 12 cells
- A reference cell left to soil naturally
- A reference cell automatically cleaned by a brush daily
- Capability to record data at one-minute intervals
- Capability for NREL to remotely retrieve data

NREL built two custom soiling measurement stations under this CRADA. The systems consist of the following components:

- Three custom mini modules with different glass coatings. Each module contains four cells, each having its own connectors for current monitoring
- Temperature measurement (t-type thermocouple) for each of the 12 cells
- A pair of reference cells. One of these is automatically cleaned by a brush every day. The ratio of irradiances measured with these two reference cells can be used to calculate the soiling ratio.
- Optical particulate matter sensor
- Ambient temperature and humidity measurement
- Measurement and communication electronics

The two fabricated stations are shown, prior to deployment, in Figure 1.

Figure 1: the two soiling stations built under this agreement

TASK 3: Station shipping

NREL will crate and ship each station to a location in the continental U.S. agreed upon by the parties.

One station was deployed in Georgia, USA, on March 28, 2024. The parties were unable to identify a site for the second station. While it was built under Task 2, it was not deployed.

TASK 4: Data Reporting

On request by Swift Coat, but not more than four times per month, NREL shall provide updated time series data collected from the stations.

Raw time series data was provided to Swift Coat as requested. Example of the soiling ratio calculated from the raw data is shown in Figure 2, with details summarized above.

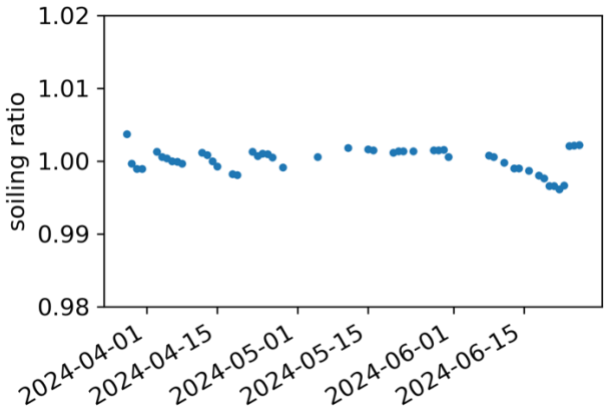

Figure 2: Soiling ratio measured with the station deployed in Georgia. Data is only shown for high-irradiance days on which the mean irradiance was above 800 W/m^2 for the time-period within an hour of solar noon.

TASK 5: Other Work

Other work mutually agreed upon by the parties, consistent with the scope and subject to the availability of funding.

No work was carried out under this task.

TASK 6: CRADA Final Report

This report serves to meet the requirement for the CRADA Final Report with preparation and submission in accordance with the agreement's Article X.

References:

Toth, S., Hannigan, M., Vance, M. & Deceglie, M. Enhanced Photovoltaic Soiling in An Urban Environment. in *2019 IEEE 46th Photovoltaic Specialists Conference (PVSC)* 2904–2907 (2019). doi:10.1109/PVSC40753.2019.8980735.

Subject Inventions Listing: None.

ROI#: None.