



Albedo Measurement of the Terra Pave White Albedo Product

Cooperative Research and Development Final Report

CRADA Number: CRD-20-16729

NREL Technical Contact: Bill Marion

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5K00-80863
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Cooperative Research and Development Final Report

Report Date: September 1, 2021

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: Ecological Estates LLC dba Eco Estates International (EEI)

CRADA Number: CRD-20-16729

CRADA Title: Albedo Measurement of the Terra Pave White Albedo Product

Responsible Technical Contact at Alliance/ National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s):

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

Joint Work Statement Funding Table showing DOE commitment:

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	\$35,000
Year 2, Modification #1	\$.00
Year 3, Modification #2	\$.00
Year 4, Modification #3	\$.00
TOTALS	\$35,000

Executive Summary of CRADA Work:

The Terra Pave team is creating an eco-friendly, cost-effective road coating that controls dust and dirt on high-traffic roads near solar field installations to reduce the dirt cover on panels, which lowers energy output. The Terra Pave White Albedo product also has the capability to increase the amount of solar radiation reflected from the ground to the backside of bifacial PV modules, thereby increasing the amount of electricity generated. This work will quantify the amount of solar radiation reflected from the Terra Pave White albedo product by measuring its albedo, which is the ratio of the reflected radiation to the incoming radiation. Albedo is measured with two horizontal pyranometers with one ground-facing and the other sky-facing.

Summary of Research Results:

NREL Tasks:

Task 1: *NREL will, pending NREL Site Operations approval:*

- a. Establish a 15' x 15' test plot for the albedo measurements.*
- b. Apply the Terra Pave White Albedo product to the ground surface of the test plot.*
- c. Install albedometers and associated data acquisition equipment for measuring albedo with a temporal resolution of one minute.*

We constructed the 15' x 15' test plot, and the Terra Pave White Albedo product was applied to the prepared ground surface, with the result shown in Figure 1. The amount of product available was not quite sufficient to cover the full dimensions of the test plot, but both parties agreed that the reduced area could be accommodated and not adversely affect the albedo measurements.



Fig. 1. Test plot and the Terra Pave White Albedo product.

For the albedo measurements, a 12' x 12' area of the albedo product was viewed by the albedometers. Normally, an albedometer has a 180° field-of-view of the ground. To view only the albedo product, we recessed the ground facing instruments in aluminum boxes such that the field-of-view was restricted. The experimental setup is shown in Figure 2. The instruments in the boxes measured the ground reflected irradiance (GRI) from the albedo product. They include both a thermal pyranometer and a crystalline silicon reference cell. A reference cell spectral response and a photovoltaic (PV) module spectral response are similar; consequently, its results may be more useful for applying to bifacial PV system predictions. The thermal pyranometer is typically used for albedo measurements.

The sky-facing global horizontal irradiance (GHI) measurements are located north of the test plot near the fence. The albedo is the GRI divided by the GHI. To account for the restricted field-of-view of the GRI measurement, the GRI was multiplied by a factor of 1.1955 for the pyranometer and by a factor of 1.2104 for the reference cell. These factors were determined experimentally and are essentially the same as the factor of 1.2034 determined analytically. A correction was also applied for the presence of shadows on the test plot. This correction was small, 2% or less.



Fig. 2. Albedometers located over the center of the test plot. Expanded view of the GRI instruments shown in upper right. GHI instruments shown in upper left.

Task 2: *NREL will measure the albedo of the Terra Pave White Albedo product and snow (when present) for 3 to 6 months.*

The albedo measurements were performed for a 3-month period, from November 21, 2020, through February 21, 2021. A time-lapse camera was used to identify times when snow was present. Daily albedo measurements are shown in Table 1 and Table 2 of Task 3.

Task 3: *NREL will provide a report summarizing the albedo of the Terra Pave White Albedo product and for different time scales (hourly, monthly, overall). The albedo will be compared to the albedo of the snow that occurred during the same period. If resources permit, the albedo will also be compared to other albedo measurements at NREL for native grass.*

The camera images were used to determine days when there was no snow on the test plot and the albedo measurements represented the albedo of the Terra Pave White Albedo product and days when the test plot was completely covered with snow and the albedo measurements represented the albedo of snow. When calculating the albedo using the reference cell GRI, the values were divided by the pyranometer GHI to show the spectral related effect. The daily albedos and averages are shown in Tables 1 and 2. The average albedo for the Terra Pave Albedo product was 0.474 and 0.494, respectively, when measured with a pyranometer and a reference cell. The comparative albedos for snow from Table 2 are 0.697 and 0.747.

Table 1. Daily Albedos of the Terra Pave Albedo Product

Month	Day	GHI (kWh/m ²)	Albedo	
			Pyranometer	Reference Cell
11	21	2.549	0.494	0.517
11	22	3.225	0.498	0.510
11	23	2.830	0.494	0.516
12	5	2.880	0.491	0.512
12	6	2.894	0.490	0.512
12	7	2.900	0.490	0.511
12	8	2.836	0.488	0.510
12	9	2.900	0.490	0.508
12	10	1.346	0.472	0.517
12	22	2.667	0.480	0.501
12	23	2.146	0.479	0.494
12	24	2.746	0.482	0.499
12	25	2.767	0.482	0.503
12	26	2.714	0.480	0.502
12	27	2.665	0.483	0.497
1	4	2.817	0.476	0.495
1	5	2.893	0.474	0.492
1	6	2.890	0.478	0.494
1	7	1.718	0.452	0.486
1	8	2.925	0.477	0.492
1	13	1.669	0.460	0.494
1	14	2.798	0.471	0.482
1	15	3.005	0.478	0.492
1	16	2.895	0.473	0.489
1	17	1.920	0.453	0.481
1	18	1.776	0.464	0.492
1	19	3.022	0.472	0.491
1	20	3.275	0.476	0.491
1	21	1.451	0.446	0.485
1	22	2.717	0.477	0.498
1	23	2.718	0.468	0.491
1	24	2.814	0.465	0.484
1	30	3.437	0.469	0.483
1	31	3.748	0.470	0.485
2	1	1.623	0.448	0.492
2	2	3.664	0.471	0.492
2	3	2.422	0.469	0.497
2	4	3.565	0.460	0.472
2	5	3.331	0.460	0.475
2	6	3.638	0.466	0.478
2	7	4.149	0.469	0.476
2	8	4.089	0.465	0.474
		Average	0.474	0.494

Table 2. Daily Albedos When Snow Covered the Test Plot

Month	Day	GHI (kWh/m ²)	Albedo	
			Pyranometer	Reference Cell
11	25	3.113	0.726	0.789
11	26	3.062	0.674	0.725
11	27	3.086	0.664	0.704
12	30	2.846	0.753	0.800
12	31	2.594	0.723	0.779
1	1	2.281	0.669	0.722
1	2	2.561	0.671	0.713
		Average	0.697	0.747

After the test period, we observed some evidence that the adhesion of the material to the ground surface decreased over time, perhaps from water intrusion from snow melt because the ground surface was not sufficiently compacted. NREL lacks road-building type equipment; consequently, hand operated equipment was used for compaction purposes. We also experienced subzero temperatures during the test period. Evaluating the durability of the material was not within the scope of the work and no issues were identified that impacted the albedo measurements.

For comparison with the albedo of other ground surfaces, NREL has recently established a data base of albedo values which can be accessed at <https://datahub.duramat.org/project/about/albedo-study>. For the 25 stations in the data base that are not subject to snow and for which the ground surface is vegetation, the median albedo is 0.21 and 80% of the stations are within ± 0.02 . The albedo of the Terra Pave White Albedo product is more than twice that of the albedo of these surfaces with vegetation. For comparison with other white surfaces, the data base includes an albedo of 0.533 for white-painted concrete and an albedo of 0.568 for a white tarp.

Participant tasks:

Task 1: *The Participant will participate in a monthly check in with the NREL Principal Investigator. If a check-in meeting is missed two months in a row, the agreement may be cancelled by the American-Made Challenges Solar Prize team.*

The participant willingly participated in all monthly check ins and other meetings requested by the NREL Principal Investigator.

Task 2: *The Participant will prepare and provide the Participant’s product to be tested at the NREL site.*

The product was prepared and received by NREL and is shown in Figure 1 as installed on the test plot.

Task 3: *The Participant will provide product specifications to NREL as needed to facilitate compliance with NREL/DOE environmental requirements.*

Product specifications were provided to NREL site operations which facilitated the approval of the test plot construction.

Task 4: *The Participant will provide instructions and consultation for the application of the Participants product to a 15' x 15' ground plot at NREL*

Instructions and consultations were provided to NREL for the application of the Terra Pave White Albedo product on the test plot. This was very useful for the completion of the installation.

Subject Inventions Listing:

None

ROI #:

None