



Solar Performance and Financial Modeling

Cooperative Research and Development Final Report

CRADA Number: CRD-23-23746

NREL Technical Contact: Brian Mirletz

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-7A40-92254
November 2024



Solar Performance and Financial Modeling

Cooperative Research and Development Final Report

CRADA Number: CRD-23-23746

NREL Technical Contact: Brian Mirletz

Suggested Citation

Mirletz, Brian. 2024. Solar Performance and Financial Modeling: *Cooperative Research and Development Final Report*, CRADA Number CRD-23-23746. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-92254. <https://www.nrel.gov/docs/fy25osti/92254.pdf>.

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-7A40-92254
November 2024

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NOTICE

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government.

This work was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, its contractors or subcontractors.

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via www.OSTI.gov.

Cover Photos by Dennis Schroeder: (clockwise, left to right) NREL 51934, NREL 45897, NREL 42160, NREL 45891, NREL 48097, NREL 46526.

NREL prints on paper that contains recycled content.

Cooperative Research and Development Final Report

Report Date: November 18, 2024

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: Solesca Energy, Inc.

CRADA Number: CRD-23-23746

CRADA Title: Solar Performance and Financial Modeling

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

Brian Mirletz | brian.mirletz@nrel.gov (PI)

Janine Keith (Co-author) | Janine.keith@nrel.gov

Matthew Prilliman (Co-author) | Matthew.Prilliman@nrel.gov

Paul Gilman (Co-author) | Paul.Gilman@nrel.gov

Steven Janzou (Co-author) | Steven.Janzou@nrel.gov

Name and Email Address of POC at Company:

Brendan Devine | bdevine@solesca.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 a/k/a Government In-Kind
Year 1	\$75000.00
TOTALS	\$75000.00

Executive Summary of CRADA Work:

Solesca is working to enhance the energy and financial modeling components of their real-time solar project design platform. In collaboration with NREL, they aim to improve the accuracy and reliability of their software by integrating best practices and knowledge from NREL.

CRADA benefit to DOE, Participant, and US Taxpayer:

- Uses the laboratory's core competencies, and/or
- Enhances U.S. competitiveness by utilizing DOE developed intellectual property and/or capabilities.

Summary of Research Results:

NREL will assist Solesca with implementing solar performance and financial modeling best practices through documentation, software integration, software tests, and code review.

Task 1: Documentation of solar modeling best practices.

a) Solesca to review Photovoltaics Performance Modelling Collaborative (PVPMC) guidelines and develop a list of terms that need definitions.

b) NREL to provide a report with definitions of these terms.

c) The report will include links to open source implemented versions of PVPMC guidelines in SAM Simulation Core (SSC).

Task 1 established a shared baseline of PV performance modeling terminology. NREL recommended resources including the PV Performance Modeling Collaborative guidelines (Sandia, 2023) and the SAM technical reference manual (Gilman et al, 2018). The Solesca team reviewed these and asked 28 questions on modeling best practices. The NREL team reviewed the questions and provided answers on topics including but not limited to transposition models, soiling, temperature coefficients. These conversations and definitions contributed to decision making in other tasks, especially task 3, and are shown in Figure 1.

account a 3-view of view.

ii. Extraterrestrial radiation doesn't seem particularly relevant to models themselves

iii. Air mass: When the sun is directly overhead (zenith angle = 0), air mass is 1, and increases as the sun approaches the horizon. Near the horizon, air mass models complicate.

iv. Direct normal irradiance (DNI): Most accurately measured with absolute cavity radiometer, but those aren't suited for outdoor use, so usually measured with pyrheliometers. If direct measurements aren't available, DNI can be calculated based on diffuse and total radiation, so long as the incident angle between the collection plane and sun is known. Decomposition models exist (as do other models, e.g. DIRINT) to

B Brendan Devine
Jun 5, 2023

Is this a fair take?

Janine Keith
Jun 9, 2023

I'd agree. Extraterrestrial radiation is more important for folks who are actually creating the modeled weather data. PV modeling generally starts downstream of this.

B Brendan Devine
Jun 5, 2023

Any suggestion on which air mass model is best to use? Looks like PVPVC specify seven models.

Figure 1: The collaborative document discussing solar modeling best practices.

Task 2: Software test suite for Solesca's model

The focus of task 2 changed somewhat during the agreement during the integration of the SAM code directly into Solesca's platform (see task 3). Since the SAM energy models are already supported by extensive tests, the main focus for tests developed under this agreement shifted to ensuring the correct implementation of the SAM interface in rust and a proper mapping of Solesca's inputs to SAM's inputs. To this end, the NREL team developed JSON files based on inputs to SAM that Solesca's software typically utilizes, and outputs including annual energy based on running those inputs in SAM. The Solesca software implementation successfully produced the same outputs, as expected, since the underlying energy model is the same. The Solesca team integrated these tests into their continuous integration platform, meaning the tests will automatically re-run as Solesca's code changes and is deployed. A local version of the tests is shown in the screenshot in Figure 2.

```

> cargo test ssc_tests
  Compiling pure_rust v0.1.0 (/Users/brendan/SolescaLocal/git/app/backend/src/pure_rust)
  Finished test [unoptimized + debuginfo] target(s) in 6.80s
  Running unittests src/lib.rs (target/debug/deps/pure_rust-3d860863532091e8)

running 7 tests
test energy::pvsamv1::ssc_tests::check_scc_version ... ok
test energy::pvsamv1::ssc_tests::test_single_axis_tracking ... ok
test energy::pvsamv1::ssc_tests::test_flush_mount_racking ... ok
test energy::pvsamv1::ssc_tests::test_dual_axis_tracking ... ok
test energy::pvsamv1::ssc_tests::test_carport_racking ... ok
test energy::pvsamv1::ssc_tests::test_east_west_racking ... ok
test energy::pvsamv1::ssc_tests::test_fixed_tilt_racking ... ok

test result: ok. 7 passed; 0 failed; 0 ignored; 0 measured; 16 filtered out; finished in 0.55s

  Running unittests src/main.rs (target/debug/deps/pure_rust-09e43e6b6b20f551)

running 0 tests

test result: ok. 0 passed; 0 failed; 0 ignored; 0 measured; 0 filtered out; finished in 0.00s

  Running tests/mod.rs (target/debug/deps/mod-9f44d4a37aaf7272)

running 0 tests

test result: ok. 0 passed; 0 failed; 0 ignored; 0 measured; 18 filtered out; finished in 0.00s

```

Figure 2: Test results of the Solesca-SAM integration, run on a local device.

Task 3: Code review and recommended improvements

NREL conducted a code review of Solesca’s original modeling code in June 2023, and upon discussing their findings both parties agreed that best path forward to improve the model was to directly integrate SAM’s pvsamv1 detailed PV performance model, as this would be the fastest way to integrate best practices and additional features in SAM’s models.

The first issue to overcome with integrating SAM into Solesca’s software was language compatibility. SAM is written in C++, whereas Solesca’s backend software is written in Rust. The Solesca team was able to integrate the SAM C++ shared libraries into their Rust software via Node.js libraries and a JSON integration with the SAM model specification, allowing access to all modeling features in the latest version of SAM. Results of this integration are shown in Figure 3.

The NREL team also advised on software mappings from Solesca’s GUI to the pvsamv1 model, including the California Energy Commission (CEC) module and inverter models. Ultimately the integration allows Solesca’s software to import data from the CEC into their software and run the underlying models in SAM.

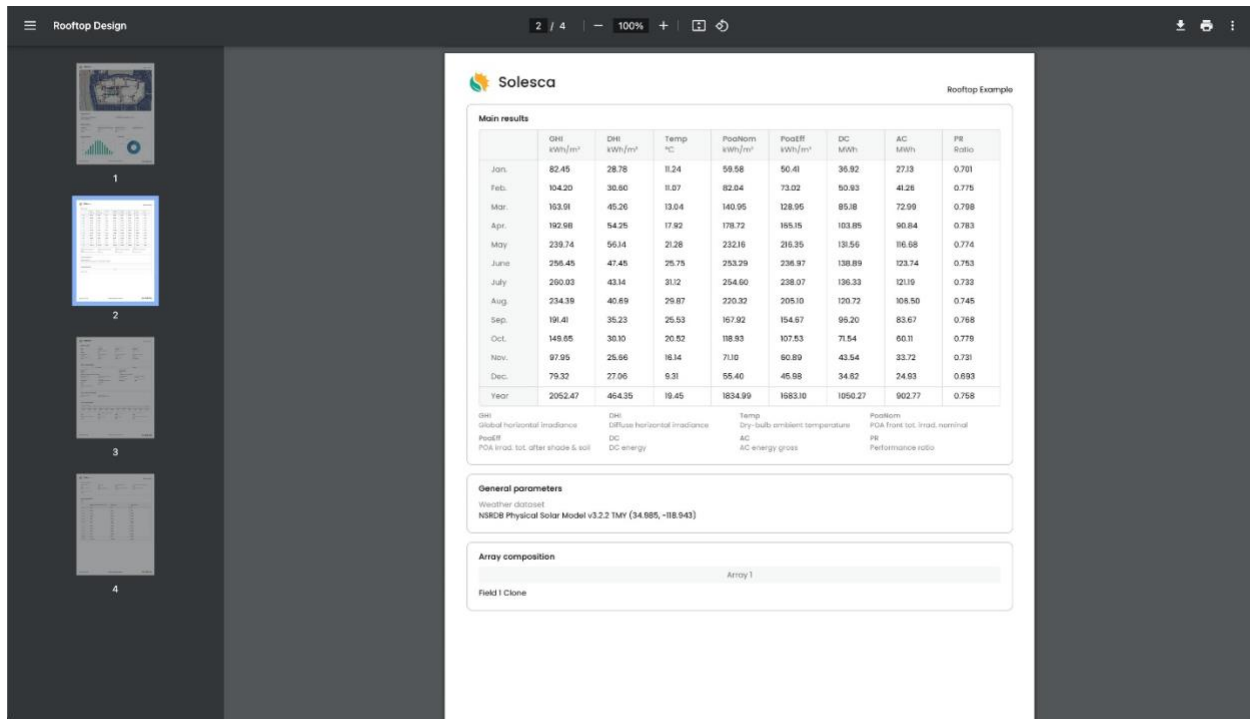


Figure 3: SAM energy modeling results displayed in Solesca's GUI

Task 4: 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 4.

Task 5: Additional Tasks

The earliest additional task in the project was the Solesca team assisting the NREL team with getting the Solesca platform running locally on the NREL team's laptops. This provided the Solesca team with feedback on how to improve building instructions and troubleshooting on additional platforms.

The NREL team assisted Solesca with integrating external shading into their platform. SAM performs external shading using the Binary Space Partitioning Trees algorithm (Naylor 1998). Given how the SAM code is partitioned, the Solesca team had to implement this algorithm directly in their GUI. Tests of this algorithm are shown in Figure 4. They were then able to utilize the outputs from the algorithm to provide inputs to SAM's shading models, and compute shading from trees, buildings, and equipment on the simulated arrays. Solesca's GUI implementation is shown in Figure 5.


```

1 use crafter: {
2   shading: {
3     sam_test_data: test_helpers: { create_scene_from_objects, CreateBoxData,
4     CreateActiveSurfaceData,
5   },
6   shared_types: DataCoordPair,
7 };
8 use lazy_static: lazy_static;
9 use nalgebra: Point3;
10 use super: SamTestData;
11
12 lazy_static! {
13   pub static ref TEST_DATA: SamTestData = SamTestData {
14     scene: create_scene_from_objects(vec! [
15       SceneObject::Box(CreateBoxData {
16         origin: Point3::new(0.0, 0.0, 0.0),
17         side_length: 15.0
18       }),
19       SceneObject::ActiveSurface(CreateActiveSurfaceData {
20         origin: Point3::new(0.0, 30.0, 0.0),
21         width: 25.0,
22         length: 18.0,
23         tilt_deg: 30.0,
24         azimuth_deg: 180.0
25       }),
26     ]),
27   },
28   diurnal_analysis_csv_path: "scene_1/scene_1_diurnal_analysis.csv".to_st
29   coord: DataCoordPair {
30     lat: 41.8781,
31     lng: -87.6298
32   },
33   diffuse_shading_percent: 4.06,
34   t2_offset_hours: -6.0,
35   comp_start_hour: 6,
36   comp_end_hour: 17
37 };
38 }

```

Figure 4: Unit tests of Solesca's shading model.

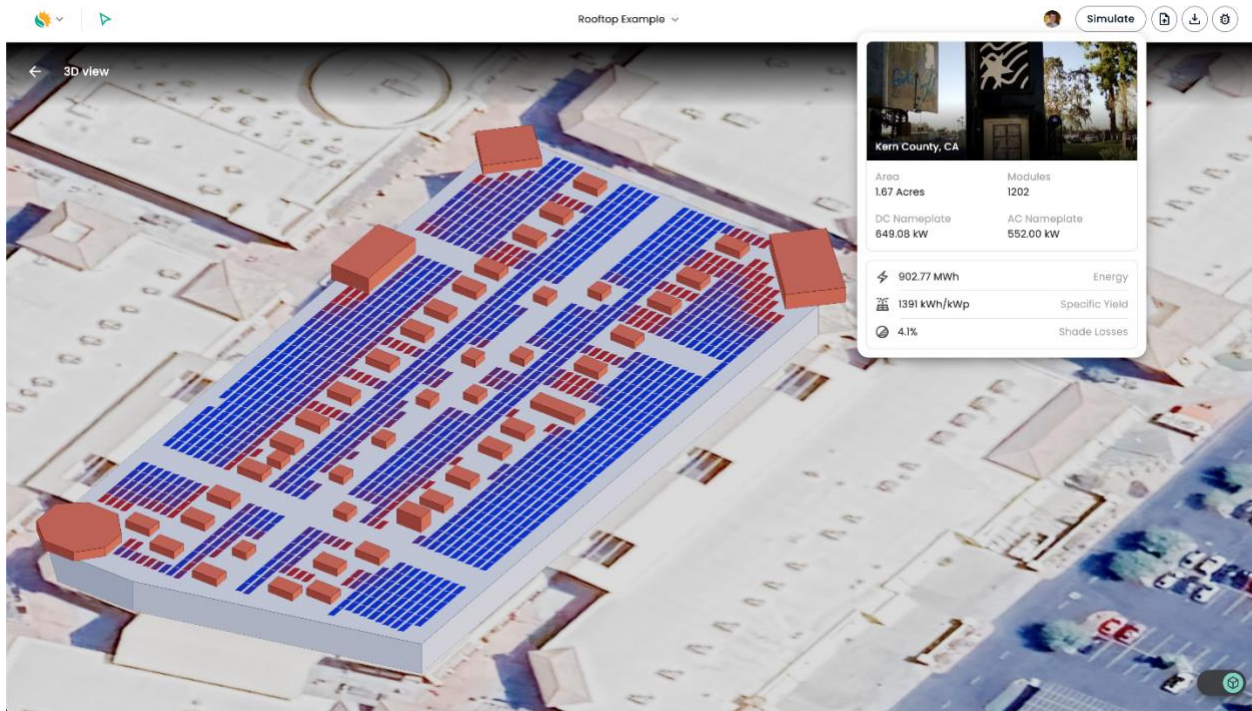


Figure 5: Solesca's GUI for creating shading data.

The NREL team advised Solesca on the integration of solar resource data from the National Solar Radiation Database and Solar Anywhere platforms, including how to calculate probability of exceedance values based on multiple years of weather data.

Finally, the NREL team assisted with interpreting one of Solesca's users' comparisons between Solesca's output and PVSyst, and helped identify the sources of discrepancies.

Summary Conclusion:

NREL assisted Solesca in improving their solar modeling platform by providing documentation, code review, code integration assistance, and unit tests.

References:

Sandia National Laboratories. (2023, June 9th) PV Performance Modeling Collaborative Modeling Guide <https://pvpmc.sandia.gov/modeling-guide/>

Gilman, Paul, DiOrio, Nicholas A., Freeman, Janine M., Janzou, Steven, Dobos, Aron, and Ryberg, David. 2018. "SAM Photovoltaic Model Technical Reference 2016 Update". United States. <https://doi.org/10.2172/1429291>. <https://www.osti.gov/servlets/purl/1429291>

Naylor, Bruce F. "A tutorial on binary space partitioning trees." ACM SIGGRAPH, 1998.

Software Record (SWR):

Technology from NREL SWR-16-02, was successfully transferred to Solesca's collaborative solar design software <https://www.solesca.com/>

Subject Inventions Listing:

None.

ROI #:

None.