



# **Steps Toward Bankability: Module and Systems Validation**

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Differentiating Quality PV  
Standards & Methodology for Underwriting Certainty  
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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,  
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# Efforts to Develop Validation Standards

## Project Validation

**Demonstrate  
Performance of Product:  
“It Works”**



**Manufacturing Quality  
Control:  
“We can make it  
reproducibly”**



**Demonstrate long-term  
Field Performance:  
“It lasts”**



**Project-Specific  
Prediction**



## National Lab-Supported Efforts

**QA Task Force – Task Group 1**

**QA Task Force – Task Groups 2-6**

**RTCs, Performance, Reliability, GI**

**RTCs, Performance, Reliability, GI**



# What are the labs' projects?

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- Materials R&D (module materials, inverter components) - *Yield*
- Module testing for performance (Sandia coefficients, .PAN files) and reliability (degradation rates, accelerated testing) – *Yield, Degradation*
- Inverters and BOS testing for performance, ancillary services, reliability testing for components and inverters – *Yield, Degradation, BOS, Standards*
- Systems testing – *Performance Analytics, BOS, Predictions, O&M*
  - Small systems
  - Regional Test Centers
  - Large systems to understand performance
  - O&M data collection in the field
- Modeling – *Performance Analytics, Predictions, O&M*
  - Module performance
  - Array performance
  - Reliability and availability
  - O&M predictions
  - PV-RPM: PV Reliability and Performance Model
- Grid Integration: Impacts of high penetration on the grid



# What are the RTCs?

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## Background:

- As part of the SunShot initiative, DOE held the PV Manufacturing Workshop in March 2011.
- Banks and insurance companies: DOE and the national laboratories take the lead role in defining validation criteria for PV components (e.g., modules, inverters, etc.).
- Stakeholders: validation efforts should be focused on larger-scale testing representative of systems being installed (MW rather than kW scale) and should occur across a variety of regions that encompass different climatic forces that lead to reliability and degradation processes.
- Product validation should consist of testing a statistically significant selection of modules tested both outdoors and in the laboratory for performance and reliability.
- In response, DOE initiated development of three Regional Test Centers (RTCs)



# What are the RTCs?

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## RTC's will:

- Supplement SunShot programs to help advance the DOE's production goals and build stakeholder confidence in new and existing PV technologies and projects.
- Accelerate maturation of the U.S. PV industry into a reliable and robust energy production sector that will encourage greater private investment.
- The RTCs will be utilized to validate the performance of PV systems, verify and validate models used to predict performance, collect detailed operations and maintenance (O&M) data, and investigate the role of various environmental (climatic) factors on reliability, durability, and safety of PV technologies.
- System sizes: 30 kW – 300 kW per system in each location
- Total capacity: ~1 MW in each location



# Vision for Regional Test Centers

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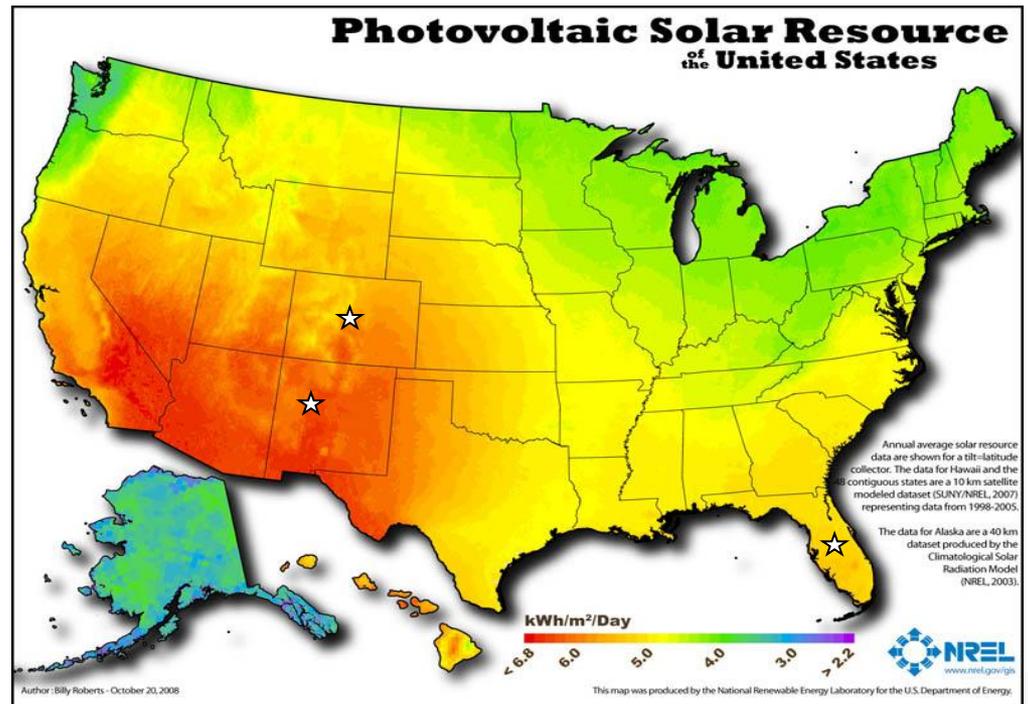
The Regional Test Centers will serve a number of purposes:

1. Develop testing, monitoring, and analysis protocols for validating the performance and initial reliability of PV modules and systems.
2. Develop the protocols for comparing the performance output and performance model results for the same system design across different climate regions.
3. Work with the PV community including the component manufacturers, integrators, independent engineers, finance companies and insurance companies to develop a standard technical bankability verification process.
4. Implement the protocols on a select number of PV systems at the RTC locations for further protocol and bankability report development.
5. Share the protocols with industry and create as guidelines or standards in the IEC, IEEE, or ASTM standards committees. This could be a part of actively managing the technical aspects of bankability.

# Where are the RTCs?

## RTC Locations chosen to leverage existing expertise:

- Denver, CO at the SolarTAC facility, managed by NREL (Steppe climate)
  - Albuquerque, NM at the National Solar Thermal Test Facility managed by Sandia (hot-dry climate)
  - Orlando, FL at the University of Central Florida managed by FSEC (hot-humid climate)
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- The concept for these RTCs is that they will host identical PV installations at each of the three sites.
  - System sizes: 30 kW – 300 kW per system in each location
  - Total capacity: ~1 MW in each location





# RTC Status: Progress

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- We are on track to be ready to accept modules and/or systems to test in May 2012 to provide increased certainty and reduced risk for bankability and to develop standards for validation and optimized monitoring.
- Our focus is validation and on developing a transparent process for the finance community
- We are laying the groundwork to be ready to move forward once we know the partners/technologies



# Motivation for PV-RPM

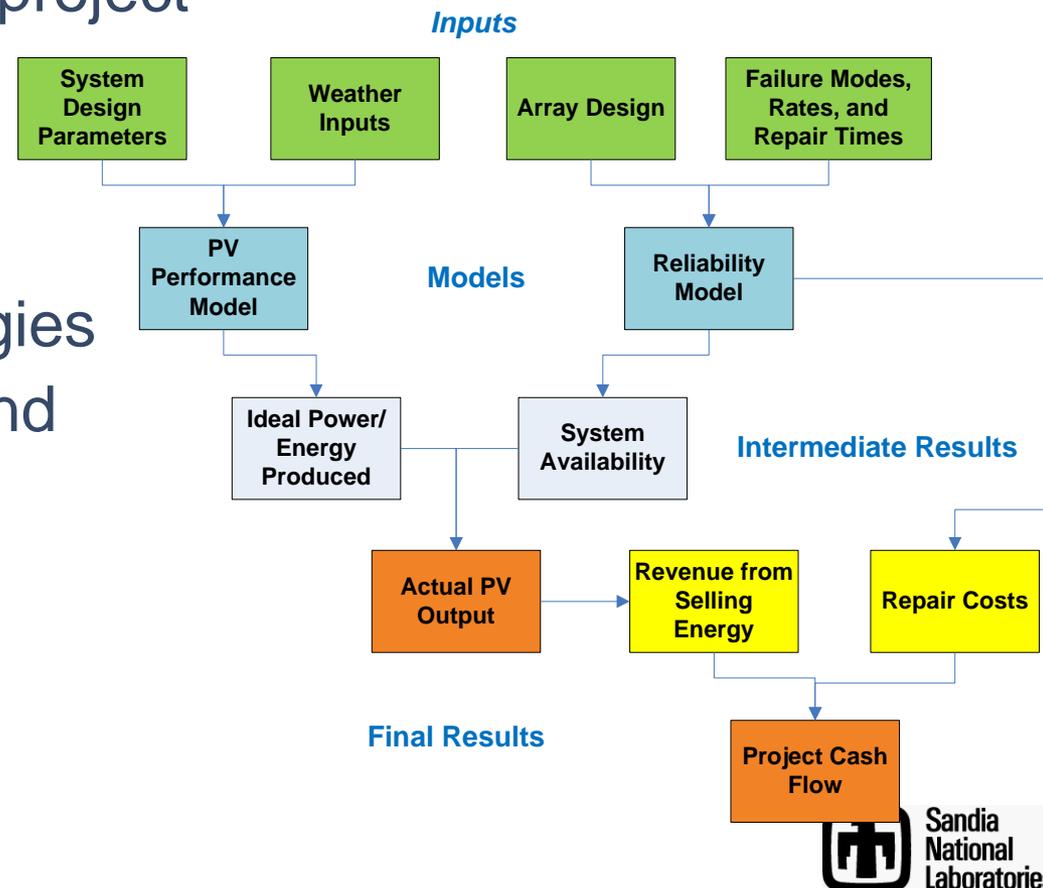
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- **Accurately predicting long-term performance is challenging but necessary to assess financial viability and risk**
- **PV plants are complex interconnected systems with thousands of components**
- **Important factors for modeling PV systems include:**
  - Location, technologies, and system design
  - Weather and solar resource variation
  - Degradation and component reliability
  - Operations and maintenance strategies

# PV Reliability and Performance Model

Sandia is developing a tool (PV-RPM) to assess decisions about PV plant design and operations

- Model output: Energy and project cash flow over time
- PV-RPM can be used to:
  - make design decisions
  - choose operating strategies
  - evaluate uncertainties and sensitivities





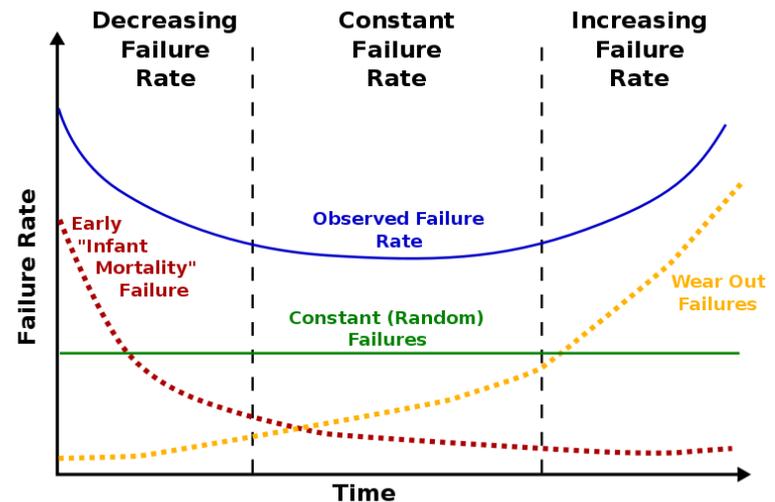
# PV-RPM Features

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- Rich analytical and visualization tool to simulate detailed PV plant operational scenarios
- All parameters can be represented as constants or stochastics (probability distributions)
- Weather Inputs
  - ✓ Typical Meteorological Year (TMY) or measured data
- PV Performance Model (King 2004)
  - ✓ Module technologies, tracking systems

# PV-RPM Features

- Reliability Model
  - ✓ Multiple failure modes
  - ✓ Variable failure rates (“bathtub curve”)
  - ✓ Variable repair times
- Simple Financial Model
  - ✓ Simulate cash flows (see pay O&M)



# PV-RPM Dashboards

## Model Settings Dashboard

GoldSim Player - PV-RPM Web Demo.gsp

### Model Settings Dashboard

**DRAFT**

*To run a new simulation, delete the old results by pressing the "Reset" button on the Run Controller and click the "Yes" button. Then set the desired model input and simulation settings given below.*

#### Model Inputs

**Location and Weather**

TMY2 Weather Data: KS, GOODLAND

Instructions: Inputting User/Weather Data | Input User Supplied Weather Data | Elevation: 0 ft

**Irradiance and Radiation Options**

Total & Beam: Perez | 1990 Data Set

Ground Reflectivity: 0.2

**PV System Setup**

Select Module: Schott Solar ASE-300-DGF/50 (300) [1999 (E)]

Select Inverter: Yeast Solar Inc.: E55300 (240V) 240V [CEC 2009]

Use single-point efficiency inverter | Efficiency: 94 %

**Define the Array**

Array Layout	
How Many Modules/String	8
How Many Strings	6
Module Sizing Factor	1
How Many Inverters	3

**Tracking and Orientation**

Select Tracking Options: Fixed | Array Tilt: 0 deg

Use Latitude Tilt

#### Simulation Settings

To set the simulation settings (button below). Under the 'Time' tab set the desired simulation duration. The time step length should ideally be set such that it equals 1 hour to match the hourly TMY2 weather data. For example, for a 30 year model simulation, set "Time Display Units" to yr, set "Duration" = 30 yr, and set "#Steps" in the "Time Phase Settings" box to 262980 (30 yr \* 365.25 days/yr \* 24 hr/day = 262980 hr).

Under the 'Monte Carlo' tab, set the number of realizations to the desired number of simulations (each realization is a possible future of the modeled system).

[Simulation Settings](#)

#### System Setup Summary

String Voc	506.4 V	Total Inverter Input Capacity	16.7135 kW (DC)
System Capacity (Modules)	14.443 kW (DC)	Total Inverter Output Capacity	15.9 kW (AC)

Modules		Inverters	
Module Output	300.9 W (DC)	Paco	5.3 kW (AC)
Vmpo	51 V	Pdco	5.57118 kW (DC)
Impo	5.9 amp	Pso	28.519 W (DC)
Voco	63.3 V	Vdco	274.9 V
Isc0	6.5 amp	Coefficient 0	-6.0281e-6 1/V
		Coefficient 1	1.92016e-5 1/V
		Coefficient 2	0.00162999 1/V
		Coefficient 3	-0.000371343 1/V

**Module Structure and Mounting**

a	-3.47	b	-0.0594	d1	3
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Note: The above inverter parameters will be zero if the single-point efficiency option is chosen.

After setting up the model settings and simulation settings above, proceed to the [Failure Modes Dashboard](#).

[Failure Modes Dashboard](#) | [Introduction Dashboard](#) | [Results Dashboard](#)

Acknowledgement and Disclaimer

Sandia National Laboratories

# PV-RPM Dashboards

Model Settings  
Dashboard

Failure Modes  
Dashboard

The image displays two overlapping software windows from GoldSim Player. The background window is the 'Model Settings Dashboard' (DRAFT), which includes sections for 'Model Inputs' (Location and Weather, Irradiance and Radiation Options) and 'Simulation Settings'. The foreground window is the 'Failure Modes Dashboard' (DRAFT), which is divided into four main sections: 'Module Inputs', 'Inverter Inputs', 'Module Repair Times', and 'Inverter Repair Times'. Each section contains specific input fields and instructions for configuring failure rates, degradation rates, and repair times. A 'Results Dashboard' button is visible at the bottom right of the Failure Modes Dashboard, with a note: 'If the Model Settings and the Failure Modes Dashboards settings have been completed, proceed to the Results Dashboard to run the simulation.' The Sandia National Laboratories logo is present in the bottom left of both windows.

# PV-RPM Dashboards

Model Settings  
Dashboard

Failure Modes  
Dashboard

Results  
Dashboard

GoldSim Player - PV-RPM Web Demo.gsp

## Model Settings Dashboard

**DRAFT**

To run a new simulation, delete the old results by pressing the "Reset" button on the Run Controller and click the "Yes" button. Then set the desired model input and simulation settings given below.

### Model Inputs

**Location and Weather**

TMY2 Weather Data: KS, GOODLAND

**Irradiance and Radiation Options**

Total & Beam: Perez

Ground Reflectivity: 0.2

Select Module: Schott Solar ASE-300-DGF/S

Select Inverter: Yeal Solar Inc.: E55300 (240)

Use single point efficiency:

Select Tracking Options: Fixed

Use Latitude Tilt:

### Simulation Settings

To set the simulation settings (button below). Under the 'Time' tab set the desired simulation duration. The time step length should ideally be set such that it equals 1 hour to match the hourly TMY2 weather data. For example, for a 30 year model simulation, set "Time Display Units" to yr, set "Duration" = 30 yr, and set "#Steps" in the "Time Phase"

GoldSim Player - PV-RPM Web Demo.gsp

## Failure Modes Dashboard

**DRAFT**

### Module Inputs

#### Module Failure Rates

Use the bathtub curve:

Poisson Failure Rate: 0.1 yr<sup>-1</sup> Mean failure rate (1/MTTF)

Define the Bathtub Curve

25% Modules that are affected early failure defect.

0.5 yr<sup>-1</sup> Mean failure rate of modules experience early failure.

25 yr Module mean lifetime.

4 yr Standard deviation of mean lifetime.

#### Module Repair Time

These values define the mean and std for the time to discover that a module complete the repair or replacement of a module. (A lognormal distribution is instance to define the repair time dist)

mean: 90 days std. dev.

Do not repair/replace wear-out failure:

### Module Degradation Rates

### Inverter Inputs

#### Inverter Failure Rates

Inverter failures will be treated in this example model as

GoldSim Player - PV-RPM Web Demo.gsp

## Results Dashboard

**DRAFT**

### Instantaneous Values for the Current Realization

	Ideal System	Includes component failures and module degradation
Cumulative Pmp:	8.349e+5 kWh	6.392e5 kWh
Cumulative Pac:	7.954e+5 kWh	6.084e5 kWh

Peak Vmp: 475.6 V (String voltage should not exceed 600 V for non-utility applications.)

Module Degradation Rate: 1.72%

Inverter Failure Rate: 0.91 yr<sup>-1</sup>

PV System Availability

0.539

Operational Availability - Inverters

0.955

Operational Availability - Modules

0.983

Module Output Degradation

0.6

Inverter Efficiency

0.953

System Performance Factor

0.688

Fraction of Energy Lost (DC)

0.234

### Time History Plots

Operational Availability of the Modules

System Availability Summary

Number of Operable Modules

Sampled Module Degradation Rates

Operational Availability of the Inverters

Total DC Energy Produced

Module Output Degradation

Sampled Inverter Failure Rates

Electrical Grid Availability

Ideal System versus System with Failures

Total Component Failures

Run Model

GoldSim Run Controller

REALIZATION: 1

TIME STEP: 2.5822e+2 steps

30 yr

STATUS: Run



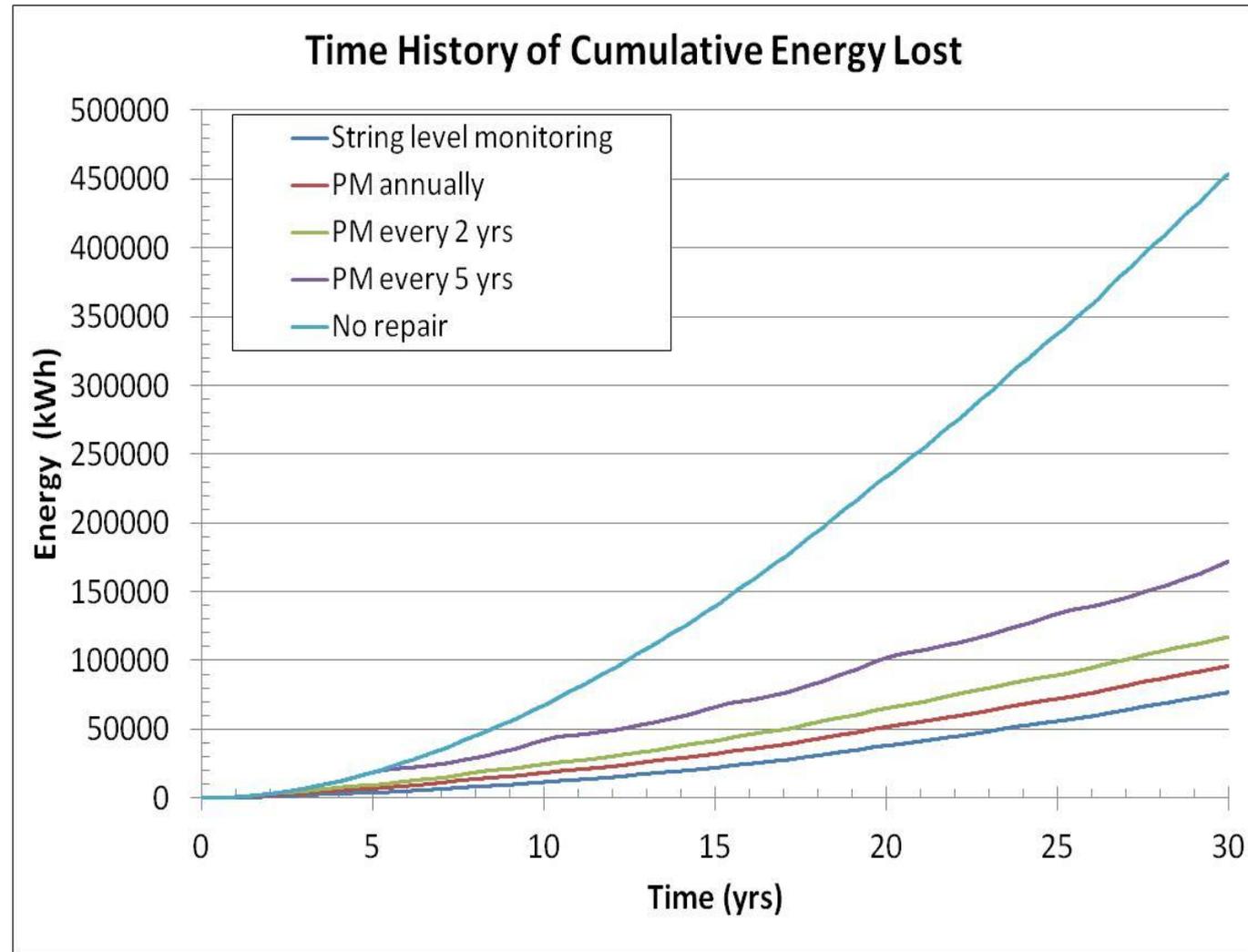
Acknowledgement and Disclaimer

Run Model

# Case Study: Which O&M Approach?

The energy lost due to failures can add up over the life of the system

There is a tradeoff between performance and cost of O&M





# PV-RPM Progress

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- Working with multiple integrators, utilities and O&M providers to input O&M events
- Currently:
  - ViaSol inputting O&M events for 3, ~MW scale systems
  - Denver Federal Center 8 MW plant is next to “go live” with O&M data
  - Partnering with EPRI to reach out to utilities



**THANK YOU**