Modern PV Plant Capacity (Performance) Testing from an EPC's Perspective

Or: How I Learned to Stop Worrying and Love PVsyst

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Presentation Outline

- Performance Testing
- Performance Testing Challenges
- Short Term Energy Testing
- Summary

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Black & Veatch: Trusted Solar IE/OE and EPC Partner

4.3 GW
Engineering, Procurement, & Construction (EPC)

19.5 GW
Owner's Engineer & Technical Consulting Services

3.5 GW
Detailed Design

14 GW
Independent Engineer

9.5 GW
Studies / Permitting / Other

50+ GW GLOBAL SOLAR PROJECT SUPPORT

9th Largest 100% Employee-Owned Company, Globally. Founded in 1915.

BLACK & VEATCH

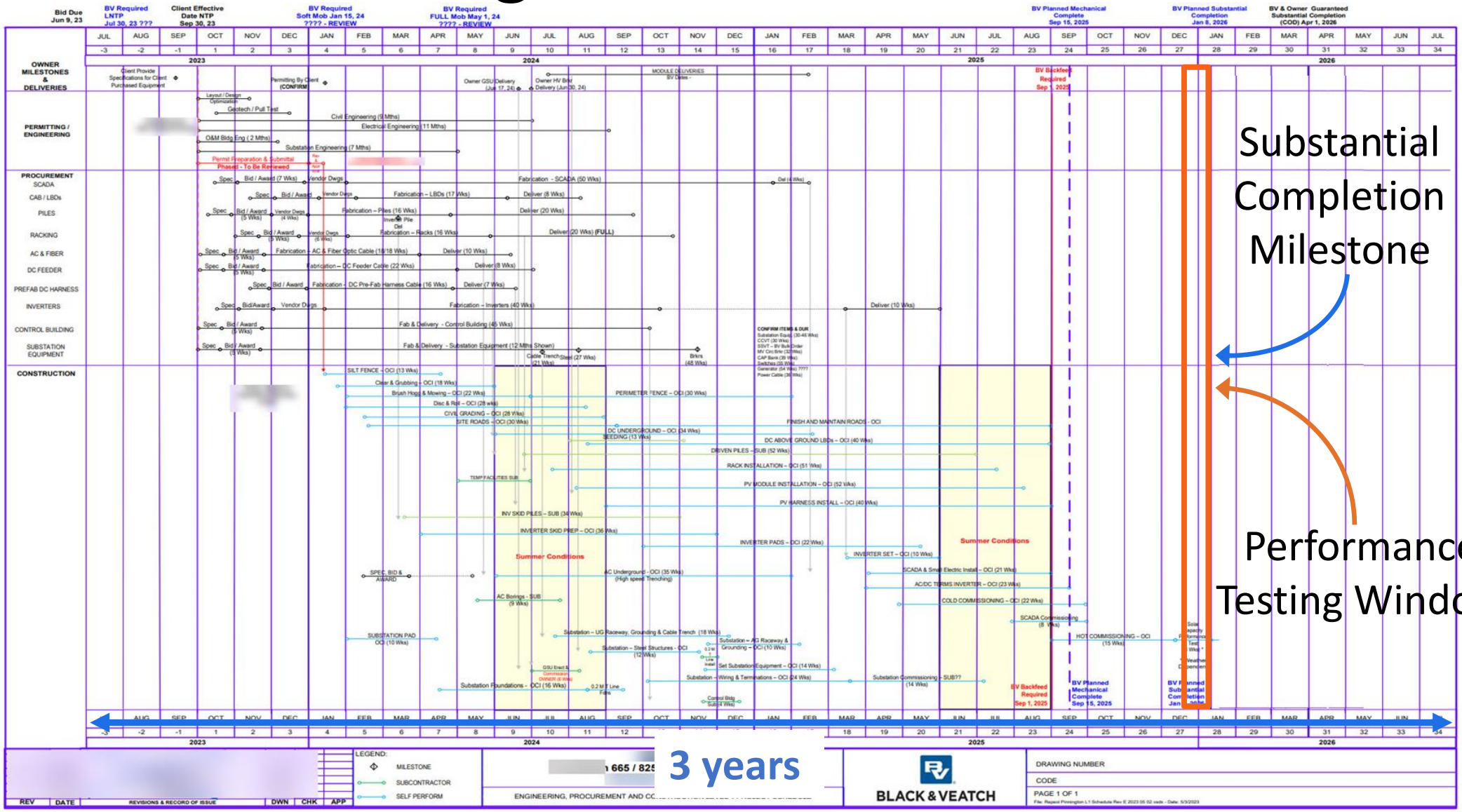
Performance Testing - Why

- Performance testing is used to validate initial performance of PV plants needed for:
  - EPC contractual obligations and milestones
  - Owner/operator performance/revenue expectations
  - De-risking acquisitions for buyers and financing for lenders and tax equity partners
- Failed performance tests or delays in testing progress can trigger performance or schedule liquidated damages (LDs) or “make right” contract clauses
- Can be high-risk scenarios for EPCs

Performance Testing provides an opportunity to benchmark a PV plant’s optimum performance level

Performance Testing - When

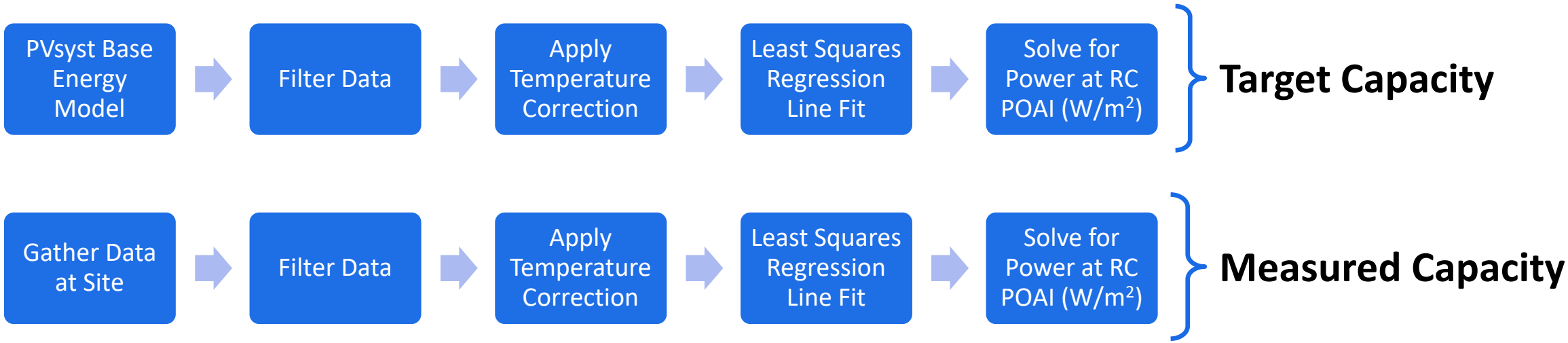
Example L-1 solar EPC schedule



The last major task in the long solar EPC project

Performance Testing - Methods

ASTM 2848/2939-Based Capacity Testing

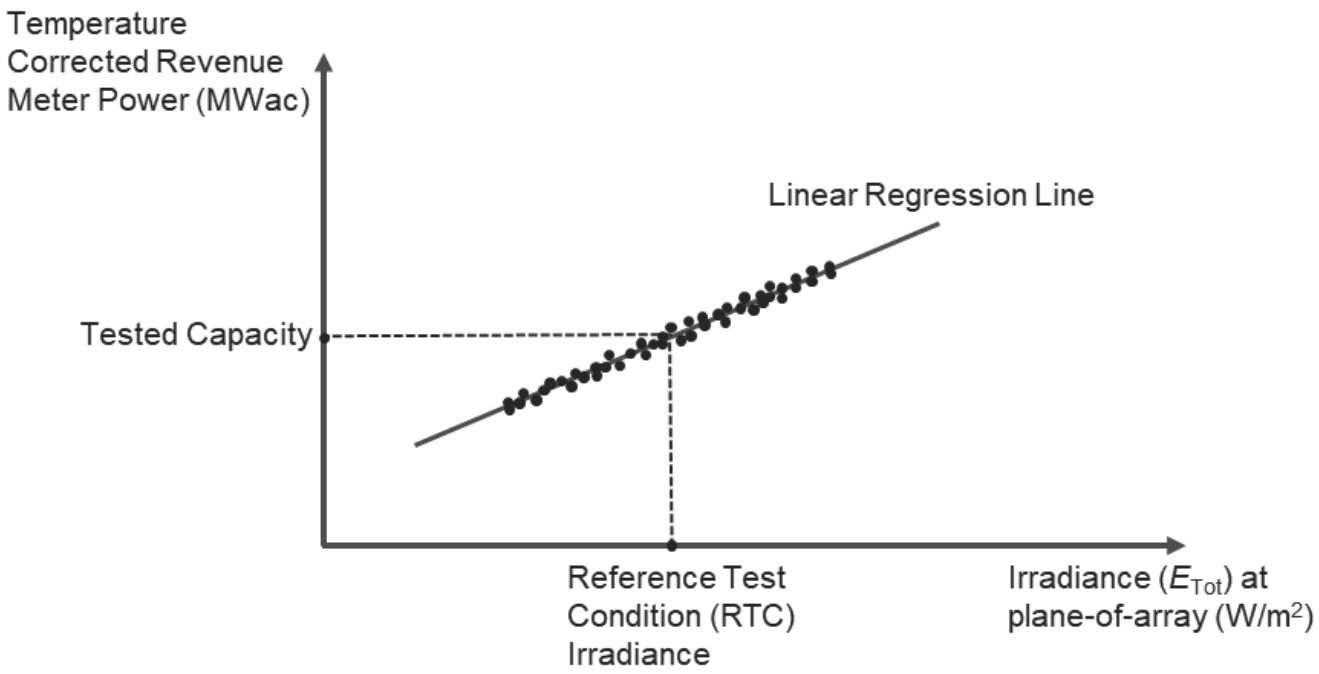


Measured Capacity Ratio (MCR) = MC/TC > 97% (Guaranteed Capacity)

ASTM 2848/2939 Capacity Testing is the dominant performance testing method employed in the US

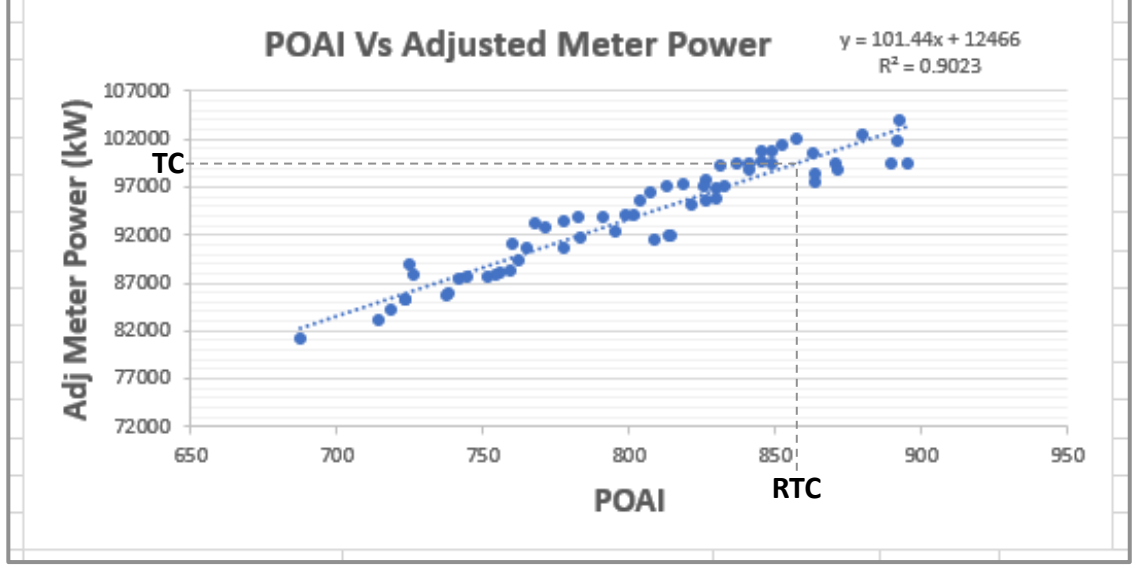
Performance Testing - Methods

ASTM 2848/2939-Based Capacity Testing



Example Capacity Test Result

Measured Capacity (kWac)	99,507
Target Capacity (kWac)	99,892
MCR	99.61%



Common to see unique performance testing language with each project

Performance Testing - Methods

Performance Ratio (PR) Testing

$$PR_{corr} = \frac{\sum_i EN_{AC\_i}}{\sum_i \left[P_{STC} \left(\frac{G_{POA\_i}}{G_{STC}} \right) \left(1 - \frac{\delta}{100} \left(T_{cell\_typ\_avg} - T_{cell\_i} \right) \right) \right]}$$

PVsyst Base Energy Model → Gather Data at Site → Filter Data → Calculate Measured Performance Ratio

If $PR_m \geq PR_{e,j}$ x $(1 - TUA)$, then the Solar Facility shall have passed the Substantial Completion Performance Ratio Test.

Performance Ratio Testing is the dominant performance testing method employed outside the US

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Weather-Corrected Performance Ratio

Timothy Dierauf and Aaron Growitz
SunPower Corporation

Sarah Kurtz
National Renewable Energy Laboratory

Jose Luis Becerra Cruz
Fichtner

Evan Riley
Black & Veatch

Clifford Hansen
Sandia National Laboratories

Prepared under Task No. SS13.4510

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Performance Testing Challenges

Early PV Plants

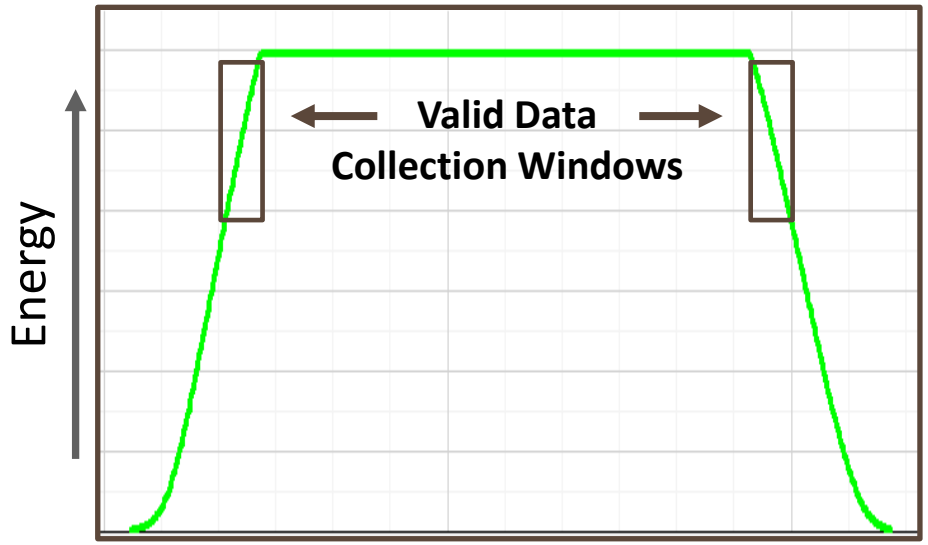
- Located on flat, dry land parcels in Western US
- Simple, homogeneous block design
- Far horizon shading and soiling losses were the biggest concerns

Modern PV Plants

- Built on hillsides, forests, extreme climates
- Complicated design layouts (varying ILRs, row pitch, mixed modules, etc.)
- High DC/AC ratios, complicated topography, near (tree) shading, etc.
- Smart SAT algorithms deployed (row-on-row & diffuse)

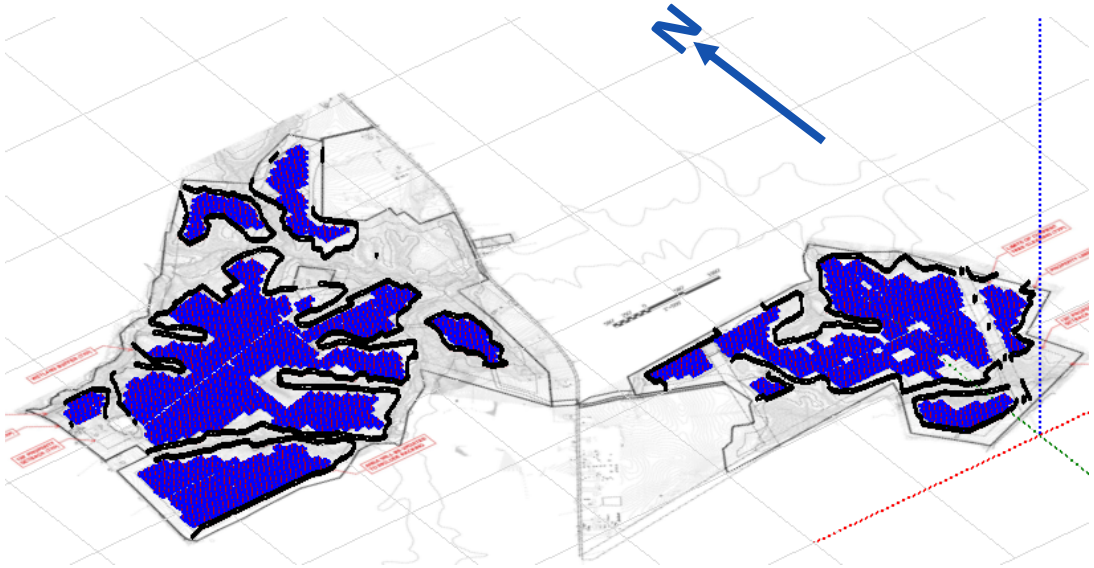
Performance Testing Challenges

- Performance testing guidelines were developed for simple, sunny location PV plants
- Weather dependent
- High DC/AC ratios limit data collection
- PVsyst base energy model heavily influences results
- PAN file caveats
- Demanding owners pushing for higher guarantee targets with less PVsyst padding
- EPCs struggle to achieve 100% availability by SC
- Have performed pre- and post-SC performance testing to demonstrate optimum PV plant status



Performance Testing Challenges – Examples

- Eastern US EPC solar Project XYZ



Complex project requiring a detailed near shading scene (imported into PVsyst from PVcase)

Performance Testing Challenges – Examples

- Eastern US EPC solar Project Y
- Tier 1 PV modules installed
- PVsyst base energy model used OEM module PAN files
- Received 3rd party tested PAN files from OEM after EPC contract signed
- Weather-corrected PR test planned for February
- Triggered design changes to mitigate PR testing risk

	PVsyst Base Model (OEM PAN)	PVsyst Base Model (3rd Party PAN)
Annual (MWh)	-	-1.71%
Jan (MWh)	-	-3.68%
Feb (MWh)	-	-2.68%
Mar (MWh)	-	-1.50%
Apr (MWh)	-	-1.04%
May (MWh)	-	-1.09%
Jun (MWh)	-	-0.95%
Jul (MWh)	-	-0.97%
Aug (MWh)	-	-1.06%
Sep (MWh)	-	-1.62%
Oct (MWh)	-	-2.19%
Nov (MWh)	-	-3.28%
Dec (MWh)	-	-4.23%

Planned PR testing month

Performance testing is challenging and not to be taken lightly

Performance Testing Challenges – PAN Files

- The PAN file holds all definitions specific for a PV module in the PVsyst database
- All PAN files should always be treated as suspect (never guaranteed)
- Have noted 1% - 4% drops in annual energy estimates when OEM and 3rd party PAN files are swapped
- Recommend using trusted 3rd party testing labs (RETC, CFV, etc.) due to observed suspect Asia-region test results
- Always ask for the 3rd party PAN file test report for review

```
PVObject_=pvModule
 Version=7.3.1
 Flags=$00900043

FOR ENTERTAINMENT PURPOSES ONLY!!!

PVObject_Commercial=pvCommercial
  Comment=http//Tatooine_solar.com (China)
  Flags=$0041
  Manufacturer=Tatooine Solar
  Model=R2D2-72C3PO-585W
  DataSource=Manufacturer
  YearBeg=2022
  Width=1.131
  Height=2.272
  Depth=0.030
  Weight=30.90
  NPieces=100
  PriceDate=05/07/21 03:05
  Remarks, Count=1
    Str_1
  End of Remarks
End of PVObject pvCommercial

Technol=mtSiMono
NCelS=72
```

BV independently procures 3rd party PAN files for most solar EPC projects

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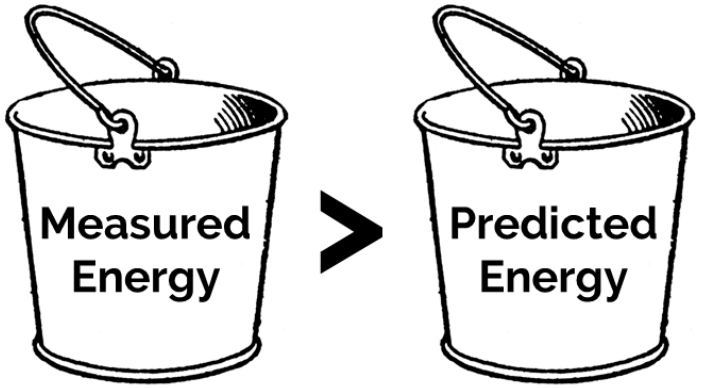
Short Term Energy Testing

- PVsyst base energy model fed with onsite weather data
- Testing typically spans sunrise to sunset over 2-4 weeks and is run between project substantial completion and final acceptance milestones
- Sometimes guided by IEC 61724-3 standards
- Provides a short term “real world” evaluation of a project’s PVsyst model

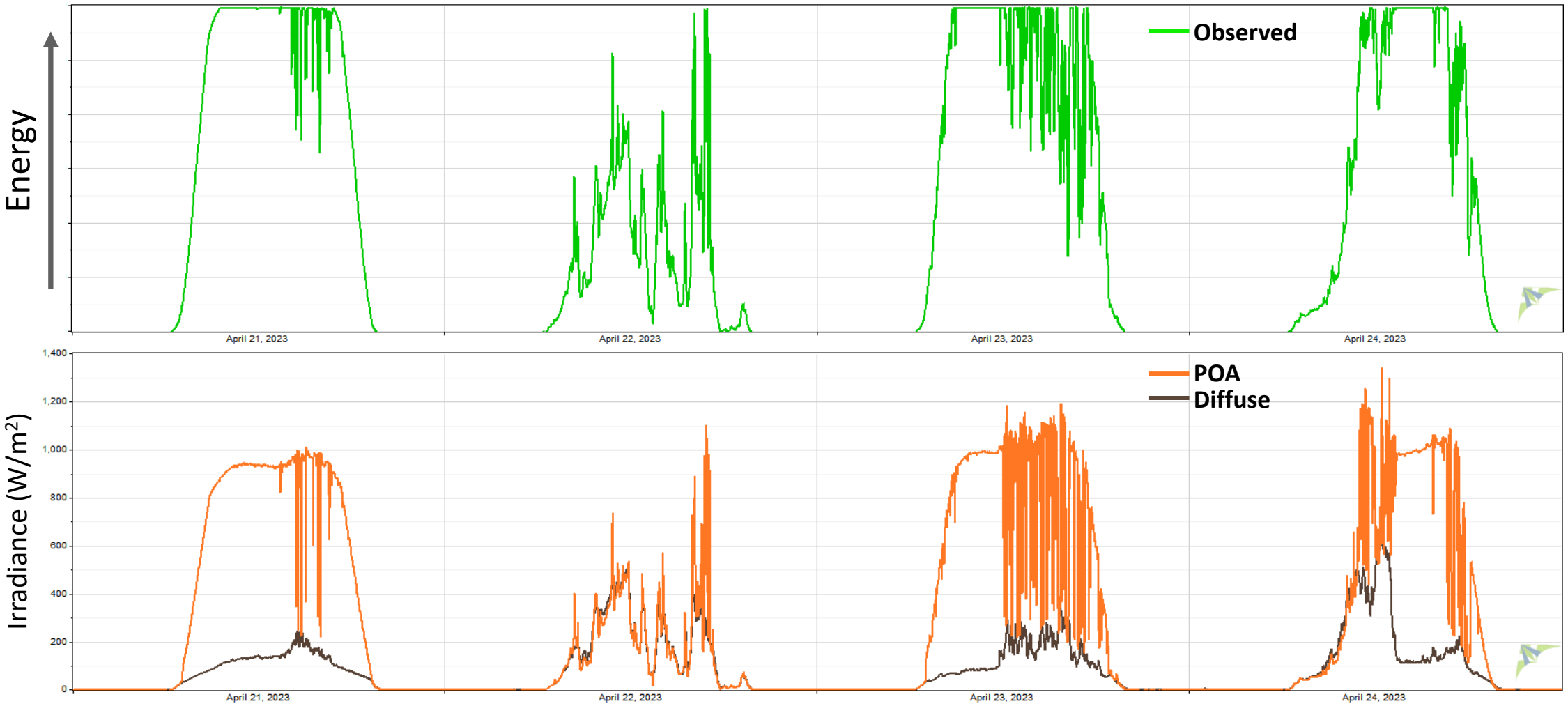


Short term energy testing is becoming more popular and is often paired with Capacity/PR testing

Short Term Energy Testing – Case Study

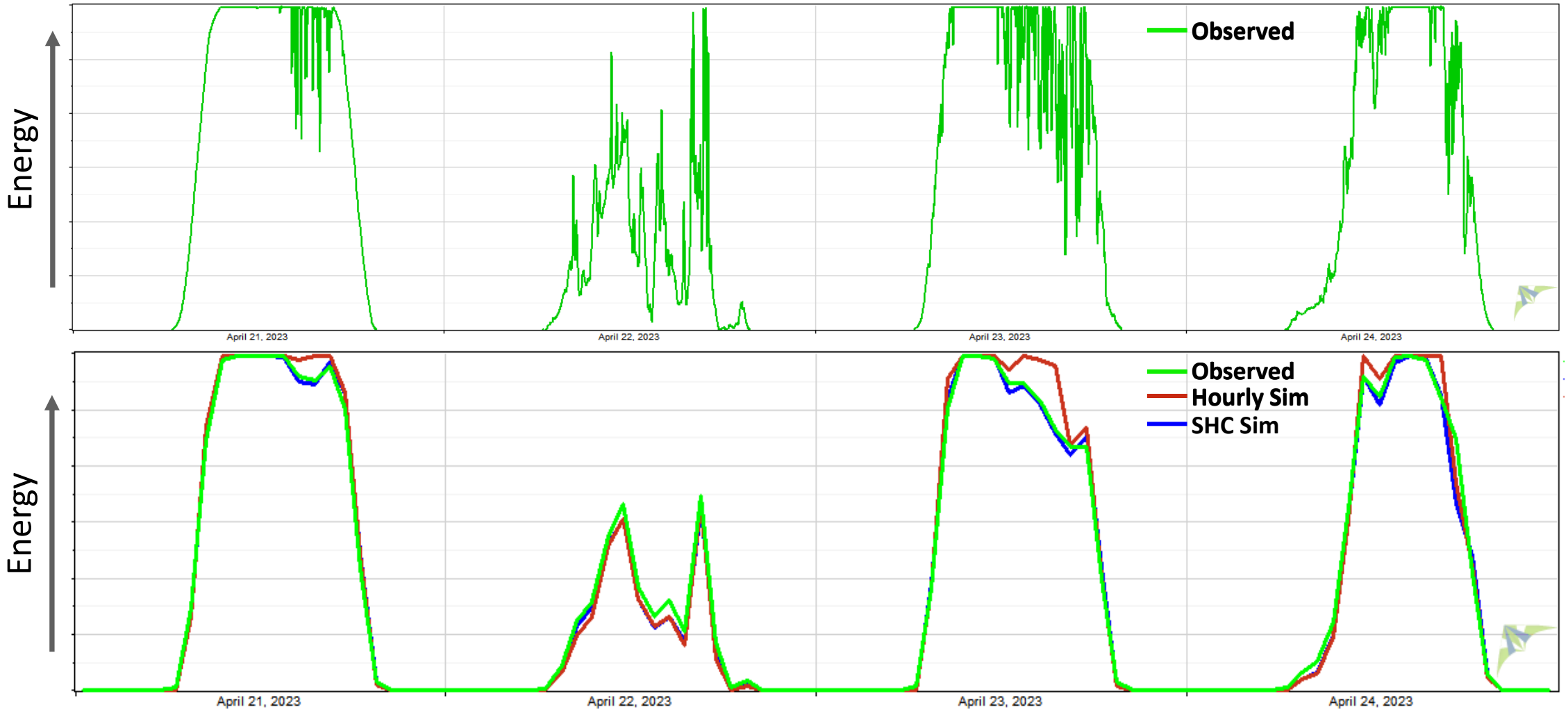
- Example 21-day energy test run at solar Project XYZ
- Standard hourly PVsyst modeling along with novel sub-hourly clipping (SHC) PVsyst modeling method results assessed
- SHC PVsyst modeling methodology:
  - Ingest one minute resolution site SCADA data into PVsyst via minute specific Met files (all 5 minute past hour values into one Met file, all 6 minute past hour values into one Met file, etc.)
  - Apply appropriate time shifts to all 60 Met files
  - Batch process 60 PVsyst Met files and post-process time series output into hourly averaged results
- Hourly POAI bias corrected via input GHI (x 0.98) and no filtering applied to PVsyst results

Short Term Energy Testing – Case Study



Four days from the energy test – Clear sky to overcast conditions observed

Short Term Energy Testing – Case Study



SHC energy results line up well with revenue meter energy observations

Short Term Energy Testing – Case Study

- Test period saw clear site conditions half the time with partly cloudy to mostly cloudy conditions for the rest of the period
- 21-day energy test results:

Revenue Meter (MWh)	Hourly PVsyst (MWh)	SHC PVsyst (MWh)
100%	98.2%	100.2%

- SHC PVsyst modeling results are noted to be more accurate than standard hourly PVsyst modeled results, especially during sub-hourly clipping conditions
- Currently evaluating SHC PVsyst method at FSLR and bifacial PV projects with favorable results

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Summary

- Increasingly complicated EPC solar PV projects are accompanied by complicated and demanding performance testing obligations
- An accurate PVsyst base energy model is crucial to successful project performance and energy testing
- Trusted 3rd Party PVsyst PAN files are a necessity
- Engaging backtracking on First Solar PV projects can help shorten performance testing timeframes
- Energy testing is becoming a popular additional solar EPC project requirement
- Sub-hourly clipping conditions can be handled explicitly in PVsyst via SHC PVsyst modeling methods for energy testing

Thank you for your attention!

Contact Us

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