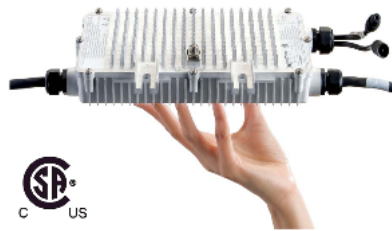
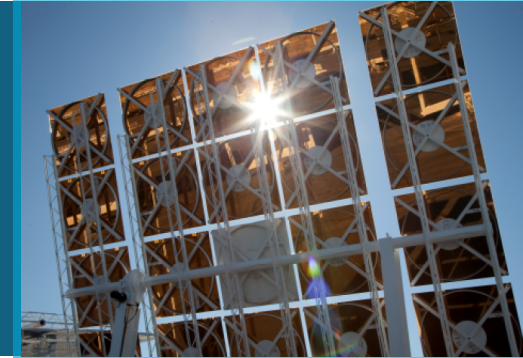




New Mexico's First Enphase Microinverter Rooftop Solar Installation

13 Years of Performance Data and Lessons Learned



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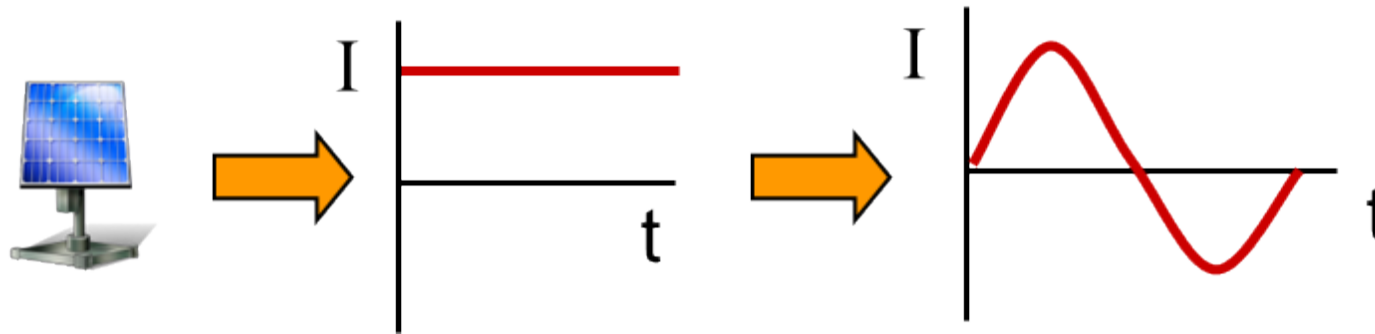


- Introduction to Microinverter System
- Performance Results
- Lessons Learned

What is an inverter?



- **Converts DC output from PV modules to AC electricity**



- **Two primary types**
 - Central (string) inverter – connected to multiple PV modules
 - Microinverter – connected to a single PV module

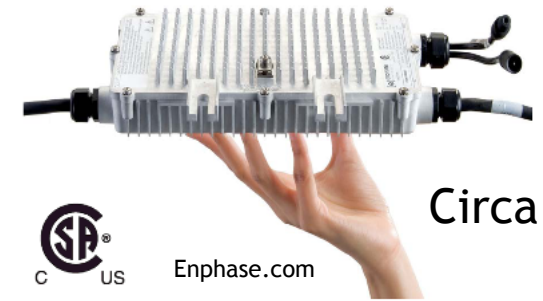
Pros and Cons of Microinverters

(claims made relative to central inverters)

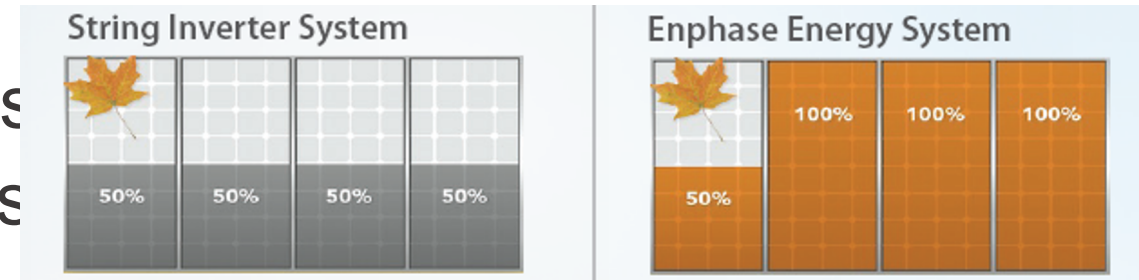


- Pros

- More energy produced with partial shading
- Greater reliability (25 year vs. 5 year warranty)
- Ease of installation
- Safety (no high-voltage DC lines)
- Monitoring of individual modules



Circa 2008



Enphase.com

- Cons

- Higher capital cost
- Placement is difficult to access (behind modules)



1st Residential PV System in New Mexico with Enphase Microinverters

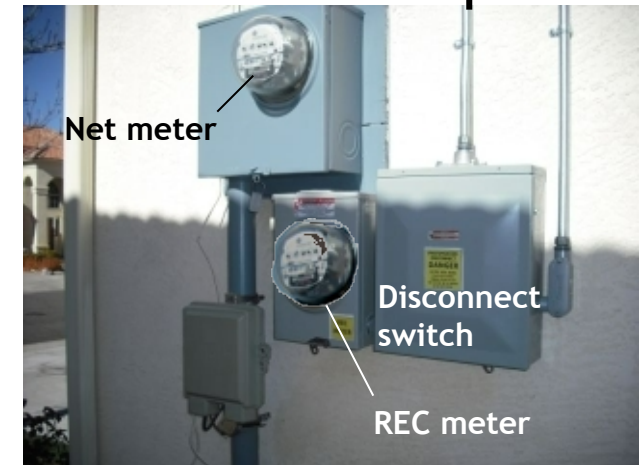


- 3 kW PV installed in 2008
- 15 modules
 - 200 W Sanyo HIP- 200BA3
- Enphase Microinverter
 - 200 W (M200-32-240)
 - 15 year warranty



Cliff's House on Google Maps

Installation (Oct – Dec 2008)



Overview

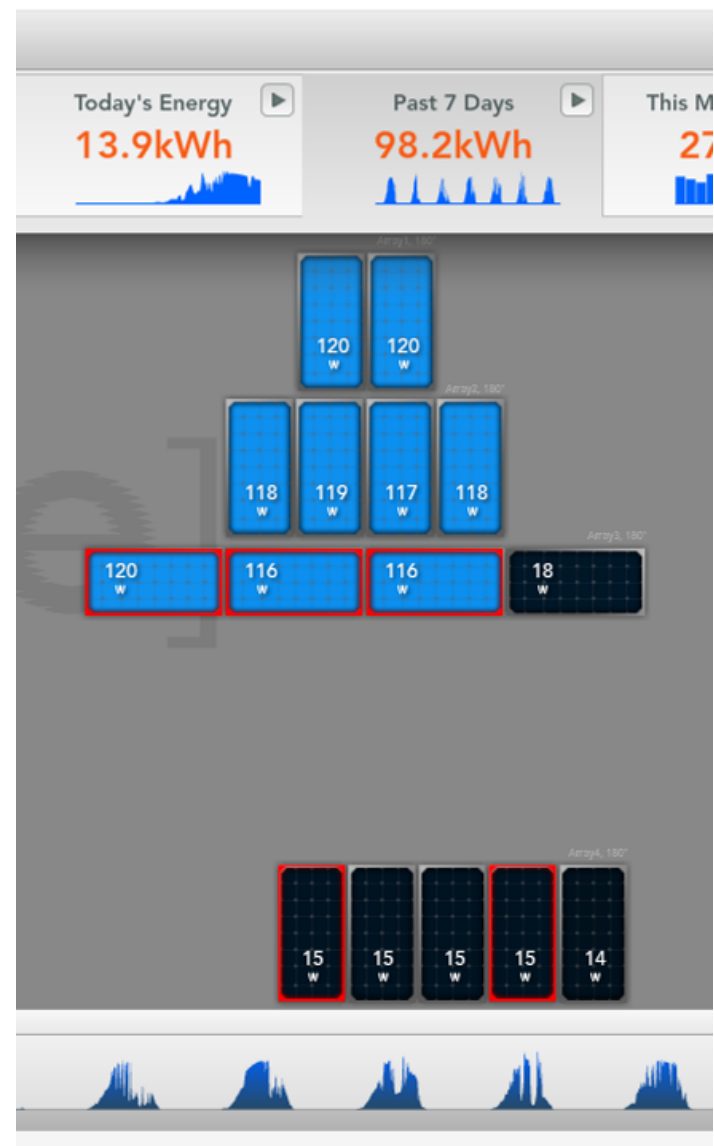


- Introduction to Microinverter System
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Website Monitoring (Enphase Enlighten)



Impact of Shading



Error Alerts

- Automated e-mail alerts
 - Some issues are self-correcting
 - For bad microinverters, I had to call Enphase to get RMA (Return Merchandise Authorization)

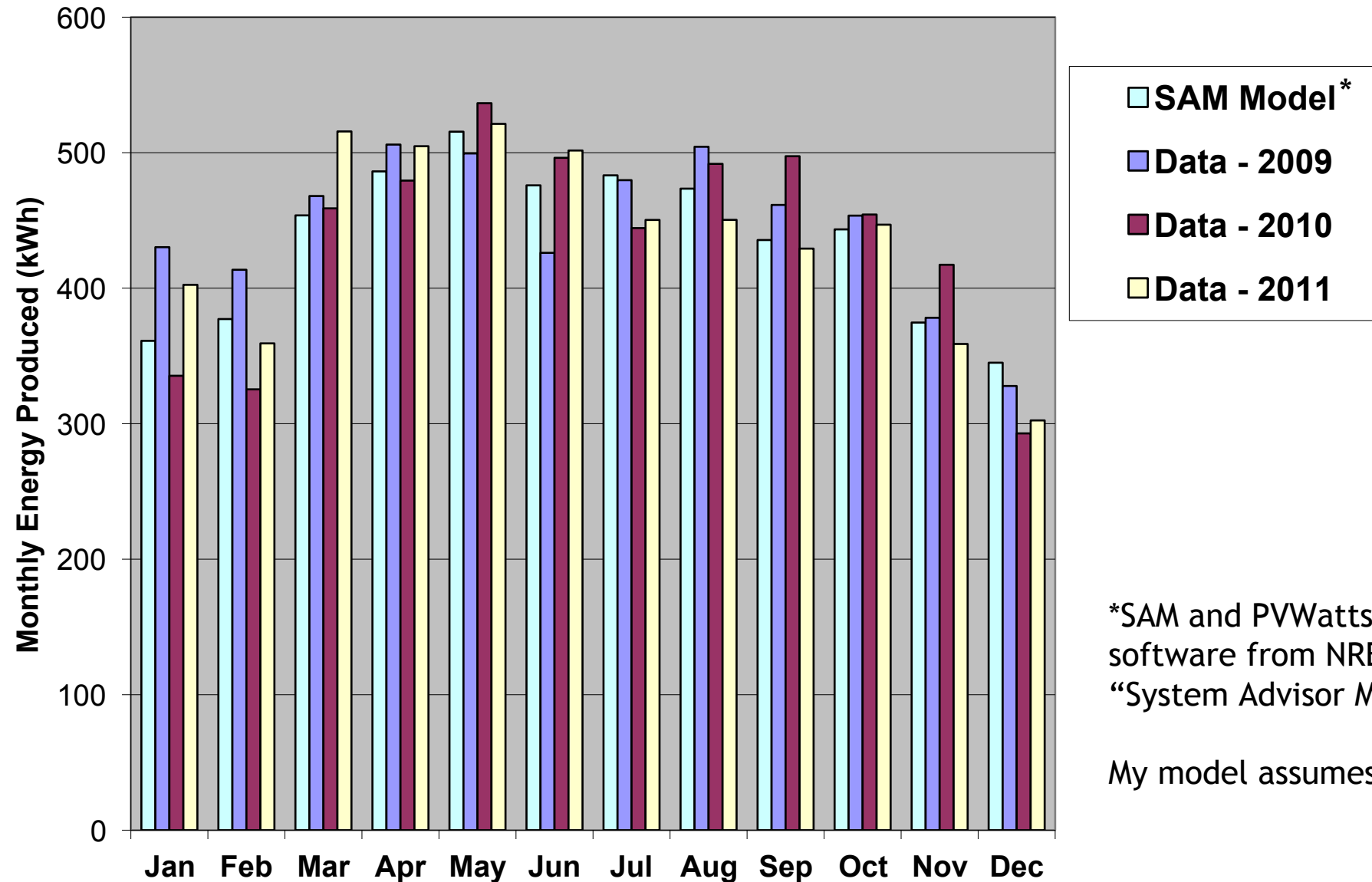
The screenshot shows a web interface window titled "Issue Details" with a close button (X) in the top right corner. Below the title bar, there is a summary text: "The following provides a summary of the detected issue. Please follow the recommended action or contact Enphase Energy for more information." The main content area is divided into several sections, each with a dark grey header and a light grey body:

- Affected Devices:** 30 occurrences from 5 devices ([show details](#))
- Alert:** AC Voltage Out Of Range
- Duration:** Started on: Wed August 03, 2011 04:58 PM MDT
Cleared on: Wed August 03, 2011 05:04 PM MDT
- Recommended action:** This condition should correct itself. No action is required.
- Details:** The microinverter reports that the AC voltage coming from the utility is either too low or too high as specified by applicable regional standards.

When the microinverter detects a voltage out of range condition, it must remain offline until the utility has been within acceptable limits a short period of time (several minutes, varies by region). If during that time the utility again exceeds or falls short of acceptable limits, the five-minute timer must restart and the microinverter may not begin producing power for an additional...

On the right side of the window, there is a vertical blue scrollbar with a small upward arrow at the top and a downward arrow at the bottom.

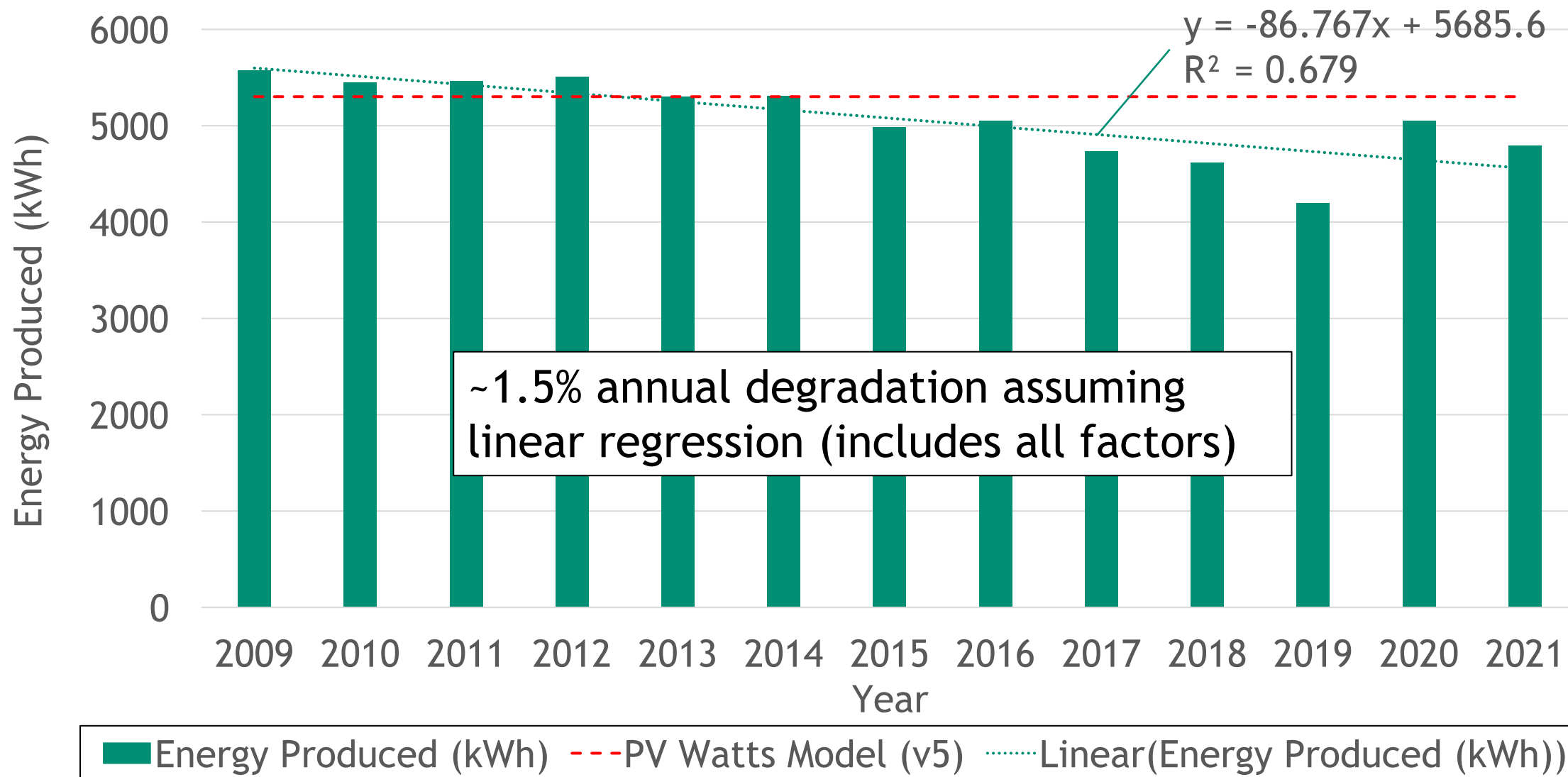
Monthly Energy Production



*SAM and PVWatts are free software from NREL (Google "System Advisor Model")

My model assumes no shading

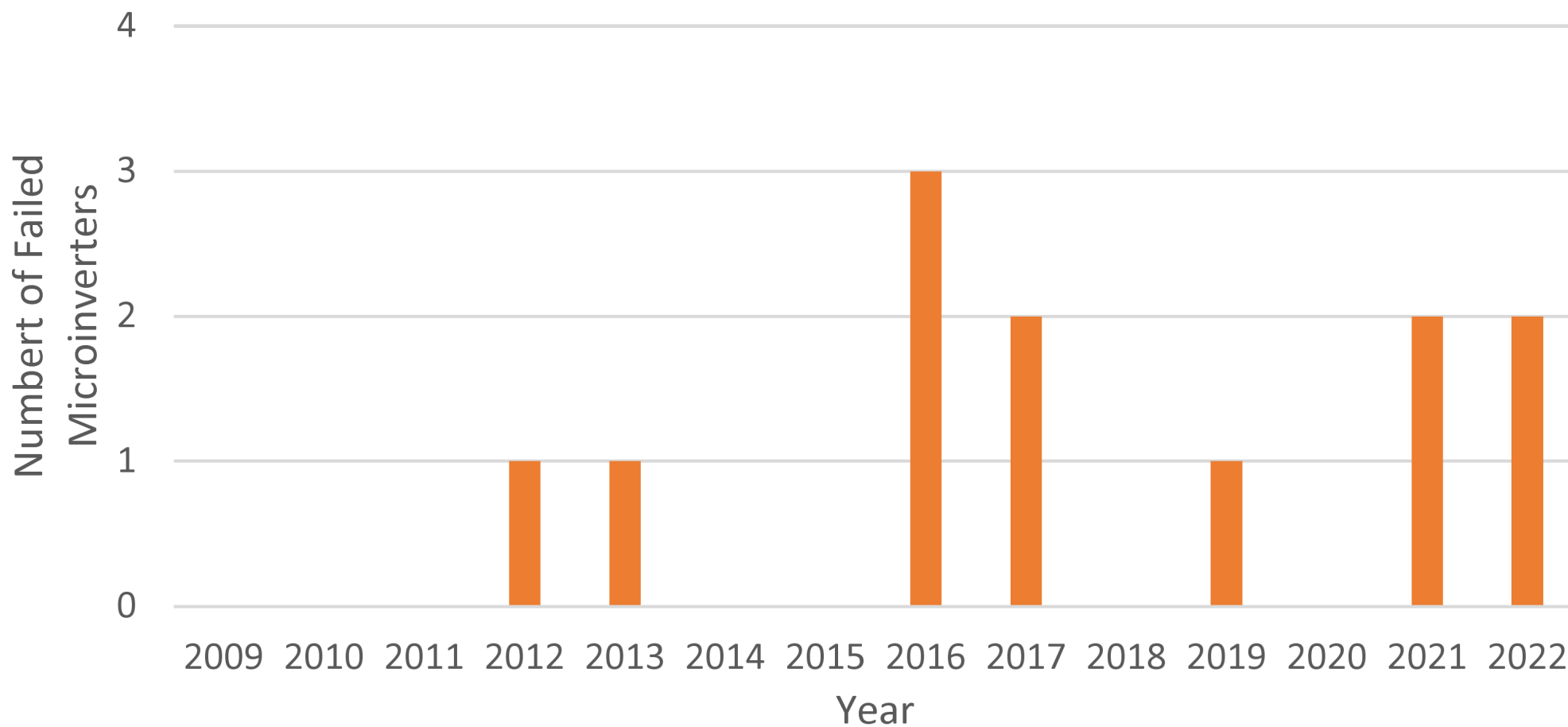
13 Years of Annual Performance



Failed Microinverters



A total of 12 microinverters on 10 PV modules have failed, and five originals remain.

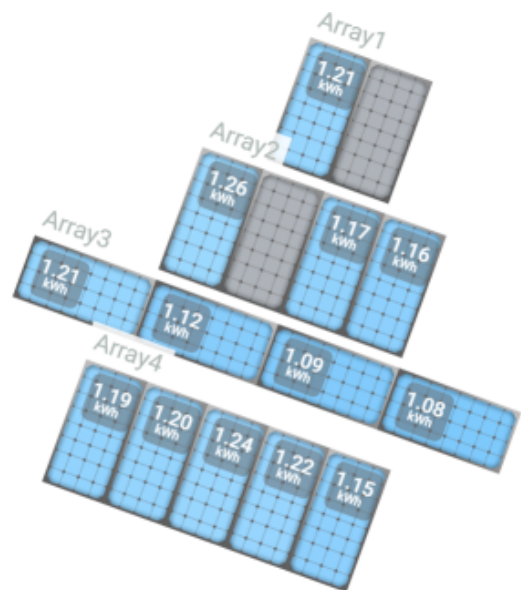


Overview

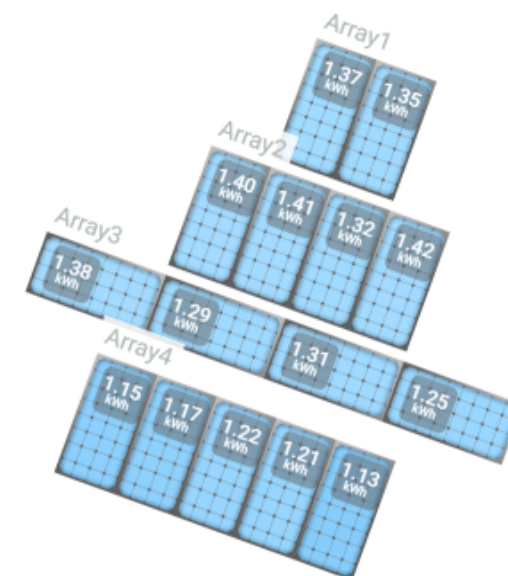


- Introduction to Microinverter System
- Performance Results
- Lessons Learned

It's Easy to Replace a Bad Microinverter



February 18, 2022 Produced



April 17, 2022 Produced

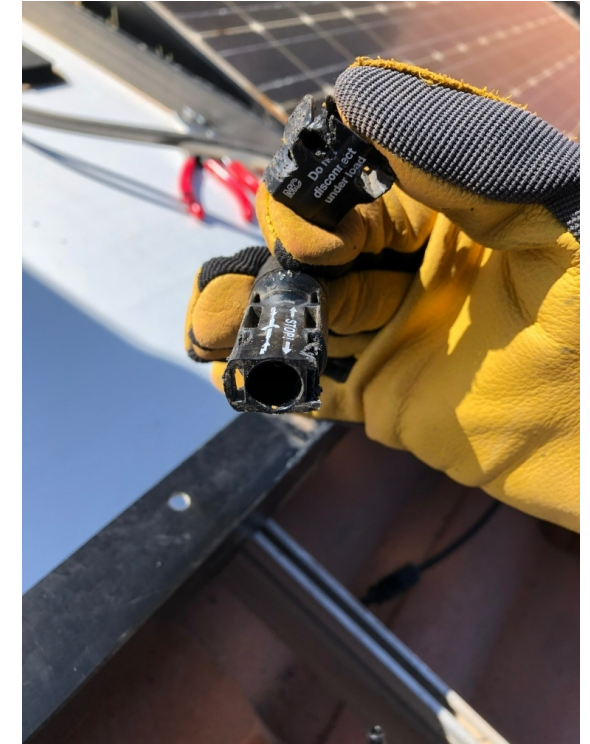
Negative coupling between PV module and 1st generation inverters difficult to remove



Positive coupler came apart easily with special tool



Tool did not fit in slots for negative coupler



Had to cut tab slots to remove coupling

Conclusions



- During the first six years of operation, the annual energy production met or exceeded predicted energy production (PV Watts model)
- During the first 13 years of operation, the annual energy production showed a $\sim 1.5\%$ annual degradation assuming a linear regression
- Ten of the 15 original first-generation Enphase microinverters have been replaced due to failures within the first 14 years of operation
 - 2 replacements also failed (total of 12 failed microinverters)

Backup Slides

Conclusions



- Optimal size (power output) of microinverter may be less than rated power output of PV module
 - E.g., for 230 W PV module, optimal microinverter may be 190 W
- Costs have come down significantly
 - Current installed costs are nearly half of what I paid in 2008

Conclusions

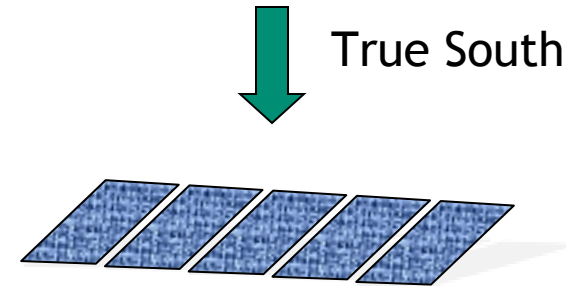


- Microinverter Pros
 - More energy produced with partial shading
 - High reliability (to be determined)
 - Ease of installation
 - Safety (no high-voltage DC lines)
 - Monitoring and power tracking of individual modules
- Microinverter Cons
 - Higher capital cost (30% - 50%)
 - Placement difficult to access

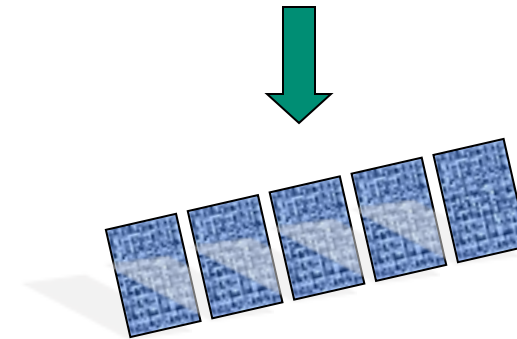
Optimization of Energy Production



- In Albuquerque
 - Face PV array 10 degrees east of true south
 - Tilt panels at 35 degrees (latitude)
- Annual energy production predicted in SAM to increase by ~3%
 - From ~5,200 kWh to ~5,400 kWh



Existing System (22 deg west of true south, <30 deg tilt)



Optimized System (10 deg east of true south, 35 deg tilt)

Optimization of Microinverter Size (Power Output)



200 W

?



200 W

Microinverter Efficiency and Sizing

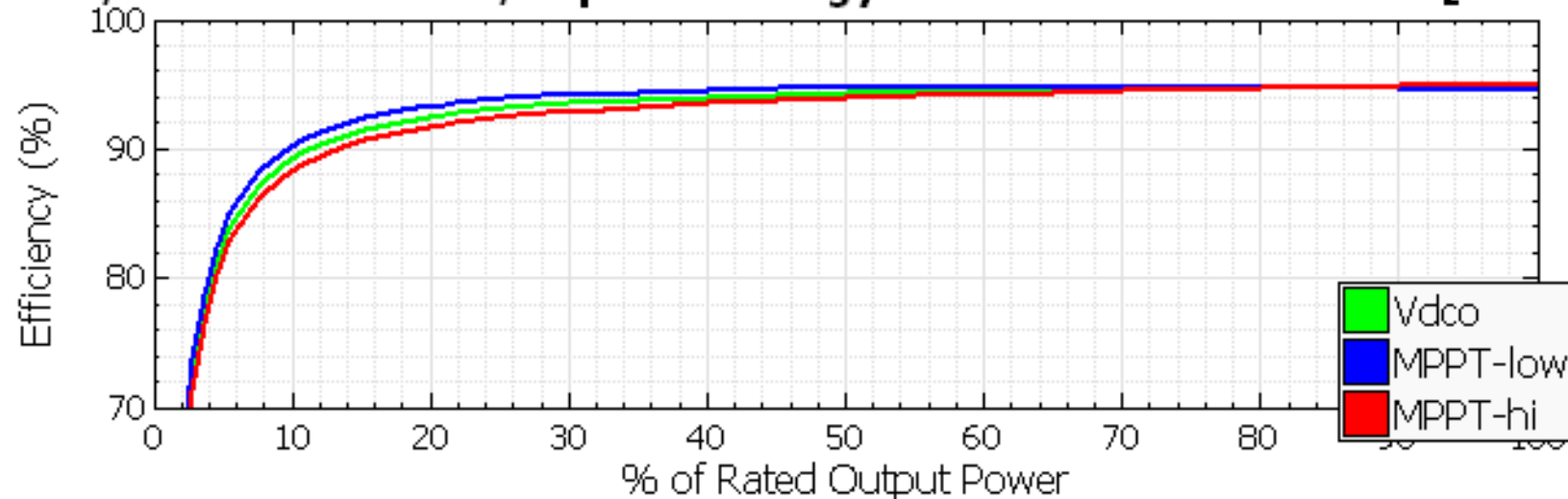


Sandia Performance Model for Grid Co

Sandia Inverter SAM/Sandia Inverters/Enphase Energy: M200-32-240-S01 240V

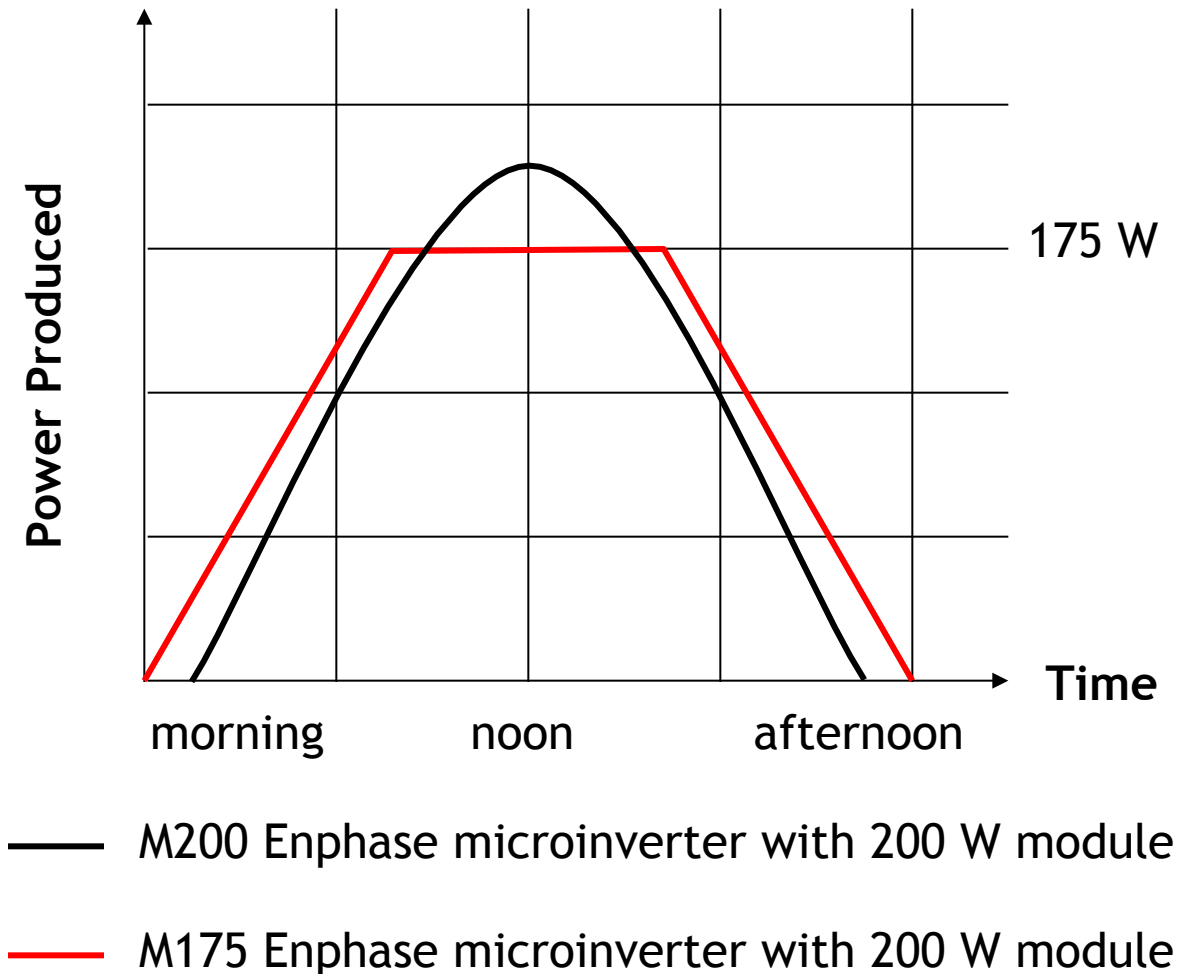
Efficiency Curve

SAM/Sandia Inverters/Enphase Energy: M200-32-240-S01 240V [CEC 2

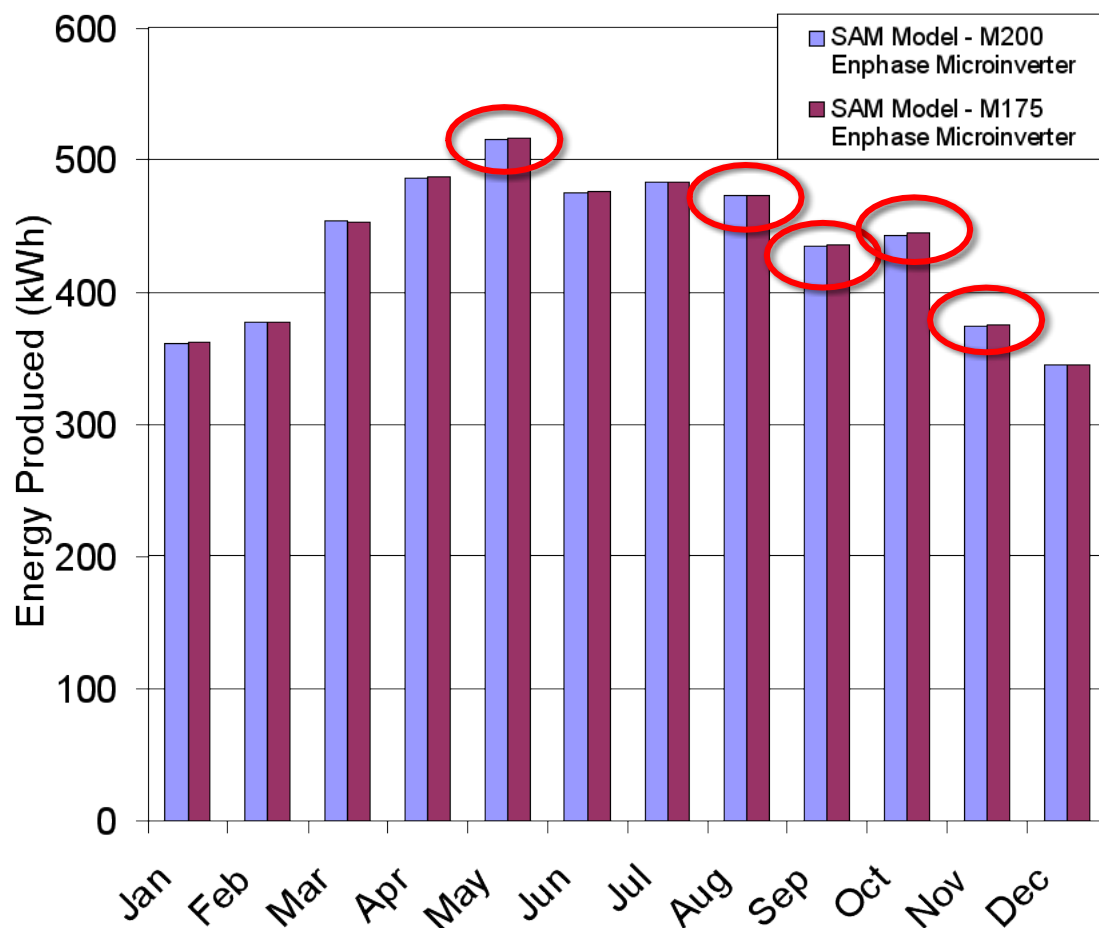


- The efficiency of an inverter decreases as the power output decreases

Sample Power Production over a Day from a 200W Module with Different Inverter Capacities

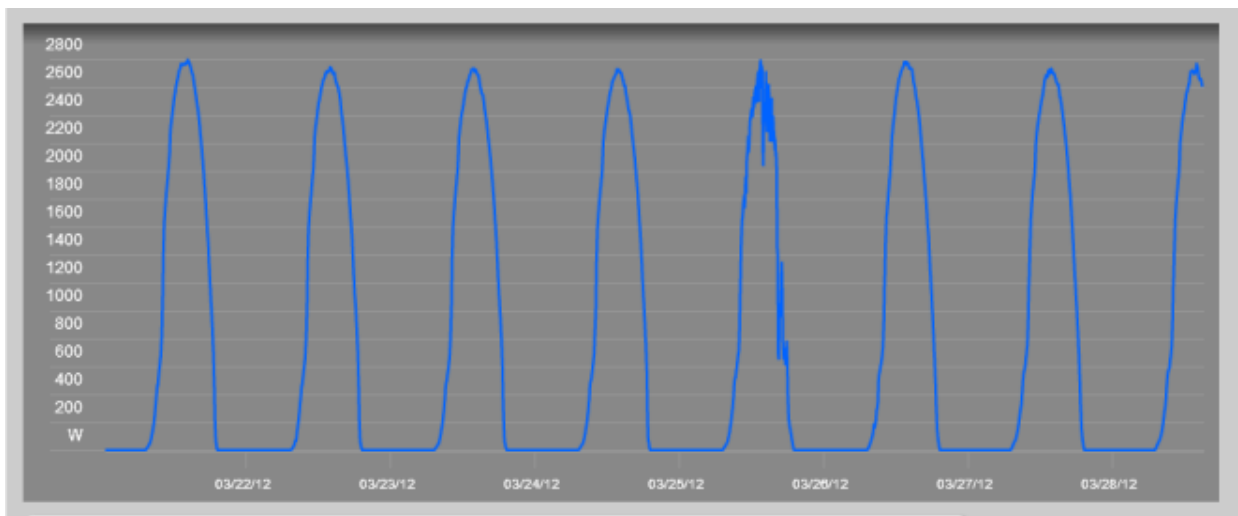


Energy Production with 200 W Modules: Enphase M175 vs. M200

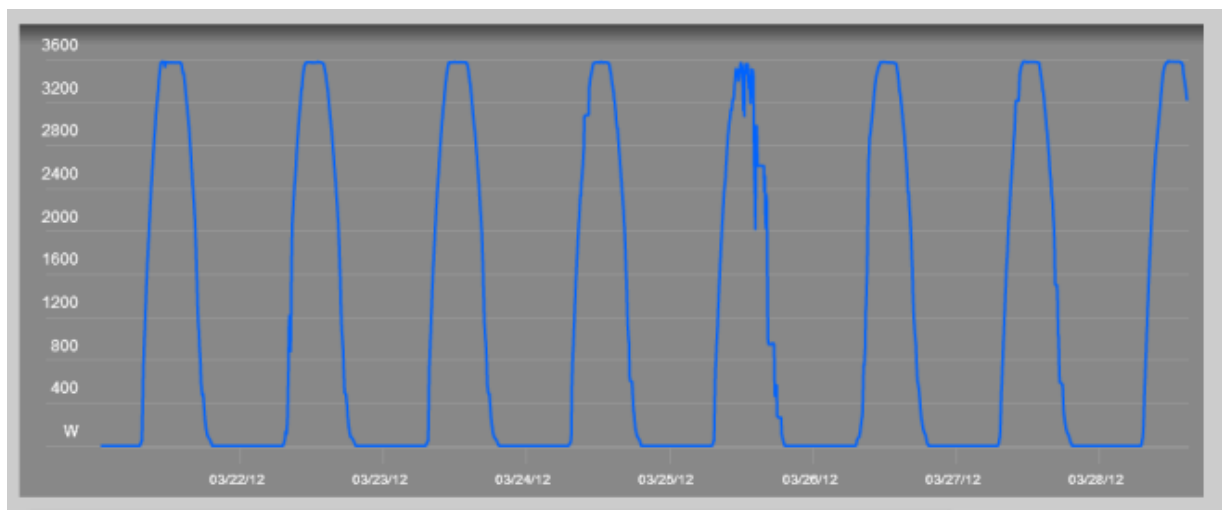


- With my 200 W modules:
 - 175 W microinverters predicted to produce 5,232 kWh
 - 200 W microinverters predicted to produce 5,225 kWh

Comparison of My System to Colleague's System with "Undersized" Microinverters



- 200 W microinverters with 200 W modules



- ~200 W microinverters with 230 W modules