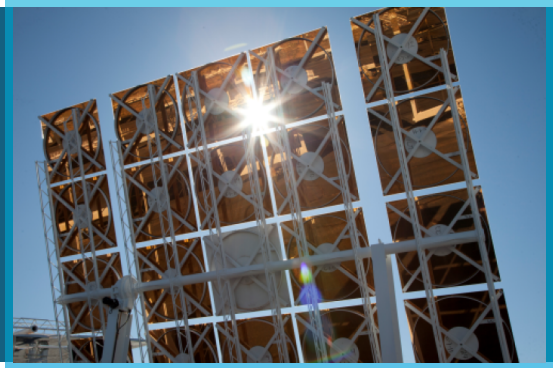
SAND2022-6544C

Sandia National Laboratories

New Mexico's First Enphase Microinverter Rooftop Solar Installation

13 Years of Performance Data and Lessons Learned



Clifford K. Ho

Sandia National Laboratories, Albuquerque, NM, ckho@sandia.gov

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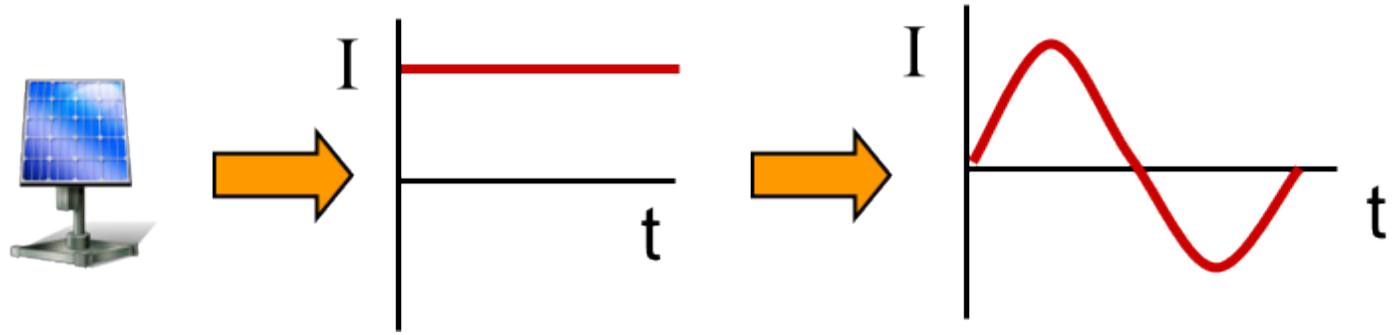
Overview

- Introduction to Microinverter System
- Performance Results
- Lessons Learned

What is an inverter?

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



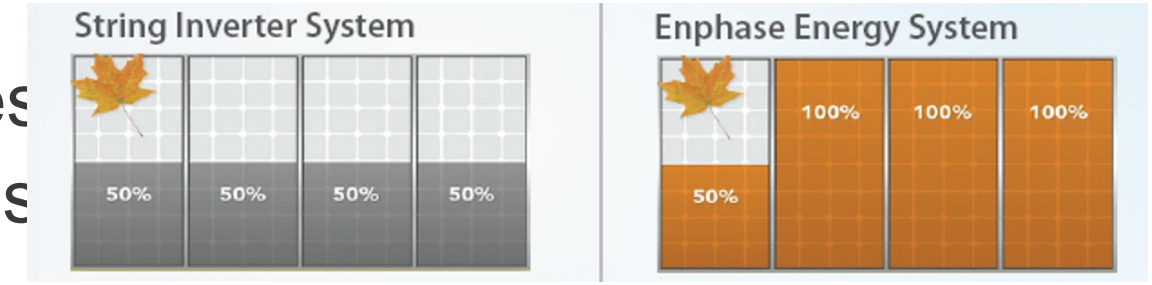
- **Two primary types**
  - Central (string) inverter – connected to multiple PV modules
  - Microinverter – connected to a single PV module

Pros and Cons of Microinverters
(claims made relative to central inverters)

Enphase.com

Circa 2008

- 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



Enphase.com

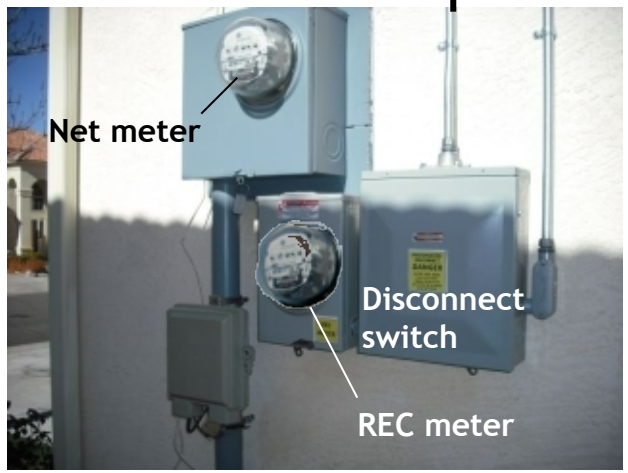
- Cons
  - Higher capital cost
  - Placement is difficult to access (behind modul

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)



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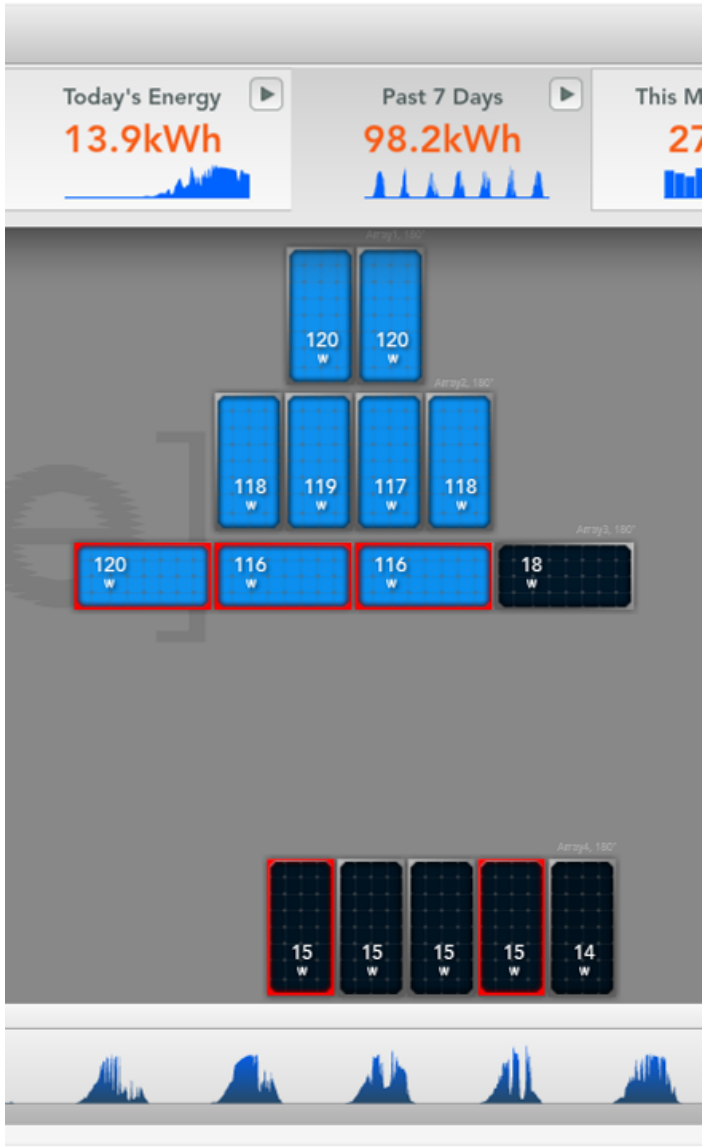
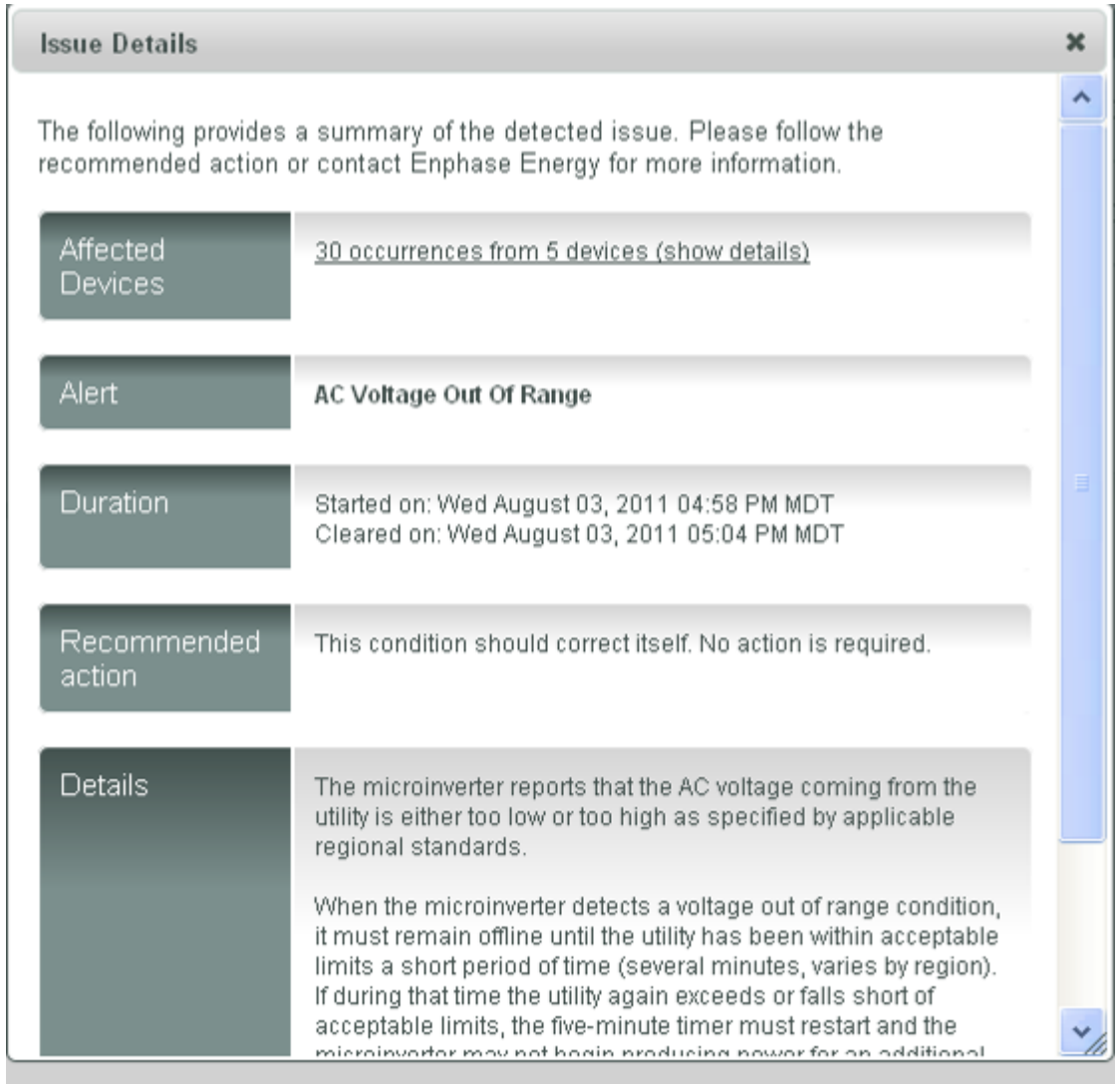
Website Monitoring (Enphase Enlighten)

Impact of Shading

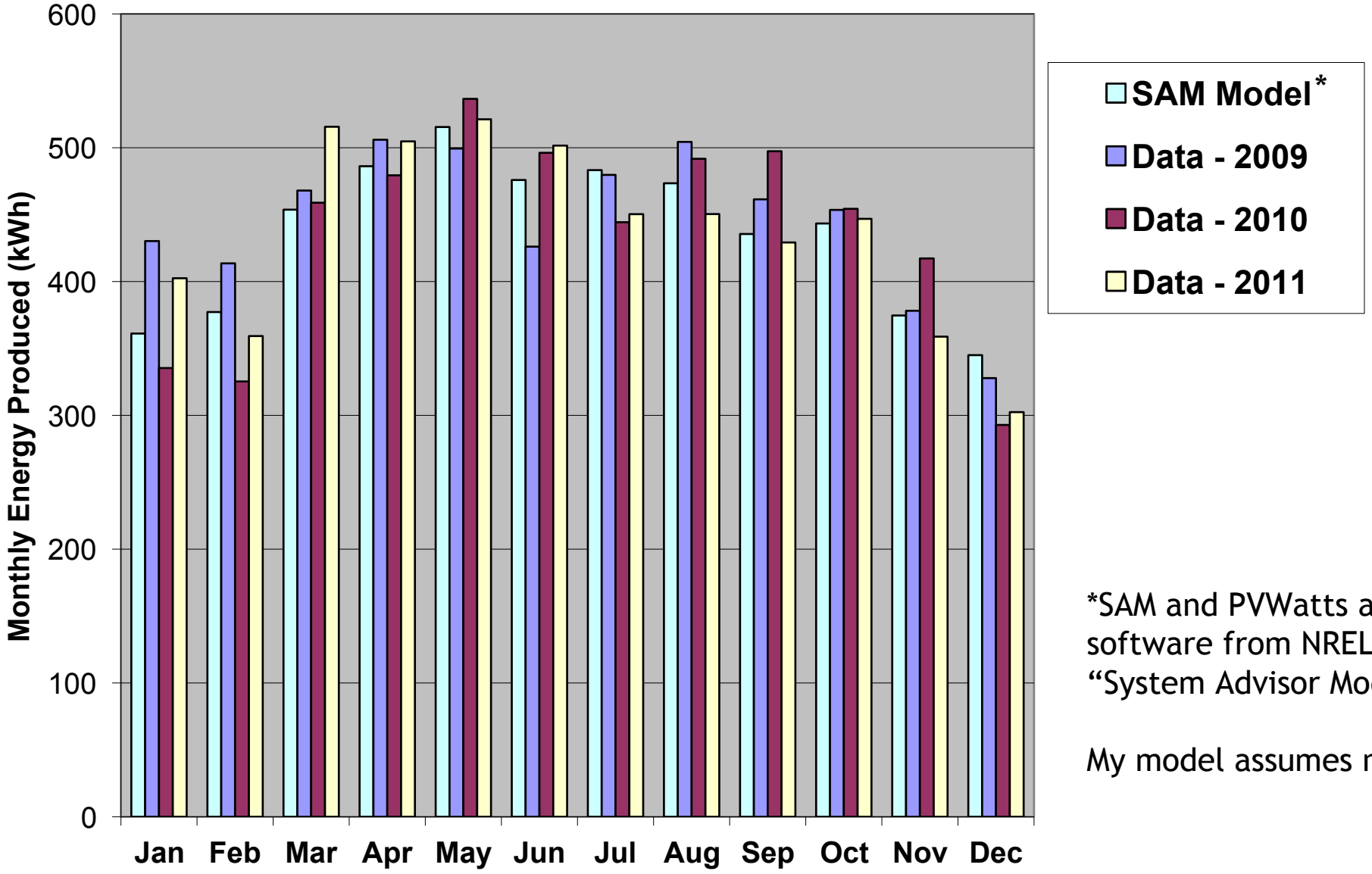


Error Alerts

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



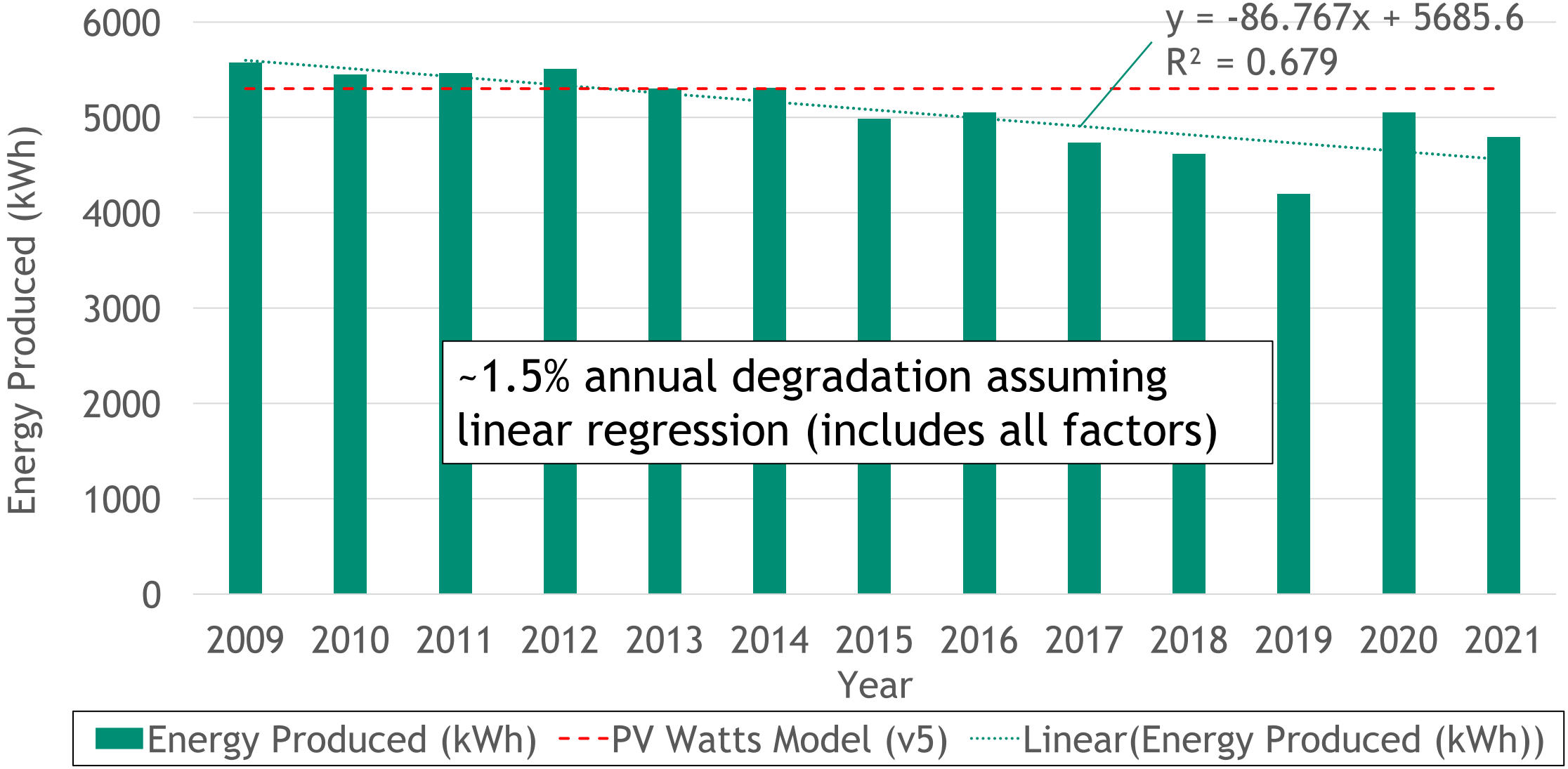
Monthly Energy Production



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

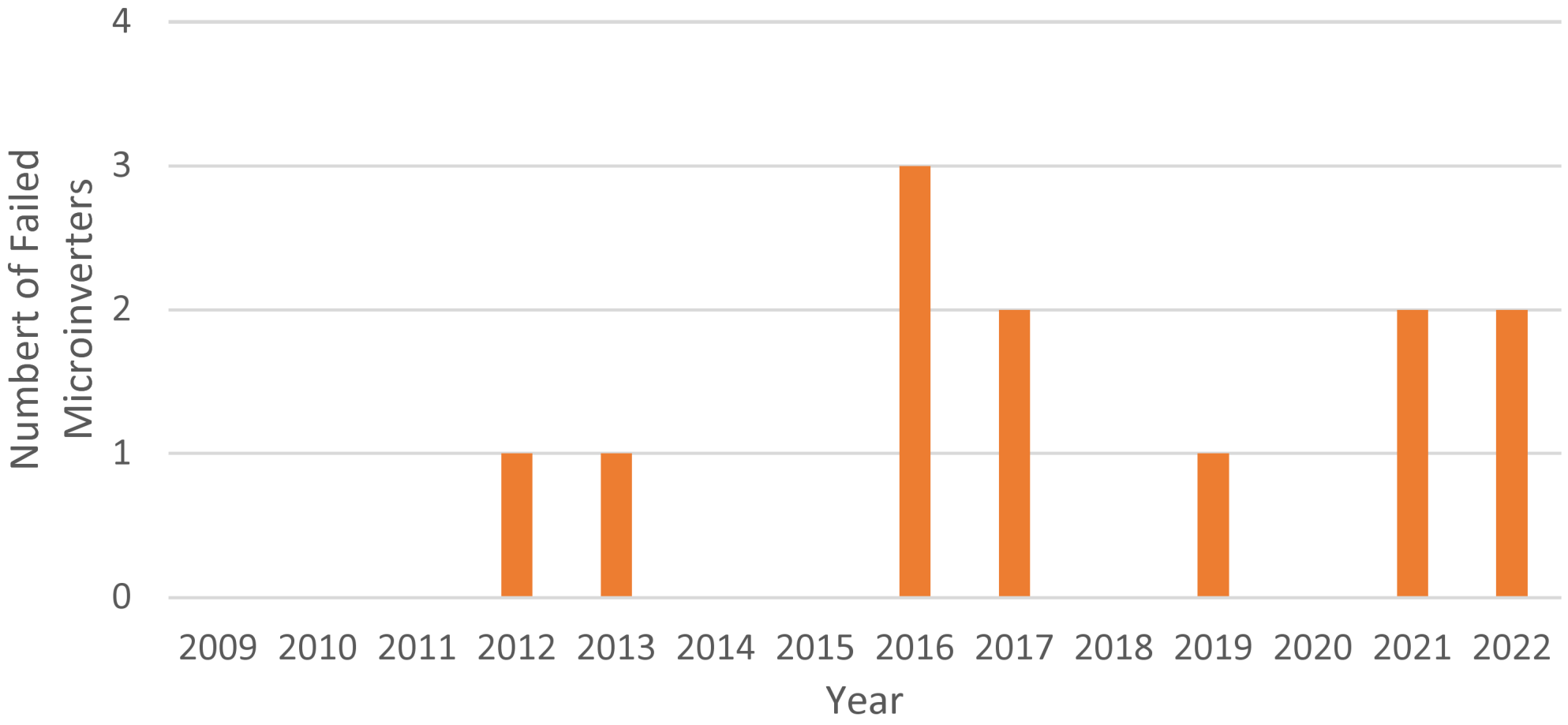
My model assumes no shading

13 Years of Annual Performance



Failed Microinverters

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



Overview

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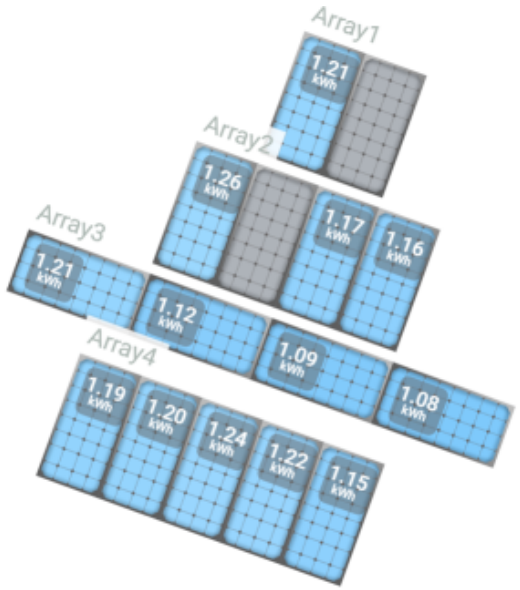
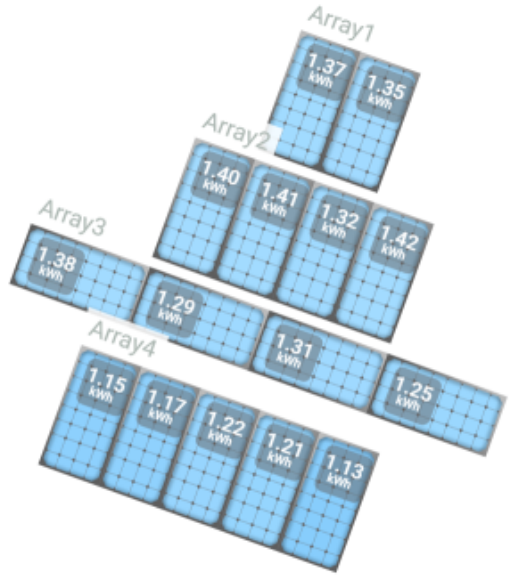
It’s Easy to Replace a Bad Microinverter



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 ~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

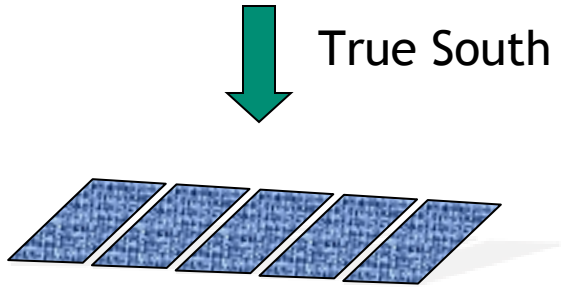
- Optimal size (power output) of microinverter may be less than rated power output of PV module
  - E.g., for 230 W PV module, optimal microinverter may be 190 W
- Costs have come down significantly
  - Current installed costs are nearly half of what I paid in 2008

Conclusions

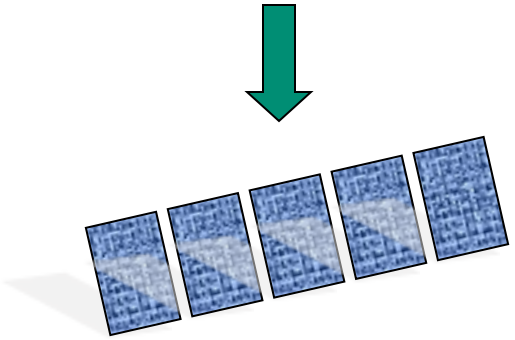
- Microinverter Pros
  - More energy produced with partial shading
  - High reliability (to be determined)
  - Ease of installation
  - Safety (no high-voltage DC lines)
  - Monitoring and power tracking of individual modules
- Microinverter Cons
  - Higher capital cost (30% - 50%)
  - Placement difficult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

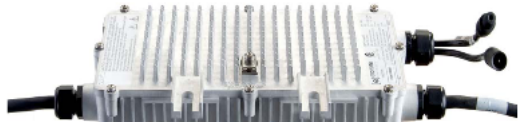


Optimized System (10 deg east of true south, 35 deg tilt)

Optimization of Microinverter Size (Power Output)

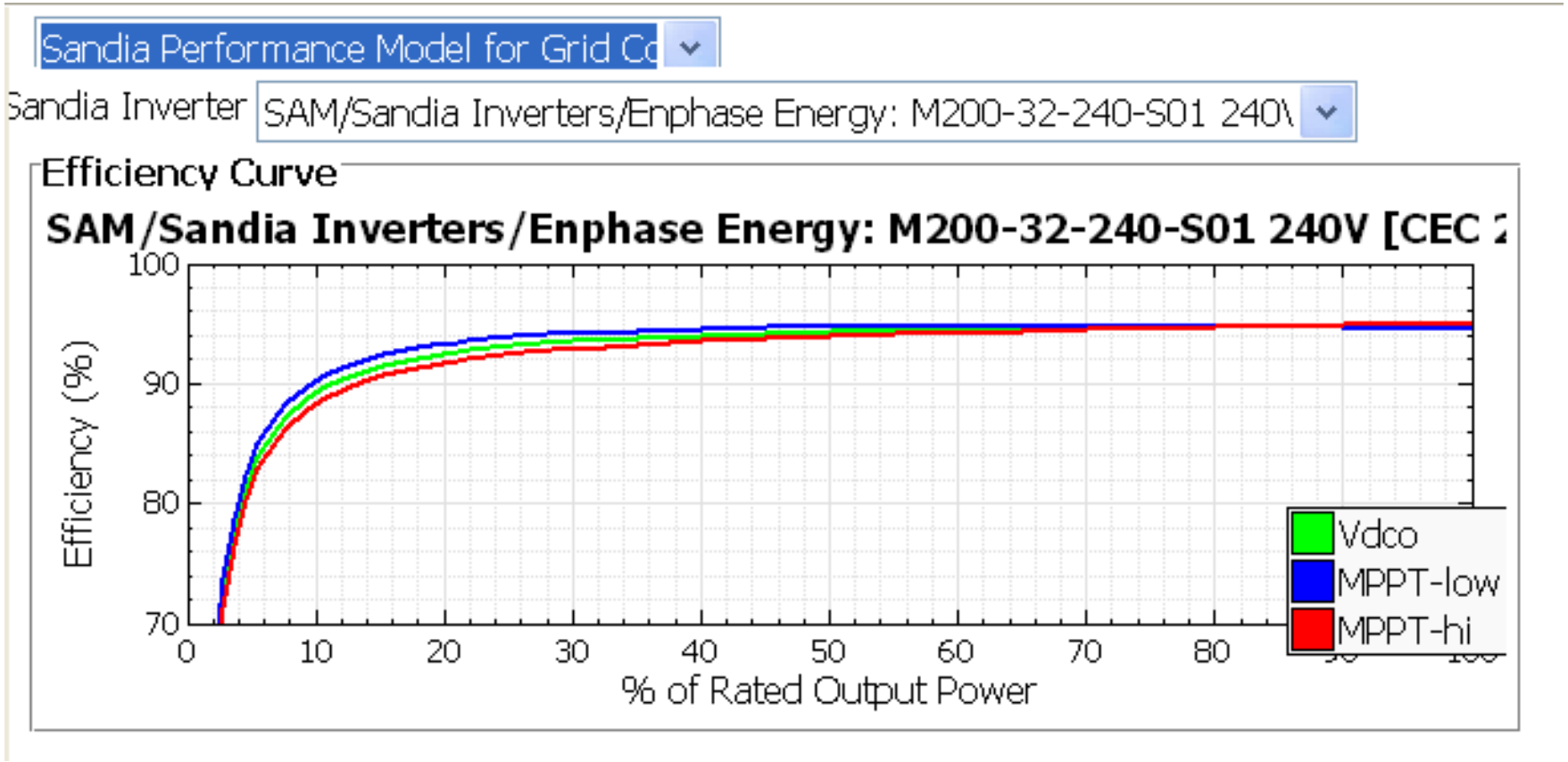
200 W

?



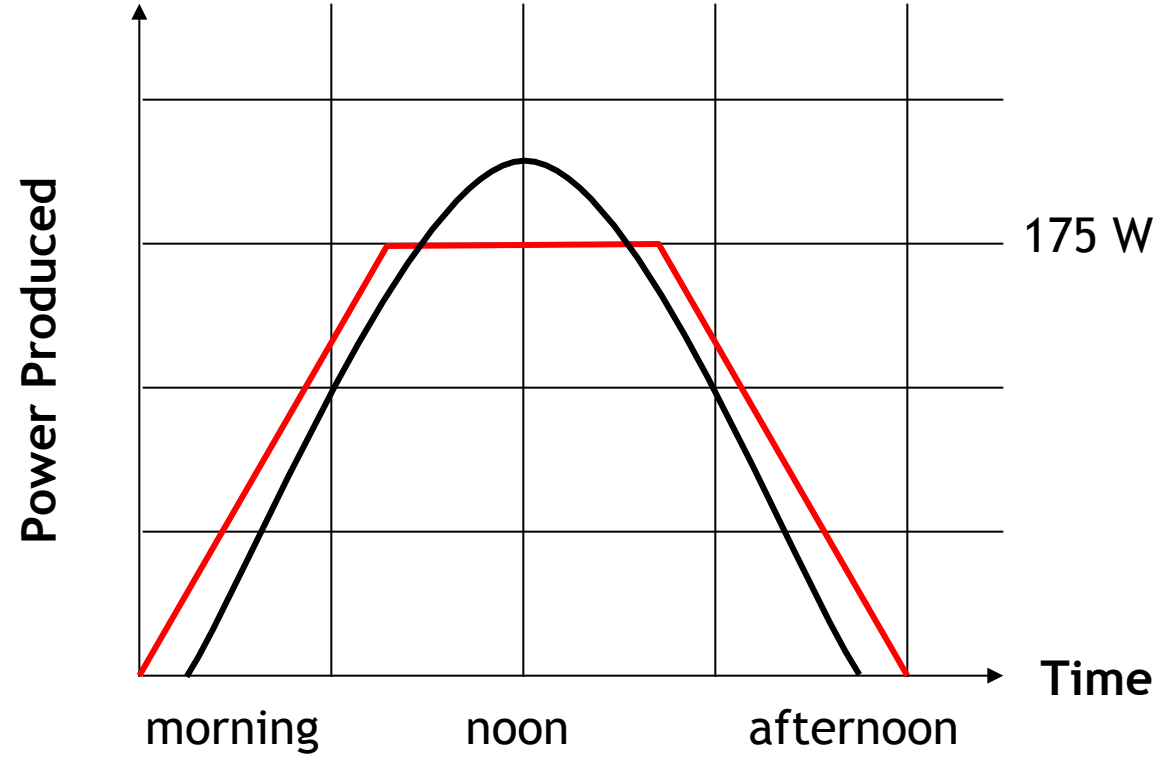
200 W

Microinverter Efficiency and Sizing



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

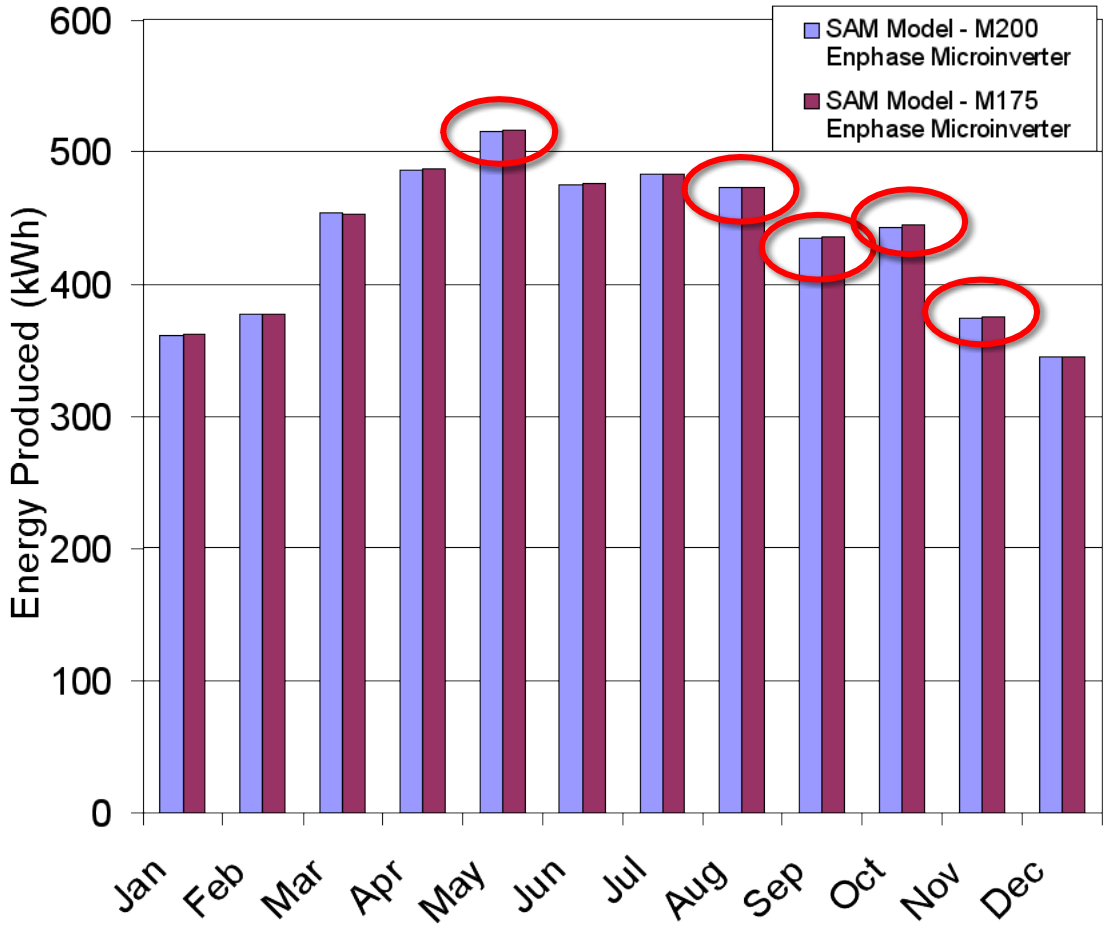
Sample Power Production over a Day from a 200W Module with Different Inverter Capacities



M200 Enphase microinverter with 200 W module

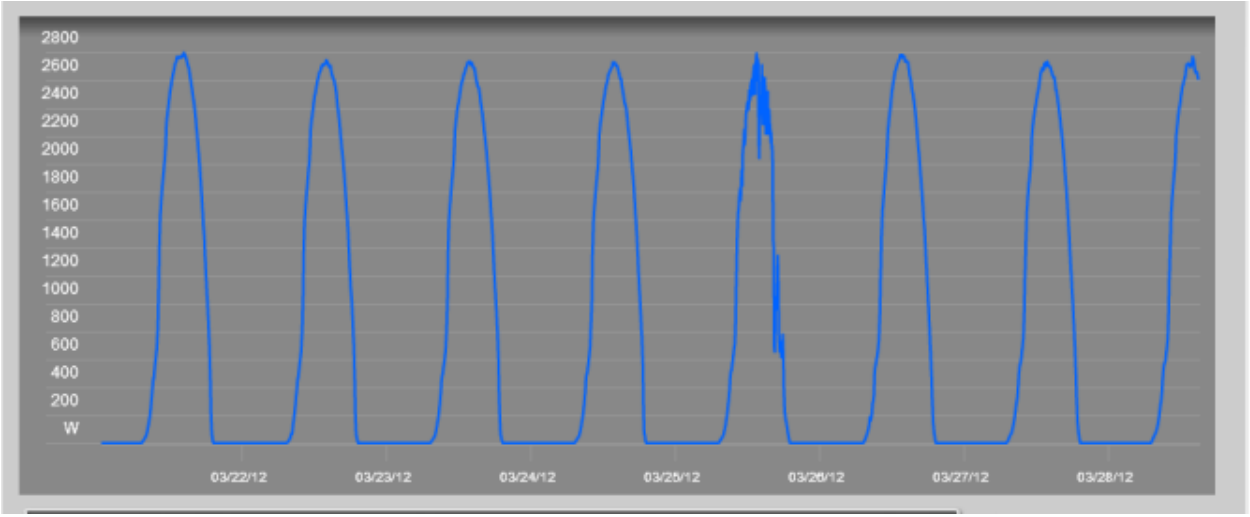
M175 Enphase microinverter with 200 W module

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

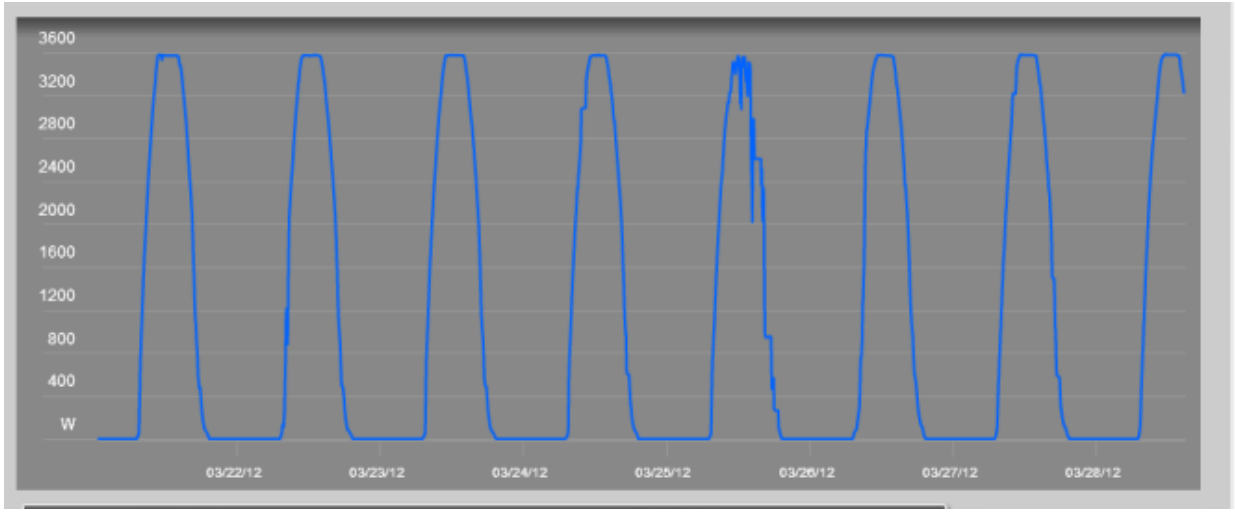


- With my 200 W modules:
  - 175 W microinverters predicted to produce 5,232 kWh
  - 200 W microinverters predicted to produce 5,225 kWh

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