SAND2011-6208C

Solar Fiesta! 2011

Albuquerque Academy, August 27, 2011

Residential Photovoltaic System with Microinverters: A Case Study of the First Three Years

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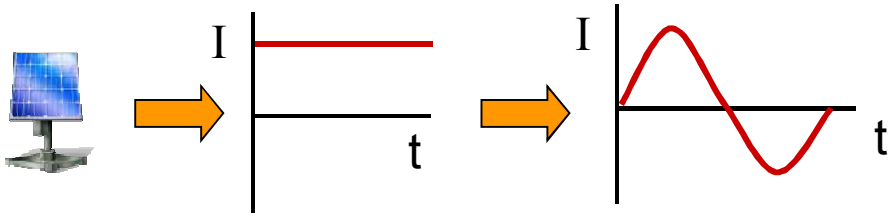
Overview

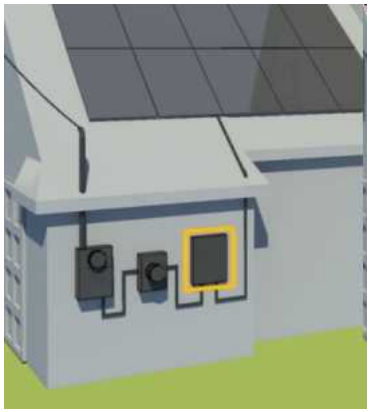
- Introduction
- Installation, Operation, and Features
- Energy Production and Costs
- Conclusions

Introduction

- **What is an inverter?**
  - Converts DC output from PV modules to AC electricity



- **Central (string) inverter**
  - Connected to multiple PV modules



- **Microinverter**
  - Connected to a single PV module

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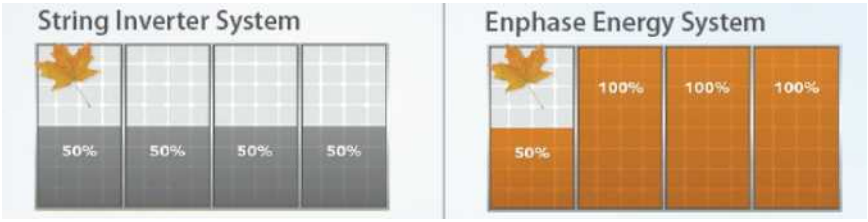
Pros and Cons of Microinverters
(claims made relative to central inverters)



Enphase.com

- **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 module)

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Which one did I choose?

1st Residential PV System in New Mexico with Enphase Microinverters

- **3 kW PV installed by Sunergy (now CleanSwitch) in 2008**
- **15 modules**
  - 200 W Sanyo HIP- 200BA3
  - Oriented 22 degrees west of true south
  - Tilt ~27 deg (top array), ~30 deg (bottom array)
- **Enphase Microinverter**
  - 200 W (M200-32-240)
  - 15 year warranty

Cliff's House on Google Maps

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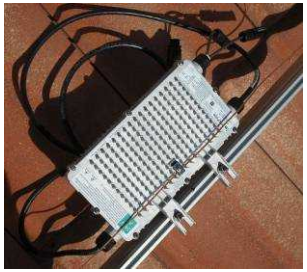
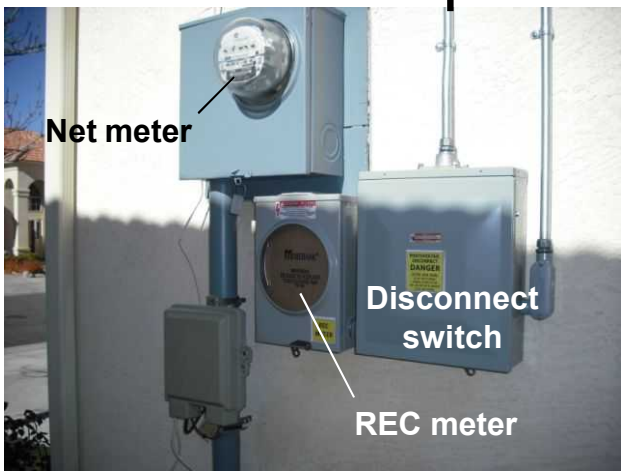
Installation
(Oct – Dec 2008)





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Operation & Monitoring

1 Enphase Micro-inverter system
- installed on the racking beneath each solar module
- maximizes energy harvest

2 AC power is sent via AC wiring to the load center
- performance data is also sent via the AC wiring
- plug and play communications

3 Envoy Communications Gateway
- plugs into any AC outlet
- collects information via the AC wiring
- transmits data through a standard ethernet router to the internet

4 Standard Ethernet Router
- information collected by Enphase Envoy is then transmitted to Enlighten in 5-minute intervals

5 Enphase Enlighten Monitoring
- provides moniforing and analysis
- performance information can be viewed from any web browser

from Enphase.com

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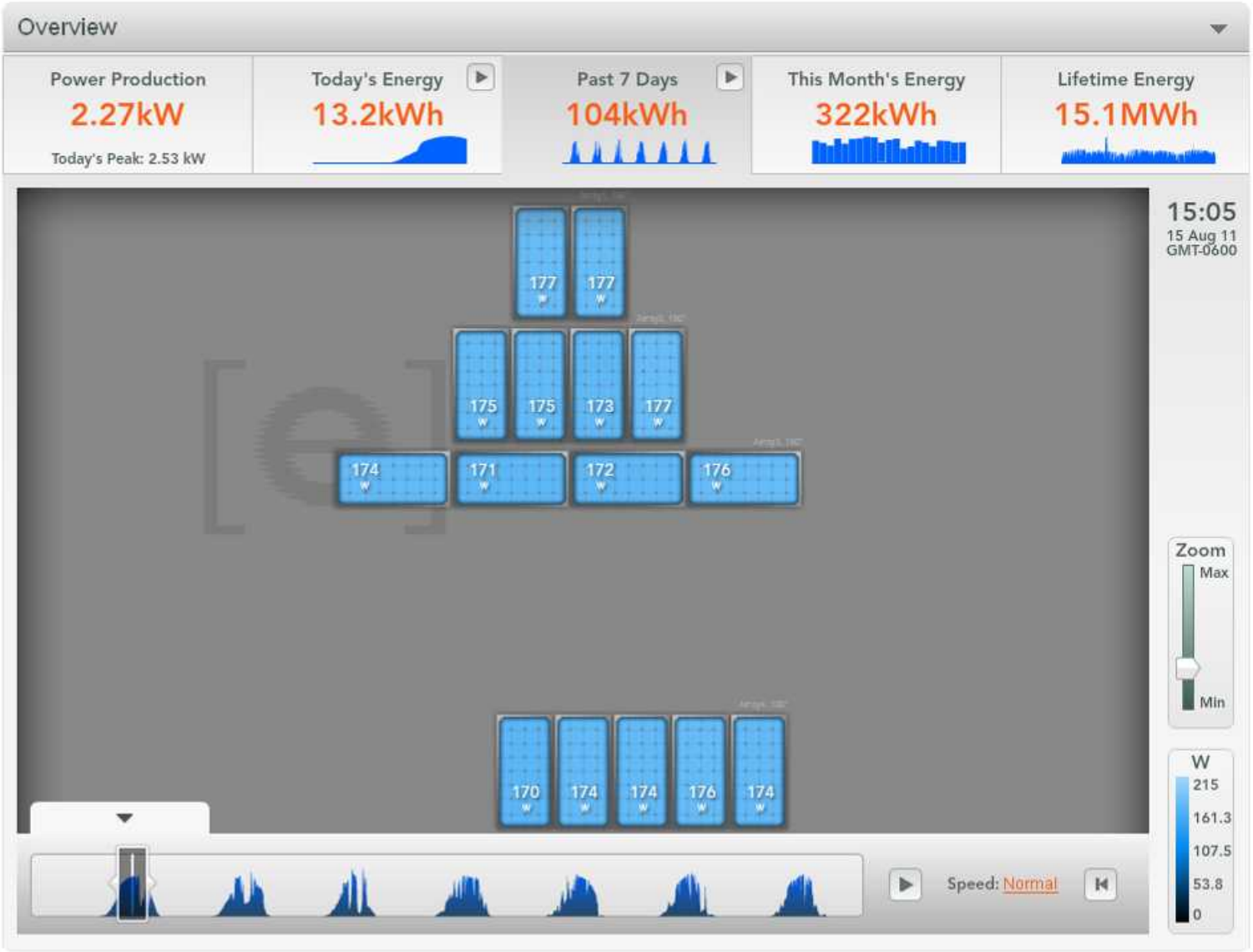
Website Monitoring
(Enphase Enlighten)



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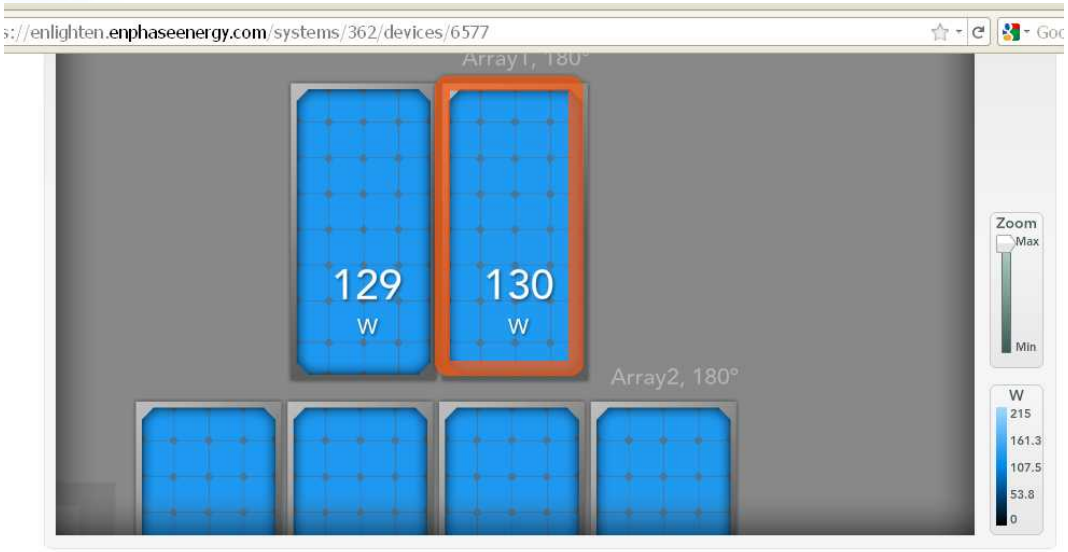
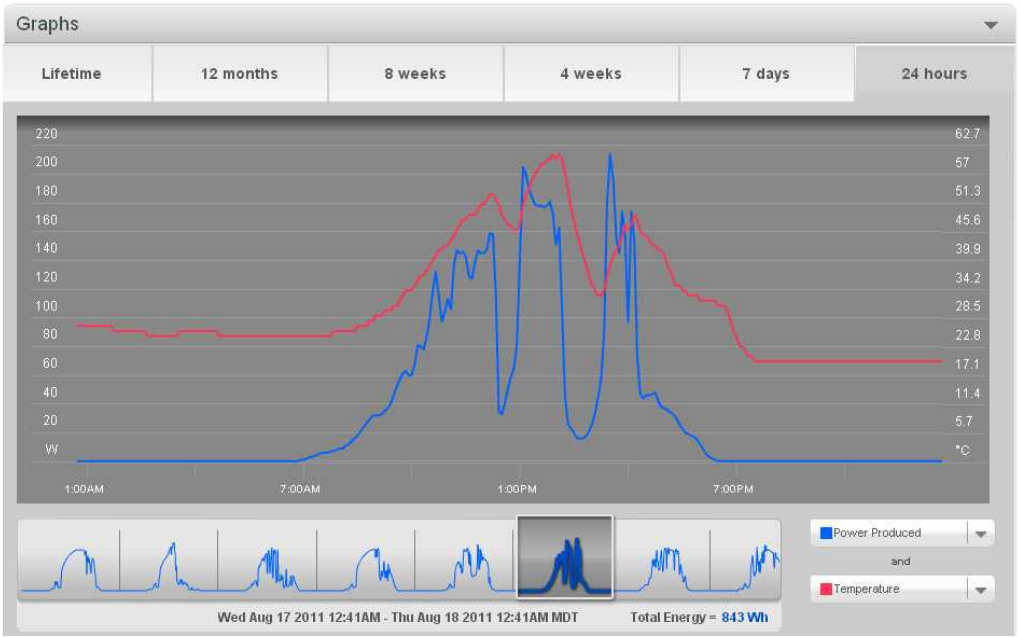
Monitoring of Individual Modules





- Energy production
- DC current
- DC voltage
- Temperature

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Impact of Shading

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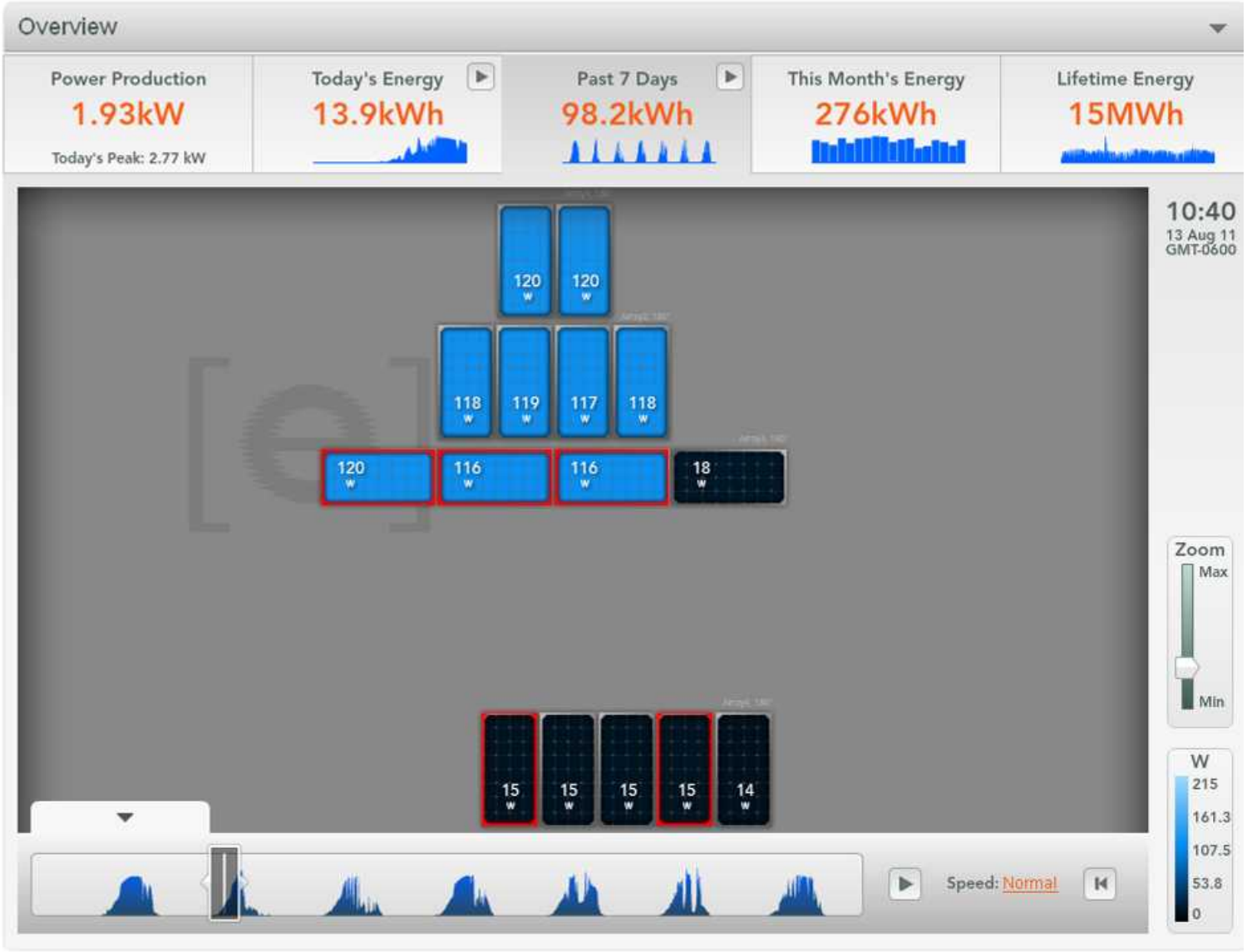
Module Performance During Partial Shading



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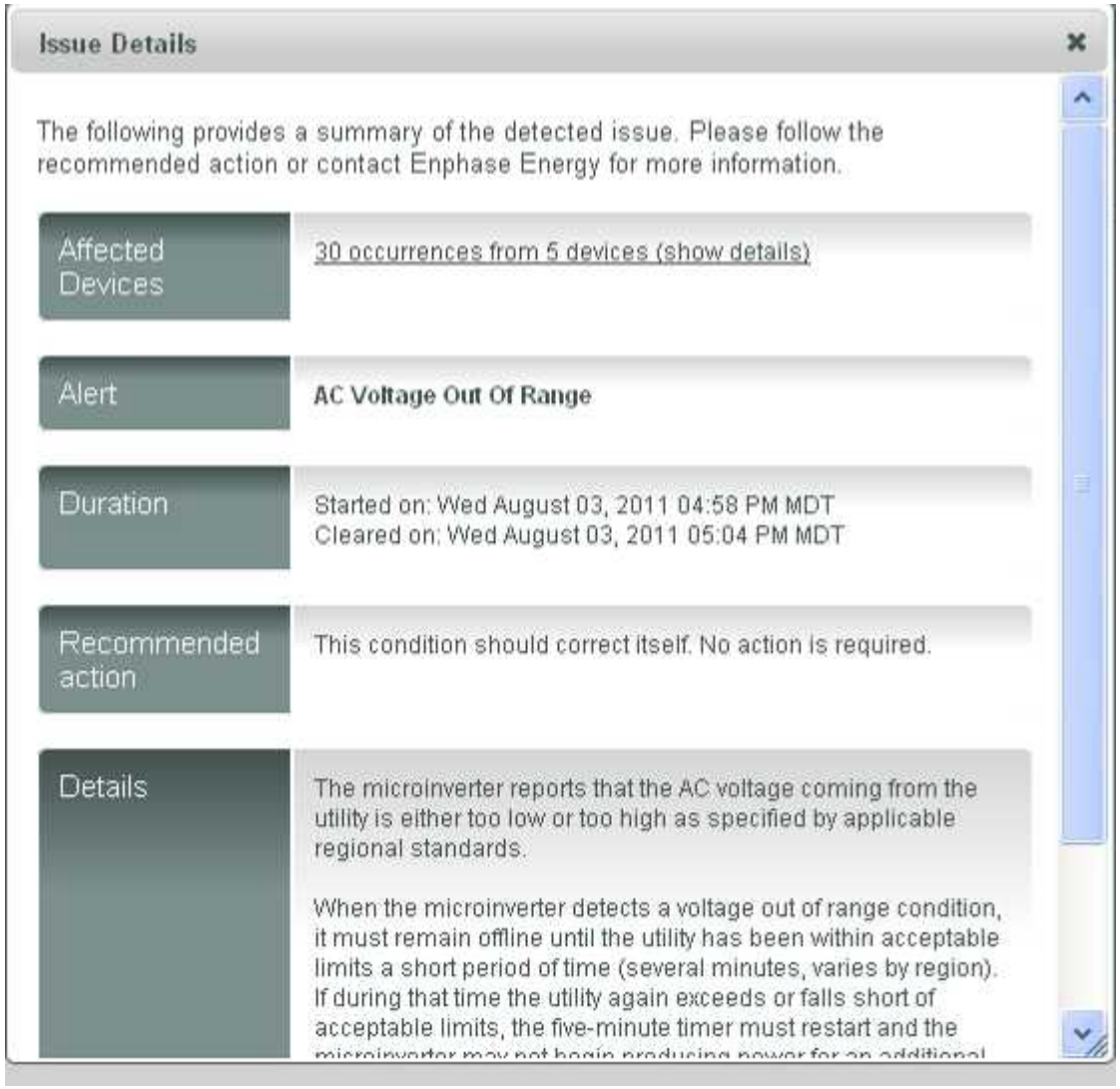
Error Alerts



- **Automated e-mail alerts**
  - Some are self-correcting
  - Several I had to call Enphase to remotely fix

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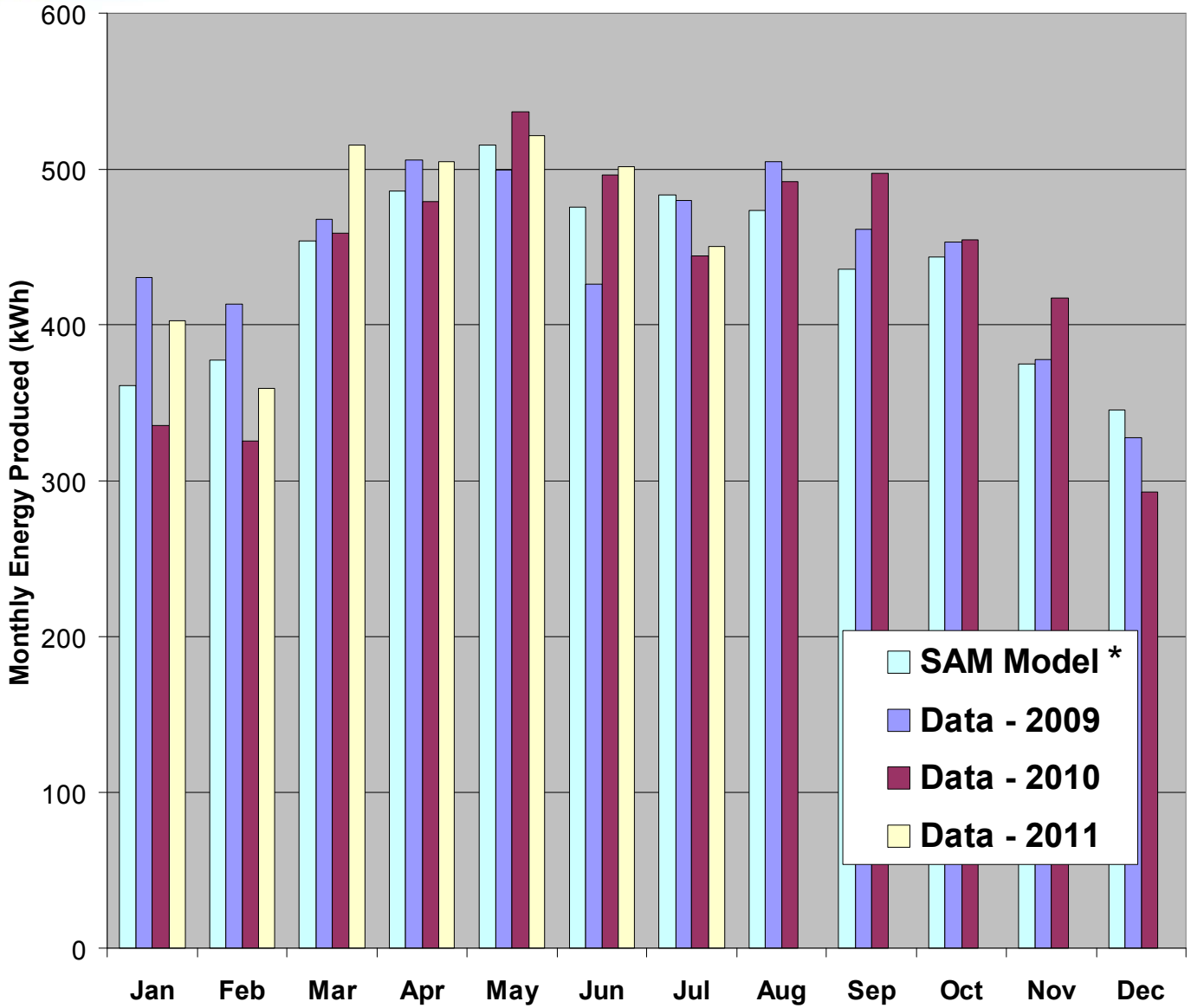
Monthly Energy Production



*SAM is free software from NREL (Google "System Advisor Model")

My model assumes no shading

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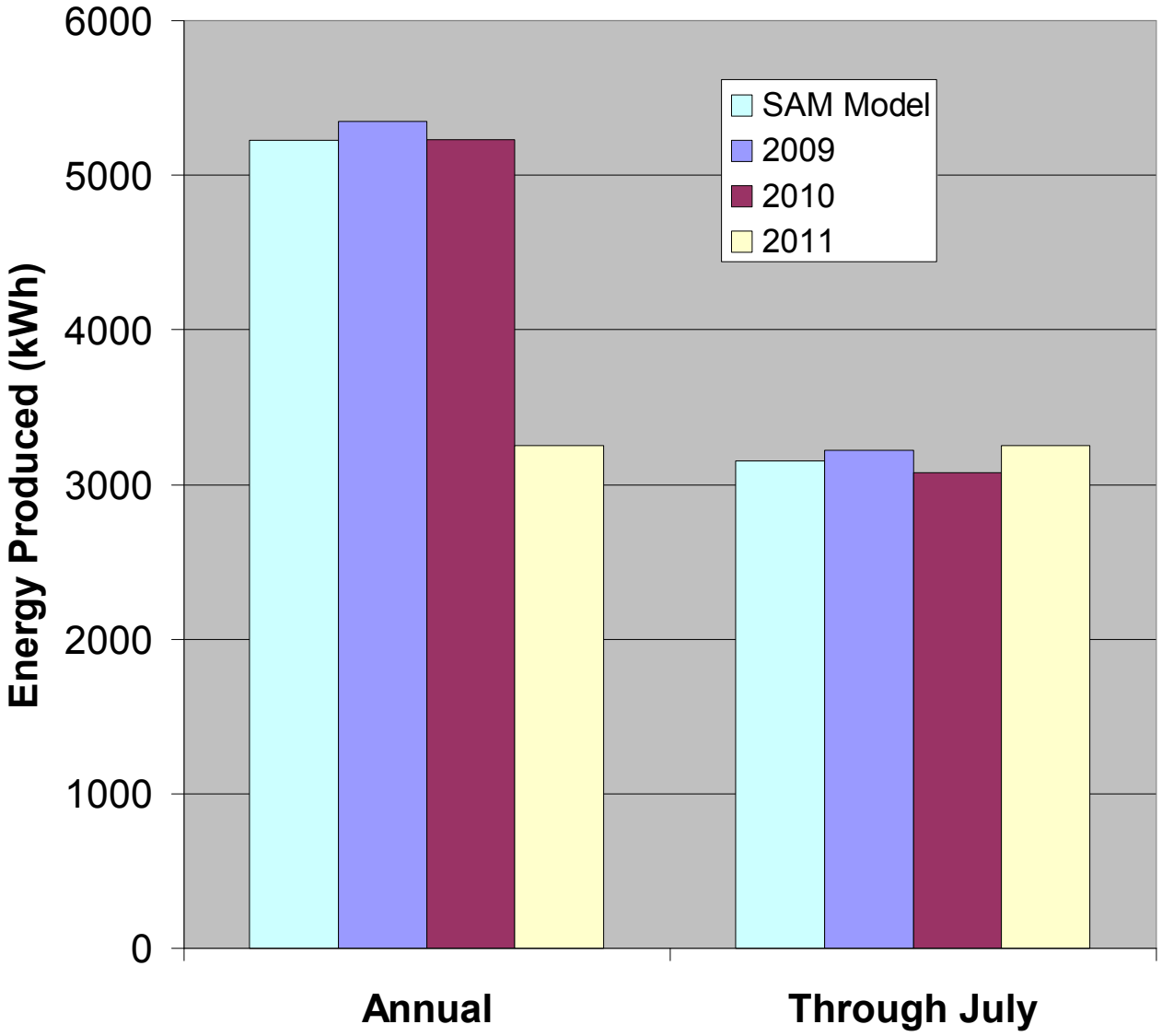
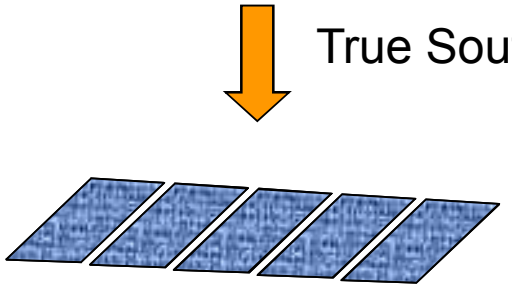
Annual Energy Production



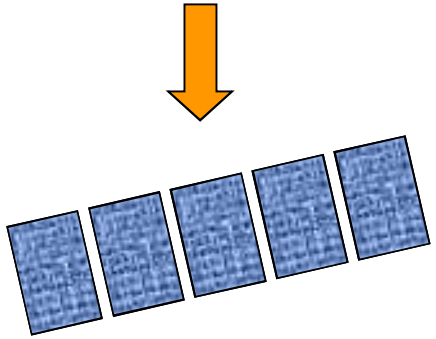
Difficult to assess if system degradation is occurring (variability in annual irradiance, temperature, rain, etc.)

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)

Costs and Revenue

Costs and PNM Payments

- **PNM pays me 13 cents for every kWh generated by my system**
  - My 3 kW system produces ~450 kWh/month
  - I receive ~$60/month from PNM (~$700/year)
- **We use about 5,000 kWh per year**
  - PV production has been greater than our use
  - So we save 5,000 kWh x $0.08/kWh = $400/year
- **Total cost of our system was ~$23,000 after tax credits**
  - It will take $23,000 ÷ $1,100/year = 21 years to recover costs
- **Current cost for similar systems is nearly half of what I paid in 2008**
  - ~$5 – $6/W vs. ~$10/W (before tax credits)
  - My levelized cost of electricity (LCOE) was ~$0.30/kWh
    - DOE SunShot goal is $1/W or ~$0.06/kWh

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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

Conclusions

- **No major issues with my 3 kW system after nearly 3 years**
  - Received several automated e-mail alerts
  - Web-based monitoring is very informative
- **Energy production comparable to model predictions (assuming no shading)**
  - Only a few percent lower than optimized configuration
- **Costs have come down significantly**
  - Current installed costs are nearly half of what I paid in 2008