

# Solar Energy Keynote Lecture

John A. Swanson  
Electric Power Industry Conference  
University of Pittsburgh  
November 12, 2012

# Energy Overview

- The next set of slides is to give an overall introduction to the energy landscape
- It leads down to my focus area, residential PV power

# Engineering's Grand Challenges (NAE)

- **Make solar energy economical**
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- **Provide access to clean water (Solar RO?)**
- Restore and improve urban infrastructure
- Advance health Informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Advance personalized learning
- Engineer the tools of scientific discovery

# Energy Map

- Energy
  - Mobile
    - Gasoline, CNG, Jet Fuel, Hybrids, Electric Vehicles
    - Sunlight + Carbon Dioxide + Water + algae = ethanol?
  - Stationary
    - Fossil Fuels
      - Coal, Natural Gas, Oil
    - Nuclear
    - **Renewable**

# Renewable Energy

- Hydroelectric
  - Most sites used
  - Available on demand
- Geothermal
  - Power generation
    - Available on demand
  - Residential heating/cooling
    - Energy storage
- Waves
- Wind
- **Solar**

# Solar Electric Energy

- Utility Scale
  - 10 Mw to 10 Gw
  - PV
  - CSP
- Commercial
  - 20Kw to 10 Mw
  - Behind the meter
- **Residential**
  - **2 Kw to 20 kW**
  - **Behind the meter**

# Utility Scale Solar Power

- Utility
  - Photovoltaic farms (fields)
  - Concentrated Solar Power (CSP)
    - Direct Sun only (Southwest US)
    - Fresnel
    - Parabolic Troughs
    - Solar Towers (Spain)
    - Solar Chimney (Australia)

# Utility Scale PV Fields





# Fresnel Mirrors



# Parabolic Troughs



# Solar Towers



# Solar Chimney



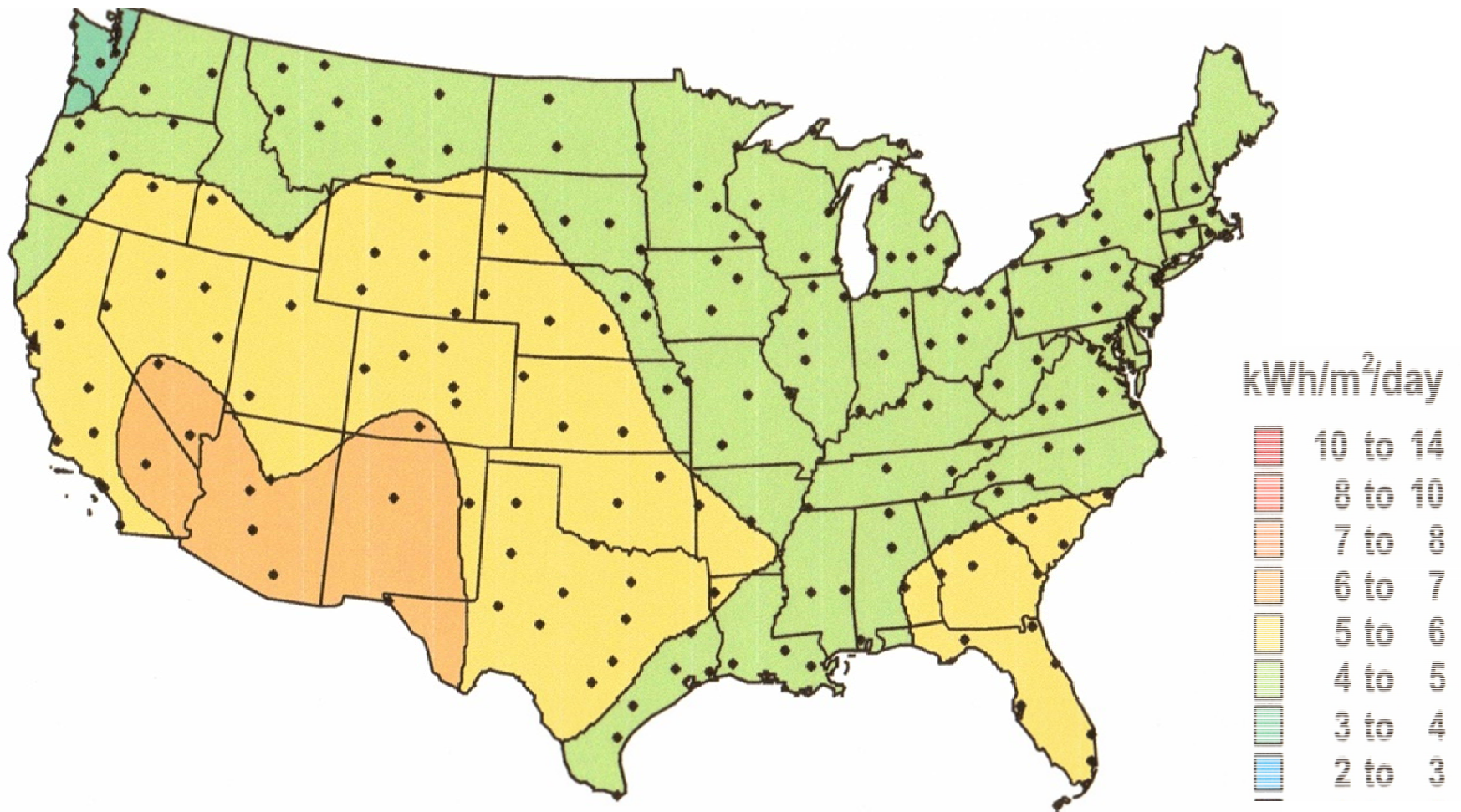
# Residential

- Residential
  - Light
    - Solar Tubes
  - Heat
    - Solar Pool Heating
    - Solar Hot Water
  - **Electricity**
    - **Solar Panels**

# The Sun

- Produces Light, Heat
- Pro:
  - Free
  - Widely available (especially in USA)
- Con:
  - Daytime only
  - Clouds
  - Jet trails

# Solar Distribution in the United States

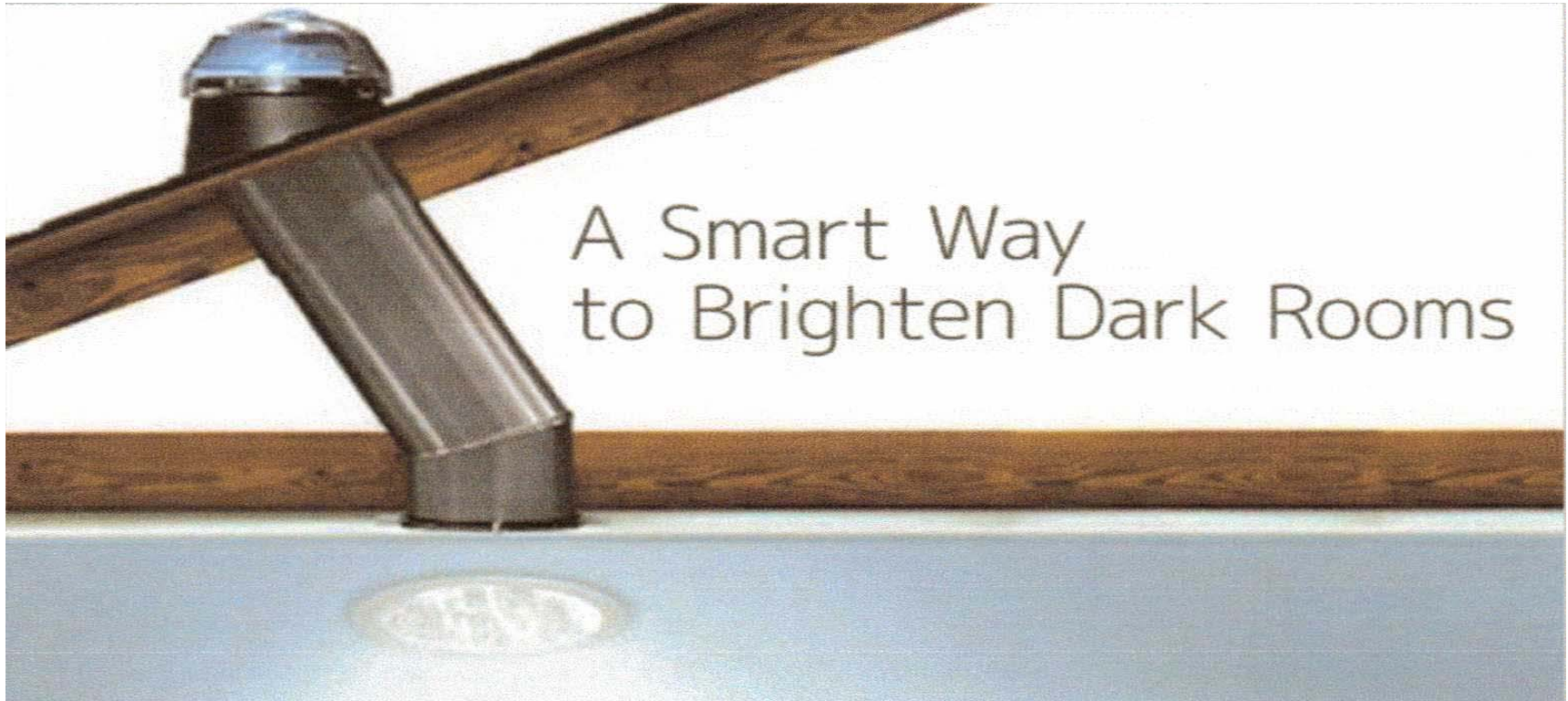


# Uses of Sun Power

- Sun Light
  - Clothes drying (not often anymore)
  - Solar Tubes
    - Interior light
    - Closets, Bathrooms, Large Rooms
- Sun Heat
  - Pool Heating
    - Heat stored in pool water
  - Solar Hot Water
    - Heat stored in large water tank



# Solar Tube



# Solar Hot Water (2) and PV (2)



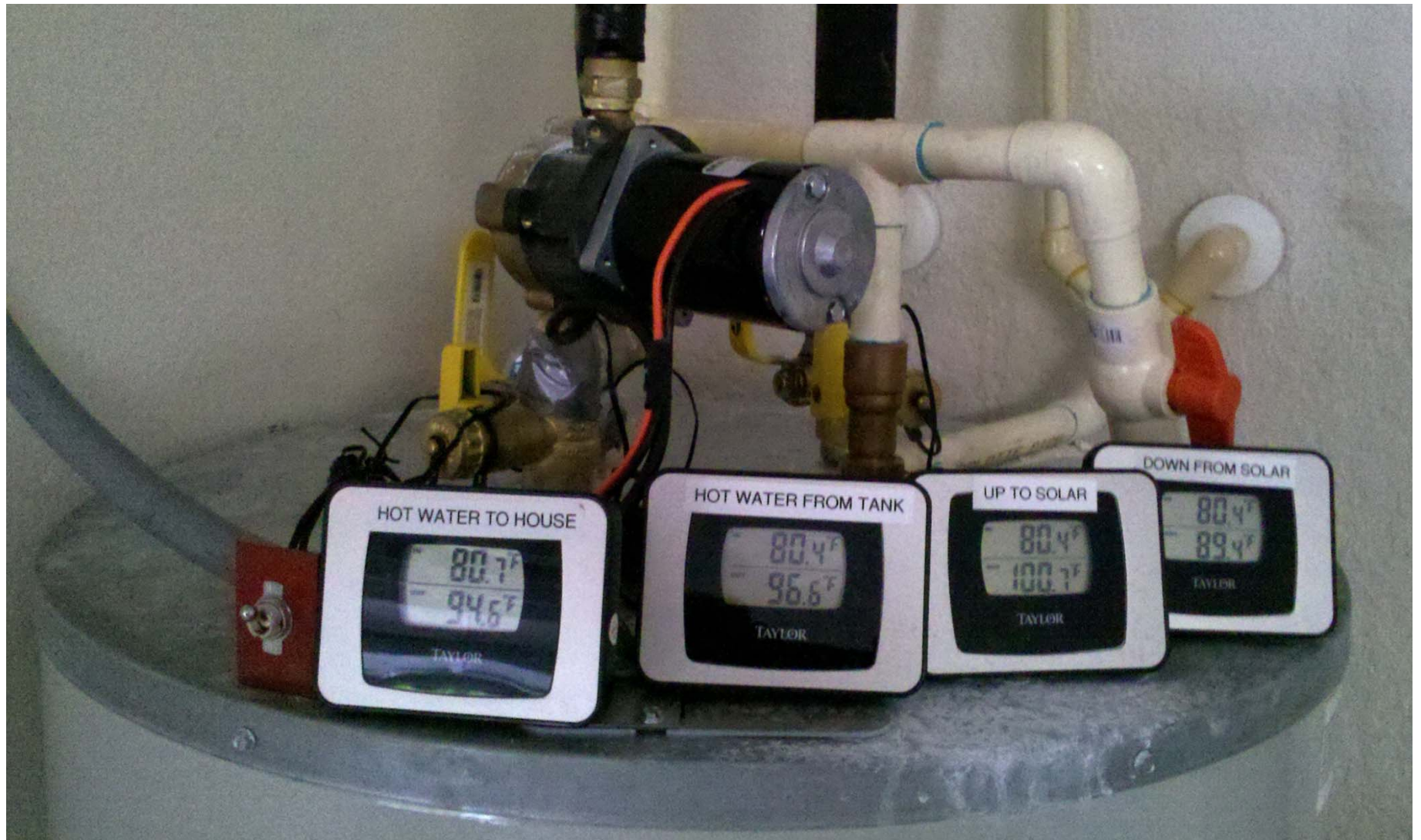
# My Solar Hot Water System

- Open Loop
  - Tank water circulates thru collector panels
  - Collector panels vent if temperature is too high
- Circulation by DC pump
  - Solar powered
  - Circulates when the sun shines

# Solar Hot Water Tank (80 gal)



# Solar Hot Water Tank (Data Collection)



# Solar Hot Water Cost (5/16/2012)

System with one collector      \$2,700 (sale)

Second collector                      500

New 80 gallon tank                      581

Tie to old electric tank (50 ft)      350

30 amp, 240 volt circuit              200

    Total                                      \$4,331

After 30% tax credit                      \$3,032

Pitt Project: Can this be done with solar panels more cheaply?

# Solar PV Hot Water Concept

**ENERGY LABS**

*"Energy for a changing world"*

*Introduces the...*

**World's Most Advanced Solar Water Heater**

[www.energylabsinc.com](http://www.energylabsinc.com)

**Say Goodbye to...** complicated plumbing installations

**Gone...** are multiple system failure points from collectors and balance of system components

**Gone...** are valves, roof flashings, pipes in the attic and chemical fluids

**Gone...** are all concerns about weather and freezing conditions

**Just pure, clean solar generated electricity providing energy for hot water**

*"Currently accepting Dealer applications"*

Tank by: **BRADFORD WHITE**

Powered by: **HELIOS**

SEIA SOLAR ENERGY INDUSTRY ASSOCIATION

All Components  
**MADE IN THE USA**

Available exclusively via Solar Energy Labs, LLC. 5191-A Shawland Rd. Jacksonville, FL 32254 904.693.4555

# Solar Hot Water Economics

Solar Hot Water Report		
80 Gallon System	Without Rebate	With Utility Rebate
System List Price	\$4,331	\$4,331
Federal Tax Credit (30%)	\$1,299	\$1,299
Utility Company Rebate	\$0	\$1,000
Net Cost	\$3,032	\$2,032
Average Yearly Savings (Est.)	\$300	\$300
SECO Electric Cost (per AC KWH)	0.11	0.11
Equivalent Yearly KWH	2730	2730
Return / Investment	9.90%	14.77%
Tax Bracket	28%	28%
After tax Annuity return	13.74%	20.51%



# Solar Electricity

- Wind
  - Produced by temperature differences
  - Not practical for residential areas
    - Tall towers
    - Noise
- Solar Panels (Photovoltaic) (PV)
  - Convert sunlight to electricity
  - Produce direct (steady) current

# PV Electric (5KW) and Solar Tubes



# Electric Only (5 KW)



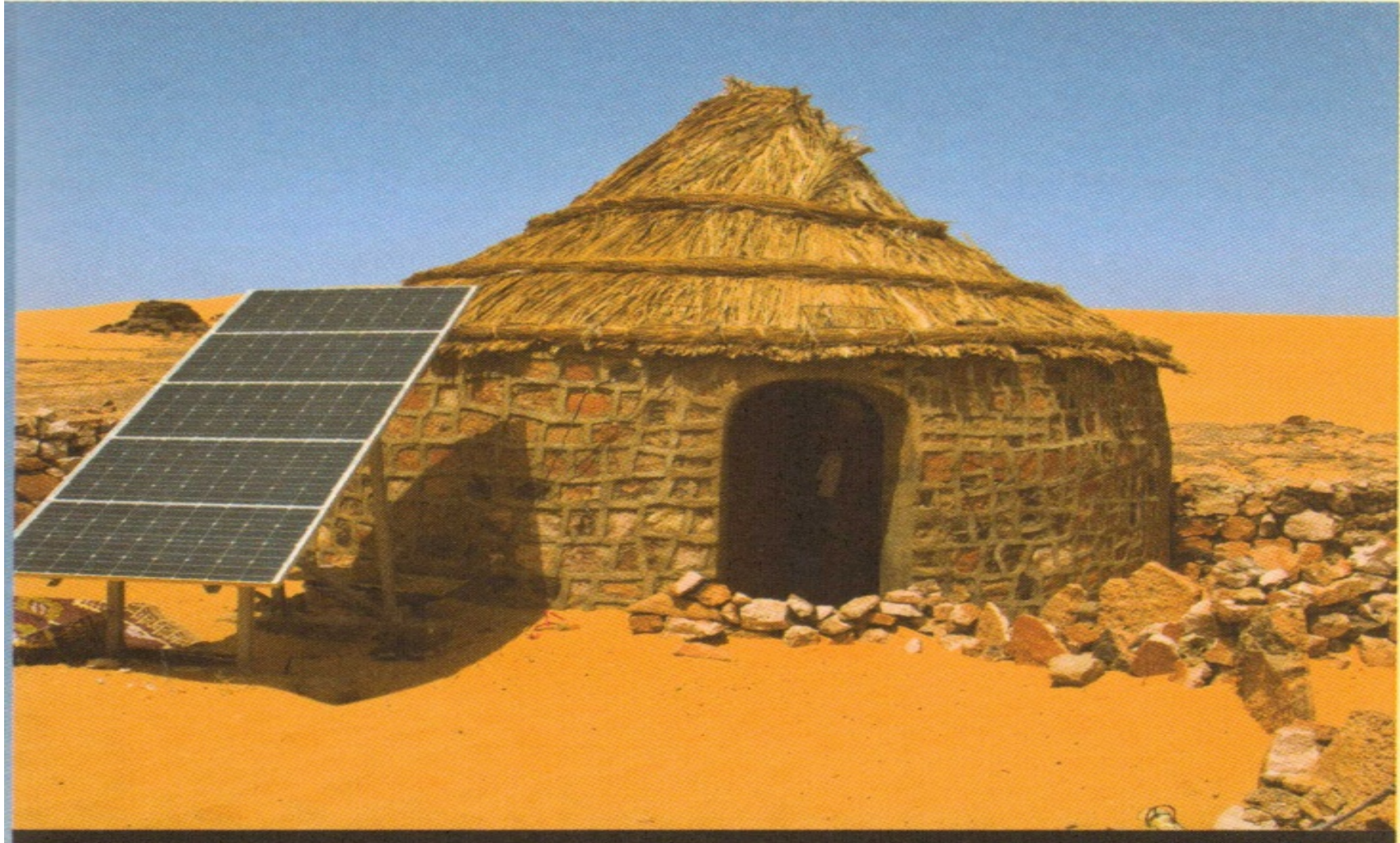
# Swanson Phase 2 (10 KW)



# Temple Shalom (37.6 KW)



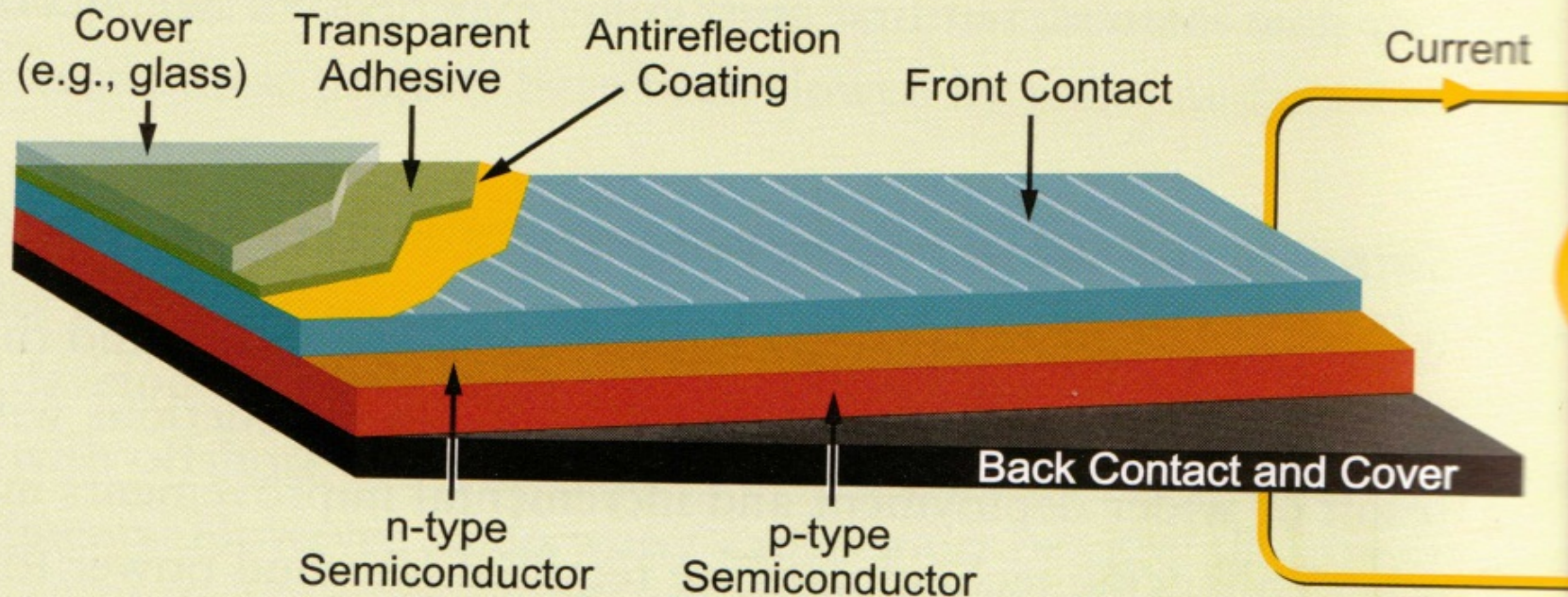
# A Far Out Application



# Solar Power System

- Solar Panels on roof
  - South facing sloped roof is best
  - Tilted panels on flat roof
  - East, West have slightly lower generation (85-90%)
  - North is not recommended
- Inverter
  - Converts DC (Direct Current) from panels to AC (Alternating Current) to match utility power
- External Disconnect
  - To protect utility workers

# PV Solar Cell Basics



$$\text{Solar Cell Efficiency (\%)} = \frac{\text{Power Out (W)} \times 100\%}{\text{Area (m}^2\text{)} \times 1000 \text{ W/m}^2}$$

**10% Efficiency = 100 W/m<sup>2</sup> or 10 W/ft<sup>2</sup>**



# Size of PV Array

- Each panel is about 3 x 5 feet (1.0x1.6 m)
- Weight is about 42 pounds
  - Similar to 3/4 inch plywood
- Panel ratings from 200 to 275 watts
- 3.0 KW – 12 panels (250W) (220 sq ft)
- 5.0 KW – 20 panels (250W) (360 sq ft)
- 10.0 KW – 40 panels (250W) (720 sq ft)
- No moving parts
- Estimate approximately 2 watts per square foot
  - \$70 saving per month for 5 KW (per SECO)

# 5 KW Inverter



# Microinverters

- One inverter per panel
- Direct conversion to AC at point of generation
- Mounts on roof, directly under panel
- AC Cabling to disconnect switch and power panel
- Current price \$140 per panel
- \$2800 for 20 panel system
  - Vs about \$2000 for 5KW inverter
- Gives real time internet monitoring
- Automatic disconnect for power outages
- Good for locations with partial shading

# Microinverter



# Warranties

- Panels (typical)
  - 10 years at 90% of rating
  - 25 years at 80% of rating
- Inverters
  - 10 years standard, 15 and 20 years optional
- Enphase Microinverters
  - 15 years
  - Now 25 years (M215 model)

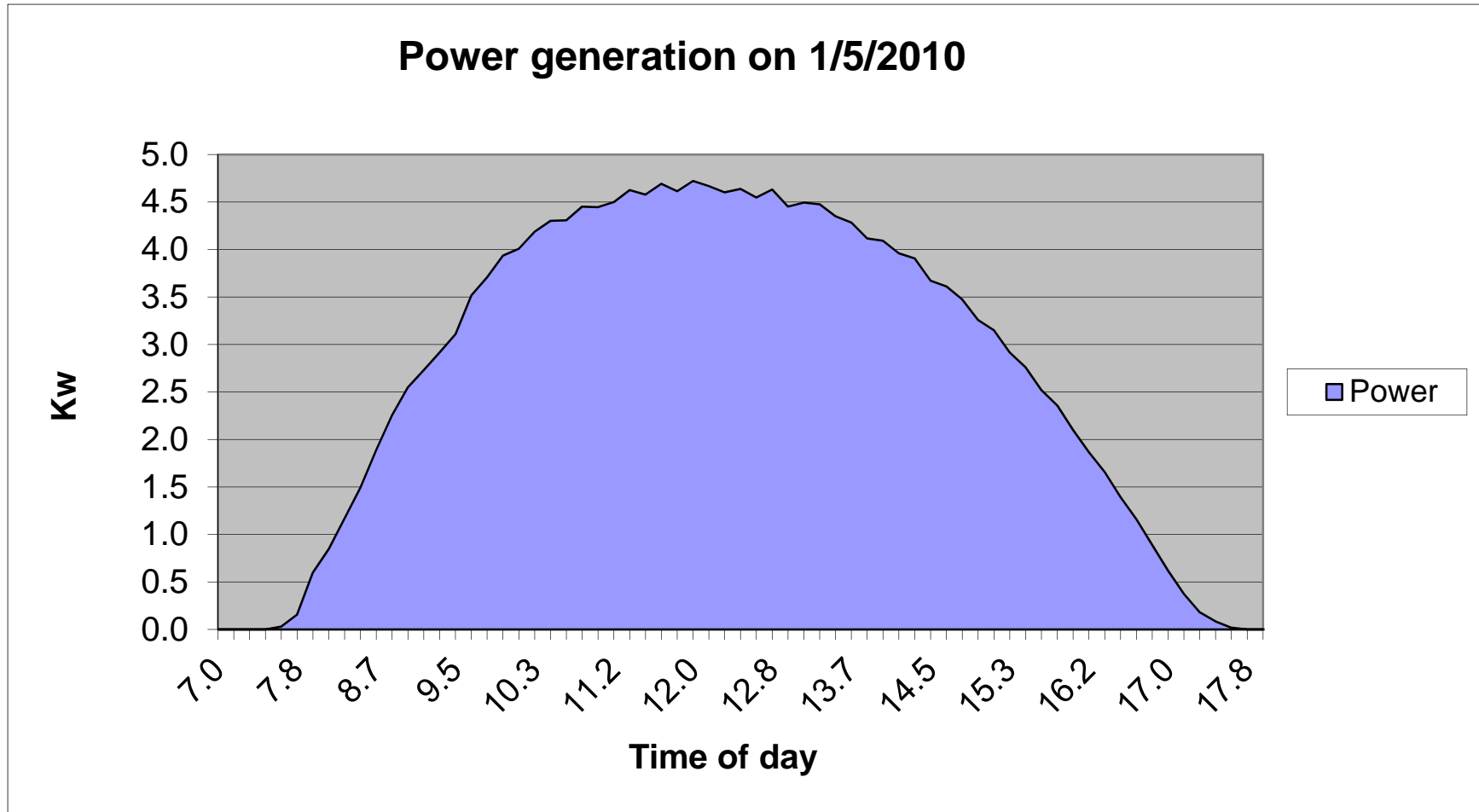
# Meter and Disconnect Switch



# December Meter Readings

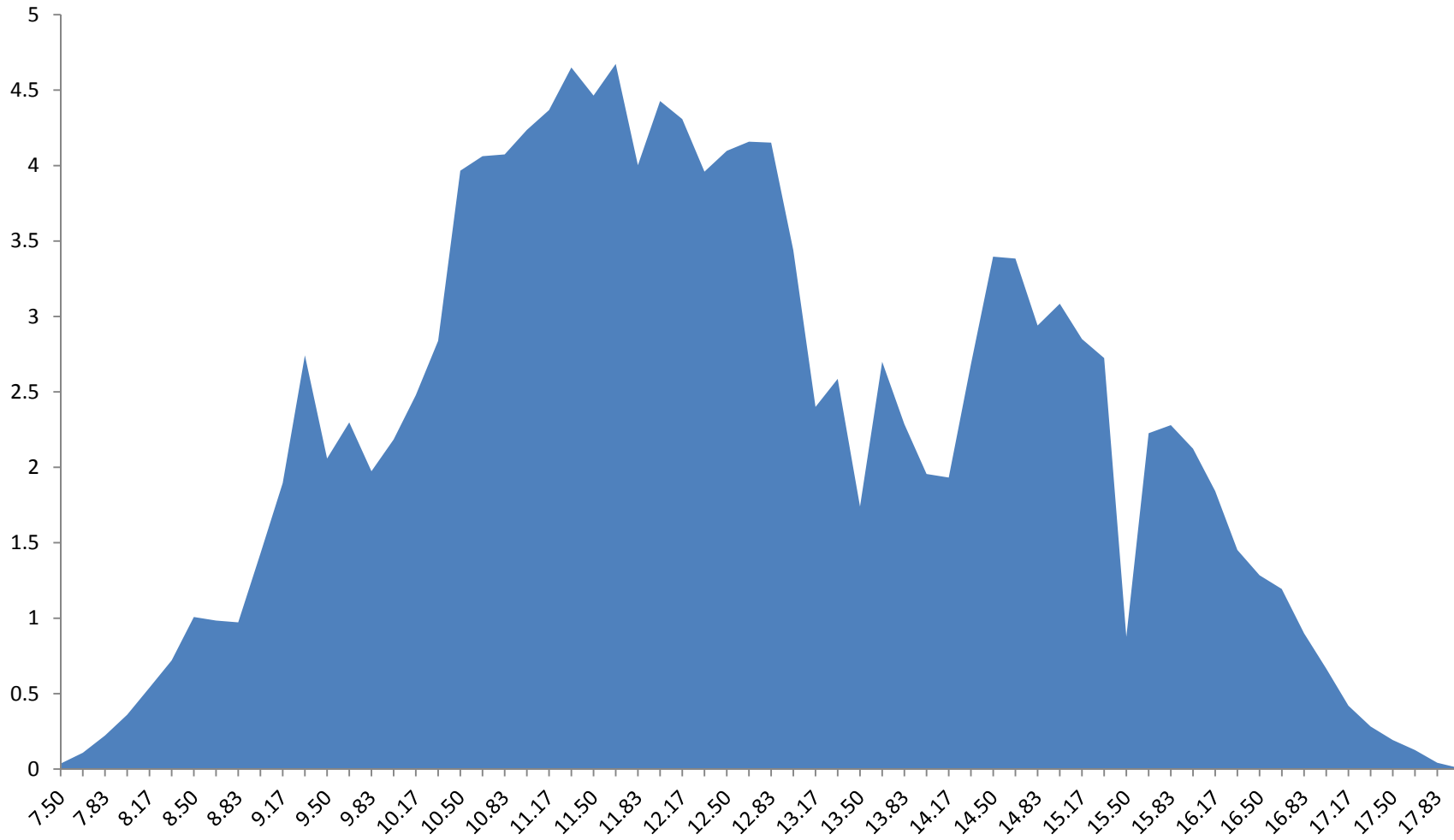
- RES NET BILL KWH USED 920
  - Power bought from the power company
- RES NET BILL KWH GENERATED 357
  - Power sent to the power company
- Notice that this does NOT indicate the amount of power generated or used

# A Beautiful Day in The Villages

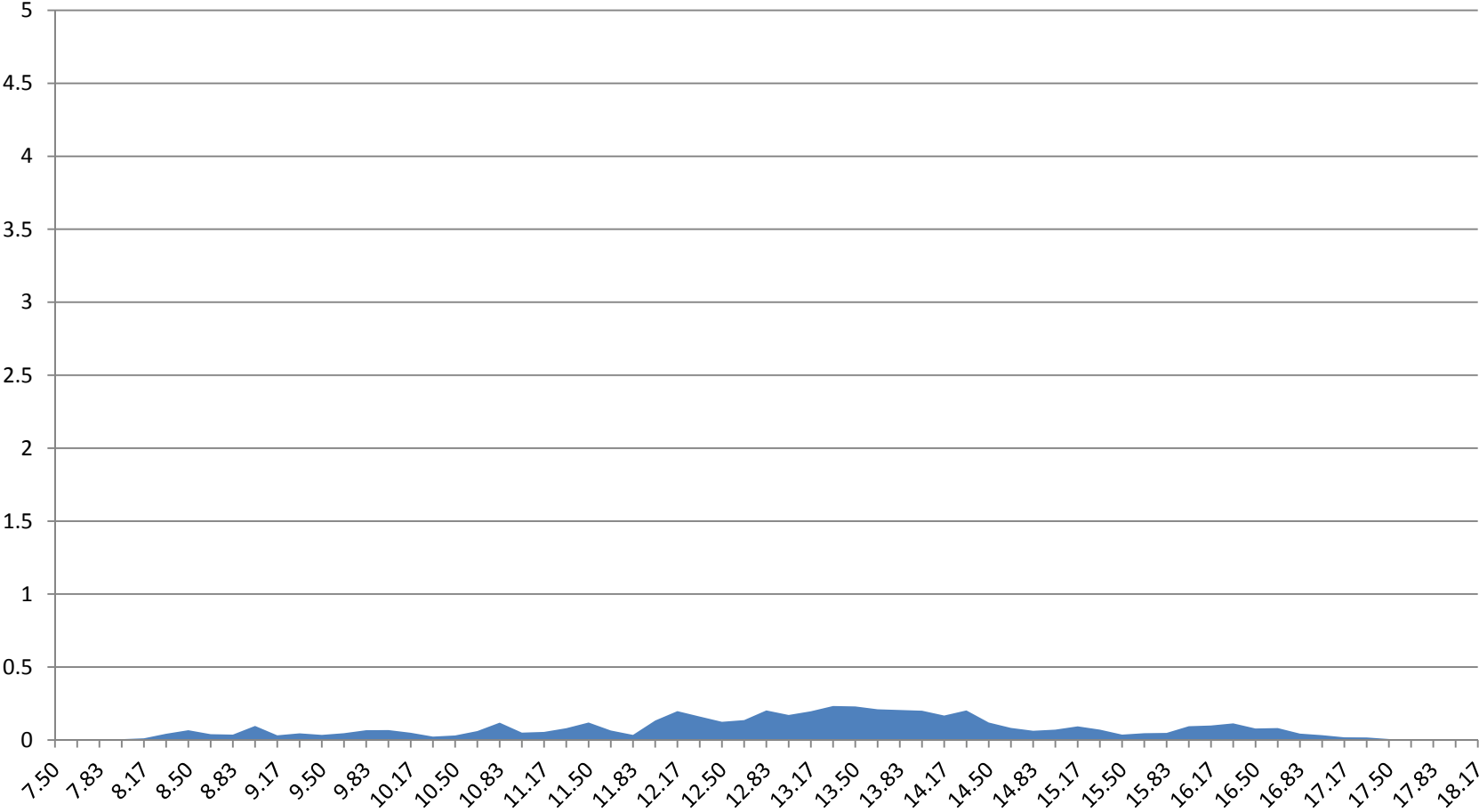




# Not so beautiful day



# Really Bad Day



# Oct 2009 Economics for 5 Kw System

<b>Swanson House Solar Power Report</b>		
	<b>System</b>	
	<b>1</b>	<b>5 KW</b>
<b>Installation Date</b>	<b>October 2009</b>	
<b>System List Price</b>		<b>\$41,500</b>
<b>Federal Tax Credit (30%)</b>	<b>\$12,450</b>	
<b>Florida Solar Rebate (Pro rata)</b>	<b>\$10,437</b>	
<b>Net Cost</b>		<b>\$18,613</b>
<b>Average Yearly Generation (KWH)</b>		<b>8,795</b>
<b>DC-AC Conversion Efficiency (est.)</b>		<b>0.90</b>
<b>SECO Electric Charge (per KWH)</b>		<b>\$0.11</b>
<b>Average Yearly Savings</b>		<b>\$869</b>
<b>Return / Investment</b>		<b>4.7%</b>
<b>Tax Bracket</b>		<b>35%</b>
<b>After tax Annuity</b>		<b>7.2%</b>

# January 2012 Economics for 5KW

	System 1	5KW	System 2	5KW
	October 2009		January 2012	
System List Price		\$41,500		\$15,000
Federal Tax Credit (30%)	\$12,450		\$4,500	
State Solar Rebate	\$10,437		\$0	
Utility Solar Rebate	\$0		\$0	
Net Cost		\$18,613		\$10,500
Average Yearly DC Generation (KWH)		8795		8795
DC-AC Conversion Efficiency (est.)		0.90		0.90
SECO Total Cost (per AC KWH)		0.11		0.11
Average Yearly Savings		\$869		\$869
Return / Investment		4.67%		8.27%
Tax Bracket		28%		28%
After tax Annuity return		6.48%		11.49%

# Dec 2012 Quantity Economics for 5KW System

Swanson House Solar Power Report							
	System 1	5KW		System 2	5KW	Quantity	5KW
Installation Date	October 2009			January 2012		Dec 2012	
System List Price		\$41,500			\$14,500		\$12,500
Federal Tax Credit (30%)	\$12,450			\$4,350		\$3,750	
Florida Solar Rebate	\$10,437			\$0		\$0	
Net Cost		\$18,613			\$10,150		\$8,750
Average Yearly Generation		8,795			8,795		8,795
DC-AC Conversion Efficiency (est.)		0.90			0.90		0.90
SECO Electric Charge (per KWH)		\$0.11			\$0.11		\$0.11
Average Yearly Savings		\$869			\$869		\$869
Return / Investment		4.7%			8.6%		9.9%
Tax Bracket		35%			35%		35%
After tax Annuity		7.2%			13.2%		15.3%

# What Happens with Aggressive Support?

	System 1	5KW	System 2	5KW	Louisiana	5KW	Progress	5KW
	October 2009		January 2012		Aug 2012		Oct 2012	
<b>System List Price</b>		\$41,500		\$15,000		\$15,000		\$15,000
<b>Federal Tax Credit (30%)</b>	\$12,450		\$4,500		\$4,500		\$4,500	
<b>State Solar Rebate</b>	\$10,437		\$0		\$7,500		0	
<b>Utility Solar Rebate</b>	\$0		\$0		\$0		\$10,000	
<b>Net Cost</b>		\$18,613		\$10,500		\$3,000		\$500
<b>Average Yearly DC Generation (KWH)</b>		8795		8795		8795		8795
<b>DC-AC Conversion Efficiency (est.)</b>		0.90		0.90		0.90		0.90
<b>SECO Total Cost (per AC KWH)</b>		0.11		0.11		0.11		0.11
<b>Average Yearly Savings</b>		\$869		\$869		\$869		\$869
<b>Return / Investment</b>		4.67%		8.27%		28.96%		173.75%
<b>Tax Bracket</b>		28%		28%		28%		28%
<b>After tax Annuity return</b>		6.48%		11.49%		40.22%		241.32%

# In Perspective

- Current price is about \$3.00 per watt
  - This is a sloped shingled roof installation
  - A flat roof installation can be done for about \$4.00
- Data from SunShot Vision Study (Feb 2012)

Table 1-1. Benchmarked 2010 Solar Prices and Projected 2020 Solar Prices  
(2010\$/W)

Technology/Market	Benchmark 2010 Price	Reference 2020 Price	SunShot 2020 Price
Utility-Scale PV (\$/W <sub>DC</sub> )	4.00	2.51	1.00
Commercial Rooftop PV (\$/W <sub>DC</sub> )	5.00	3.36	1.25
Residential Rooftop PV (\$/W <sub>DC</sub> )	6.00	3.78	1.50
CSP (\$/W <sub>AC</sub> )	7.20 <sup>a</sup>	6.64 <sup>a</sup>	3.60 <sup>b</sup>

<sup>a</sup> CSP system with 6 hours of thermal storage

<sup>b</sup> CSP system with 14 hours of thermal storage

# Why Large Drop in Prices?

- Solar Panels from \$5.00 per watt to \$1.00
  - China has made large investment
    - Is this dumping? Will tariffs be added?
    - Major opportunity for United States
      - 25 years of free energy at bargain price
      - Lots of jobs installing systems
      - Rare materials are from China (indium, selenium)
    - If tariffs added, will production move to Mexico?
- Inverters only minor drop in price
  - Not as much competition
- Installation only minor drop
  - Multiple installations will help

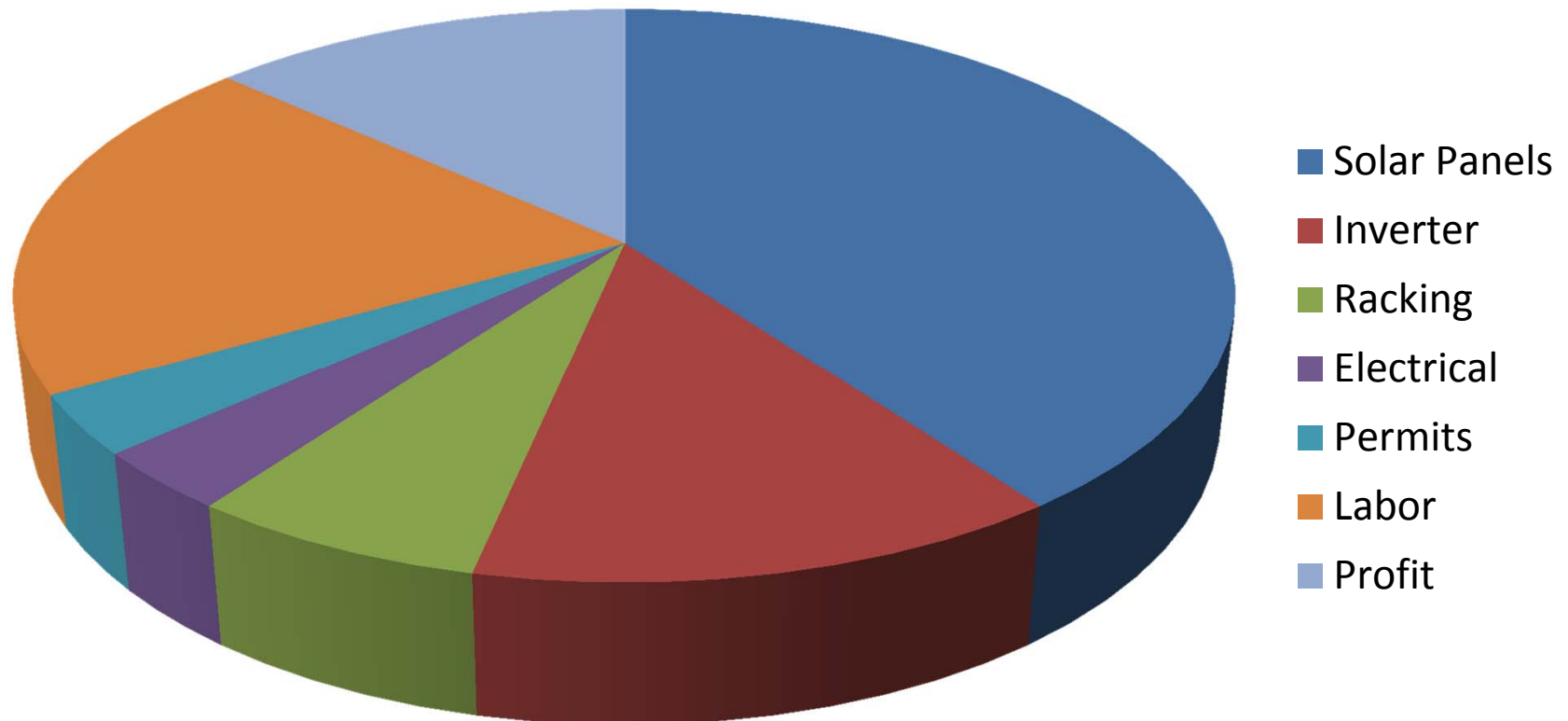


# If the Tariff holds at 250%

<b>Swanson House Solar Power Report</b>							
	<b>System 1</b>	<b>5KW</b>		<b>System 2</b>	<b>5KW</b>	<b>250% Tariff</b>	<b>5KW</b>
<b>Installation Date</b>	<b>October 2009</b>			<b>January 2012</b>		<b>January 2013</b>	
<b>System List Price</b>		<b>\$41,500</b>			<b>\$14,500</b>		<b>\$22,500</b>
<b>Federal Tax Credit (30%)</b>	<b>\$12,450</b>			<b>\$4,350</b>		<b>\$6,750</b>	
<b>Florida Solar Rebate</b>	<b>\$10,437</b>			<b>\$0</b>		<b>\$0</b>	
<b>Net Cost</b>		<b>\$18,613</b>			<b>\$10,150</b>		<b>\$15,750</b>
<b>Average Yearly Generation</b>		<b>8,795</b>			<b>8,795</b>		<b>8,795</b>
<b>DC-AC Conversion Efficiency (est.)</b>		<b>0.90</b>			<b>0.90</b>		<b>0.90</b>
<b>SECO Electric Charge (per KWH)</b>		<b>\$0.11</b>			<b>\$0.11</b>		<b>\$0.11</b>
<b>Average Yearly Savings</b>		<b>\$869</b>			<b>\$869</b>		<b>\$869</b>
<b>Return / Investment</b>		<b>4.7%</b>			<b>8.6%</b>		<b>5.5%</b>
<b>Tax Bracket</b>		<b>35%</b>			<b>35%</b>		<b>35%</b>
<b>After tax Annuity</b>		<b>7.2%</b>			<b>13.2%</b>		<b>8.5%</b>

# Breakdown of Current Price

5 KW Price



# What is Net Metering?

- If you are generating more than you need
  - Utility buys excess at current price
- If you need more than you are generating
  - You buy from utility at current price
- Eliminates the need for local storage
  - Batteries are expensive
- Net metering is the law in Florida
- “Behind the meter”
  - Priced at the meter, the highest electricity price

# Solar Assistance Programs

- Federal Tax Credit (30% to 2016)
- Rebates
  - State (not in Florida any more)
  - Local (none available)
- Renewable Portfolio Standard (RPS) (not in FL)
  - State set required renewable percentage
  - Creates Solar Renewable Energy Credits (SREC)
- Feed-in Tariff (FIT) (Local utility, rare)
  - Payment per Kwh produced for next xx years
- State sales tax exemption (yes in Florida)
- Property Tax Exemption (not in Florida)

# Advantages of PV Solar Power

- Produced at point of use
  - No utility network loads
  - No large distribution lines needed
- Environment effects
  - No CO<sub>2</sub> production
  - Reduces individual Carbon Footprint
- Improved United States energy independence
  - Zero fuel cost

# Other Factors

- How much will electric rates increase?
  - They only go up (Carbon charges?)
  - Compare with marginal (highest) electrical rate
    - Higher usage is not more expensive here
- How much will tax rates increase?
  - They only go up
- How does PV effect property value?
  - Appraisal's Journal showed \$20,000 increase for every \$1,000 per year saved in electricity
  - This is enough to pay for the system
  - Still valid with current system pricing?
- How about inflation?
  - Better to own things than money during inflation

# Top 10 States for PV (2011)

- California (542 Mw)
- New Jersey (313 Mw)
- Arizona (273 Mw)
- New Mexico (116 Mw)
- Colorado (91 Mw)
- Pennsylvania (88 Mw)
- New York (60 Mw)
- North Carolina (55 Mw)
- Texas (47 Mw)
- Nevada (44 Mw)
- Where is Florida, “The Solar Power State”

# What is Government Role Now?

- Federal
  - Maintain 30% credit until end of 2016
  - Ramp credit down until 2020
- State (FL)
  - Net metering (done in FL)
  - Enhance net metering for commercial installs
    - Buyback at residential rate (current marginal rate)
  - Sales tax exemption (done in FL)
  - Add Property tax exemption
  - Publicity and education
  - Disallow restrictive covenants (done in FL)



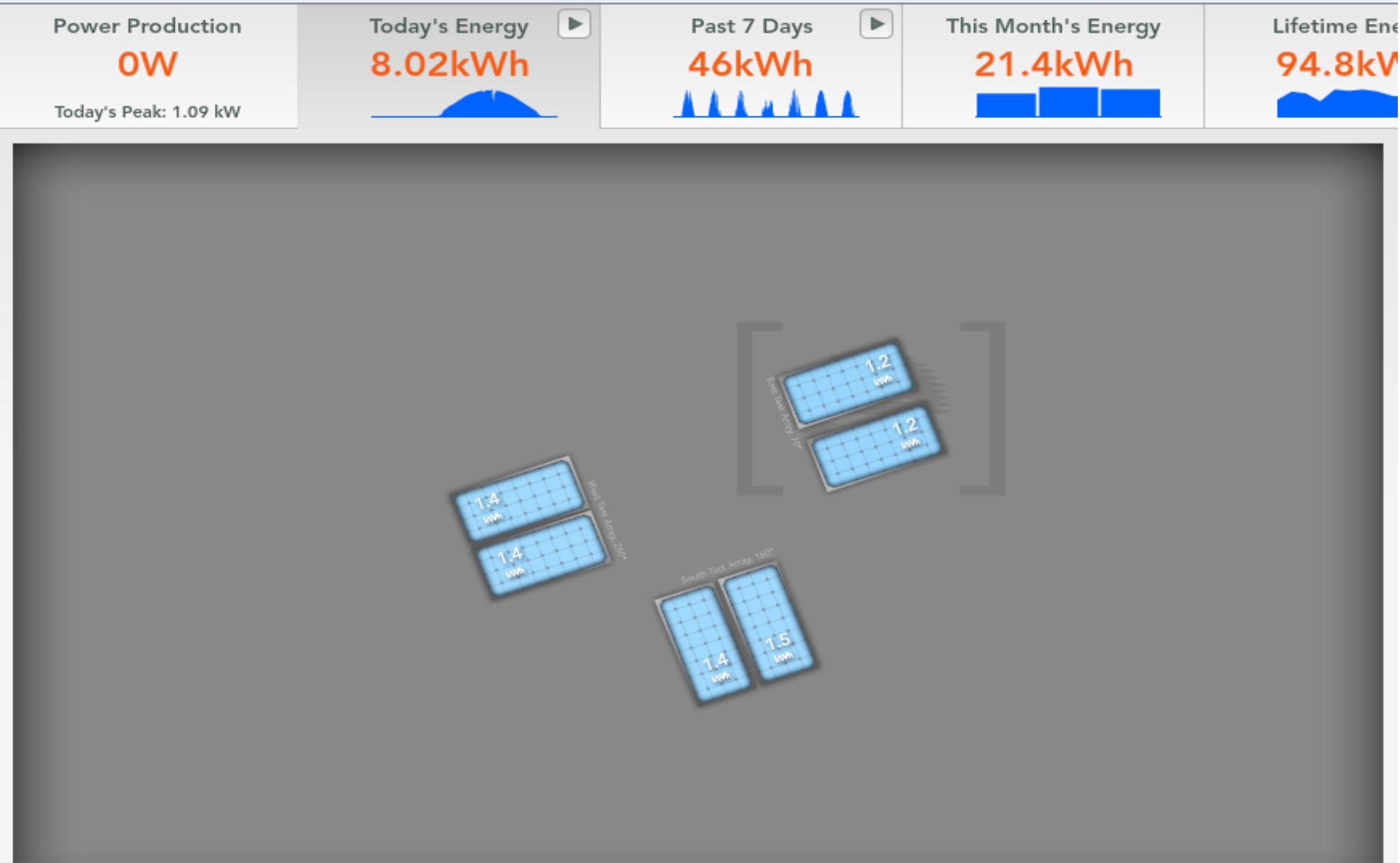
# Government Role (continued)

- Local Governments
  - Simplify licensing and inspections
    - Remote licensing over internet (reduce travel time)
    - Single final inspection, 2 hour window
    - Standard code requirements
- Utilities
  - Simple net metering application (SECO ok)
  - Dual meters on a timely basis (SECO ok)
  - Allow more than 100% generation

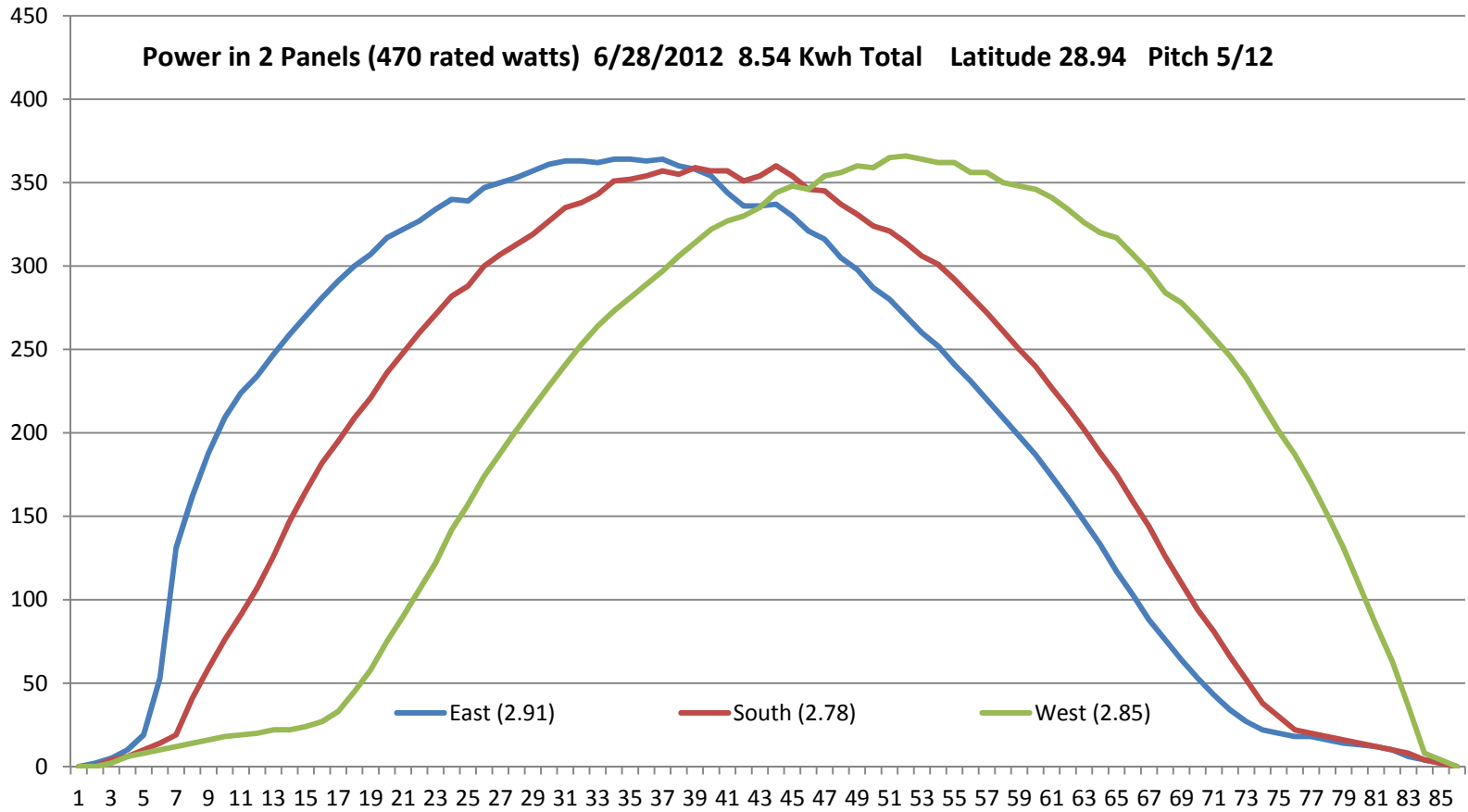
# Swanson Directional Test

- The following slides show the three directional test being run on the Swanson garage

# Directional Layout (4/4/12)



# Directional Performance 6/28/12



# Shift of Power Curves

- East (70 degrees) peaks at 11:05 am
- South (160 degrees) peaks at 12:30 pm
- West (250 degrees) peaks at 1:55 pm
- This will be important in the future for load balancing

# Solar Power at Pitt

- University of Pittsburgh
  - Swanson School of Engineering
- Solar power laboratory
- Panel setup
  - East, South, West
  - 25 degrees, 45 degrees (maximum rack)
  - 3 panels in each configuration
  - 2 panel suppliers (240 watt panels)

# Showing two panels, sunshine



# Adam, John, and team





# For Information Regarding Access to the Benedum Hall Roof contact

Donald C. Shields  
Executive Director -- Center for Energy  
dcs23@pitt.edu  
412-624-8120

# Summary

- Residential/commercial PV Solar Power is ready for wide application
  - Cost effective if:
    - Behind the meter
    - Net metering is available
    - Electric Marginal Cost > \$0.10 per watt
- Solar Hot Water is good, and price should come down
- Questions?