



U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

2011

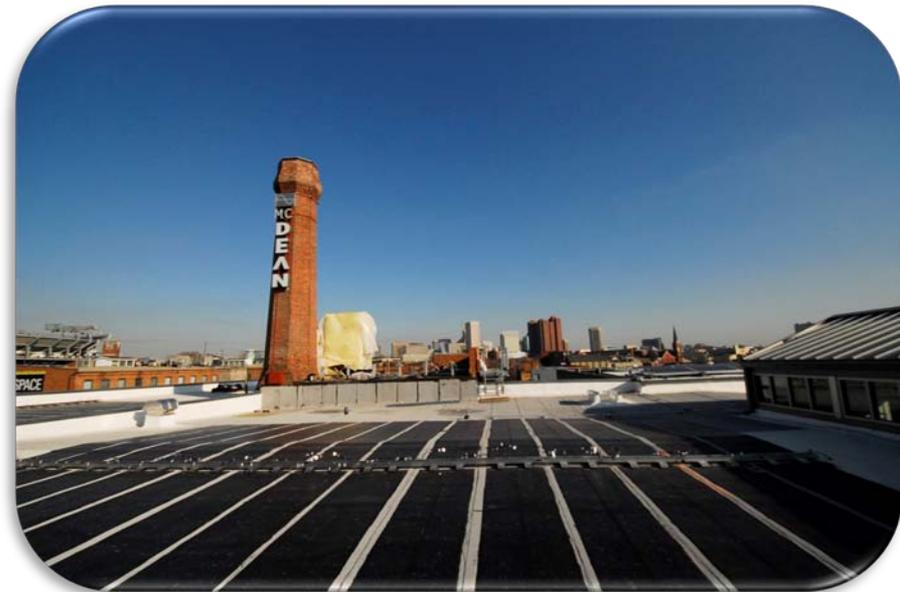
M.C. Dean, Inc.
Scott Solomon, MSEE
Adam Kristanc, LC

Solar Panel Overview for
Residential and Commercial
Applications



Presentation Outline

- Design Basics
- Shadowing & Cleaning
- Testing & Commissioning
- Off Grid Systems





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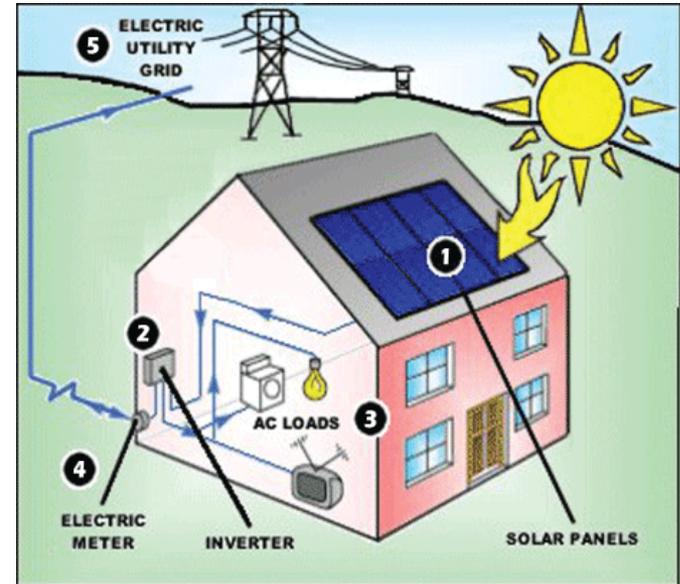
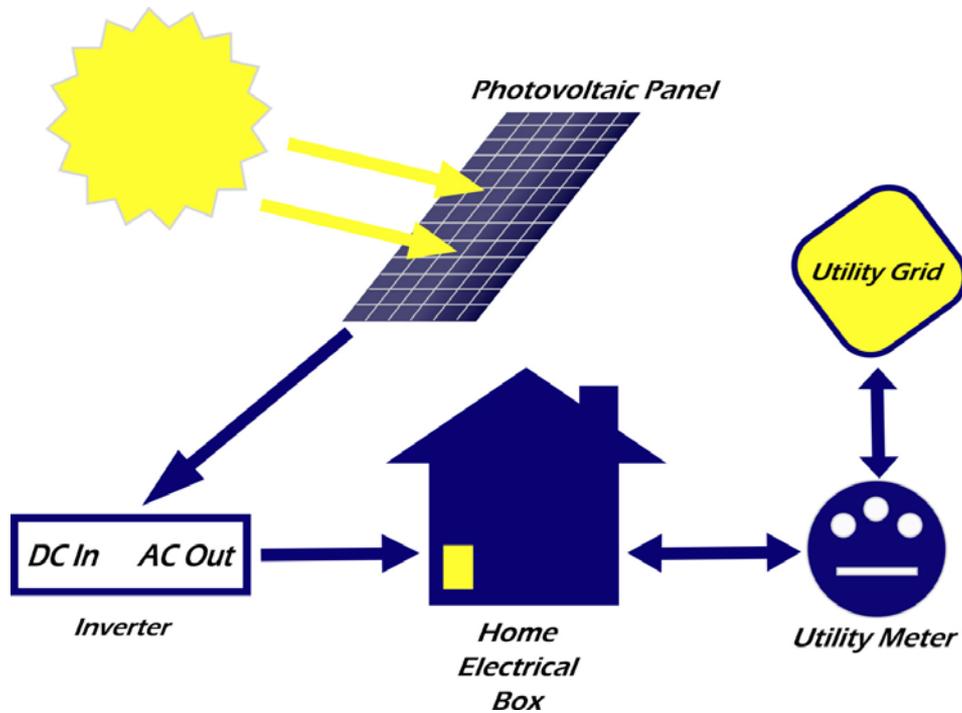
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Design Basics

Solar Panel Overview for
Residential and Commercial
Applications



Design Basics





Design Basics

- Where to begin? Is solar for me?
 - Determine Installation Site
 - South facing area (or close to it), ability to tilt
 - Structural integrity of roof, if used
 - No shading, i.e. nearby trees, tall buildings
 - Weather
 - Does it rain 50% of the year?
 - Severe weather?
 - Hurricanes
 - Hail storms
 - Blizzards



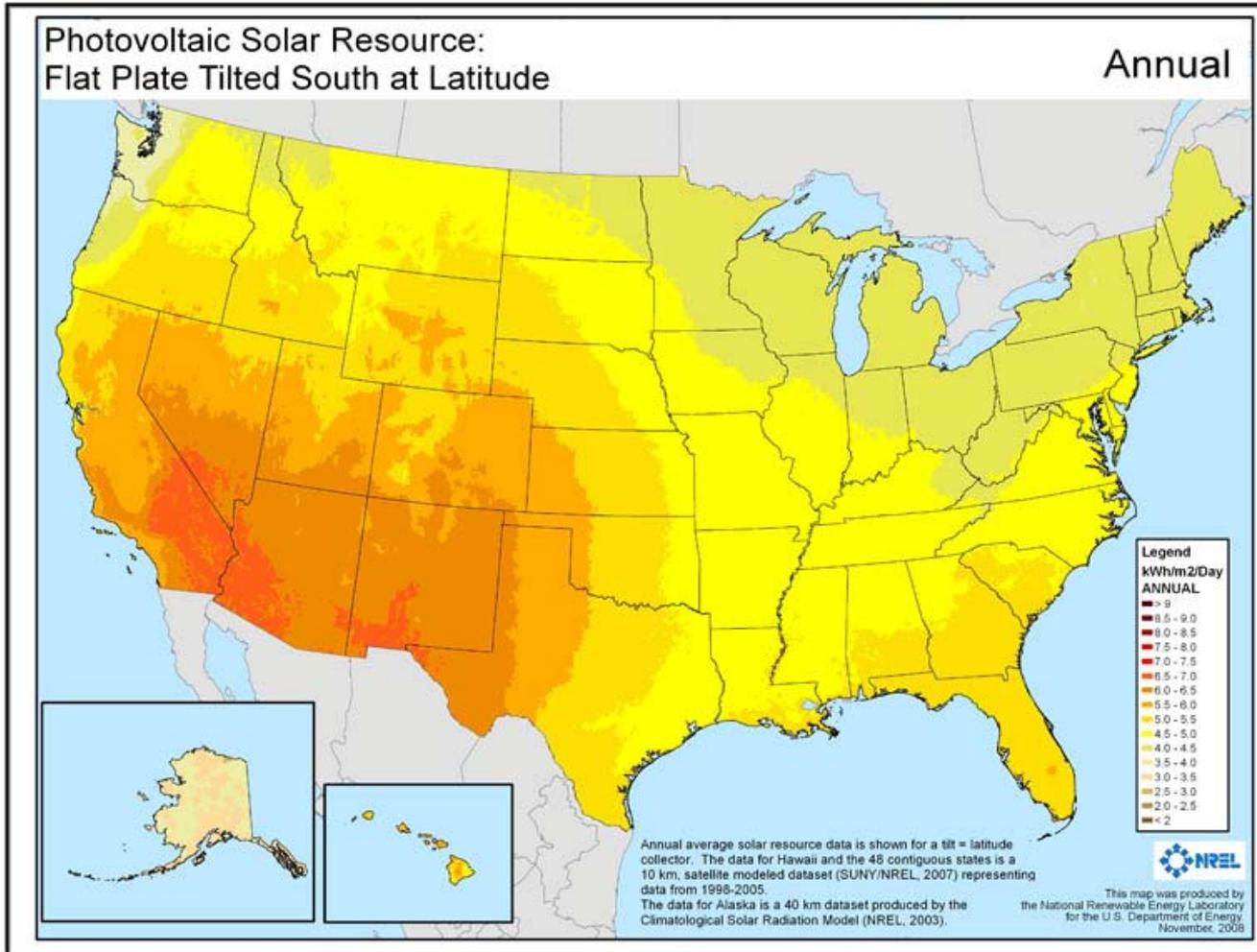
Design Basics

- Where to begin? Is solar for me?
 - Determine Available Sun Hours
 - National Renewable Energy Laboratory (NREL)
 - PVWatts – Provides calculated average of solar irradiance at your location
 - Energy Savings and Cost
 - Do you have any energy requirements?
 - In My Backyard (IMBY) – Estimates the electricity you can produce with a photovoltaic (PV) array at your home or business
 - Initial cost can be reduced by taxes
 - Tax incentives – www.dsireusa.org
 - Database of State Incentives for Renewables & Efficiency



Design Basics

- Annual Available Sun Hours in the United States





Design Basics





Design Basics

- Solar Panel Mounting Types
 - Roof
 - Pole
 - Ground





Design Basics

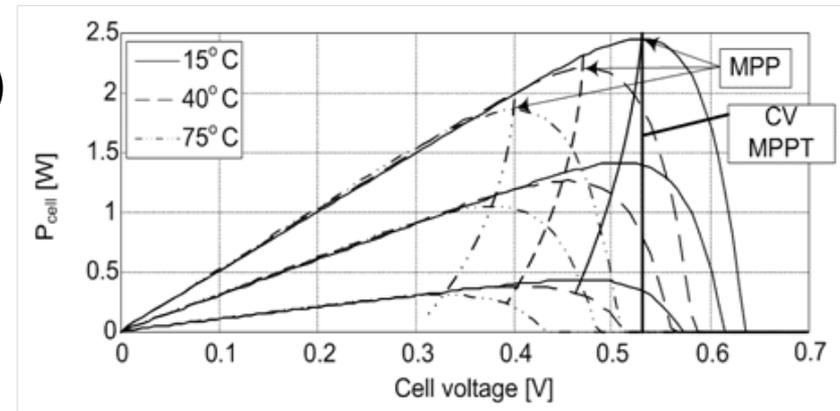
- Panel Selection
 - Square footage available
 - Panel Material Type
 - Monocrystalline Silicon
 - Polycrystalline Silicon
 - Amorphous Silicon
 - Thin Film
 - Wattage
 - Voltage
 - String Size (i.e. how many panels are tied together)





Design Basics

- Inverter Selection
 - Verify power rating
 - Energy from extra panels won't be collected.
 - Max Power Point Tracking (MPPT)
 - Maximizes collected power from solar panels as sun moves across the sky
 - Voltage Selection (input and output)
 - Input sizes your string





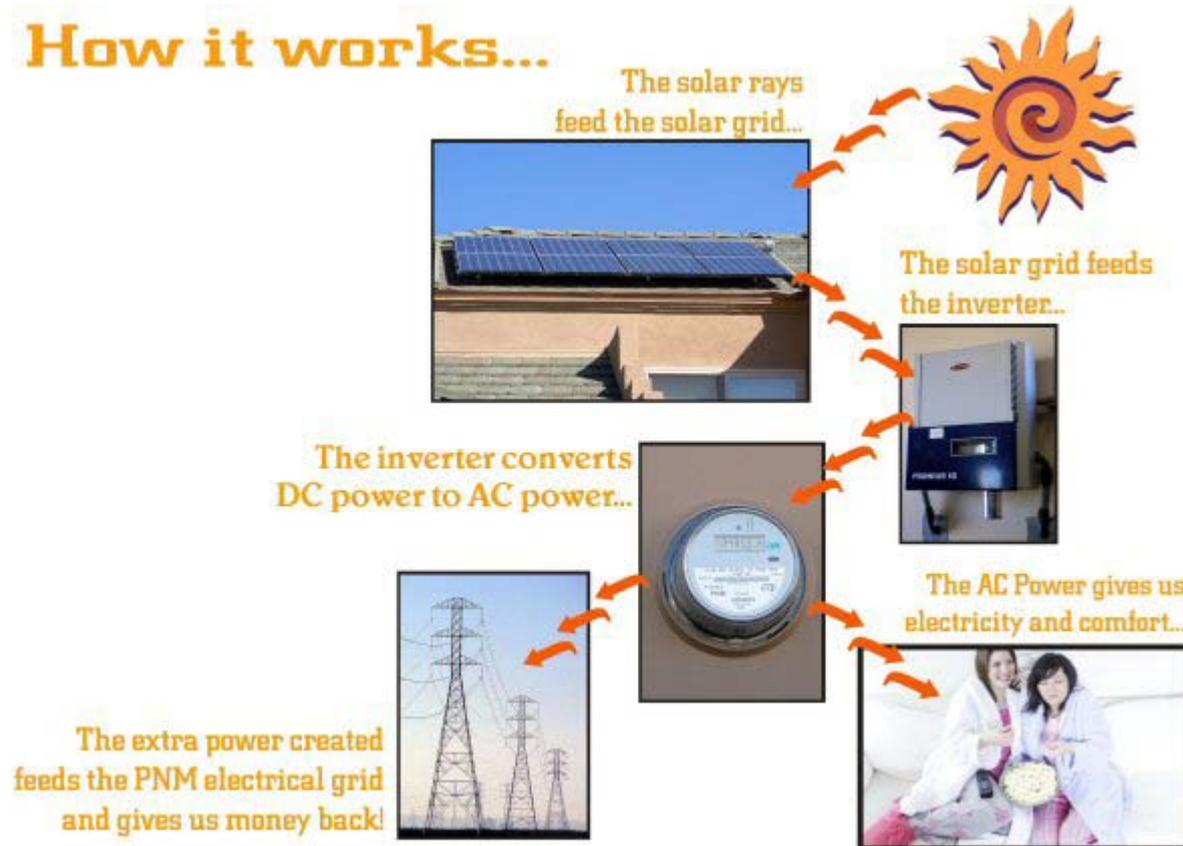
Design Basics

- Anti-Islanding
 - Inverters need to “see” grid voltage (reference voltage)
 - All inverters require anti-islanding functionality
- Off-Grid Example: Sunny Island
 - Meant for small distribution system (i.e. off-grid village in remote region)
 - “Grid tied”, off-grid battery, generator, wind, PV – all in the same device
 - Islanding is “encouraged” here...



Design Basics

How it works...





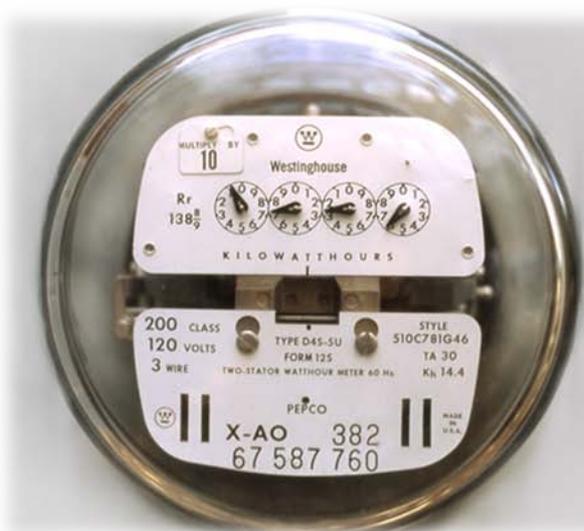
Design Basics

- Understanding Power
 - Power – rate at which energy is consumed
 - Direct Current kilowatt (DC kW)
 - Rating of your PV system.
 - Most often referred to before losses
 - Alternating Current kilowatt (AC kW)
 - the power you actually receive and use



Design Basics

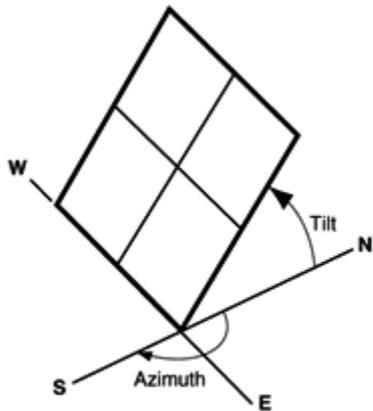
- Understanding Energy
 - Energy – amount of power consumed
 - Alternating Current kilowatt-hour (AC kWh)
 - Measure of power used, or provided, over time.
 - 1 kW for 1 Hour is 1 kWh. This costs about 11-12 cents from the utility here in DC, after taxes and fees.



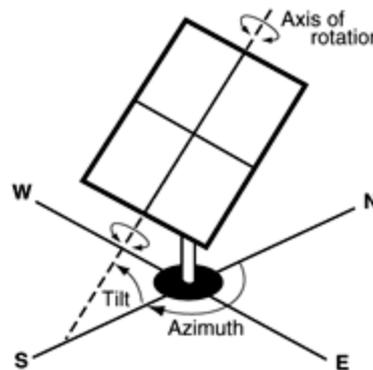


Design Basics

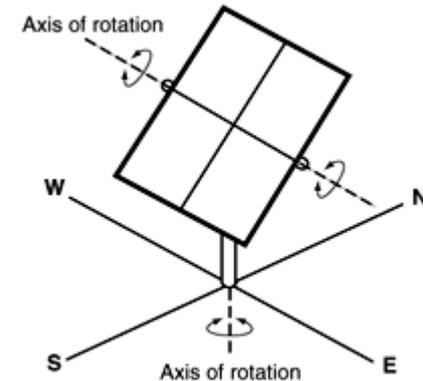
- To Track or Not to Track...
 - In larger commercial systems, tracking is often considered
 - Single Axis Tracking (20%-35% kWh gain vs. fixed)
 - Dual Axis Tracking (35%-45% kWh gain vs. fixed)



PV array facing south at fixed tilt.



**One axis tracking PV array
with axis oriented south.**



Two-axis tracking PV array



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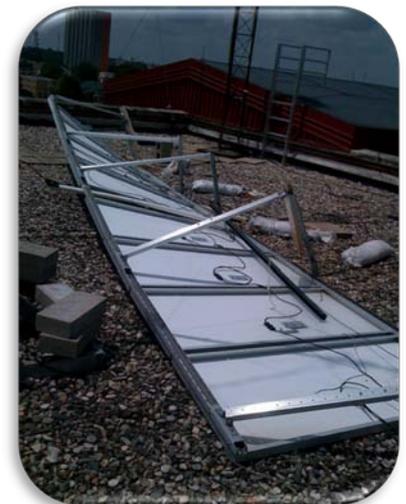
Shadowing & Cleaning

Solar Panel Overview for
Residential and Commercial
Applications



Solar PV Shadowing

- Causes for PV Panel Energy Loss
 - Position of the Sun – Nearby buildings or other obstructions
 - Nature
 - Dust/dirt, snow, cloud coverage, tree limbs, leaves, bird droppings, high winds
 - Approximately 20% or greater losses occur with partial panel blocking
 - Ask us for our test results after the presentation!





Solar PV Shadowing

- How to Avoid Energy Loss
 - Clean with water, rubbing alcohol
 - Install sprinkler system to remove dust
 - Avoid panel placement near trees/shadowing

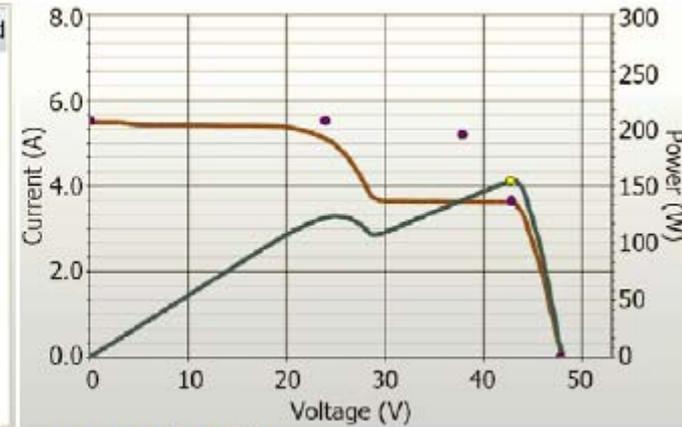




How Shadows Affect Power Output



	Predicted	Measured
Pmax (W)	196.70	154.75
Vmp (V)	37.84	42.69
Imp (A)	5.20	3.62
Voc (V)	47.77	47.66
Isc (A)	5.52	5.47
Tpv (C)	58.5	54.4
Epoa (W/m ²)	1011	1022
Rseries (Ohms)		0.03



Results of Small Shading on a Single Cell

- Monocrystalline Panel
 - PV Cells wired in series (common: 60 cells)
 - Single cell shading can reduce power output by 19%



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Testing & Commissioning

Solar Panel Overview for
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Applications



Safety First

- Occupational Safety & Health Administration (OSHA)
 - Green Job Hazards: Solar Energy
 - <http://osha.gov/dep/greenjobs/solar.html>
 - Provides information on hazards solar industry workers may face
- National Fire Protection Agency (NFPA)
 - NFPA 70: National Electric Code (NEC)
 - Article 690, Solar Electric Systems
 - Article 705, Interconnected Electrical Power Production Sources
 - NFPA 780: Standard for the Installation of Lightning Protection Systems



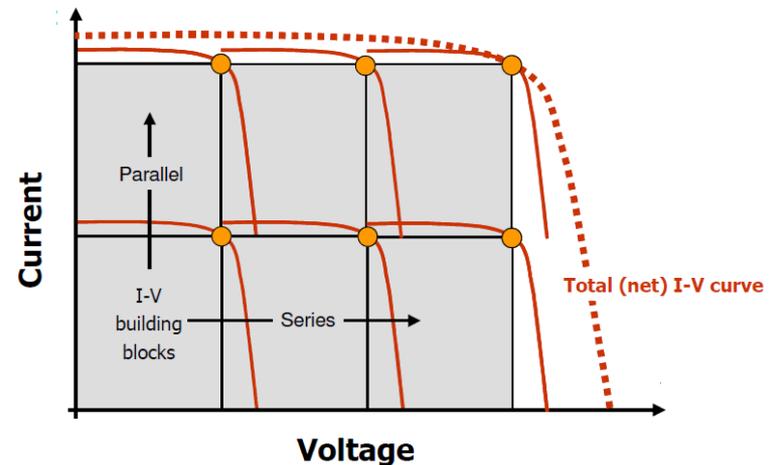
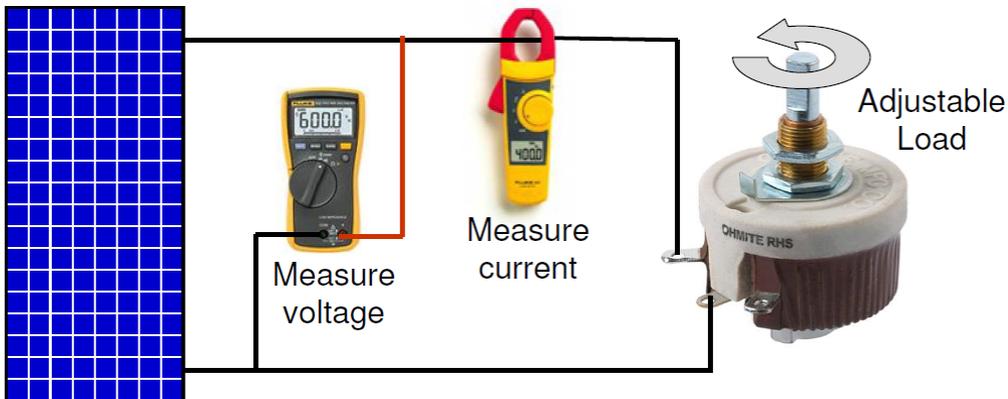
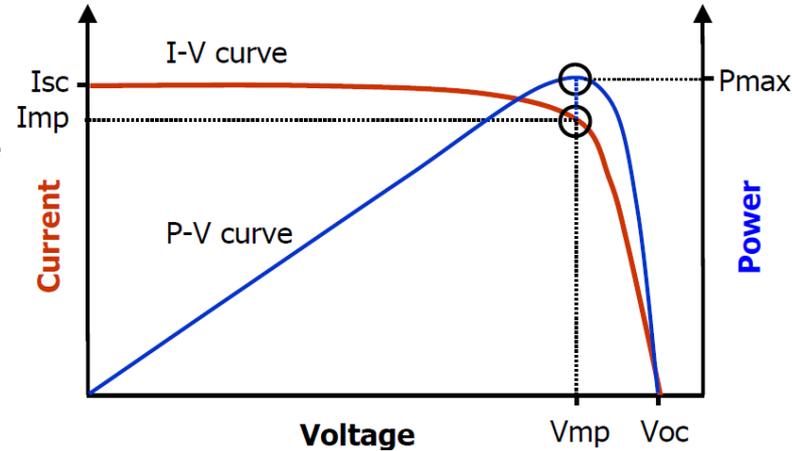
Testing & Commissioning

- Common Terms
 - Irradiance
 - Amount of power generated by the sun
 - Measured in watts / meters²
 - Standard Testing Conditions (STC)
 - Generally how manufacturers determine solar panel ratings
 - Irradiance of 1,000 W/m²
 - Solar spectrum of Air Mass (AM) of 1.5
 - Module temperature at 25°C



Testing & Commissioning

- I-V Curve Tracing
 - Accepted method for testing PV module
 - Or series/parallel strings



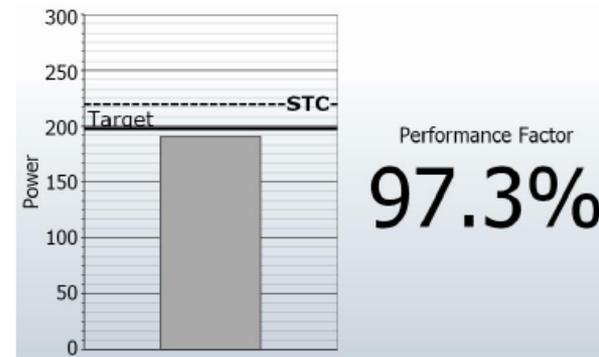
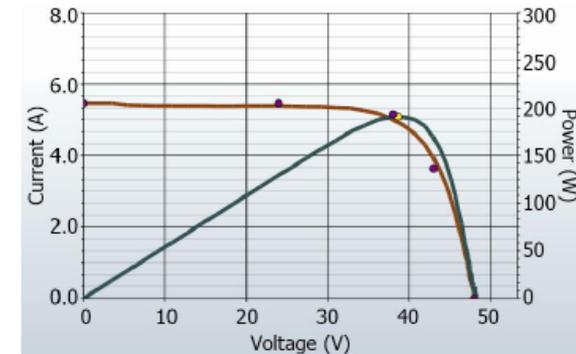


Testing & Commissioning

- Curve Tracing in Action
 - Type of Solar Panel
 - Monocrystalline PV Module
 - Tilt Angle: 31°, Facing South
 - Time: 1:15pm
 - Sunny day, few clouds



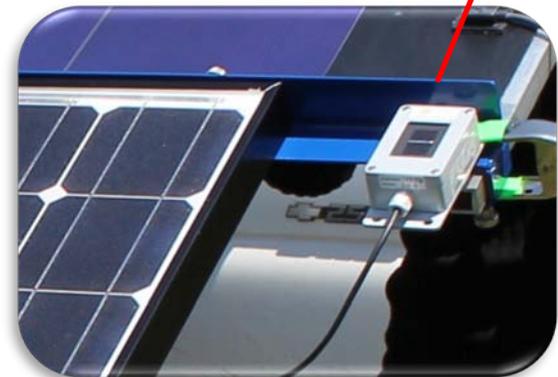
	Predicted	Measured
Pmax (W)	196.18	190.83
Vmp (V)	38.05	38.64
Imp (A)	5.16	4.94
Voc (V)	47.98	47.89
Isc (A)	5.46	5.47
Tpv (C)	56.9	52.8
Epoa (W/m ²)	1011	1013
Rseries (Ohms)		0.03





Testing & Commissioning

- Curve Tracing in Action
 - Solar Panel Power
 - 220 STC watts
 - 17.4% STC efficiency
 - Expected Power (current conditions)
 - 196 watts
 - Solar Power Available (Irradiance)
 - **1013 w/m²**
 - Solar Power Captured
 - 174.6 w/m²
 - Measured efficiency (current conditions)
 - 17.2%



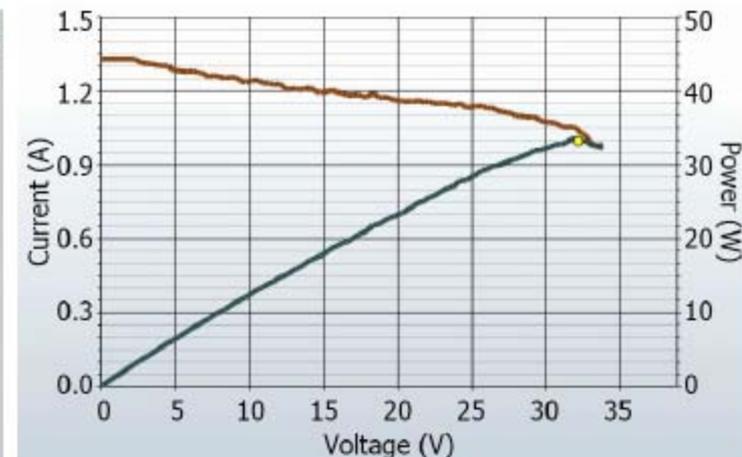


Testing & Commissioning

- Cloudy Days
 - Large Affect on PV arrays
 - Inconsistent irradiance
 - Power (current) directly proportional to irradiance!
 - Clouds can also give **higher** irradiance
 - Snow can as well



	Predicted	Measured
Pmax (W)	32.77	33.24
Vmp (V)		32.14
Imp (A)		1.03
Voc (V)		39.69
Isc (A)		1.33
Tpv (C)	62.1	54.4
Epoa (W/m ²)	245	239
Rseries (Ohms)		0.03





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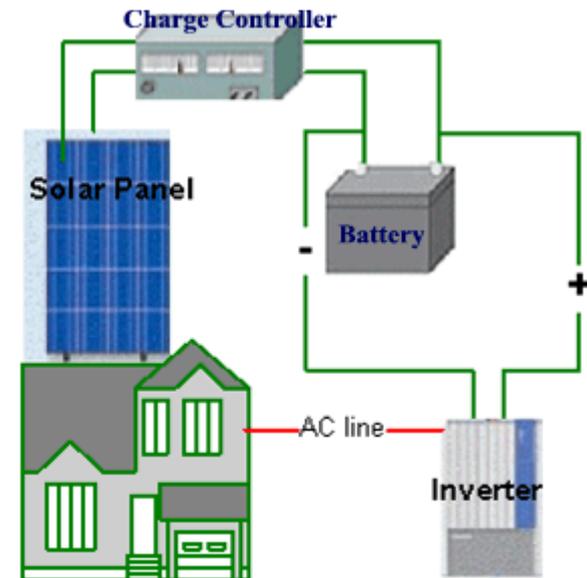
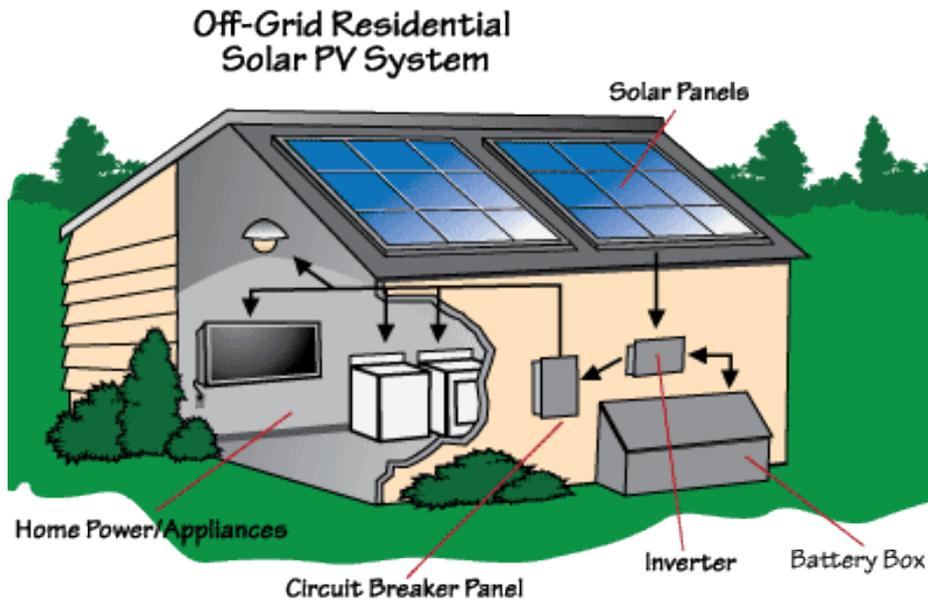
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Off Grid Solar Power

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Off Grid Solar Power





Off Grid Solar Power

- Benefits vs. Grid-Tie:
 - Non-reliance on others for electricity
 - Potential Backup Power Solution
 - No grid power means no bills, and no overhead power lines
 - (Ideal for those who can't access power lines)
- Disadvantages:
 - Bigger impact (zero power is possible) with clouds, damage over time, snow coverage, etc...
 - Initial \$\$\$ Cost
 - Battery Maintenance



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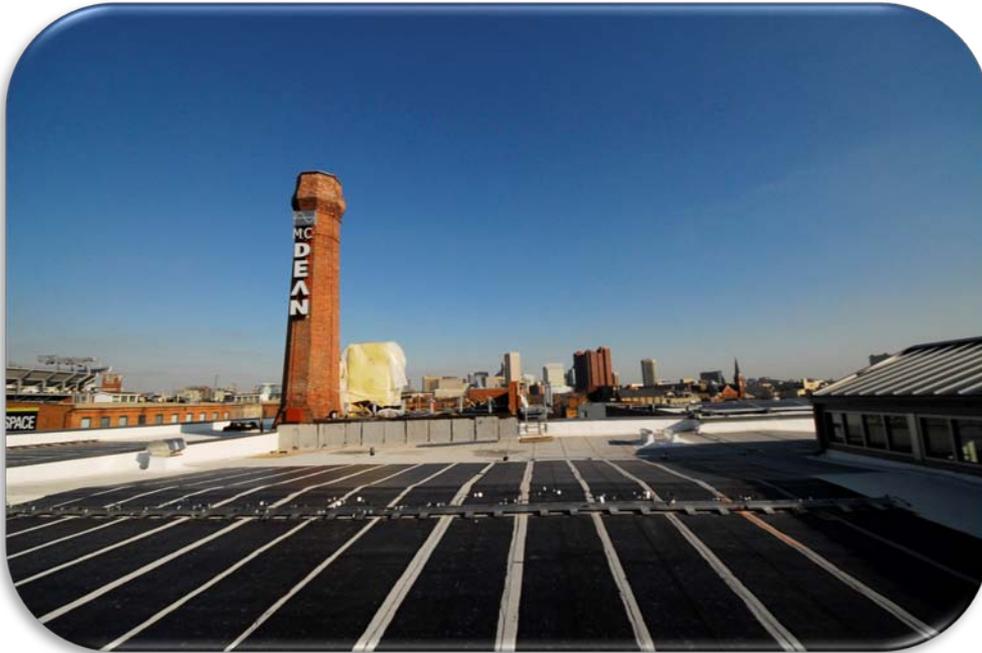
Solar Power Examples

Solar Panel Overview for
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Applications



Solar Power Examples

- M.C. Dean 180 W. Ostend Street,
Baltimore, MD





Solar Power Examples

- Scott Jenkins Memorial Park
 - Location: Loudoun County, VA





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Questions?
Comments?

Email Us: **green@mcdean.com**

On the Web: <http://www.mcdean.com/services/energy/solar.htm>