SOLAR ELECTRIC INVESTMENT ANALYSIS SERIES

# Estimating System Production

Agricultural Energy Efficiency Initiative of
Virginia Cooperative Extension / Virginia Tech
December, 2017

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## Program Learning Objectives

- Introduction
- The Silicon solar cell
- Estimating solar production at a site.
- What Factors that Influence System Production?
  - Orientation
  - Tilt
  - Shading
  - Degradation
- Additional Resources

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# DISCLAMER:

This presentation and/or the information provided is not meant and should not serve as financial or legal advice and should only be used as an educational resource. Be sure and consult with your financial advisor, tax accountant, and/or attorney before signing an agreement.

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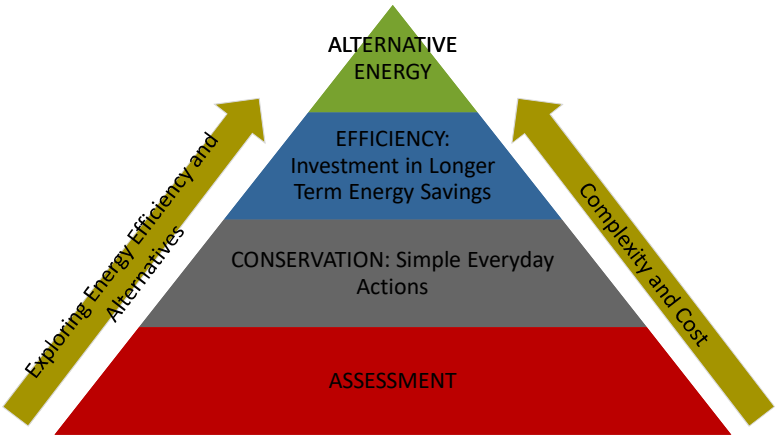


Source: University of Wyoming and Montana State University. (2011, October). *E3A User's Guide Assessment and Fact Sheets*. E3A-UG.1.

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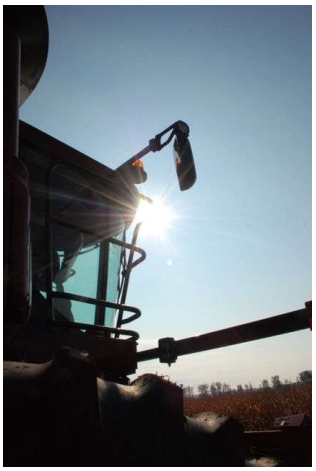
What factors influence the production and value of electricity from your system?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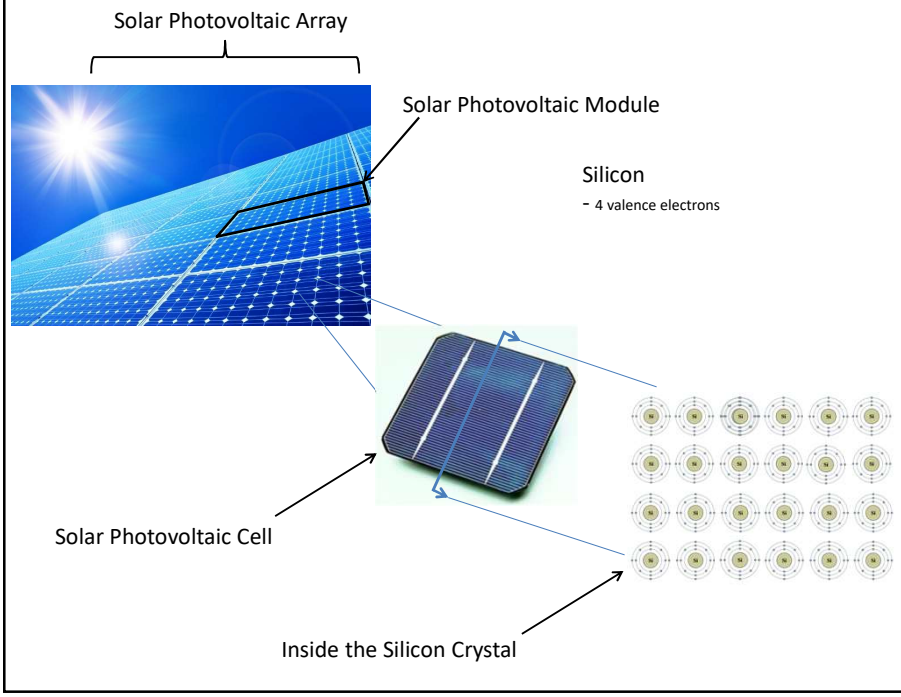
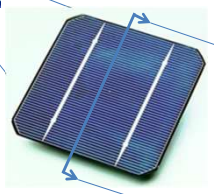
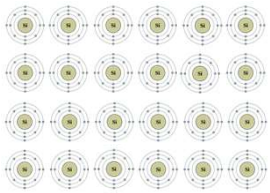




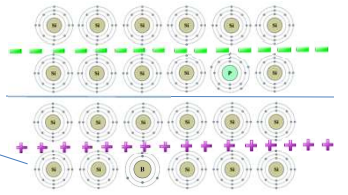


Silicon
- 4 valence electrons

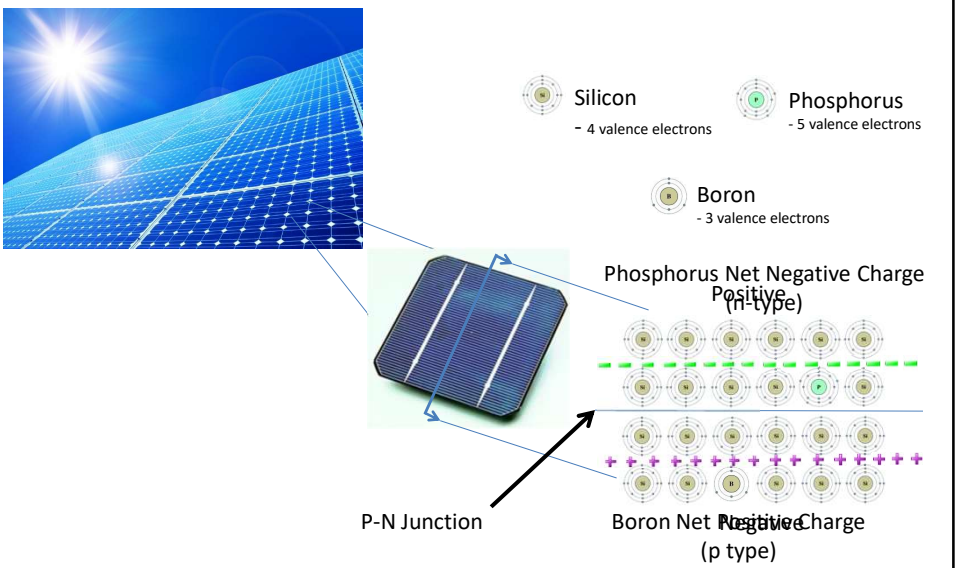
Phosphorus
- 5 valence electrons

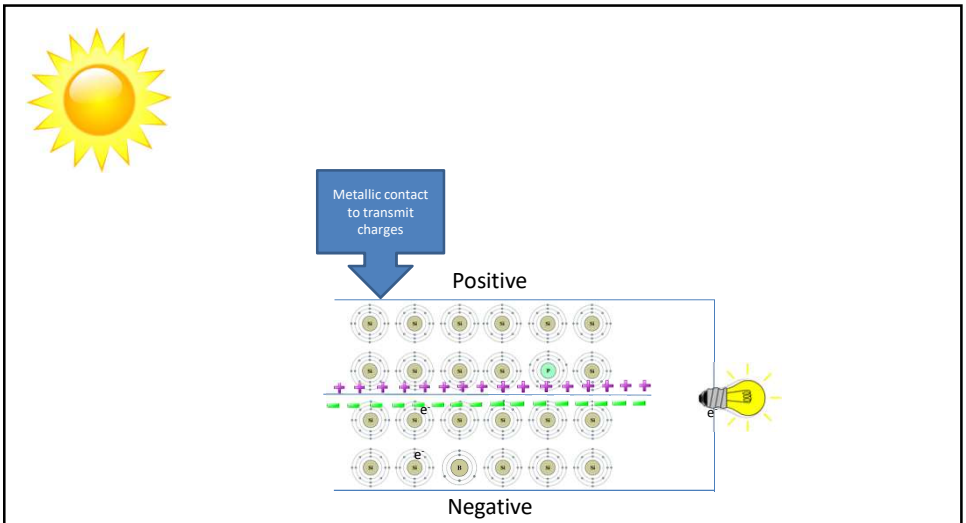
Boron
- 3 valence electrons

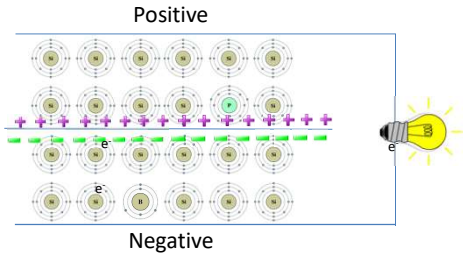
Phosphorus Net Negative Charge

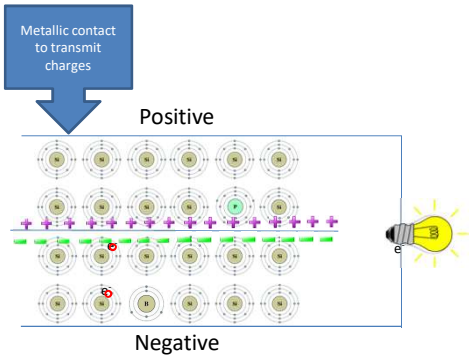


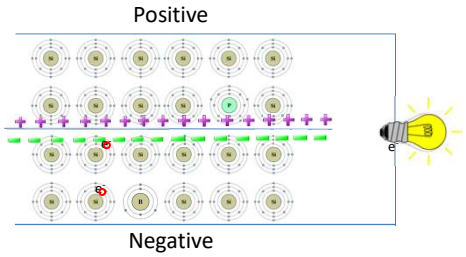
Boron Net Positive Charge

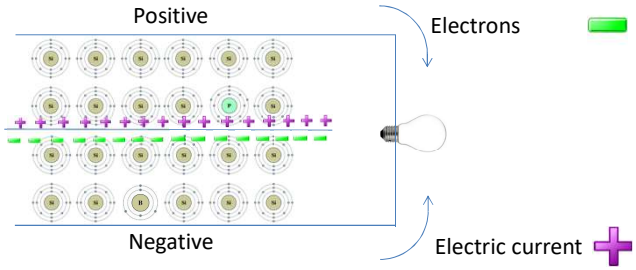

Silicon
- 4 valence electrons
Phosphorus
- 5 valence electrons
Boron
- 3 valence electrons
Phosphorus Net Negative Charge
Positive
(n-type)
P-N Junction
Boron Net Negative Charge
(p type)


Metallic contact to transmit charges
Positive
e-
e-
e-
Negative


Positive
e-
e-
e-
Negative


Metallic contact to transmit charges
Positive
e-
e-
e-
Negative


Positive
Negative


Positive
Electrons
Negative
Electric current

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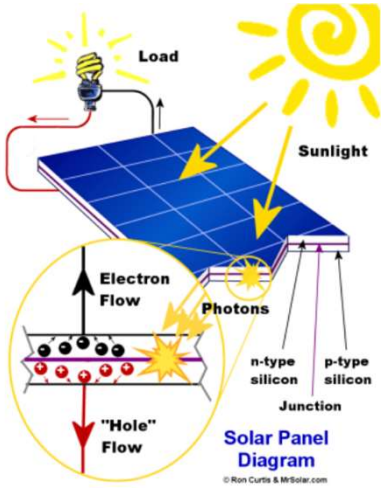


# Photovoltaic Solar: How Does It Work?

Light knocks loose electrons from semiconductor material creating free positive and negative charges which results in an internal electric field that pushes charges through the cell, creating an electric current

Source: E3A Solar Electricity for Home, Farm & Ranch

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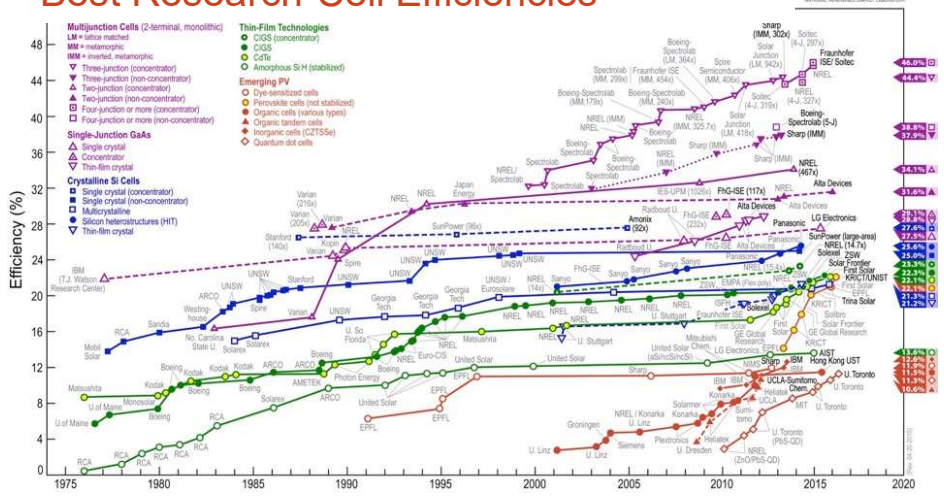
# Best Research-Cell Efficiencies

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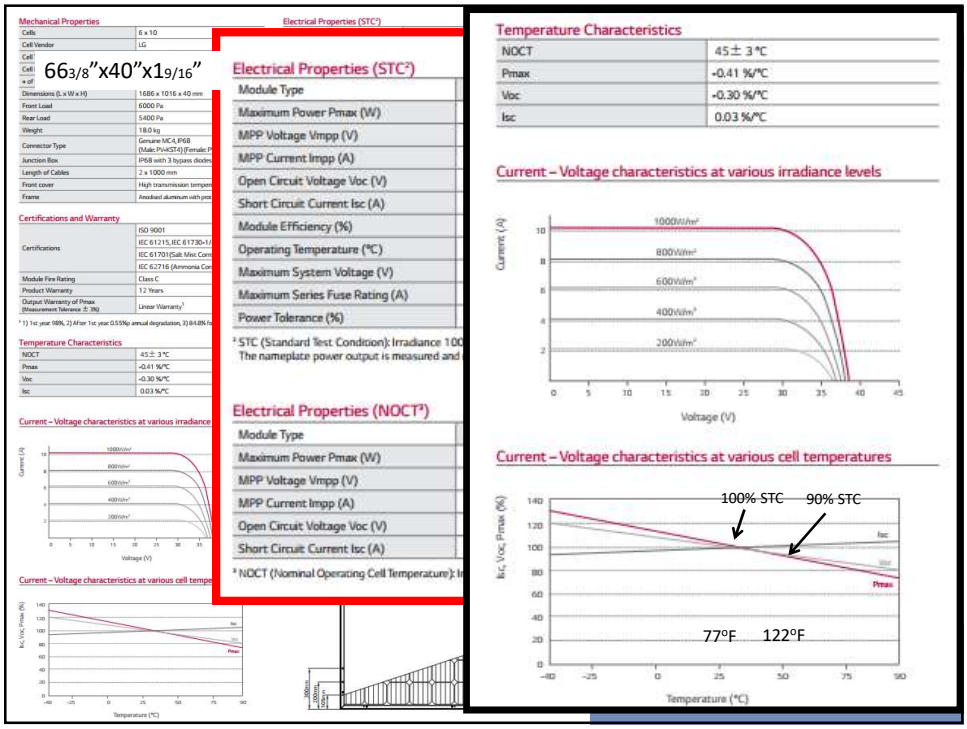


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# Not All Photovoltaic Solar Systems Are Created Equal!

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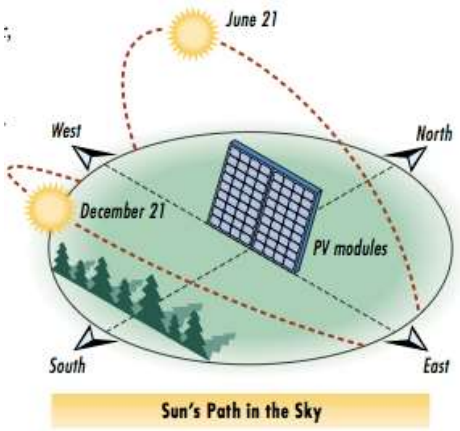
# System Production - Orientation

System Orientation - Departure from true south affects production, as panels facing east or west will generally produce less than the same installation facing due south.

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# System Production – Module Tilt

Roof or ground mount system, tilt of the panels also influences production, as flatter angles will increase production in the summer but decrease the production in winter.

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## System Production – Shade

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## System Production – Module Layout

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## System Production – Temperature

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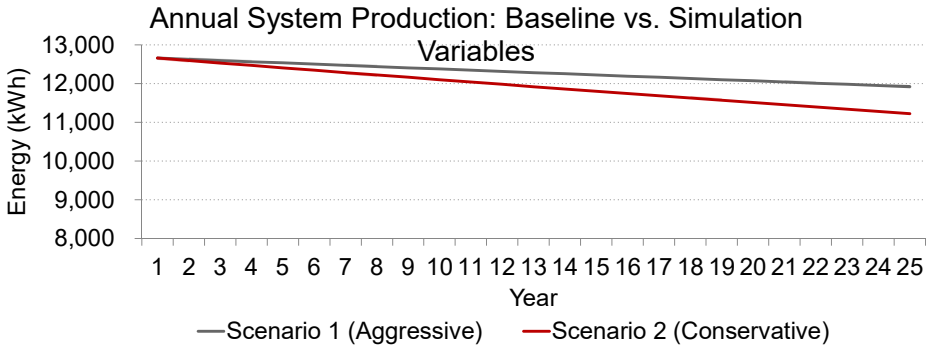
## Panel Degradation (10kW example system)

- Panel Degradation - Warranties typically guarantee production declines will be less than 0.5% a year.

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## System Orientation and Tilt Influence Production

Some system owners prefer rooftop systems located on the top of existing agricultural buildings. However, you should consider the difference in system production before making a decision. For example, a 10 kW system on a barn oriented to the east (90°) with a 4:12 pitch roof would produce an 18° panel tilt. This rooftop system would **produce roughly 13% less** that a ground mount system facing south (180°) with panels tilted at 40°.

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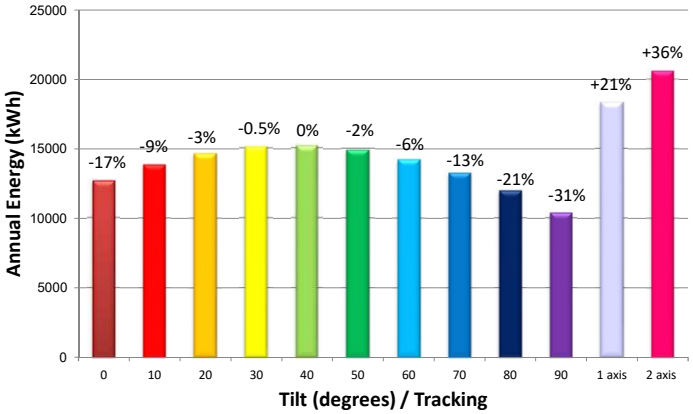
**Impact of Tilt and Tracking on Solar PV Production**
**(10 kW Solar PV Array, Grand Island Nebraska)**




Production data from NREL PV Watts Model http://pvwatts.nrel.gov

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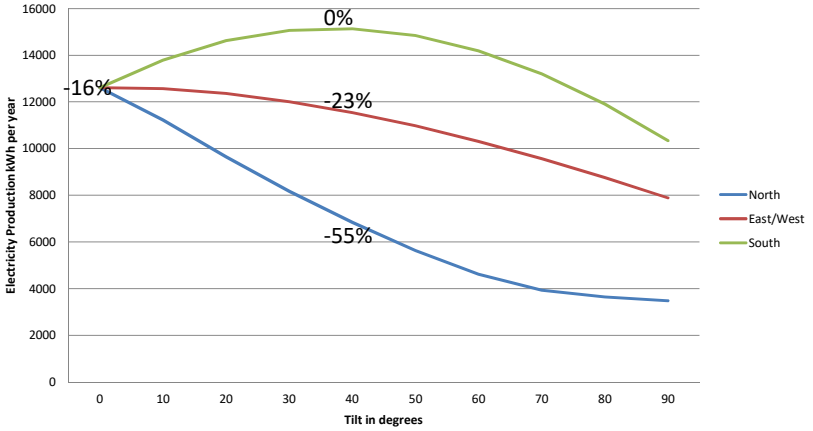
**Influence of Tilt and Azimuth (degrees) on a 10 kW Solar PV Array (Grand Island Nebraska)**




Production data from NREL PV Watts Model http://pvwatts.nrel.gov

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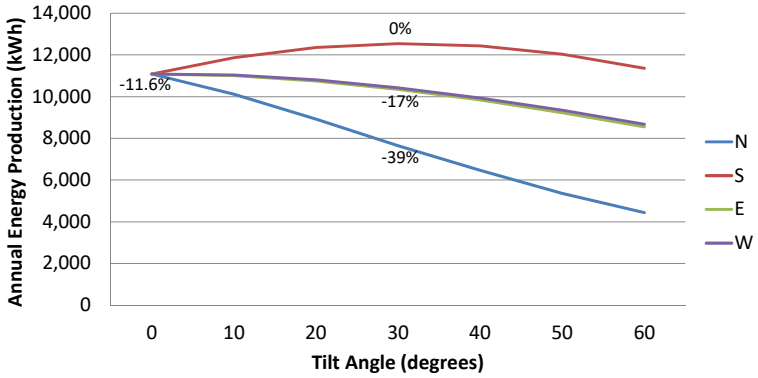
**Influence of Tilt and Azimuth on Production (Danville VA)**




Production data from NREL PV Watts Model http://pvwatts.nrel.gov

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# Simple Solar Production Estimate

- Standard Test Conditions Capacity of System
- Peak Sunlight Hours
  - Estimate of solar energy for a site http://rredc.nrel.gov/solar/pubs/redbook/
- 365 Days per year
- Derate factor for real life conditions vs STC 0.70-0.80
- $\mathbf{10kW \times 5.0 \times 365 \times 0.70 = 12,775\ kWh/year}$



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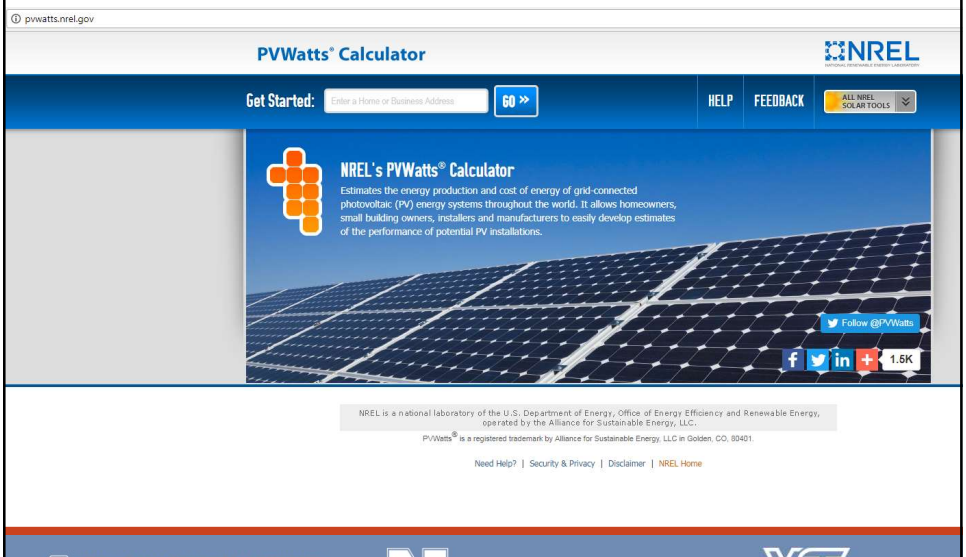


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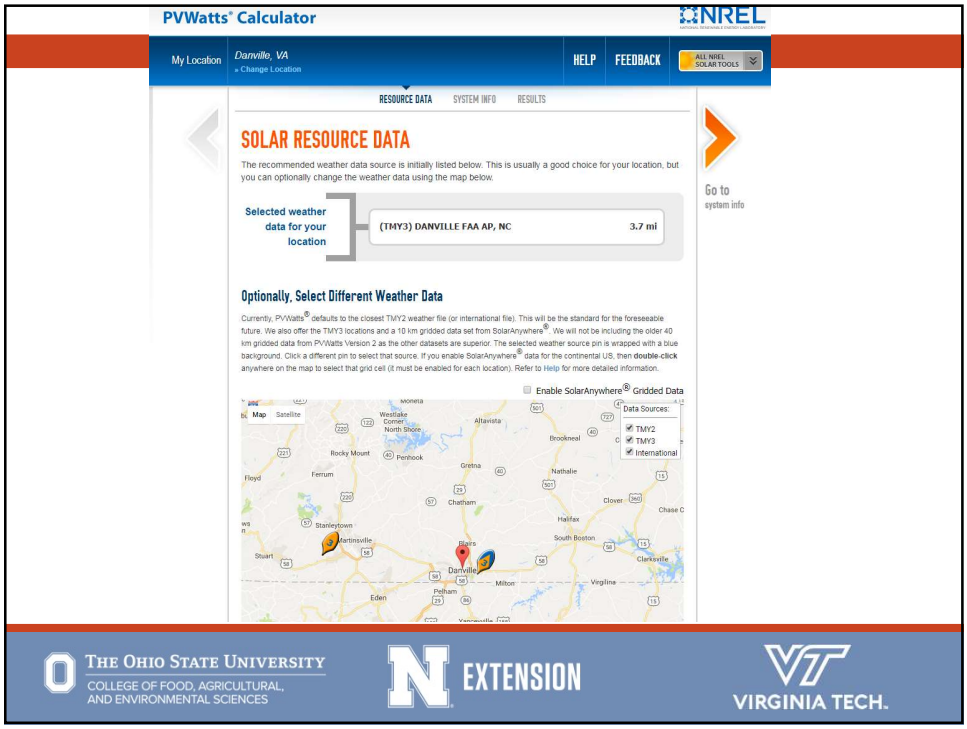
PVWatts® Calculator
NREL
My Location
Danville, VA
» Change Location
HELP
FEEDBACK
ALL NREL SOLAR TOOLS
RESOURCE DATA
SYSTEM INFO
RESULTS
SOLAR RESOURCE DATA
The recommended weather data source is initially listed below. This is usually a good choice for your location, but you can optionally change the weather data using the map below.
Selected weather data for your location
(TMY3) DANVILLE FAA AP, NC
3.7 mi
Optionally, Select Different Weather Data
Currently, PVWatts® defaults to the closest TMY2 weather file (or international file). This will be the standard for the foreseeable future. We also offer the TMY3 locations and a 10 km gridded data set from SolarAnywhere®. We will not be including the older 40 km gridded data from PVWatts Version 2 as the other datasets are superior. The selected weather source pin is wrapped with a blue background. Click a different pin to select that source. If you enable SolarAnywhere® data for the continental US, then double-click anywhere on the map to select that grid cell (it must be enabled for each location). Refer to Help for more detailed information.
Enable SolarAnywhere® Gridded Data
Map
Satellite
Data Sources:
TMY2
TMY3
International
Go to system info
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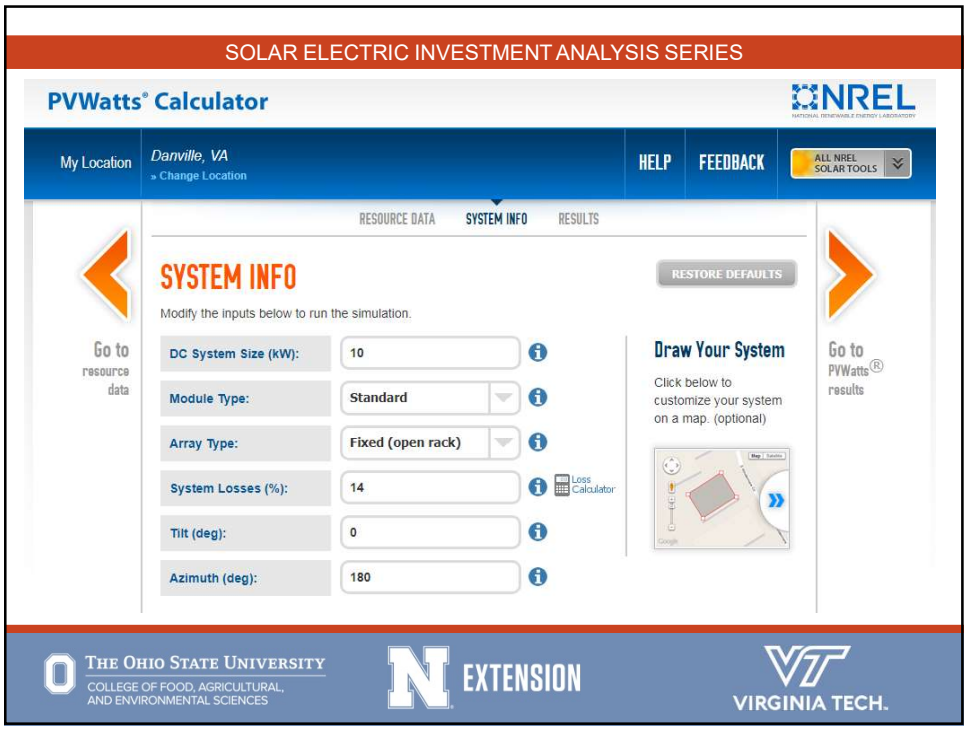
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PVWatts® Calculator
NREL
My Location
Danville, VA
» Change Location
HELP
FEEDBACK
ALL NREL SOLAR TOOLS
RESOURCE DATA
SYSTEM INFO
RESULTS
SYSTEM INFO
RESTORE DEFAULTS
Modify the inputs below to run the simulation.
Go to resource data
DC System Size (kW): 10
Module Type: Standard
Array Type: Fixed (open rack)
System Losses (%): 14
Loss Calculator
Tilt (deg): 0
Azimuth (deg): 180
Draw Your System
Click below to customize your system on a map. (optional)
Go to PVWatts® results
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PVWatts® Calculator

NREL

My Location | Danville, VA » Change Location | HELP | FEEDBACK | ALL NREL SOLAR TOOLS

RESOURCE DATA | SYSTEM INFO | RESULTS

Go to system info

RESULTS

Print Results

12,506 kWh/Year*

System output may range from 11,934 to 12,738kWh per year near this location. Click HERE for more information.

| Month | Solar Radiation ( kWh / m² / day ) | AC Energy ( kWh ) | Energy Value ( $ ) |
|---|---|---|---|
| January | 2.94 | 765 | 83 |
| February | 3.45 | 794 | 86 |
| March | 4.79 | 1,184 | 128 |
| April | 6.04 | 1,394 | 151 |
| May | 4.90 | 1,174 | 127 |
| June | 4.74 | 1,085 | 117 |
| July | 4.55 | 1,051 | 114 |
| August | 5.06 | 1,162 | 126 |
| September | 5.89 | 1,315 | 142 |
| October | 4.34 | 1,042 | 113 |
| November | 3.35 | 833 | 90 |
| December | 2.74 | 706 | 76 |
| Annual | 4.40 | 12,505 | $ 1,353 |

From our simple estimate **12,775 kWh/year**

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## Additional Resources








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# Thank You!

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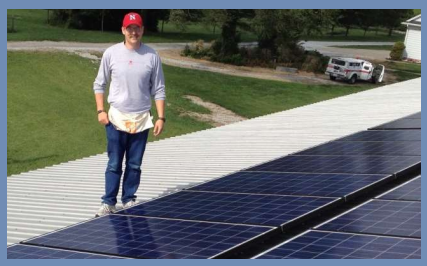

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