Farm Energy IQ

Farms Today Securing Our Energy Future

Solar Energy on Farms

Ed Johnstonbaugh, Penn State Extension

Farm Energy IQ

Farm Energy IQ

Presents:

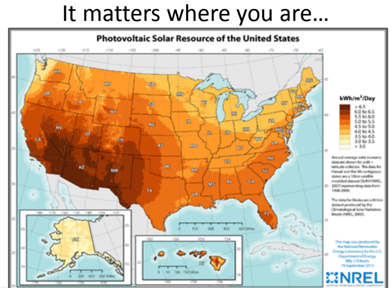
Solar Energy on Farms:
Photovoltaic (PV) Electric and Thermal

What you will learn

- How sunlight is converted to electric (PV) and thermal energy
- How to harness useful electricity from PV systems
- How to estimate system performance
- How solar energy systems can benefit your operation

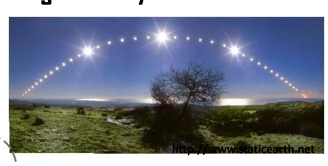
Fundamentals of renewable energy

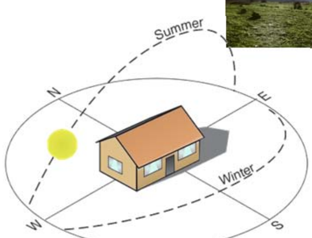
It matters where you are…



Sun's daily path through the sky

Northern hemisphere





http://www.ecowho.com

The Sun as a Moving Energy Source

- Fixed solar collectors can be aligned to:
  - Optimize annual energy production (e.g., kWh from solar PV)
  - Optimize afternoon energy production (to maximize power [kW] in solar PV systems when customer wants to reduce electric utility demand charges)
  - Optimize winter energy production (typically for solar thermal systems for which summer production typically exceeds heating needs)
- Tracking solar collectors maximize energy production by tracking the sun's position.
  - Increase complexity and cost of system
  - Beyond the scope of this presentation

Solar Equipment Siting

- Important considerations when considering solar PV or thermal energy systems:
  - Panels should not be shaded at any time during the year
  - Site must accommodate reasonable orientation of the collector panels
  - Site must be accessible for inspection and cleaning
  - Site system close to point of use

Solar PV modules

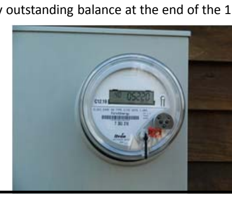
- A solar PV module is an electrical device which contains a string of PV cells that produce, under full direct sunlight, a specific voltage and current flow. This voltage and current is called the capacity.
- PV modules produces direct current (DC) electricity. In most cases, DC electricity is converted to more widely used alternating current (AC) electricity
- Modules have no moving parts and are typically warranted for 25 yr
- Over 10 years, single module capacity increased from < 200 watts to 230–300 watts

Solar PV system integration

- **Solar Modules** are strung together to form arrays. Arrays feed Direct Current (DC) to inverters that convert DC to Alternating Current (AC).
- **Inverters** act as safety equipment during outages and interrupt the solar array's ability to produce electricity and send it to the building or grid
- **Meters** measure the electricity produced so that Renewable Energy Credits (RECS) can be applied
- **With net-metering, meters** measure electricity purchased from the grid and electricity sent back to the grid.
- **Virtual metering** is a net metering system in which surplus energy is applied to another account.

Net Metering
Page I

- **Net metering** rules vary by state. In general, net metering permits a PV system owner to:
  - **Purchase** energy from the grid at the standard tariffed rate
  - **Use** solar-produced electricity to offset grid-purchased electricity (deduct one kWh purchased from the grid for each kWh supplied to the grid)
  - **Carry** excess generation forward to succeeding months to apply against purchases from the grid
  - **Cash** out any outstanding balance at the end of the 12-month period



Net Metering
Page II

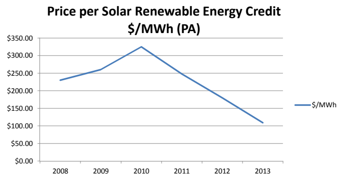
- Notice the "01" channel number which indicates the **net** amount of electricity that has been purchased from the grid
- The "04" channel number in the upper right indicates the electricity that has been purchased **from** the grid
- At bottom, the "40" channel number indicates the total amount of electricity that has been sold **to** the grid
- Do the math to see if it adds up

Fundamentals of Renewable Energy

- National Renewable Energy Laboratory (NREL) data shows that the solar resource for Greensburg, PA is 4.35 $kWh/m^2/day$ or 0.404 $kWh/ft^2/day$.
- This equals approximately 147.5 $kWh/ft^2/yr$
- At a conversion efficiency of 16%, a PV system in Greensburg, PA would produce about 24 $kWh/ft^2/yr$

Fundamentals of Renewable Energy

The value of Alternative Energy Credits (a.k.a. Renewable Energy Credits or certificates) vary by year and location:



Source: http://www.puc.pa.gov/consumer_info/electricity/alternative_energy.aspx

Cash Value of Sunlight

1 ft^2 of panel area ≈ 24 kWh$_{electric}$/yr

24 kWh x (10¢ per kWh + 11¢ per AEC/kWh) = $5.04 per ft^2 of panel area per yr

Corn @ 150 bushel/acre and $7.50/bushel = $0.03/ft^2 of growing area

PVWatts Calculator*

Station Identification	
City:	Pittsburgh
State:	Pennsylvania
Latitude:	40.50° N
Longitude:	80.22° W
Elevation:	373 m
PV System Specifications	
DC Rating:	4.0 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.1 kW
Array Type:	Fixed Tilt
Array Tilt:	30.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	9.6 ¢/kWh

Results			
Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	2.49	244	23.42
2	3.36	298	28.61
3	4.20	391	37.54
4	5.04	452	43.39
5	5.45	481	46.18
6	5.76	476	45.70
7	5.58	475	45.60
8	5.58	478	45.89
9	4.65	394	37.82
10	4.00	364	34.94
11	2.52	226	21.70
12	1.80	163	15.65
Year	4.21	4442	426.43

* PVWatts can be accessed at http://pvwatts.nrel.gov/pvwatts.php

Modularity Supports Flexibility

- Cells are grouped in modules to accommodate output voltage and current
- Modules are grouped to accommodate space and design power output
- Mounting structures and inversion (DC-AC) equipment are sized to accommodate modules
- Systems are easily expandable to accommodate growth

Roof Mounted Solar PV

Modular Racking

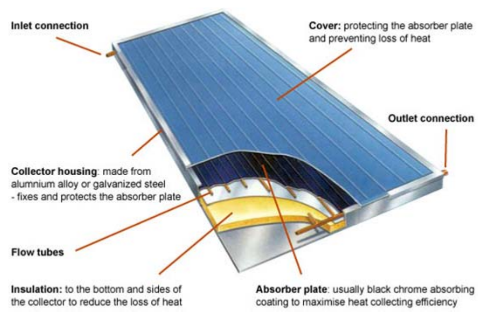
Ground Mounted Solar PV

Safety Issues

An outdoor, visible disconnect is required for solar PV systems

Mounting Thermal Collectors

Solar Hot Water Collector



Source: http://www.greenspec.co.uk

Additional Equipment - Thermal

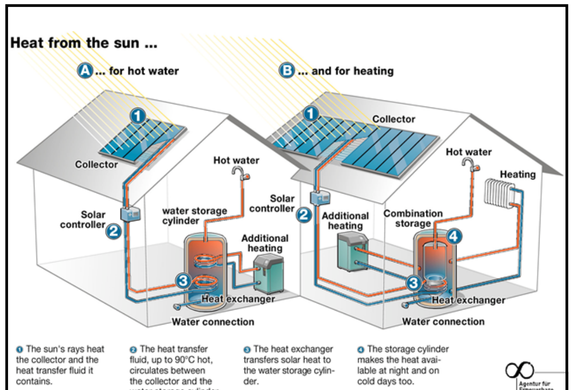
Plumbing

Storage tank
Heat exchanger

Auxiliary heat

Expansion tank

Controller



Source: http://www.unendlich-viel-energie.de

Solar Thermal System Types

- Since our region is frosty at times, systems must be freeze resistant. Two options are:
  - Drain back system – all fluid is drained from the collector when it's cold
  - Antifreeze system – antifreeze is used in the collector loop to prevent freezing

Solar Thermal System Issues

- Typical installations cost between $6,000 and $10,000 (professionally installed)
- A typically-sized system produces about half the typical household's hot water needs in the Northeast
- Solar thermal was the more attractive option years ago before PV equipment dropped in price and reliable, high-efficiency heat pump water heaters became available

The Case for Solar

- Transitioning from fossil based energy to renewables calls for a financial analysis
- Analysis must consider all benefits and expenses to produce a realistic financial scenario
- Payback period expectations should be realistic
- Market stability creates a stable playing field
- Other considerations are non-economic (i.e., doing the right thing)

The Economic Case

- Total system costs, permits, insurance, overall efficiency, expected system life, maintenance, etc.
- Value of incentives such as grants, tax credits, rebates, avoided future costs, Renewable Energy Credits, etc.
- Opportunities to participate in hourly pricing, demand response, or other innovative energy programs (PV only)
- Innovative financing opportunities

Making the Economic Case - PV

A typical 5,000 watt solar system produces about 6,000 kWh annually in the Northeast

System cost @ $4.00/watt……………………$20,000

Estimated annual return on investment

Avoided kWh cost/yr @ $0.10/kWh…………..$600

Federal tax credit @ 30% = $20,000 x 30% ………$6,000

Renewable Energy Credits @ $110/1000 kWh…….$660

Making the Economic Case - PV

Sum of installation costs………………..$20,000

Less tax credit………………………………..<u>$6,000</u>

Total…………………………………………….$14,000

<u>Calculated simple payback</u>

$$\$14{,}000 \div (\$600 + \$660) = 11 \text{ yr}$$

Payback period will improve as energy costs rise

The Economic Case – Thermal

- Typical solar thermal system: with two, 4' x 8' collectors, producing 40 to 60% of hot water needs annually depending on climate
- Assume: 44 gal/day family hot water use (16,000 gal/yr); 60% produced by solar thermal is ≈ 9,600 gal; Water heated from 50° to 120°F. (To heat 1 gal water by 70 °F requires approximately 0.17 kWh)

9,600 gal/yr x 0.17 kWh/gal = 1,642 kWh/yr

1,642 kWh/yr x $0.10 per kWh = $164/yr avoided electricity costs

The Economic Case – Thermal

Investment in solar thermal system……….$10,000
Estimated annual return on investment:
Federal tax credit @ 30% = $10,000 x 30%………$3,000
Net cost…………………………………….....................$7,000
Avoided kWh cost/yr @ $0.10 /kWh…………………$164
Renewable Energy Credits @ $110/1000 kWh……$180 JS2
$7,000/($164 + $180) = 20 yr simple payback

Solar PV pays back much more quickly!

Summary

- You now have a basic understanding of the equipment needed and the workings of a solar PV system
- You now have a basic understanding of a solar thermal system
- You have an idea of the costs and benefits related to these systems including tax credits and Renewable Energy Credits
- You also have an appreciation of the environmental benefits each such system provides

Farm Energy IQ

Questions?

FEIQ: Solar Energy on Farms

Slide 32

JS2 check my math in here--I made the RECS equivalent to hte RECs in the previous slide ($110 per MWh)
Jeannie Sikora, 12/1/2014