

Solar Electric Systems in Homes

NEHERS Conference Call
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Robb Aldrich
Steven Winter Associates, Inc.
raldrich@swinter.com

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Photovoltaics (PV) on Homes



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Solar Water Heating



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Both PV and Solar HW

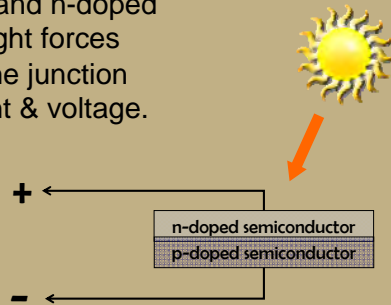


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PV: How it Works

At a junction of p- and n-doped semiconductors, light forces electrons across the junction creating DC current & voltage.

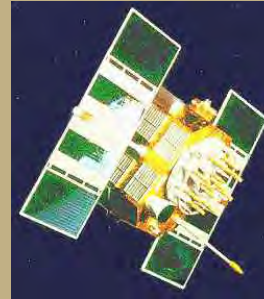


<http://www1.eere.energy.gov/solar/>

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First Practical Application



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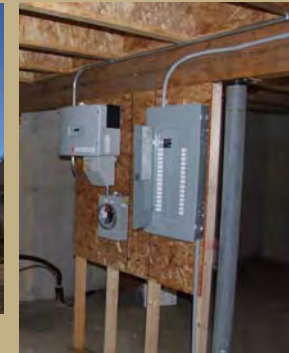
Off-Grid Power



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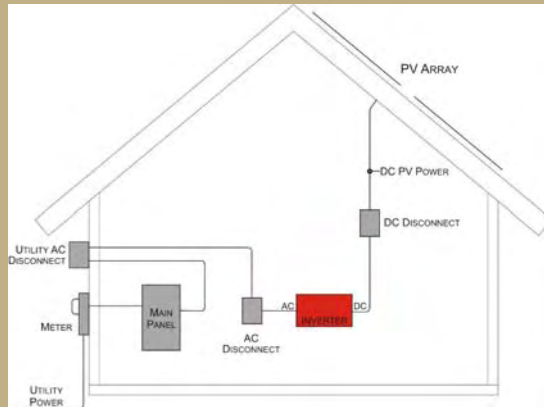
Grid-Tied Applications



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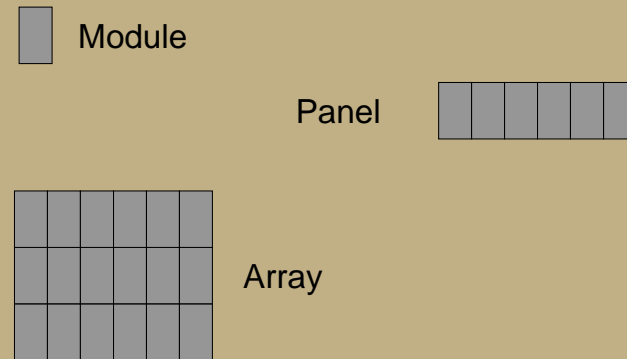
Grid-Tied PV: How it Works



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PV Nomenclature



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PV Generation

Power vs. Energy

Power: Rate of energy (use or generation)

- Watt, kilowatt [kW] = Power
- Watt-hour, kilowatt-hour [kWh] = Energy

- 100-watt lamp
- 100-W lamp on for 1 hour → 100 Wh
- 100-W lamp on for 10 hours → 1 kWh

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PV Generation

Power vs. Energy

- 100-Watt PV module
- In full sun for one hour (under design conditions) → 100 Wh
- In full sun for ten hours (under design conditions) → 1 kWh

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Home Electricity Consumption

Average home electricity use in northeast:

- 7,600 kWh per year
- 630 kWh per month
- 21 kWh per day



<http://www.eia.doe.gov>

STC: Standard Test Conditions

Nameplate ratings of PV Modules.

- 1,000 W/m²
- 25°C module temperature

PTC: PV-USA Test Conditions

- 1,000 W/m²
- 20°C air temperature
- 1 m/s wind speed

PTC ratings are approximately 85-90% of STC ratings.

PV Generation

NREL's PVWatts Calculation Tool

- 1-kW_{STC} System
- Albany
- Facing due South
- Tilt at Latitude (43° N)
- Derate Factor of 0.77 (default)

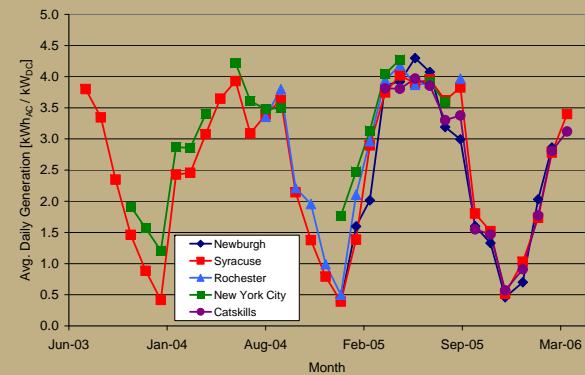
PVWatts Prediction: **1,159 kWh/year**

REM/Rate Prediction: **1,212 kWh/year**

Monitored PV Generation

Site	Ann. Generation [kWh/kW _{STC}]
Hadley, MA	1,031
Syracuse, NY	980
Rochester, NY	1,028
Bronx, NY**	1,100
Newburgh, NY	914
Fleischmanns, NY	972

Monitored PV Generation



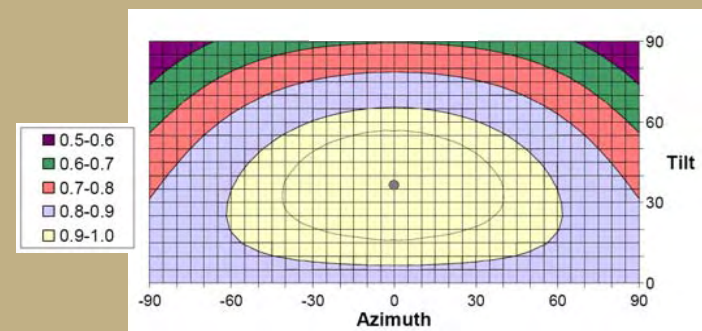
Why Less PV Generation?

Average of 6 Sites:
1004 kWh/yr-kW_{STC}

Albany PV Watts Prediction:
1159 kWh/yr-kW_{STC}

13% Less generation than PVWatts
(17% less than REM/Rate)

Tilt and Orientation



Christensen, C. and G. Barker. "Effects of Tilt and Azimuth on Annual Incident Solar Radiation for United States Locations." Proceedings of American Solar Energy Society Conference, 2001.

Shading



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Shading

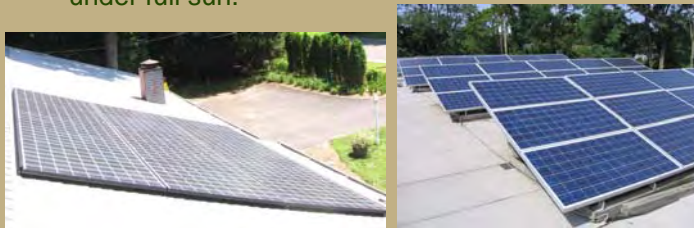


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Hot Modules

- Modules lose about 0.5% of output for every °C above 25°C.
- A 100-W module at 50°C will generate 87.5 W under full sun.



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Dirty Modules



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Other Collector Issues

- Snow
- Wiring Losses
- De-rating over Time



Inverter Efficiencies

Almost all inverters operate at >90% efficiencies...



...until they break.

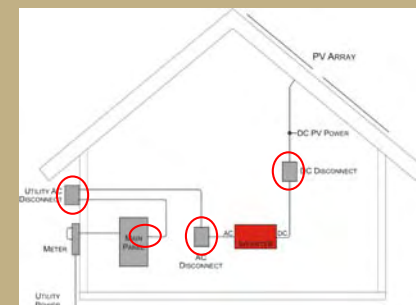
PV Operation & Maintenance

PV's reliability reputation:

- Plug & Play
- No moving parts
- Little or no Maintenance

All TRUE! For the most part...

Turn Systems ON



~5% of systems are OFF.

Inverter Failure



Inverters do fail!
Warranties are typically 5-10 years.

PV Performance Guidelines

- Face South
- Reasonable tilt (20-50°)
- Minimal shading
- Keep systems turned ON
- Fix inverters when they break.

PV: Costs and Savings

Installed Costs: \$7 - \$11 per Watt
(before incentives)

Average: \$9 per Watt, \$9,000 per kW
(before incentives)

PV: Costs and Savings

For 1-kW_{STC} of PV

- Initial Cost: \$9,000
- Energy Generation: 1,100 kWh/year
- Interest/Discount Rate: 6%
- Initial Electricity Cost: \$0.17

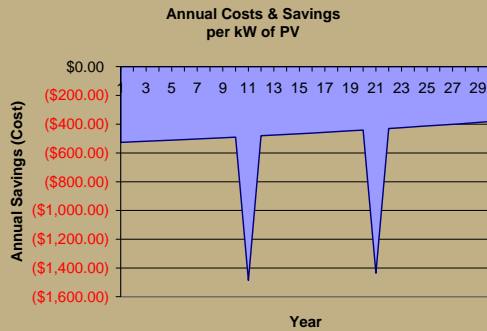
PV: Costs and Savings

Energy Inflation Rate: 2%

Initial Cost: \$ (9,000)
 Incentives: \$ -
 O&M Costs (Pres.Val.): \$ (821)
 Net Pres.Val. Cost: \$ (9,821)

Energy Savings (Pres.Val.): \$ 3,201

Net Pres.Val. Savings (Cost): \$ (6,620)



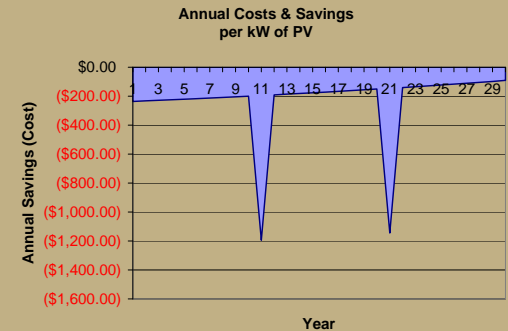
PV: Costs and Savings

Energy Inflation Rate: 2%

Initial Cost: \$ (9,000)
 Incentives: \$ 4,000
 O&M Costs (Pres.Val.): \$ (821)
 Net Pres.Val. Cost: \$ (5,821)

Energy Savings (Pres.Val.): \$ 3,201

Net Pres.Val. Savings (Cost): \$ (2,620)



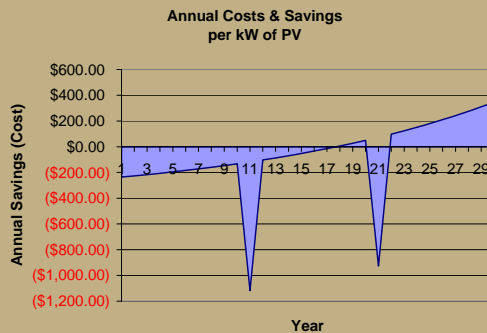
PV: Costs and Savings

Energy Inflation Rate: 5%

Initial Cost: \$ (9,000)
 Incentives: \$ 4,000
 O&M Costs (Pres.Val.): \$ (821)
 Net Pres.Val. Cost: \$ (5,821)

Energy Savings (Pres.Val.): \$ 4,628

Net Pres.Val. Savings (Cost): \$ (1,193)



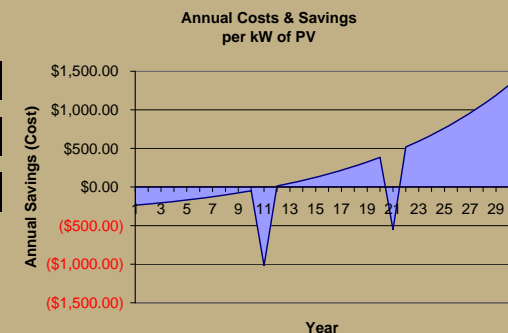
PV: Costs and Savings

Energy Inflation Rate: 8%

Initial Cost: \$ (9,000)
 Incentives: \$ 4,000
 O&M Costs (Pres.Val.): \$ (821)
 Net Pres.Val. Cost: \$ (5,821)

Energy Savings (Pres.Val.): \$ 7,031

Net Pres.Val. Savings (Cost): \$ 1,210



Other Benefits

Other Factors

- Tax & other Incentives
- Renewable Energy Credits (REC's)
- Time-of-Use Electric Rates
- Energy Independence
- Carbon Emissions
- Environmental Benefits

PV for the Average, NE Home

“How much does a PV system cost to power a 3,000-sq.ft. home?”

- Average Northeast electricity use: 7,600 kWh/year
- One kW of PV generates 1,100 kWh/year
- One kW of PV costs approx. \$9,000

PV on Efficient Homes

“How much does a PV system cost to power a 3,000-sq.ft. home?” **is the wrong question.**

A better question:

“How can a home be efficient enough so a reasonable PV system (~3 kW) can provide all the energy needed?”

Links

- On-line database of solar contractors: www.findsolar.com
- PVWatts PV Modeling tool: http://rredc.nrel.gov/solar/codes_algs/PVWATTS/version1/
- Database of state incentives for renewable energy: <http://www.dsireusa.org>
- DOE Energy Efficiency and Renewable Energy site: <http://www1.eere.energy.gov/solar/>
- Energy Information Administration: <http://www.eia.doe.gov>

Contact Information

 Robb Aldrich
Steven Winter Associates, Inc.
50 Washington St.
Norwalk, CT 06854
203-857-0200
raldrich@swinter.com

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<http://www.nyserda.org/>

Long Island Power Authority (LIPA) Clean Energy Initiative
<http://www.lipower.org/cei/solar.html>