PV 101 Basic PV

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Presentation Overview

- Introductions, agenda, goals
- Resources, definitions
- PV Basics
- System types, virtual tour
- Movement of the sun, solar window, SPF
- Ohms Law, general math, load profiles
- Energy efficiency
- Sizing systems
- System pricing
Resources

Books

- Photovoltaics Design and Installation Manual, SEI
- Photovoltaic Systems, American Technical Publishers
- Power from the Sun, Dan Chiras
- The Homeowner’s Guide to Renewable Energy, Dan Chiras
Resources

Periodicals
- Home Power Magazine
- Solar Today
- Solar Pro
- Sun & Wind Energy
Resources

Websites

• dsireusa.org
• http://www.quickmountpv.com/training/webinars/index.html?cur=0
• renewwisconsin.org
• midwestrenew.org
• http://pvwatts.nrel.gov/
• the-solarfoundation.org
• http://openpv.nrel.gov/index
• http://www.rbisolar.com/solar-calculator/
• http://solar-estimate.org/?page=estimatoroverview
• http://design.unirac.com/tool/project_info/solarmount/?pitched=true#max-span-help
• http://www.energyperiscope.com/
Definitions

Watt (W)

- Watts is a measure of power.
- Volts X Amps = Watts
- Indicates amount of power a module or PV system can produce or the amount of energy a device will consume
kiloWatt (kW)
• One thousand Watts (W) of power.
• $W / 1000 = \text{kiloWatts}$
Definitions

kilo Watt hour (kWh)
• Units in which power is bought and/or sold
• kilo Watts X time = kilo Watt hour
• 1 kW X 3 hours = 3 kWh
Definitions

Grid/Utility Grid

• Network of wires that run up and down the streets and highways of the US used for electrical distribution

• Can be used to store excess electrons generated by a renewable source for future use.
Definitions

Net Metering
Investor owned utilities are required by law to credit customer accounts for their over production of RE electricity at retail rates.

• Maximum output varies from state to state

• Amount of over production is usually based on nameplate output not kilowatt-hours/year
Definitions

Net Metering
- WI - 20 kW
- IL - 40 kW
- NE – 25 kW (credited at avoided cost on next bill)
- OK - 100 kW or 25,000 kWh/yr of production whichever is less
- IA - 500 kW
- ON - 500 kW
- WV – 25 kW residential, 50 kW commercial
Definitions

Net Metering
• Maximum allowable system size, based on rated output

REI
960 W PV
1,200 W PV
2,000 W PV
2,200 W PV
3600 W Wind
9,960 W rated output
10,040 W to go
Definitions

Irradiance, Irradiation, and Insolation

Solar irradiance – the power of solar radiation per unit surface area. It is expressed in W/m²
Power (rate)

Solar irradiation – the energy of solar radiation over a given period of time. It is expressed in kWh/m²
Energy (quantity)

Insolation – the measure of solar radiation energy received on a given surface area in a given time. It is commonly expressed as average irradiance in kilowatt-hours per square meter per day, kWh/m²/day
Peak Sun Hours
Definitions

Standard Test Conditions (STC)
• Manufactures specification for power output of a PV module.

• Predicts output under ideal test conditions.
  • 25° C (77°F)
  • 1000 W/M²
  • 1.5 AM (Sea level)
Air Mass

Definitions

Rated Output
   Maximum amount of power a PV system will produce in full sun

- Expressed in watts or kiloWatts
- ten 100 W modules wired together would equal a 1000 Watt system
- May also be called Nameplate Rating
Solar Irradiation as a Function of Weather

This graph shows the approximate global solar irradiation values on a horizontal plane as a function of the weather. On clear days, there are very high levels of irradiance, which can be in the order of 800 to 1000 W/m², while on completely overcast days, only 200 W/m² or less are obtained. Seasons can also have an effect on irradiance levels.

Output as a Function of Solar Irradiation

Module Label

PTC Performance Test Conditions
- 800 W/M²
- Sea level (1.5 AM)
- 50°C (122°F)

Photovoltaic Cell

Photovoltaic Module

Amorphous

String Ribbon

Multicrystal

Monocrystal
Photovoltaic Module

Monocrystal
• Single crystal grown
• Silicon based
• Most expensive process
• Most efficient cell (18%)
• Solid navy blue color
Photovoltaic Module

Multicrystal
- Silicon based
- Molten silicon is cast into mold
- Cheaper manufacturing process
- Cell efficiency up to 14%
- More efficient use of surface area
Photovoltaic Module

String Ribbon
- Silicon based
- least expensive manufacturing process
- Cell efficiency up to 13%
Photovoltaic Module

Amorphous
• Some are silicon based
• Can be flexible
• Inexpensive
• Efficiency up to 9%
• Poor track record
Photovoltaic Module

• Building Integrated
Photovoltaic Module

- Field applied

Photovoltaic Module

- Building block of an array
- Each cell .47 V
- Each cell linked series/parallel
- Rated output at STC in Watts
Make Up of a Module

- Frame
- Glass
- Cells
- Backer
- J Box
- Connections
Module Variations

Curb Appeal

• Clear glass with an uncolored aluminum frame

• Black frame with tinted glass

• Shapes vary

• Peel-and-stick amorphous modules

• Translucent modules for carport, walkway roof, awning, etc.
Module Variations

Module Choices

- Clear backsheet

Module Variations

Module Choices

- Black frame
- Black backsheet

Module Variations

Module Choices

• Roof tile

Module Variations

Module Choices

- Slate roof tile

Module Variations

Module Choices

- Solar window

Photovoltaic Array
PV Mounting
PV Mounting

Mounting

• L-foot mounted on deck with lots of silicone

PV Mounting

Mounting
• Stanchion on roof deck without protection

PV Mounting
PV Mounting

Rail

PV Mounting

Rail

PV Mounting

End Clamp

**PV Mounting**

Mid Clamp

PV Mounting

Mounting

• Based on many factors:
  • Visibility
  • Space constraints
  • Shading
  • Performance optimization
  • Security
  • Cost
  • Integrated architecture designs
PV Mounting

Mounting

• Quick mount
  • Stainless steel 12” x 12” flashing
  • Stainless steel hardware
  • 2,554 lbs. av. pullout

PV Mounting

Mounting

- Quick mount

PV Mounting

Mounting
- Quick mount

PV Mounting

Mounting

• Quick mount

PV Mounting

Mounting

• Fast Jack
  • Single bolt
  • Proper flashing
  • Variable height stanchion

PV Mounting

Mounting

• Fast Jack

PV Mounting

Mounting

- Fast Jack

PV Mounting

- Mounting
  - Fast Jack

PV Mounting

- Mounting
  - Fast Jack

PV Mounting

Mounting

- Fast Jack

PV Mounting

Mounting

• Fast Jack

PV Mounting

Mounting
• S-5 clamp
• Standing seam

PV Mounting

Flush-mount

• Subtle, low cost
• Requires adequate roof space facing a southerly direction and no shading from adjacent structures

PV Mounting

Pole-mount

• Good choice where the array size is larger than available roof space
• Easy to change tilt angle
• Easy for snow removal
• Requires trenching

Source: Ammond, Chuck. “Pole mount.”
PV Mounting

Ground Racking

- Simple structure
- Structural integrity
- Ease of access
- Simple foundation
- Easy to change the tilt angle for seasonal optimization

Source: Ammond, Chuck. “Ground racking.”
PV Mounting

Flat Roof Racking

• Able to use ballasted racks to avoid roof penetrations for mounting
• Ability to remove snow or dirt easily
• Modules in a secure location
• Hidden from outside view
• Only one penetration – conduit with the wiring

Source: Ammond, Chuck. “Flat roof racking.”
PV Mounting

Integrated Architecture Designs

- Awnings – take advantage of passive solar
- Carport – used as primary roof
- Translucent – allow sunlight to filter in

PV Mounting

Tracker

- Single or dual axis
- Tracks sun daily
- Adjusts for seasonal change in sun angle
- 25 – 30% more production

PV Mounting

Tracker

Angle of Incidence

Percent of available solar energy intercepted by one unit of area

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System Types

Utility Interactive System
  AKA: Utility Intertied without Batteries
  Simplest System

Bimodal System
  AKA: Utility Intertied with Batteries
  Power all the time

PV Direct System
  Power only when needed

Stand-Alone System
  You are your own utility
Utility Interaction

Energy Sources to the Home

Utility Interactive

Array

- Collection of modules
- Produce DC electricity
- Sized for needs or goals
- Generally, high-voltage configuration (250 – 400+ VDC)

Source: “PV Array at The Center for Energy Education Laboratory.” Sinclair Community College Energy Education Center.
Utility Interactive

Combiner Box

• Located at the array
• Combines strings of sub arrays to form one large array
• Allows one set of wires to go to the balance of system instead of multiple sets of wires in series/parallel strings

Utility Interactive

- Watertight electrical box that contain touch safe fuses or breakers
- Circuits are collected and connected in parallel
- Circuits exit at a higher amperage through a single, larger conductor where it connects to the BOS

Utility Interactive

Inverter
• Converts high-voltage DC electricity to utility-grade AC
• Maximum power point tracking of array
• Monitor utility match the array voltage and Hertz to utility
• Disconnect from utility during utility outage (anti-islanding)
• Sine wave

Utility Interactive

Disconnects

- Isolation of components to safely service of equipment
- Provide overcurrent protection of system

Utility Interactive

Lightning Arrestors

• Provide some protection of electronics of a system from lightning
• Required by most insurance companies
• Cheap form of protection, may or may not prevent all damage

Utility Interactive

Load Center

- Conventional breaker panel
- Location where renewable energy system will physically meet the utility

Utility Interactive

Utility Meter

- Accountant of consumption and/or production
- Interconnection Agreement

## Utility Interactive – System Cost

### Installed Cost

- Simple utility interactive, fixed mount - $4-6/watt
- Simple utility interactive, tracking array - $5-7/watt

Prices change as the industry changes

Check The Open PV Project for updated costs:

http://openpv.nrel.gov/
Utility Interactive – System Cost

Installed Cost

- Building Integrated simple utility interactive - $8-11/watt
- Simple utility interactive, fixed mount - $7-10/watt
- Simple utility interactive, tracking array - $8-12/watt

Prices change as the industry changes
Check The Open PV Project for updated costs:
http://openpv.nrel.gov/
Bimodal
Bimodal System - Components

Array

- Produces DC electricity
- May be low- or high-voltage (24 or 48 VDC or greater)
- Sized for the loads or goals of the owner

Source: “PV Array at The Center for Energy Education Laboratory.” Sinclair Community College Energy Education Center.
Bimodal System - Components

- **Charge Controller**
  - Regulates battery voltage during charging process
  - Protects batteries from overcharge, maintains battery at 100%, can initiate equalizing cycle
  - Can transform array high-voltage to battery low-voltage
  - Can maximum power point tracking
  - Can be simple to very complex
  - Brain of a system

Bimodal System - Components

Battery Charging
PWM (pulse width modulation)

High speed connection and disconnection between batteries and charging source
A series of short charging pulses are sent to battery depending on state of charge
Low battery long pulse, charged battery short pulse
Juggling electrons

Maximum Power Point Tracking-MPPT

MPPT charge controllers trick PV module, by adding resistance to the circuit, to increase maximum voltage output.

Bimodal System - Components

Batteries

- Storage of electrons for critical loads
- Maintained at 100%
- Usually flooded lead acid
- Needs venting for hydrogen
- Large footprint, spill containment, significant owner participation

Bimodal System - Components

Inverter

• More sophisticated, must interact with utility and as stand-alone during power outage
• Sine wave
• Will charge batteries off of utility when solar resource not available
• Anti-islanding

Bimodal System - Components

Load Center and Critical Load Center

• Critical load center
• Loads you need to run during a typical power outage
• Need a transfer switch to manually disconnect from utility panels to critical loads panel
Bimodal System - Components

Other Components

• Lightning arrestors
• AC and DC Disconnects
• Combiner Boxes
• Interconnection agreement
Bimodal System - Components

Installed Cost

- Bimodal, fixed mount - $9-12/watt
- Bimodal tracking, - $10-13/watt

Prices change as the industry changes
Check The Open PV Project for updated costs:
http://openpv.nrel.gov/
Stand Alone

PV panels → Charge controller → Batteries → Inverter → Load
Stand Alone – Components

Array
Sized for needs of the home, sized different than other system types

Seasonal tilt angle is critical

Array voltage generally matches battery voltage, can be high-voltage

Stand Alone – Components

**Charge Controller**

- Charges, regulates, and protects batteries
- Regulates battery voltage during charging process
- Can maximum power point tracking
- Can be simple to very complex
- Brain of a system

Stand Alone – Components

Batteries

- Sized for three-five days of autonomy
- Usually flooded lead acid batteries
- Always require back-up

Stand Alone – Components

Batteries Metering

- Gas gauge of system
- Real time readings
- Historic information

Stand Alone – Components

Inverter

- Can be of lesser quality wave form
- Can have auto functions to turn on generator or divert loads
- Sized for maximum loads and start-up

Stand Alone – Components

Back-Up
- Gas generator
- Wind machine
- Micro-hydro

Stand Alone – Components

Other Components

- Standard issue load center
- Lightning arrestors
- AC and DC Disconnects
- Combiner Boxes
Stand Alone – System Costs

Installed Cost

• Stand-alone, fixed array - $12-16/watt

Prices change as the industry changes
Check The Open PV Project for updated costs:
http://openpv.nrel.gov/
PV Direct System

PV Direct System - Components

Array

- Sized for function

PV Direct System - Components

Device or Appliance

• Fans
• Lights
• Circulation pumps
PV Direct - System Cost

Prices change as the industry changes
Check The Open PV Project for updated costs:
http://openpv.nrel.gov/
Virtual Tour

MREA Carport

10 – 230 W MAGE Solar

Virtual Tour
MREA Carport

10 – 230 W MAGE Solar
Rated output?

Virtual Tour

MREA Carport

10 – 230 W MAGE Solar

10 x 230 = 2,300 W

Virtual Tour

MREA Carport

10 – 230 W MAGE Solar
10 x 230 = 2,300 W

Virtual Tour

MREA Carport

Solar Edge Optimizer

- DC to DC converter
- Tune individual module output to the array
- Any fault goes to 1 volt

Virtual Tour

MREA Carport

Solar Edge Inverter

- 3,300 W

Virtual Tour

MREA Carport

Load Center

MREA Training Roof

10 – 225 W Kyocera

MREA Training Roof

10 – 225 W Kyocera
Rated output?

MREA Training Roof

10 – 225 W Kyocera
10 x 225 = 2,250 Watts

MREA Training Roof

MREA Training Roof

SolaDeck

MREA Training Roof

DC Disconnect

MREA Training Roof

Inverter – Magnatek (Power One)

MREA Training Roof

Utility Disconnect

MREA Training Roof

Load Center

13 kW Central Waters Brewery
13 kW Central Waters Brewery
13 kW Central Waters Brewery
NWMC Enphase Install
NWMC Enphase Install
NWMC Enphase Install
NWMC Enphase Install
1000 W, 30-32 W Arco modules
Battery Pack
Low Voltage BOS
Load Center
PV Direct

PV panels

→

DC load
BIPV, Exelon Pavilion, Millennium Park Chicago
459 – 75 W modules, 34.5 kW array est. 16,175 kWh/yr, actual 2,967 kWh 10 months 2009
Solar Window

Latitude (North/South)
- 90°N
- 45°N
- 0°
- 45°S
- 90°S

Equator

Longitude (West/East)

Latitude varies from 0° at the equator to 90° North and South at the poles

Longitude varies from 0° at Greenwich to 180° East and West
Solar Window

Seasonal Changes

Solar Window

Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Custer WI Latitude = 45 deg N
Fall/Spring = 45 deg, Summer = 30 deg, Winter = 60 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Iowa City, IA Latitude = 41 deg N
Fall/Spring = 41 deg, Summer = 26 deg, Winter = 56 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Traverse City, MI Latitude = 45 deg N
Fall/Spring = 45 deg, Summer = 30 deg, Winter = 60 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Parkersburg, WV  Latitude = 39 deg N
Fall/Spring = 39 deg, Summer = 24 deg, Winter = 54 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Decatur, IL  Latitude = 40 deg N
Fall/Spring = 40 deg, Summer = 25 deg, Winter = 55 deg
Solar Window PV

Optimal tilt angle year round fixed mount: Custer, WI
Outputs for a 1 kW array at various angles
30 deg = 1127 kWh/year summer angle
31 deg = 1129 kWh/year
32 deg = 1130 kWh/year
33 deg = 1130 kWh/year
34 deg = 1131 kWh/year
35 deg = 1131 kWh/year
36 deg = 1131 kWh/year
37 deg = 1130 kWh/year
38 deg = 1129 kWh/year
39 deg = 1128 kWh/year
40 deg = 1127 kWh/year
45 deg = 1116 kWh/year fall/spring angle
60 deg = 1046 kWh/year winter angle
Solar Window PV

Optimal tilt angle year round fixed mount: Custer, WI
Outputs for a 1 kW array at various angles 4.0 SH

30 deg = 1127 kWh/year  Lat – 15 deg (summer angle)

37 deg = 1130 kWh/year Lat – 8 deg Optimal year round angle

45 deg = 1117 kWh/year Latitude (fall/spring angle)

60 deg = 1046 kWh/year Lat + 15 (winter angle)
Solar Window PV

Optimal tilt angle year round fixed mount: Traverse City, MI
Outputs for a 1 kW array at various angles 4.0 SH

30 deg = 1,137 kWh/year  Lat – 15 deg (summer angle)

37 deg = 1,134 kWh/year Lat – 8 deg (Optimal year round angle Custer)

45 deg = 1,116 kWh/year Latitude (fall/spring angle)

60 deg = 1,034 kWh/year Lat + 15 (winter angle)
Solar Window PV

Optimal tilt angle year round fixed mount: Iowa City, IA
Outputs for a 1 kW array at various angles

5/12, 22 deg = 1,225 kWh/year flush mount

27 deg = 1,240 kWh/year Lat – 15 (summer angle)

34 deg = 1,247 kWh/year Lat – 8 deg Optimal year round angle

42 deg = 1,237 kWh/year Latitude

57 deg = 1,165 kWh/year Lat + 15 (winter angle)
Solar Window PV

Optimal azimuth angle year round fixed mount: Iowa City, IA
Outputs for a 1 kW array at various angles

E 90, 5/12, @ 22 deg = 1,015 kWh/year flush mount

S 180, @ 22 deg = 1,225 kWh/year

W 270, @ 22 deg = 1,030 kWh/year
Solar Window PV

Optimal tilt angle year round fixed mount: Traverse City MI
Outputs for a 1 kW array at various angles

E 90, 5/12, @ 22 deg = 954 kWh/year flush mount
165, 5/12, @ 22 deg = 1,117 kWh/year
S 180, @ 22 deg = 1,124 kWh/year
195, 5/12, @ 22 deg = 1,121 kWh/year
W 270, @ 22 deg = 963 kWh/year
Solar Window PV

Optimal tilt angle year round fixed mount: Decatur, IL
Outputs for a 1 kW array at various angles 4.8 SH

25 deg = 1262 kWh/year  Lat – 15 deg (summer angle)

32 deg = 1271 kWh/year Lat – 8 deg Optimal year round angle

40 deg = 1269 kWh/year Latitude (fall/spring angle)

54 deg = 1193 kWh/year Lat + 15 (winter angle)
Solar Window PV

Optimal tilt angle year round fixed mount: Tucson AZ

Outputs for a 1 kW array at various angles

17 deg = 1613 kWh/year summer angle
18 deg = 1619 kWh/year
19 deg = 1625 kWh/year

29 deg = 1660 kWh/year
30 deg = 1662 kWh/year
31 deg = 1662 kWh/year
32 deg = 1663 kWh/year fall/spring angle
33 deg = 1663 kWh/year
34 deg = 1662 kWh/year

45 deg = 1626 kWh/year
46 deg = 1620 kWh/year
47 deg = 1614 kWh/year winter angle
Solar Window PV

Optimal tilt angle year round fixed mount: Charleston SC
Outputs for a 1 kW array at various angles
17 deg = 1304 kWh/year summer angle
18 deg = 1308 kWh/year
19 deg = 1313 kWh/year

28 deg = 1335 kWh/year
29 deg = 1336 kWh/year
30 deg = 1336 kWh/year
31 deg = 1336 kWh/year
32 deg = 1336 kWh/year fall/spring angle
33 deg = 1336 kWh/year
34 deg = 1335 kWh/year

45 deg = 1303 kWh/year
46 deg = 1299 kWh/year
47 deg = 1293 kWh/year winter angle
Solar Window PV

Optimal tilt angle year round fixed mount: Charlotte NC
Outputs for a 1 kW array at various angles
20 deg = 1293 kWh/year summer angle
21 deg = 1297 kWh/year
22 deg = 1301 kWh/year

30 deg = 1318 kWh/year
31 deg = 1319 kWh/year
32 deg = 1319 kWh/year
33 deg = 1319 kWh/year
34 deg = 1319 kWh/year
35 deg = 1318 kWh/year fall/spring angle
36 deg = 1317 kWh/year

48 deg = 1280 kWh/year
49 deg = 1275 kWh/year
50 deg = 1269 kWh/year winter angle
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Lac du Flambeau WI Latitude = 46 deg N
Fall/Spring = 46 deg, Summer = 35 deg, Winter = 61 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Charlotte NC Latitude = 35 deg N
Fall/Spring = 35 deg, Summer = 20 deg, Winter = 50 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Charleston SC Latitude = 32 deg N
Fall/Spring = 32 deg, Summer = 17 deg, Winter = 47 deg
Solar Window

Seasonal Tilt Angles:
Summer = Lat – 15 deg, Winter = Lat + 15 deg, Fall/Spring = Lat

Ex. Tucson AZ Latitude = 32 deg N
Fall/Spring = 32 deg, Summer = 17 deg, Winter = 47 deg
Solar Window

Solar Window

Average Daily Solar Radiation Per Month

ANNUAL

Flat Plate Tilted South at Latitude

NREL
2010
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</tbody>
</table>
Site Assessment Tools

Solar Pathfinder ~ $290

Solmetric ~ $2200
Solar Window
Performing a Site Assessment
Starting Point
20 ft. (from starting point)
40 ft. (from starting point)
60 ft. From starting point
Sighting Considerations

• Neighbors

• Distance to BOS

• Future construction

• Aesthetics

• Vegetative growth
SPF Exercise
SPF Exercise

Dec. 2+3+7+3+2 = 17\% \text{ Shade} = 100-17=83\% \text{ Sun}
Dec. $2+3+7+3+2=17\%$ Shade $= 100-17=83\%$ Sun
Jan. $2+3+7+3+2=17\%$ Shade $= 100-17=83\%$ Sun
Nov. $1+2+3+7+3+2+1=19\%$ Shade $= 100-19=81\%$ Sun
Feb. $1+2+3+7+7+3+2+1=25\%$ Shade $= 100-25=75\%$ Sun
SPF Exercise
Using PVWatts

Online, free software from National Renewable Energy Lab (NREL)

• Calculates the output of a PV array of essentially any wattage and any elevation angle, at any azimuth angle

• Generates a report that gives production numbers for every month of the year

• Does not account for snow shading

• Helps size an array to meet the load requirements and site conditions
Using PVWatts

PVWatts® Calculator

Estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations.
Using PVWatts

PVWatts® Calculator

My Location

49684
» Change Location

Beta Release (?)
HELP
FEEDBACK

ALL NREL SOLAR TOOLS

RESOURCE DATA SYSTEM INFO RESULTS

SOLAR RESOURCE DATA

The recommended weather data source is listed below.

Recommended weather data for your location

TRAVERESE CITY CHERRY CAPITAL, 7.5 mi. CHANGE

Currently, PVWatts® defaults to the closest TMY3 weather file (or international file). This will be the standard for the foreseeable future. We also offer the TMY2 locations (which allow you to mimic PVWatts Version 1) and a 10k gridded data set from SolarAnywhere. We will not be including the older 40k gridded data from PVWatts Version 2 as the other datasets are superior. Click the “Change” button above to see what data is available for your location. Refer to Help for more detailed information.
Using PVWatts

PVWatts® Calculator

SYSTEM INFO
Modify the inputs below to run the simulation:
- DC System Size (kW):
- Array Type: Fixed (open rack)
- DC-to-AC Derate Factor: 0.77
- Tilt (deg): 44.3
- Azimuth (deg): 180

INITIAL ECONOMICS (Optional)
Modify the inputs below to provide an initial rough estimate of the cost of energy produced by the system. Note that complex utility rates and third-party financing can significantly change these values:
- System Type: Residential
- Average Cost of Electricity Purchased from Utility ($/kWh): 0.10
- Initial Cost ($/Wdc): 3.70
Using PVWatts

PVWatts® Calculator

The SYSTEM INFO values have been restored to the defaults.

SYSTEM INFO
Modify the inputs below to run the simulation.
- DC System Size (kW): 1
- Array Type: Fixed (open rack)
- DC-to-AC Derate Factor: 0.87
- Tilt (deg): 44.5
- Azimuth (deg): 180

INITIAL ECONOMICS (Optional)
Modify the inputs below to provide an initial rough estimate of the cost of energy produced by the system. Note that complex utility rates and third-party financing can significantly change these values.
- System Type: Residential
- Average Cost of Electricity Purchased from Utility ($/kWh): 0.10
- Initial Cost ($/Wdc): 3.70

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

PVWatts® is a registered trademark by Alliance for Sustainable Energy, LLC, in Golden, CO 80401.
Using PVWatts

### RESULTS

**1,116 kWh per Year**

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar Radiation (kWh/m²/day)</th>
<th>AC Energy (kWh)</th>
<th>Energy Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.22</td>
<td>57</td>
<td>5</td>
</tr>
<tr>
<td>February</td>
<td>3.44</td>
<td>81</td>
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</tr>
<tr>
<td>December</td>
<td>1.61</td>
<td>40</td>
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<tr>
<td><strong>Annual</strong></td>
<td><strong>4.02</strong></td>
<td><strong>1,116</strong></td>
<td><strong>$ 106</strong></td>
</tr>
</tbody>
</table>
Using PVWatts

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies or site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Similarly, the “Energy Value” column simply multiplies the utility-average electricity price by production. Complex utility rates and financing can significantly impact the energy value. See Help for additional guidance.

<table>
<thead>
<tr>
<th>Location and Station Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requested Location</td>
</tr>
<tr>
<td>Weather Data Source</td>
</tr>
<tr>
<td>Latitude</td>
</tr>
<tr>
<td>Longitude</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PV System Specifications (Residential)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Rating</td>
</tr>
<tr>
<td>DC to AC Derate Factor</td>
</tr>
<tr>
<td>Array Type</td>
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<td>Array Tilt</td>
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<table>
<thead>
<tr>
<th>Initial Economic Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Cost of Electricity Purchased from Utility</td>
</tr>
<tr>
<td>Cost of Electricity Generated by System</td>
</tr>
</tbody>
</table>

These values can be compared to get an idea of the cost-effectiveness of this system. However, system costs, system financing options (including 3rd party ownership) and complex utility rates can significantly change the relative value of the PV system.
Using PV Watts

<table>
<thead>
<tr>
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<th>Solar Radiation (kWh / m² / day)</th>
<th>AC Energy (kWh)</th>
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Using PVWatts

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<td>4.02</td>
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</table>

Dec = 83% Sun

\[0.83 \times 40 = 33.2 \text{ kWh}\]
Using PVWatts

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar Radiation (kWh / m² / day)</th>
<th>AC Energy (kWh)</th>
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\[0.83 \times 57 = 47.3\]

\[0.75 \times 81 = 60.8\]

\[0.81 \times 51 = 41.3\]

\[0.83 \times 40 = 33.2\]
## Using PVWatts

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<tr>
<td>Annual</td>
<td><strong>4.02</strong></td>
<td><strong>1,116</strong></td>
</tr>
</tbody>
</table>

\[0.83 \times 57 = 47.3\]
\[0.75 \times 81 = 60.8\]

\[0.81 \times 51 = 41.3\]
\[0.83 \times 40 = 33.2\]

1,070.6
General Math Problems

24 V (E) × 15 A (I) = _____360_____ Watts

360 Watts × 12 hours/day run time = _____4320_____ Watt hours/day

4320 Watt hours/day × 7 days/week = _____30,240_____ Watt hours/week

30,240 Watt hours/week × 4 weeks/month = Watt hours/month

120,960 Watt/hours/Mo / 1000 = _____120.96_____ kWh/month

kWh/Mo. × $0.16 = $_____19.35_____ to operate device/month
General Math

1. 115 V (E)  5 A (I)  2.5 hours/day run time.  Find:
   \[ 575 \text{ W} \quad 1437.5 \text{ Wh/d} \]

2. 75 W  115 V (E)  Find:
   \[ 0.65 \text{ A (I)} \]

3. 110 V (E)  15 A (I)  12 hours run time  Find:
   \[ 1,650 \text{ Watts} \quad 19,800 \text{ Watt hours/day} \quad 594,000 \text{ Watt hours/month} \]

4. 120 Wh/d  2 A (I)  3 hrs/day  Find:
   \[ 40 \text{ W} \quad 20 \text{ V (E)} \]

5. 2 – 60 watt incandescent lights run 5 hours per day. Find:
   \[ 600 \text{ Wh/day} \quad 4200 \text{ Wh/week} \]
General Math

1. 115 V (E) 5 (I) 2.5 hours/day run time. Find:

_________ W

_________ Wh/d

2. 75 W 115 V (E) Find:

_________ A (I)

3. 110 V (E) 15 A (I) 12 hours run time Find:

_________ Watts

_________ Watt hours/day

_________ Watt hours/month

4. 120 Wh/d 2 A (I) 3 hrs/day Find:

_________ W

_________ V (E)

5. 2 – 60 watt incandescent lights run 5 hours per day. Find:

_________ Wh/day

_________ Wh/week
6. 4 – 40 watt incandescent lights run 3 hours per day. Find:
   
   480 Wh/day  3,360 Wh/week

7. 3 – 75 watt incandescent lights run 3 hours per day. Find:

   675 Wh/day  4,725 Wh/week

8. A pop machine has a label that says: 115 V 12 A. We know that the machine operates 12 hours per day. Calculate:

   1,380 Watts  16,560 Watt hours/day  16.6 kWh/d

   $ 2.65 /day to operate @ $0.16/kWh
General Math

6. 4 – 40 watt incandescent lights run 3 hours per day. Find:

__________ Wh/day   __________ Wh/week

7. 3 – 75 watt incandescent lights run 3 hours per day. Find:

__________ Wh/day   __________ Wh/week

8. A pop machine has a label that says: 115 V  12 A. We know that the machine operates 12 hours per day. Calculate:

__________ Watts   __________ Watt hours/day   __________ kWh/d

$ __________ /day to operate @ $0.12/kWh
9. A swimming pool has a pump that operates 24 hours/day during the summer months. The nameplate on the motor says: 220 V 16 A. Calculate:

- **3,520** Watts
- **84,480** Watt hours/day
- **84.48** kWh/d
- **2,534.4** kWh/month
- **$405.50**/month to operate @ $0.12/kWh

\[2,534.4 \times 2 = 5,068.8 \text{ kWh/month}\]

10. A refrigerator nameplate says: 115 V 6 A. We know that the refrigerator runs time is 10 hours each day. Calculate:

- **690** Watts
- **6900** Watt hours/day
- **6.9** kWh/d
- **$1.10**/day to operate @ $0.12/kWh

11. A 40 gallon electric water heater data sheet indicates that it consumes 4828 kWh per year and operates on a 220 V circuit. Calculate:

- **13.2** kWh/day consumption
- **13,200** Wh/day consumption
9. A swimming pool has a pump that operates 24 hours/day during the summer months. The nameplate on the motor says: 220 V 16 A. Calculate:

__________ Watts  ____________ Watt hours/day  ___________ kWh/d

__________ kWh/month $___________ /month to operate @ $0.12/kWh

10. A refrigerator nameplate says: 115 V 6 A. We know that the refrigerator runs time is 10 hours each day. Calculate:

__________ Watts  ____________ Watt hours/day  ___________ kWh/d

$___________ /day to operate @ $0.12/kWh

11. A 40 gallon electric water heater data sheet indicates that it consumes 4828 kWh per year and operates on a 220 V circuit. Calculate:

__________ kWh/day consumption  ___________ Wh/day consumption
12. A 80 gallon electric water heater data sheet indicates that it consumes 5047 kWh per year and operates on a 220 V circuit. Calculate:

13.8 kWh/day consumption  13,800 Wh/day consumption

13. An 840 Watt wash machine does 6 loads per week, .5 hours per load. Calculate:

420 Wh/load  2,520 Wh/load

14. Average the following monthly kWh consumption and find the following:

429.2 Average kWh/month  14.1 kWh/day
14,100 Wh/day

Jun 410 kWh  May 420 kWh  Aug 620 kWh  Jul 340 kWh
Sep 490 kWh  Oct 350 kWh  Nov 400 kWh  Dec 350 kWh
Feb 440 kWh  Jan 500 kWh  Apr 370 kWh  Mar 460 kWh
12. A 80 gallon electric water heater data sheet indicates that it consumes 5047 kWh per year and operates on a 220 V circuit. Calculate:

__________ kWh/day consumption    __________ Wh/day consumption

13. An 840 Watt wash machine does 6 loads per week .5 hours per load. Calculate:

__________ Wh/load    __________ Wh/load

14. Average the following monthly kWh consumption and find the following:

__________ Average kWh/month    __________ kWh/day

__________ Wh/day

Jun 410 kWh       May 420 kWh      Aug 620 kWh       Jul 340 kWh
Sep 490 kWh       Oct 350 kWh      Nov 400 kWh       Dec 350 kWh
Feb 440 kWh       Jan 500 kWh      Apr 370 kWh       Mar 460 kWh
15. Average the following monthly kWh consumption and find the following:

<table>
<thead>
<tr>
<th>Month</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>353 kWh</td>
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<tr>
<td>Feb</td>
<td>428 kWh</td>
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<tr>
<td>Mar</td>
<td>550 kWh</td>
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<tr>
<td>Apr</td>
<td>431 kWh</td>
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<tr>
<td>May</td>
<td>431 kWh</td>
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<td>Jun</td>
<td>444 kWh</td>
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<td>Jul</td>
<td>475 kWh</td>
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<td>Aug</td>
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<td>Sep</td>
<td>484 kWh</td>
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<tr>
<td>Oct</td>
<td>518 kWh</td>
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<tr>
<td>Nov</td>
<td>335 kWh</td>
</tr>
<tr>
<td>Dec</td>
<td>651 kWh</td>
</tr>
</tbody>
</table>

Average kWh/month: 450.9
Average kWh/day: 14.8
Wh/day: 14,800
15. Average the following monthly kWh consumption and find the following:

<table>
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<tr>
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<tr>
<td>Jun</td>
<td>444 kWh</td>
</tr>
<tr>
<td>Jul</td>
<td>475 kWh</td>
</tr>
<tr>
<td>Aug</td>
<td>311 kWh</td>
</tr>
<tr>
<td>Sep</td>
<td>484 kWh</td>
</tr>
<tr>
<td>Oct</td>
<td>518 kWh</td>
</tr>
<tr>
<td>Nov</td>
<td>335 kWh</td>
</tr>
<tr>
<td>Dec</td>
<td>651 kWh</td>
</tr>
</tbody>
</table>

__________ Average kWh/month   __________ kWh/day

__________ Wh/day
Load Profiles

6 - 60 W __________ W X 3hrs/d __________ X 7 days = __________ Wh/wk

1 - 25 W __________ W X 1 hrs/d __________ X 7 days = __________ Wh/wk

2 – 65 W __________ W X 15 min/d __________ X 7 days = __________ Wh/wk

5 – 60 W __________ W X 1 hrs/d __________ X 7 days = __________ Wh/wk

1 – 100 W __________ W X 6 hrs/d __________ X 7 days = __________ Wh/wk

1 – 100 W __________ W X 6 hrs/d __________ X 7 days = __________ Wh/wk

4 – 60 W __________ W X 1 hrs/d __________ X 7 days = __________ Wh/wk

4 – 60 W __________ W X 1 hrs/d __________ X 7 days = __________ Wh/wk

4 – 60 W __________ W X 2 hrs/d __________ X 7 days = __________ Wh/wk

1 – 100 W __________ W X 6 hrs/d __________ X 7 days = __________ Wh/wk

= __________ total Wh/week

360 1080 7560
25 25 175
130 32.5 227.5
300 300 2100
100 600 4200
100 600 4200
240 240 1680
240
240 1440
240 480
100 600 4200
100 600 4200

= 29,142.5
Load Profiles

6-60 W _________ W X 3hrs/d _________ X 7 days = _______________ Wh/wk

1 -25 W _________ W X 1 hrs/d _________ X 7 days = _______________ Wh/wk

2 – 65 W _________ W X 15 min/d _________ X 7 days = _______________ Wh/wk

5 – 60 W _________ W X 1 hrs/d _________ X 7 days = _______________ Wh/wk

1 – 100 W _________ W X 6 hrs/d _________ X 7 days = _______________ Wh/wk

1 – 100 W _________ W X 6 hrs/d _________ X 7 days = _______________ Wh/wk

4 – 60 W _________ W X 1 hrs/d _________ X 7 days = _______________ Wh/wk

4 – 60 W _________ W X 6 hrs/week = _______________ Wh/wk

4 – 60 W _________ W X 2 hrs/d _________ X 7 days = _______________ Wh/wk

1 – 100 W _________ w X 6 hrs/d _________ X 7 days = _______________ Wh/wk

= _______________ total Wh/week
System Sizing Basics

- Add 12 months electrical bills = kWh/year
- Divide by 365 days = kWh/day
- kWh/day divided by solar resource for location = system size in kW
- Divide system size by .80 (derate factor) = system size corrected for inefficiencies
Load Profiles

= 29,142.5 total Wh/week

29,142.5 Wh/week

= 4163 Wh/d

4163 Wh/d

= 1040.7 W system

1041 W System / .80 (derating factor 20%)

= 1301.3 W system size
Load Profiles

= _______________ total Wh/week

_________________________ Wh/week
7 days

= _________________________ Wh/d

_________________________ Wh/d
4 Sun Hours

= _________________________ W system

_________________________ W System /.80 (derating factor 20%)

= _________________________ W system size
## Load Profiles

**Phantom Load Profile**

<table>
<thead>
<tr>
<th>Device</th>
<th>Power (Watts)</th>
<th>24 hrs/day X 7 days =</th>
<th>Total Wh/wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell phone charger</td>
<td>10</td>
<td>1680</td>
<td></td>
</tr>
<tr>
<td>Cordless phone transformer</td>
<td>5</td>
<td>840</td>
<td></td>
</tr>
<tr>
<td>Answering machine</td>
<td>10</td>
<td>1680</td>
<td></td>
</tr>
<tr>
<td>Radio battery charger</td>
<td>6</td>
<td>1008</td>
<td></td>
</tr>
<tr>
<td>Fax transformer</td>
<td>6</td>
<td>1008</td>
<td></td>
</tr>
<tr>
<td>Cable box</td>
<td>5</td>
<td>840</td>
<td></td>
</tr>
<tr>
<td>Wall clock</td>
<td>4</td>
<td>672</td>
<td></td>
</tr>
<tr>
<td>Wall clock</td>
<td>4</td>
<td>672</td>
<td></td>
</tr>
<tr>
<td>Alarm clock</td>
<td>4</td>
<td>672</td>
<td></td>
</tr>
</tbody>
</table>

= **9072** total Wh/wk
# Load Profiles

## Phantom Load Profile

<table>
<thead>
<tr>
<th>Device</th>
<th>Power (Watts)</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell phone charger</td>
<td>10</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Cordless phone transformer</td>
<td>5</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Answering machine</td>
<td>10</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Radio battery charger</td>
<td>6</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Fax transformer</td>
<td>6</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Cable box</td>
<td>5</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Wall clock</td>
<td>4</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Wall clock</td>
<td>4</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
<tr>
<td>Alarm clock</td>
<td>4</td>
<td>24 hrs/day X 7 days = _______ Wh/wk</td>
</tr>
</tbody>
</table>

= _______________ total Wh/wk
Load Profiles

Phantom Load Profile

\[ \frac{9,072}{7 \text{ days}} = \frac{1,296}{4 \text{ Sun Hours}} = \frac{324}{\text{W system} / .80 \text{ (derate factor 20%)}} = 405 \text{ W system size} \]

Energy Efficiency recommendations:
Load Profiles

Phantom Load Profile

\[ \text{total Wh/wk} = \frac{\text{Wh/wk}}{7 \text{ days}} \]

\[ \text{Wh/d} = \frac{\text{Wh/d}}{4 \text{ Sun Hours}} \]

Energy Efficiency recommendations:
Energy Efficiency

Energy Efficiency =

Doing the *same* work ... 

with *less* energy
Energy Efficiency

Cost-Effectiveness of Efficiency

(4) 25 Watt PV panels

(1) 100 Watt Incandescent bulb
Energy Efficiency

Cost-Effectiveness of Efficiency

(1) 25 Watt PV Panel

(1) 25 Watt CFL (100 W Equivalent)
Energy Efficiency

Cost-Effectiveness of Efficiency

EQUAL LUMENS (light output)

<table>
<thead>
<tr>
<th>100 Watt Incandescent</th>
<th>25 Watt CFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 - 25 W PV panels</td>
<td>1 - 25 W PV panel</td>
</tr>
<tr>
<td>4 X $150 = $600</td>
<td>1 X $150 = $150</td>
</tr>
<tr>
<td>1 – 100 W bulb = $0.25</td>
<td>1 CF bulb = $5</td>
</tr>
</tbody>
</table>

Total: $600.25  
Total: $155.00
Energy Efficiency

Cost-Effectiveness of Efficiency

(2) Refrigerators - one old, one new  
Both 18 cubic ft

Old
3.6 kWh/day $0.11/kWh = $0.40/day $146/year

New
1.3 kWh/day $0.11/kWh = $0.14/day $ 51.10/year
Energy Efficiency

Cost-Effectiveness of Efficiency

Refrigerator scenario - PV System Size

Old
3.6 kWh/day X $0.11/kWh = $0.40/day X 365 = $146/ year
3600 Wh/day / 4 SunHrs = 900 W X $10/W = $9000 PV system

New
1.3 kWh/day X $0.11/kWh = $0.14/day X 365 = $ 51.10/ year
1300 Wh/day / 4 SunHrs = 325 W X $10/W = $3250 PV system
Energy Efficiency

Cost-Effectiveness of Efficiency

Every $1 spent on energy efficiency can reduce system cost by $3 - $5!
Energy Efficiency

Cost-Effectiveness of Efficiency

Opportunities for Energy Efficiency

- Water heating - 9% to 50% of load (varies greatly)
- Refrigeration - typically 13% of load
- Lighting - 9% of load
Energy Efficiency

Phantom Loads

Appliances that are turned off, but are not *really* off!
Energy Efficiency

Phantom Loads

Computer
TV
Stereo
DVD player
CD player
Cell phone chargers
Energy Efficiency

Phantom Loads

<table>
<thead>
<tr>
<th>Device</th>
<th>Power (w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereo</td>
<td>3</td>
</tr>
<tr>
<td>DVD player</td>
<td>2</td>
</tr>
<tr>
<td>CD player</td>
<td>2</td>
</tr>
<tr>
<td>TV</td>
<td>3</td>
</tr>
<tr>
<td>Computer</td>
<td>21</td>
</tr>
<tr>
<td>Cell phone charger</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>
Energy Efficiency

Phantom Loads

32 W x 24 hrs/day = 768 Watt hours/day
0.768 kWh x 365 days = 280 kWh/year

280 kWh/yr x 30 people = 8,400 kWh!

Enough to power one WI home for 8 months

... free!
Energy Efficiency

Fuel Switching

Running an appliance with a cheaper fuel source
Energy Efficiency

Fuel Switching

• Electric water heater to gas or gas and solar water
• Electric stove to gas stove
• Electric space heating to gas and/or wood heat
• Electric dryer to gas dryer or clothes line
System Sizing Basics

- Add 12 months electrical bills = kWh/year
- Divide by 365 days = kWh/day
- kWh/day divided by solar resource for location = system size in kW
- Divide system size by .80 (derate factor) = system size corrected for inefficiencies
System Sizing Basics Example

Traverse City, MI sun resource = 4.0 Sun Hours/day
Annual load = 5,876 kWh/year

\[
\frac{5,876 \text{ kWh/year}}{365} = 16 \text{ kWh/day}
\]

\[
\frac{16 \text{ kWh/day}}{4.0 \text{ sun hours/day}} = 4 \text{ kW system}
\]

\[
4 \text{ kW} \\
.80 \text{ derate factor} = 5.0 \text{ kW system}
\]

or

5,000 Watt system
System Sizing Basics Example

Custer WI sun resource = 4.5 Sun Hours/day (use 4)
Annual load = 5,876 kWh/year

\[
\text{5,876 kWh/year} \\
\text{365} = 16 \text{ kWh/day}
\]

\[
\text{16 kWh/day} \\
\text{4.0 sun hours/day} = 4 \text{ kW system}
\]

\[
\text{4 kW} \\
.80 \text{ derate factor} = 5.0 \text{ kW system}
\]

or

\[
\text{5,000 Watt system}
\]
Estimated Residential Install Costs

Utility Intertied Battery Free, Fixed Mount $7-10/W

Utility Intertied Battery Free, Tracking $8-12/W

Utility Intertied with Batteries, Fixed $9-12

Utility Intertied with Batteries, Tracking $10-13/W

Stand Alone $12-16/W

* Summer 2010, FOE
Estimated Residential Install Costs

Utility Intertied Battery Free, Fixed Mount $7-10/W
Utility Intertied Battery Free, Tracking $8-12/W
Utility Intertied with Batteries, Fixed $9-12
Utility Intertied with Batteries, Tracking $10-13/W
Stand Alone $12-16/W
Estimated Residential Install Costs

Utility Intertied Battery Free, Fixed Mount $4-6/W
Utility Intertied Battery Free, Tracking $5-8/W
Utility Intertied with Batteries, Fixed $6-10/W
Utility Intertied with Batteries, Tracking $7-12/W
Stand Alone $8-12/W
System Pricing Basics

System Size = 5,000 W

Utility Intertied Battery Free, Fixed Mount $7-10/W
Utility Intertied Battery Free, Tracking $8-12/W
Utility Intertied with Batteries, Fixed $9-12
Utility Intertied with Batteries, Tracking $10-13/W
Stand Alone $12-16/W

System size X $/W install cost

Ex. 6,000 W X $10/W - $50,000 installed
System Pricing Basics

System Size = 5,000 W

- Utility Intertied Battery Free, Fixed Mount $4-6/W
- Utility Intertied Battery Free, Tracking $5-8/W
- Bimodal, Fixed $6-10/W
- Bimodal, Tracking $7-12/W
- Stand Alone $12-16/W

System size X $/W install cost

Ex. 5,000 W X $5/W - $25,000 installed
PV Sizing - Exercise

Add 12 months of utility bills
Jan 720 kWh
Feb 550
Mar 540
Apr 327
May 390
Jun 357
Jul 363
Aug 402
Sep 560
Oct 446
Nov 623
Dec 598
Total: ???
PV Sizing - Exercise

Add 12 months of utility bills
  Jan 720 kWh
  Feb 550
  Mar 540
  Apr 327
  May 390
  Jun 357
  Jul 363
  Aug 402
  Sep 560
  Oct 446
  Nov 623
  Dec 598
Total: 5,876 kWh/year