Solar Electricity for Home, Farm & Ranch

Using The Sun To Produce Electricity
Exploring Energy Efficiency and Alternatives

- Home energy efficiency
- Farm energy efficiency
- Solar electricity
- Solar hot water
- Small wind
- Biodiesel
- Anaerobic digester
- Micro-hydropower
E³A Folder & Factsheets: Solar Electricity for Home, Farm & Ranch
Why Install a Solar PV System

• I want renewable
  – What’s the payback
• I want to produce my own
• I need the electricity
  – Remote location
• Marketing
  – Needs to be seen by customers?
• Investment
The Money Bottom Line

“You’re not actually saving any money until you have recaptured the money you spent to do the energy measure.”
Reduce Solar Cost = Tighten Home First

A kWh saved is always the best way to start

The $100 solution for your home = PLUG THE HOLES

- Expandable foam
- Weatherstrip
- Outlet insulators
- Caulking
- Foil duct tape
- Water heater insulation blanket
Agriculture Electricity Use
How We Generate Electricity
Electricity Generation
82% of Missouri’s electricity
Exploring Energy Efficiency and Alternatives

• Home energy efficiency
• Farm energy efficiency
• Solar electricity
• Solar hot water
• Small wind
• Biodiesel
• Anaerobic digester
• Micro-hydropower
Photovoltaics or “PV”

Photo = Light; Voltaics = Electricity

Credit: www.flickr.com

Credit: http://www.solarplusuk.com/solar-electricity
Some History

Photo credit: NASA
PV Materials Absorb the Sun’s Light Energy
How Does It Work?

**Diagram: Solar Panel Diagram**

- **Load**
- **Sunlight**
- **Electron Flow**
- **Photons**
- **"Hole" Flow**

**Layers:**
- Negative Layer
- Positive Layer

© Ron Curtis & MrSolar.com
Photovoltaics

Cell

Module or Panel

Array
PV Materials

Crystalline Silicon

Thin-Film
Building & Site Assessment
Solar Orientation

Sun's Path In the Sky

North

South

West

East

June 21

December 21

Photovoltaic modules

Solar windows
Do You Have Enough Space for Panels?

The rule of thumb for PV panels is 100 square feet of space is needed for every kilowatt (kW) of electricity produced. For thin-film PV materials (such as solar shingles), about 175 square feet of space per kW is needed.
Got Shade?

Credit: CleanTechies.com

Solar PathFinder

Credit: www.energyefficientheatingandcooling.com

Solmetric’s SunEye
Shading Analysis Tool
using SketchUp (www.sketchup.com)

Courtesy of Bozeman Green Build
The Solar Resource

Miami, Florida
12, 230 watt PV panels = 2,760 watts
= 2.76 PV System

2.76 kW \times 5.2 \, 	ext{kWh/m}^2/\text{day} \times 0.8 \, \text{(derate factor)}
\times 365 \, \text{days/year} = 4,190 \, \text{kWh of electricity/year}

Seattle, Washington
12, 230 watt PV panels = 2,760 watts
= 2.76 PV System

2.76 kW \times 3.7 \, 	ext{kWh/m}^2/\text{day} \times 0.8 \, \text{(derate factor)}
\times 365 \, \text{days/year} = 2,981 \, \text{kWh of electricity/year}
Missouri averages 4.5-5.0 kWh/m²/day

Source: www.nrel.gov/gis/pdfs/eere_pv/eere_pv_h_missouri.pdf
What’s Your Angle?

Spring & Fall Equinox Sun Angles

Summer Solstice Sun Angle

Winter Solstice Sun Angle

37° = 9/12 roof pitch
Mounting Options

• Roof mount
• Ground-mounted
• Pole-mounted
  – Fixed south-facing position
  – Single-axis tracking
  – Dual-axis tracking
What is Roof Condition?

- Will it support panel weight?
  - 2-5 lbs./sq.ft.
  - 230-watt panel (3.5’ x 5.5’) weighs 50 lbs. = 2.6 lbs./sq.ft.
  - How many layers of shingles already there?

- Panels can last 30+ years
  - Will roof need repairs before then?
  - Are panels easily removed?
System Components
PV Material + “BOS” = PV System

PV Material
(panels or shingles, rack)

Balance of System (BOS) =
(the remaining components)
“BOS” Components

- Inverter(s) or inverter/charger
- Batteries
- Charge controller
- Meters
- Switches & disconnects
- Grounding
- Wires

- Conduit
- Weatherproofing
- Permits
- Electrician
- Electrical inspection
- Structural support
- Lift rental
- Monitoring equipment
System Options
Grid-Connected (Tied) Solar Electric

PV Panels

Inverter

Utility Meter

Utility Grid System

Electrical Load

Electrical Panel/Box

= Electricity Flow
Grid-Connected (Tied) Solar Electric with Battery Backup
PV Direct Systems

Water-pumping system
Credit: National Center for Appropriate Technology

PV-powered electric fence
Credit: SolarEnergyPros.com
PV-Powered Livestock Water Pumping
16, 200-watt PV panels = 3,200 watts = 3.2 kW  
Powers the pump system; supplies 28 GPM over 3.5 ac.

4, 40-watt PV panels = 160 watts  
Powers the miniature pivot system motors.

PV-Powered  
Irrigation  
Water Pumping  

All Credits: Oasis Montana, Inc.
NRCS Handbook 652
Irrigation Guide: Ch. 12: Energy Use & Conservation

Solar-Powered Pump System Calculator
System Sizing & Costs
System Sizing

• Depends on:
  – Electricity used
  – What % of electricity you want provided by the sun
  – Type of PV material
  – Local solar resource
  – Budget
Determining Electricity Used
(Example Home)

• Electricity used:
  – 2001-2011: 105,323 kWh
  – 78 months
  – Avg. use per **year** = 16,200 kWh
    Avg. use per **month** = 1,350 kWh
    Avg. use per **day** = 45 kWh
  – Cost: 11 cents/kWh = $1,782 per year
Energy Conservation?

• How many kWh can you eliminate through energy conservation and efficiency?
  -- Assume 25% for this home

• Plan for 50% of electricity to be provided by the sun
Estimating Production
(Greenfield, MO)

• Formula for energy per panel:
  \[
  \text{Panel watts} \times \text{daily sun hours} \times 365 \times \text{system efficiency} / 1000
  \]

• Get average daily sun hours from:
  www.solarenergybyzip.com/#mymap
  = 4.83 daily sun hours for Greenfield, MO

• System efficiency = 75–80%

• Example:
  \[
  \frac{230 \text{ watts} \times 4.83 \text{ hr} \times 365 \text{ dy} \times 0.75}{1000} = 304 \text{ kWh per panel}
  \]
Estimating Production
(Greenfield, MO)

- 16,200 kWh/yr x 25% conserv. (1 - 0.25) = 12,150 kWh/yr
- 12,150 kWh/yr x 50% from solar = 6,075 kWh/yr
- 6,075 kWh/yr ÷ 304 kWh per panel = 19.9 = 20 panels
- 20 panels x 230 watts/panel = 4,600 watts
  = 4.6 kW system
Peak Sun Hours

• NREL is good source
  www.nrel.gov/gis/pdfs/eere_pv/eere_pv_h_missouri.pdf
• For southern Missouri, expect 4.9 kWh/m²/day

(Greenfield, MO)

- 4.6 kW size
- Roof-mount
- South-facing
- 37° tilt angle
- Utility cost = $0.11/kWh
- $3.00/watt initial cost
- 30% tax credit

### RESULTS

**6,536 kWh per Year** *

System output may range from 6,227 to 6,764 kWh per year near this location. Click [HERE](http://pvwatts.nrel.gov/) for more information.

<table>
<thead>
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(West Plains, MO)

- 4.6 kW size
- Roof-mount
- South-facing
- 37° tilt angle
- Utility cost = $0.09/kWh
- $3.00/watt initial cost
- 30% tax credit

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**Annual**

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Solar PV Economics

- **Simple payback period**
  - Period of time required to recoup cost expended
- **Rate of return**
  - Gain or loss over time (as a % increase over initial cost)
- **Net present value**
  - How much the system will generate (save) above costs
- **Levelized Cost of Electricity**
  - Total life-cycle cost ÷ total lifetime energy production

No one of these is a perfect measure
Cost

• Cost depends on a variety of factors: the solar resource, PV materials used, and system type and size, etc.

• Small to medium grid-tied systems range from $2,750 to $4,000 per kilowatt (kW). Larger systems are less per installed kW.

• An energy efficient home, farm and ranch can purchase a smaller, less expensive PV system and meet more of the electrical load using the sun.
Estimating Costs

• Rule of thumb for cost of system = $2.75-$4.00/watt
• PV Size = 4.6 kW
• Cost = $12,650 to $18,400
• Minus incentives
  – 30% Federal Tax Incentive = $3,795 to $5,520
• Adjusted cost = $8,855 to $12,880
  – Let’s assume $3.00/watt = $9,660
Estimating Payback

• Adjusted cost of system = $9,660
• PV size x (Energy Production Factor) x (Electricity Rate) = $/year saved
• Energy Production Factor = 4.83 kWh/m²/day x 365 days/year = 1763
• Savings: 4.6 kW x 1763 x $.11 = $892/year
• Simple Payback: $9,660/$892 = 10.8 years
Residential Incentives
(as of April 2016)

1. **30% Federal Tax Credit** (reduces 12-31-2019 for solar)
   Must have tax burden to claim it

2. **Missouri State Tax Credit**
   No credit

3. Some **utilities offer rebates** for renewable energy systems and energy efficiency upgrades.

   **DSIRE Website:** [www.dsireusa.org](http://www.dsireusa.org)

4. DOE’s Lawrence Berkeley National Laboratory study: **homes with PV systems sell at a premium**
   — In CA, a 3.1 kW avg. system size adds $17,000 value
Net Metering Incentive

- Electricity produced offsets electricity used on bill
- Full retail credit is granted only up to usage during a month; any generation contributed to the grid above monthly usage is credited at a utility’s wholesale rate (generally 20% or so of retail)
- [www.renewmo.org/net-metering.html](http://www.renewmo.org/net-metering.html)
Rural Incentives
(as of April 2016)

1. **30% Federal Tax Credit** (reduces 12-31-2019 for solar)
2. **USDA Rural Energy for America Program (REAP)**
   - Up to 25% grant for renewable installed at farm or rural business
   - $2 million in grants available for MO
   - $450 energy audit through MU Extension for $112.50
     - Ag producers with 50% or more gross income from ag.
     - “Rural business” applies to areas <50,000 population
     - Grant applies after 30% Federal Tax Credit is applied
     - Purchase, install or construct systems:
       - solar, wind, biomass, geothermal, hydropower, hydrogen
Installation
Pre-Installation Considerations

- Talk to your power supplier first
- Check local building codes, zoning, HOA covenants
- National Electric Code (NEC) Article 690
- Contact utility company for hookup requirements
- Historic district restrictions
- Future shading?
- Talk with neighbors about your plans
Who Will Install Your System?

• Does company or contractor have experience?
• Offer warranty, references, customer service?
• Provide system commissioning?
• Licenses
  – No license requirement in MO for solar contractors
  – Licensed electrician must connect grid-tied system
• Insurance
  – Liability, workman’s compensation, safety training?
  – Certifications, trade association memberships?
• System monitoring service through Web?
• Missouri Renewable Resources Directory
Installation

The Components
For PV materials, ask about STC or PTC test conditions. For PV materials and BOS components, ask about Underwriter’s Laboratories (UL) certifications.

The Installer
Make sure the installer you hire is qualified. Ask about certifications, trainings, or licenses.

To find installers in Missouri, contact the Missouri Solar Energy Industries Association, http://adminmoseia.hypermart.net/
Installation – Comparing Bids

• Get bids from more than one company
• Bids should specify type, size, electrical output, maintenance requirements, cost
• Questions for the company
  – Is this a packaged system; are components UL-certified?
  – What is electrical output at the inverter?
  – What is kWh estimate of system on annual basis?
  – How will panels be attached to roof (mounting system)?
  – What is whole system or individual component warranties?
  – Ask bid to include costs of installation, setup, commissioning, hardware, NEC signage, permits, taxes, warranties
  – Does bid include incentives deductions; who files paperwork?
Operation and Maintenance

• Does installer conduct system inspections/maintenance?

• Solar panel array
  – Check for panel shading?
  – Glass and seals (esp. after storms)?
  – Mounting system nuts and bolts tight?
  – Wiring connections tight and secure?

• Roof penetrations
  – Flashing and sealant in good condition?

• Batteries
  – Check electrolyte levels?
  – Connections secure and clean of corrosion?
  – Stored at proper temperature?

• Monitoring system
  – Web-based, data logging
Exploring Energy Efficiency and Alternatives

- Home energy efficiency
- Farm energy efficiency
- Solar electricity
- **Solar hot water**
- Small wind
- Biodiesel
- Anaerobic digester
- Micro-hydropower
How We Heat Water
How We Heat Water
(without Spot’s help)

We typically heat water using natural gas or electricity.

Inside a natural gas-fueled water heater.
Heating Water With the Sun’s Energy

Three, roof-top solar hot water collectors

Credit: http://www.solarplusuk.com/solar-thermal-hot-water
Does Your Roof Have Enough Space?

Wall-mounted solar hot water collectors
Credit: Liquid Solar Systems

Ground-mounted solar hot water collectors
Credit: HotBoxSolar.com

Rule of thumb for residential systems: Allow 20 sq. ft. of collector roof/surface area per person for the first two people in a household. Add 12 -14 sq. ft. of collector area for each additional hot water user.
1. Sunlight enters the collector through the glass covering.

2. The sunlight hits and is absorbed by the black metal plate. The absorbed energy turns into heat energy.

3. The heat transfers directly to the tubes and their fluid. The heat also radiates out into the collector air space.

4. Just like in the car example, the glass traps the heated air. The collector’s insulation helps retain the heat.
Solar Hot Water System Components

1. Collectors

2. Solar Water Tank

3. Back-Up

Credit: Rheem Manufacturing Company
1. The Collectors

- **Flat-plate**
  solar hot water collectors

- **Evacuated tube**
  solar hot water collectors

Credit: http://switchsource.co.uk/solarthermal.html
2. Solar Water Tank

- The heat transfer takes place through a heat exchanger.

- The collector-heated fluid never makes contact with the potable water in a “closed loop” system.
3. Back-Up

Water Heater Options

• An existing (or new) traditional water heater.

• One tank can serve as both the solar water tank and back-up.

• A tankless (on-demand) water heater.
Traditional Water Heater Back-Up

Credit: Rheem Manufacturing Company
Solar Water Tank = Back-Up

Credit: Rheem Manufacturing Company
Tankless Back-Up

Credit: Rheem Manufacturing Company
Why is a Back-Up Needed?

- If the solar hot water system is designed to produce only a portion of the hot water used.
- If the solar hot water system does not heat water to the desired temperature.

<table>
<thead>
<tr>
<th>Collector</th>
<th>Heating Temperatures</th>
<th>(Credit: homepower)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>Summer 140-180°F</td>
<td>Winter 120-150°F</td>
</tr>
<tr>
<td>Cloudy</td>
<td>Summer 70-90°F</td>
<td>Winter 50-60°F</td>
</tr>
</tbody>
</table>

- If there is a higher-than-normal demand.
Commercial Resources

Magazines:

• Home Power:
  
  www.homepower.com/articles/solar-electricity/basics/what-solar-electricity

  www.homepower.com/articles/solar-water-heating/basics/what-solar-water-heating

• Home Energy:
  
  www.homeenergy.org/
Government Resources

• U.S. Department of Energy’s Energy Savers
  energy.gov/energysaver/energy-saver

• Energy Savers Booklet:
  Tips on Saving Energy & Money At Home
  energy.gov/energysaver/downloads/energy-saver-guide

• U.S. Environmental Protection Agency’s Energy Star
  www.energystar.gov

• A Consumer’s Guide:
  Get Your Power From the Sun
  www.nrel.gov/docs/fy04osti/35297.pdf
University Resources

• University of Missouri Extension
  extension.missouri.edu/webster/energy_management.aspx

• Farm Energy Auditing Checklist and Tips
  www.ag.ndsu.edu/pubs/ageng/structu/ae1366.pdf

www.extension.org/ag_energy
Questions?

Robert A. (Bob) Schultheis  
Natural Resource Engineering Specialist  
Webster County Extension Center  
800 S. Marshall St.  
Marshfield, MO 65706  
Voice: 417-859-2044  
Fax: 417-468-2086  
E-mail: schultheisr@missouri.edu  
Web: extension.missouri.edu/webster

Program Complaint Information
To file a program complaint you may contact any of the following:

University of Missouri
- MU Extension AA/EEO Office  
  109 F. Whitten Hall, Columbia, MO 65211  
- MU Human Resources Office  
  130 Heinkel Bldg, Columbia, MO 65211

USDA
- Office of Civil Rights, Director  
  Room 326-W, Whitten Building  
  14th and Independence Ave., SW  
  Washington, DC 20250-9410

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