Exploring Energy Efficiency and Alternatives

- Home energy efficiency
- Farm energy efficiency
- Solar electricity
- Solar hot water
- Small wind
- Biodiesel
- Anaerobic digester
- Micro-hydropower
E³A

Solar Electricity for Home, Farm & Ranch

Using The Sun To Produce Electricity
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
System Components
Photovoltaics
PV Materials

Crystalline Silicon

Thin-Film
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
Grid-Connected (Tied) Solar Electric with Battery Backup
Off-Grid Solar Electric

PV Panels → Charge Controller → Batteries → Inverter/Charger → DC Electrical Loads (Optional) → Back-Up Generator

Electricity Flow

AC Electrical Loads → Electrical Panel/Box
PV Direct Systems

Water-pumping system

PV-powered electric fence
PV-Powered Livestock Water Pumping
PV-Powered Irrigation 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.

All Credits: Oasis Montana, Inc.
Solar-Powered Pump System Calculator

NRCS Handbook 652
Irrigation Guide:
Ch. 12: Energy Use & Conservation
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
(Nevada, MO)

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

• Get average daily sun hours from:
  www.solarenergybyzip.com/#mymap
  = 4.87 daily sun hours for Nevada, MO

• System efficiency = 75–80%

• Example:
  \[ \frac{230 \text{ watts} \times 4.87 \text{ hr} \times 365 \text{ dy} \times 0.75}{1000} = 307 \text{ kWh per panel} \]
Estimating Production
(Nevada, 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 ÷ 307 kWh per panel = 19.8 = 20 panels
- 20 panels x 230 watts/panel = 4,600 watts
- 4.6 kW system
Peak Sun Hours

- NREL is a good source
  www.nrel.gov/gis/pdfs/eere_pv/eere_pv_h_missouri.pdf
- For southern Missouri, expect 4.9 kWh/m²/day
### PV Watts Calculator

http://pvwatts.nrel.gov/

(Nevada, MO)

- 4.6 kW size
- Roof-mount
- South-facing
- 37° tilt angle
- Utility cost = $0.11/kWh
- $3.70/watt initial cost
- 30% tax credit

### Results

#### Monthly Results

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar Radiation (kWh/m²/day)</th>
<th>AC Energy (kWh)</th>
<th>Energy Value ($)</th>
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</thead>
<tbody>
<tr>
<td>January</td>
<td>3.90</td>
<td>475</td>
<td>51</td>
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<tr>
<td>February</td>
<td>4.17</td>
<td>455</td>
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<td>March</td>
<td>5.18</td>
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<td><strong>Annual</strong></td>
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<td><strong>6,546</strong></td>
<td><strong>$ 706</strong></td>
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</tbody>
</table>

(Ava, MO)

- 4.6 kW size
- Roof-mount
- South-facing
- 37° tilt angle
- Utility cost = $0.08/kWh
- $3.70/watt initial cost
- 30% tax credit

### Results

6,546 kWh per Year *

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**Annual**  

4.98  
6,546  
$502
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 $3,000 to $4,500 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 = $3.00-$4.50/watt
• PV Size = 4.6 kW
• Cost = $13,800 to $20,700
• Minus incentives
  – 30% Federal Tax Incentive = $4,140 to $6,210
• Adjusted cost = $9,660 to $14,490
  – Let’s assume $3.70/watt = $11,914
Estimating Payback

• Adjusted cost of system = $11,914

• PV size x (Energy Production Factor) x (Electricity Rate) = $/year saved

• Energy Production Factor = 4.9 kWh/m²/day x 365 days/year = 1789

• Savings: 4.6 kW x 1789 x $.11 = $905/year

• Simple Payback: $11,914/$905 = 13.2 years
Residential Incentives
(as of June 2015)

1. **30% Federal Tax Credit** (exp. 12-31-16)
   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 June 2015)

1. **30% Federal Tax Credit** (exp. 12-31-16)
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
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- Home energy efficiency
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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.

Collector Heating Temperatures (Credit: homepower)

<table>
<thead>
<tr>
<th>Collector</th>
<th>Heating Temperatures</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>140-180°F</td>
<td>120-150°F</td>
<td></td>
</tr>
<tr>
<td>Cloudy</td>
<td>70-90°F</td>
<td>50-60°F</td>
<td></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](http://energy.gov/energysaver/energy-saver)

• Energy Savers Booklet: *Tips on Saving Energy & Money At Home*

• U.S. Environmental Protection Agency’s *Energy Star*
  [www.energystar.gov](http://www.energystar.gov)

• A Consumer’s Guide: *Get Your Power From the Sun*
  [www.nrel.gov/docs/fy04osti/35297.pdf](http://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?

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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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