Solar Electricity
for the Home, Farm, and Business

University of Minnesota Extension
Montana State University Extension
Western SARE Sustainable Agriculture Research & Education
University of Wyoming Extension

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. Costs
7. Installation
8. Electricity Use Worksheet

WILL SOLAR WORK FOR YOU?

Solar Electricity for the Home, Farm, and Business is a series of factsheets designed to help you determine if a solar electric system will work for you.

Overview of Steps:

1. **Introduction:** Basic educational information, myth busting, and orientation.
2. **Building & Site Assessment:** Building and site conditions to consider.
3. **Conservation & Efficiency:** Conserving and using energy more efficiently can reduce the system size and cost.
4. **System Components:** Provides detailed information about system options and components.
5. **System Sizing:** Proper sizing is important for a resource-efficient and cost-effective system. Includes a Panel and System Sizing Worksheet.
6. **Costs:** System costs depend on various factors. Rebates and incentives lower the cost.
7. **Installation:** Finding and hiring a contractor and considerations for operations and maintenance.
8. **Electricity Use Worksheet**

Thank you!

This series was adapted from the series, *E3A: Exploring Energy Efficiency & Alternatives*, specifically the section "Solar Electricity for the Home, Farm, and Ranch." Thanks to University of Wyoming Cooperative Extension Service, Montana State University Extension, and Western Sustainable Agriculture Research & Education (SARE) for making this publication available to University of Minnesota Extension. The full and original publication covering energy efficiency and more renewable energy technologies is available at http://www.e3a4u.info.

Thanks is also due to Minnesota technical reviewers Jack Kluempke, Brian Ross, and David Schmidt.

Questions?

If you have questions, please contact Dan Thiede at 612-626-0556 or thie0235@umn.edu, Lissa Pawlisch at 612-624-2293 or pawl0048@umn.edu, or Alexis Troschinetz at 612-626-0455 or atroschi@umn.edu.

University of Minnesota Extension

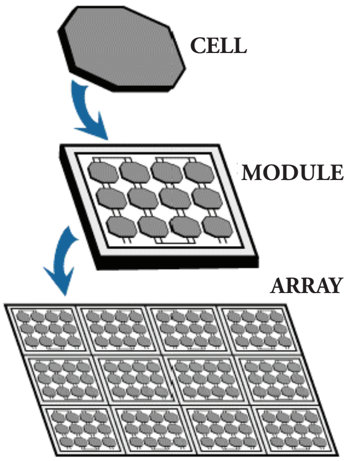
E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Lissa Pawlisch.

Steps in the Solar Electricity Series

1. **Introduction**
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. Costs
7. Installation
8. Electricity Use Worksheet

STEP 1: INTRODUCTION



Courtesy of NASA http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/

Minnesota's single largest source of electricity is coal-fired power plants. An alternative is to use the sun's energy as the fuel to produce electricity. This is accomplished using photovoltaic (PV) technology. The letters PV stand for "Photo" = light and "Voltaics" = electricity. PV technology can potentially be used anywhere the sun shines.

Solar electricity is produced through the PV Effect: when sunlight hits a solar cell, electrons are released and flow as electricity through wires to your building or equipment. Solar cells are connected together to form a panel (also called a module). Panels are wired together to form an array.

PV technology is used to power everything from calculators and outdoor lighting fixtures to buildings and satellites. Whatever is powered by electricity (appliances, machinery, etc.) is called the electrical "load." The sun can provide electricity for your home, greenhouse, and barn. It can also electrify fences and pump water.

In addition to the PV panels, a solar electric system (also called a PV system) includes an inverter, meter, and safety equipment. It may include batteries and a charge controller. These systems contain no moving parts, are silent, very durable and reliable, and are low maintenance. Once installed, they only use the sun's energy and their operation produces no emissions. Solar electric systems can produce all or a portion of the electricity that you need. PV panels can be added to an existing system over time.

System costs depend on a variety of factors. As a general rule of thumb, a grid-tied residential system without batteries costs between $4,000 and $7,000 per kilowatt (kW) of electricity produced. A 2014 study by the Lawrence Berkeley National Lab found the installed price of residential and commercial PV systems in Minnesota to be between $5,100 and $8,200 per kW. This includes installation costs. Utility rebates and government incentives can significantly reduce the final cost. A 2015 analysis by the Minnesota Department of Commerce found that the average installed costs of 2014 and 2015 Made in Minnesota approved systems (700 systems total) ranged from $4,700 to $6,100 per kW.

8.3 kW solar PV installation on a Oronoco, MN barn. Photo by Solar Connection Inc. Used with permission.

4 kW solar installation on Minneapolis, MN home. Photo by Rebecca Lundberg, Powerfully Green. Used with permission.

Dispelling the myths

The number one myth about solar in Minnesota is that it's just not sunny enough. Actually, Minnesota has a good solar resource, comparable to parts of Texas and Florida, that makes solar electric systems worth considering.

There is a myth that it takes more energy to make a PV system than it produces over its lifetime. "Energy payback" is the term used to describe the amount of energy it takes to develop/manufacture a system versus the amount of energy it generates. How long does a PV system have to operate to recover the energy that went into making it? The energy payback for rooftop PV systems ranges from 1 to 4 years depending on the type of PV panel. A properly designed, installed, and maintained system can produce energy for 30 years or more.

There is a myth that solar is simply too expensive for most people. This is no longer the case; solar prices have come down dramatically in recent years, making it more cometitive with other energy resources.

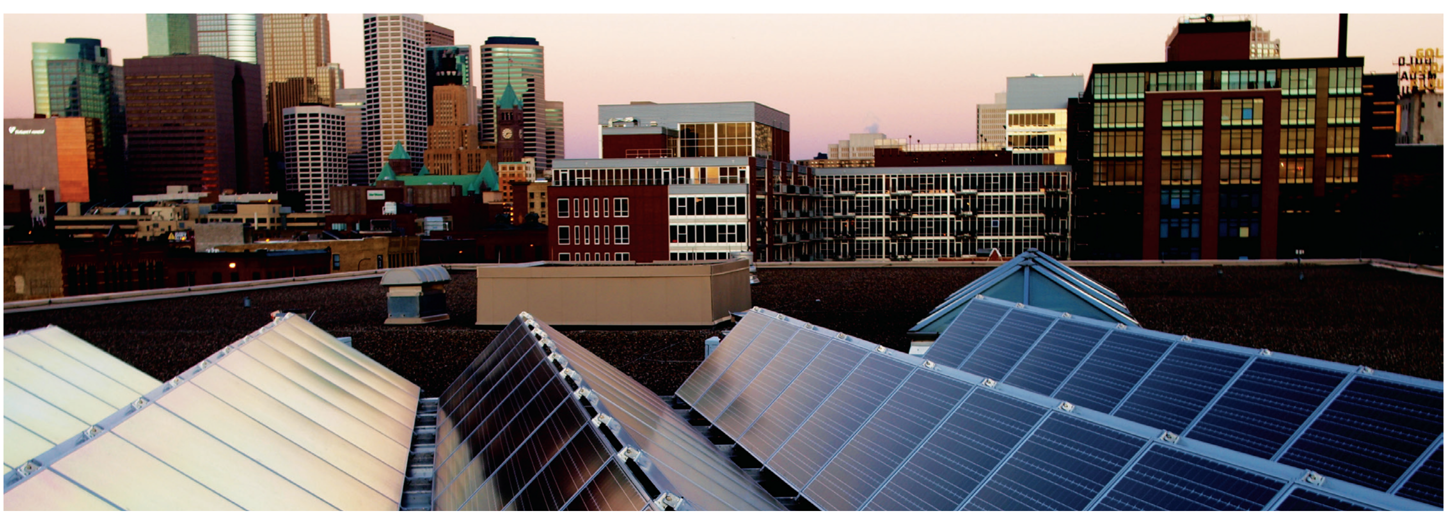
Why go solar?

People invest in solar electric systems for a variety of reasons: they want a clean, reliable source of electricity, they want independence from a utility company and/or electricity price increases, or they want to have a smaller environmental footprint. Investing in a system also helps support local renewable energy companies and their employees. Minnesota has and continues to build an infrastructure of qualified and certified companies and independent contractors who install and service solar electric systems.

Using this guide

You do not need to be an electrician or PV installer to understand how solar electricity systems work. These factsheets provide basic information that can help you decide if a solar electric system will work for you and help you discuss the topic knowledgeably with an installer. The sheets can be used separately or together for a step-by-step decision-making process.

1. **Introduction:** You are here!
2. **Building & Site Assessment:** Building and site conditions to consider.
3. **Conservation & Efficiency:** Conserving and using energy more efficiently can reduce the system size and cost.
4. **System Components:** Provides detailed information about system options and components.
5. **System Sizing:** Proper sizing is important for a resource-efficient and cost-effective system. Includes a Panel and System Sizing Worksheet.
6. **Costs:** System costs depend on various factors. Rebates and incentives lower the cost.
7. **Installation:** Finding and hiring a contractor and considerations for operations and maintenance.
8. **Electricity Use Worksheet**



30 kW solar PV installation in Minneapolis, MN. Photo by Sundial Solar. Used with permission.

Additional Resources

Barbose, Galen; Samantha Weaver; and Naïm Darghouth. (2014, September). *Tracking the Sun VII: The Installed Price of Photovoltaics in the United States from 1998 to 2013*, Figures 16 and 17. Retreived July 6, 2015 from http://emp.lbl.gov/sites/all/files/lbnl-6858e.pdf.

Havey, Kim, Minnesota Department of Commerce. Email July 2, 2015.

IHS Inc. Solarbuzz. (2012). *Solar Energy Industry Electricity Prices – March 2012 Update*. Retrieved September 28, 2015, from http://www.solarbuzz.com/facts-and-figures/retail-price-environment/solar-electricity-prices.

Minnesota Department of Commerce. (2012). *Solar In Minnesota*. Retrieved September 28, 2015 from http://mn.gov/commerce/energy/businesses/renewable-energy/solar/index.jsp.

National Renewable Energy Laboratory (produced) for U.S. Department of Energy. (2009, January). *Own Your Power! A Consumer Guide to Solar Electricity for the Home*. DOE/GO-102009-2656.

National Renewable Energy Laboratory (produced) for U.S. Department of Energy. (2004, January). *PV FAQs: What is the Energy Payback for PV?* DOE/GO-102004-1847.

U.S. Department of Energy. *Planning a Home Solar Electric System*. Retrieved September 29, 2015, from http://energy.gov/energysaver/planning-home-solar-electric-system.

U.S. Department of Energy. *Small Solar Electric Systems*. Retrieved September 29, 2015, from http://energy.gov/energysaver/small-solar-electric-systems.

UNIVERSITY OF MINNESOTA
EXTENSION

E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Lissa Pawlisch.

Steps in the Solar Electricity Series

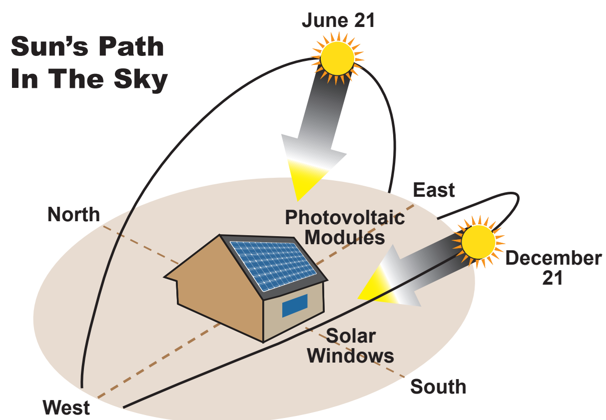
1. Introduction
2. **Building and Site Assessment**
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. Costs
7. Installation
8. Electricity Use Worksheet

STEP 2: BUILDING & SITE ASSESSMENT

Answering these questions will help you determine if a solar electric system will work for your building or site.

1. Do you have a south-facing roof?

Because Minnesota is in the northern hemisphere, PV panels (modules) need to face south for maximum performance. This placement allows panels to take full advantage of the sun's path in the sky. The sun shines longest on a building's south side. Southeast- and southwest-facing panels will perform about 5 percent less efficiently.



☐ Yes! — Move to Question #2

☐ No — Options: PV panels can be used as structures such as porch covers or window awnings. They can also be ground-mounted or pole-mounted. If you cannot place PV panels to face south, a solar electric system will likely not be an efficient investment. You may choose to participate in a community solar garden (CSG), also known as a community shared solar (CSS) program if your utility offers one. Find out if your utility offers a CSG program at cleanenergyresourceteams.org/solargardens.

Panels can be mounted on east- or west-facing roofs to face south, but they stick up and are highly visible, and can be perceived by some as unattractive. Architects and builders can address this by designing "solar ready" buildings and integrating solar technology components into their designs. One can read more about these guidelines in "Solar Ready Building Design Guidelines for the Twin Cities, Minnesota."

CC BY-NC 3.0 Roslynn Brain
http://farmenergymedia.extension.org

2. Does your roof have enough space for PV panels?

There may be other technical considerations to comply with building codes, but the rule of thumb for PV panels is 100 square feet of space is needed for every kilowatt (kW) of electricity produced.

☐ Yes! — Move to Question #3

☐ No — Options: If your roof does not have enough space, review the Options section under the previous question.

Photo by Namaste Solar Electric NREL, 15620

3. Is your roof unshaded?

Photovoltaic panels are very sensitive to shading. Any shading will dramatically reduce electricity generation. Installers use a Solar Pathfinder device to determine if there are shading concerns from trees (consider mature height), chimneys, nearby buildings, etc. In Minnesota, people considering solar can enter their address into the Minnesota Solar Suitability App to get a sense for whether or not they may have a good solar site: http://mn.gov/solarapp. Keep in mind the sun's path changes throughout the year. For maximum electricity production, make sure panels will be unshaded year-round (especially from 9/10am until 3pm).

☐ Yes! — Move to Question #4

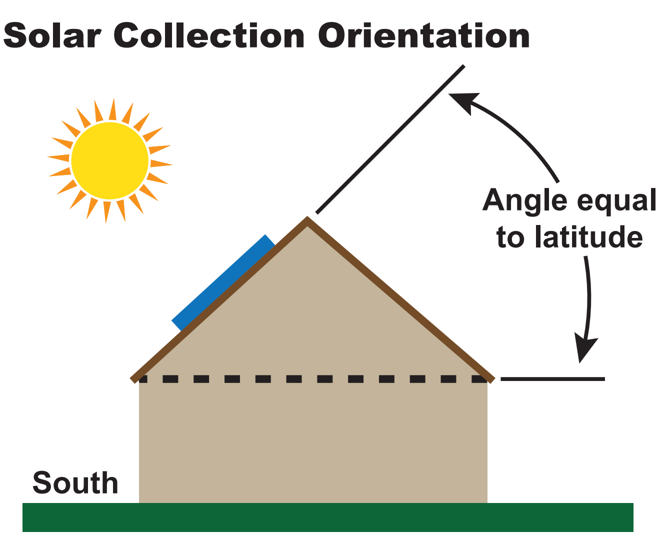
☐ No — Options: If the shade is from landscaping, consider removing the plants. Check local and state codes regarding "solar access" rights if a neighbor might produce shade on any solar system you are considering (MN statute 500.30). See the Pre-Installation section of Step 6: Installation. If some shade is inevitable, ask the installer about microinverters.

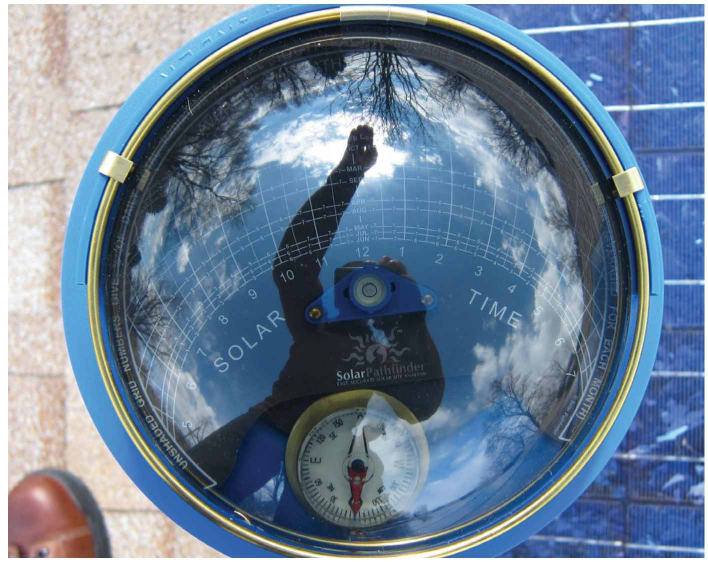
4. What is the angle of your roof?

Installers typically mount panels directly (flush) on an existing south-facing roof for aesthetics. To maximize electricity generated year-round, mount modules at an angle equal to or close to your site's latitude (44 degrees for Rochester; 47.5 degrees for Bemidji). Installers can tilt at an angle best for your site, system type, and electricity needs.

For more summer electricity production, tilt at latitude minus 10 degrees to 15 degrees; for more winter production, tilt at latitude plus 15 degrees. As a rule of thumb, the ideal pitch for a PV system in Minnesota is between 35-38 degrees.

Flat Roofs: Panels can be angled on flat roofs (often found on commercial, industrial, and institutional buildings) using a racking system, but should not be placed flat (horizontal) because of snow build-up that will block the sun.





Solar pathffinder. CC BY-NC-SA 2.0 Sam Ley
www.flickr.com/photos/phidauex/4436387544/

In Minnesota, people considering solar can enter their address into the Minnesota Solar Suitability App to get a sense for whether or not they may have a good solar site. The website offers detailed results for every square meter of the state at http://mn.gov/solarapp.

5. Is your roof in good condition?

Most roofs can safely support PV panels and mounting system weight. The rule of thumb is 2 to 5 pounds per square foot depending on the panel type and installation method. For example, a 230 watt crystalline panel (3.5 feet x 5.5 feet) weighs about 50 pounds. An installer should determine if the roof/structure can handle the added static weight. Innovative mounting systems can make panel removal easy, but because panels can last 30+ years, it may be less expensive and labor intensive to make needed roof repairs before installing panels.

☐ Yes! — Move to What's Next?

☐ No — Options: Complete any needed repairs first. If considering a new roof, contact a PV system installer/contractor for roof options/ recommendations that might make panel installation easier or less expensive.

What's Next?

If you answered yes to every question or can make adjustments where you answered no, your building or site is a good solar electric system candidate! A system supplier or installer can provide a more detailed assessment. Next, consider how conservation and efficiency measures can result in an efficient and affordable system; then, learn about system options.

Additional Resources

Dunlop, James P. 2012. Photovoltaic Systems, 3rd Edition. Published by America Technical Publishers, Inc. Orland Park, Illinois.

Lunning Wende Associates. September 2010. "Solar Ready Building Design Guidelines." Downloaded on July 7, 2015 from https://mn.gov/commerce/energy/images/Solar-Ready-Building.pdf.

Minnesota Department of Labor and Industry. "Solar Photovoltaic (PV) Systems Questions and Answers." Downloaded July 13, 2015 from http://www.dli.mn.gov/CCLD/PDF/solarFAQ.pdf.

University of Minnesota
EXTENSION

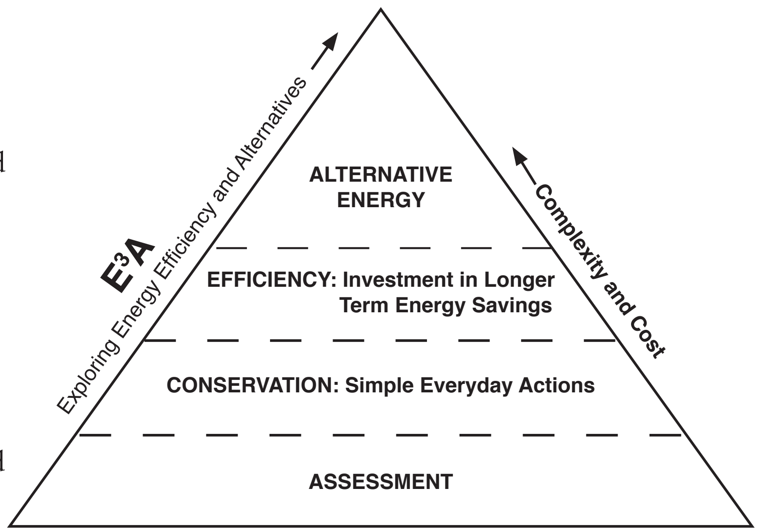
E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Alexis Troschinetz.

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. **Conservation and Efficiency**
4. System Components
5. System Sizing
6. Costs
7. Installation
8. Electricity Use Worksheet

STEP 3: CONSERVATION & EFFICIENCY



Energy conservation and efficiency provide the foundation for a smaller, more efficient and affordable solar electric system.

It is easy to get excited about solar PV and other renewable energy technologies, but energy conservation and efficiency measures should be considered first. Why? Because when you or a contractor sizes your solar PV system, it is based on the amount of *electricity* you use. The less you use, the smaller, more efficient and affordable the system will be.

It is almost always cheaper to reduce energy use than to buy a larger renewable energy system. Replacing inefficient lights, appliances, equipment, and machinery can significantly reduce the size and cost of your solar PV system. Plus, the electricity savings continue for the life of the replacements.

You or a solar installer can review past utility bills to determine your electrical load in order to properly size your system. A Minnesota home's average electricity use is 800 kWh/month.

EXTRA: If interested, use Step 7: Electricity Use Worksheet to make a list of everything that uses electricity and how much. This exercise will create an awareness of what will be powered by your PV system, how electricity use changes throughout a day, month, or a season, and will help you determine ways to reduce your electrical load. Alternatively, use a watt meter to measure and record electricity use in Step 7's worksheet. Many Minnesota libraries and utilities lend watt meters. The information can also be used for calculating your system size in Step 5: System Sizing.

According to the Minnesota Department of Commerce, Division of Energy Resource's Home Energy Guide (mncerts.org/home-energy-guide), the typical Minnesota home's total energy use (electric and thermal) is proportioned by the following uses: 55% for space heating and cooling, 15% for water heating, 15% for appliances, 10% for lighting, and 5% for electronics.

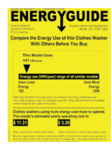
Space Heating and Cooling

The data above shows that by far home heating and cooling is the largest energy use in a Minnesota home. Even in homes that use natural gas for space heating, electricity is still used to power blowers and motors in a forced air system; depending on insulation and air sealing levels, up to 40% of a winter electric bill can be attributed to the heating system. Also, in some parts of Minnesota, particularly Northwest Minnesota, over 30% of households have electric space heating. Conserving electricity associated with space heating means improving the building envelope, using a programmable thermostat, and maintaining heating and cooling equipment. The Home Energy Guide, referenced below, offers comprehensive information about these topics and specifically, air sealing, insulating, and improving windows and doors.

Water Heating

With water heating making up 15% of a home's total energy use, conserving hot water becomes a major means of reducing the home's electrical load when an electric water heater is used. See the Home Energy Guide for more infomation about water heating energy savings.

Appliances



Among appliances, the two largest users can be the refrigerator and the clothes dryer. The biggest way to cut on refrigeration costs is to reduce the number of units overall at the residence. Many homes have a second refrigerator or separate freezer. Simply using these appliances only when needed or eliminating one or more extra storage units can go a long way toward reducing a home's overall electricity use. When upgrading to a new refrigerator be sure to select an ENERGY STAR certified model. A new ENERGY STAR model could use a quarter of the energy used by a comparable refrigerator made 20 years ago.

In Minnesota, homes may have gas or electric clothes dryers. Similar to a natural gas forced air furnace, even a gas clothes dryer uses electricity to operate. People considering solar for their homes or businesses may choose electric dryers so that it is yet another appliance that can be accommodated by the on-site electricity generation. Clothes dryers can be ENERGY STAR rated as of 2015. ENERGY STAR models use 20% less energy than dryers not certified.

The Home Energy Guide offers many tips for maintaining refrigerators, clothes dryers, and other appliances for optimal energy efficiency, as well as what to look for when buying new, energy-efficient models.

Lighting

Whether for your home, farm, or business, upgrading to efficient lighting is one of the easiest ways to save money and reduce electricity use. Install ENERGY STAR light emitting diode (LED), compact fluorescent lamps/lights (CFL), or other energy efficient bulbs/tubes and Design Lights Consortium (DLC) certified fixtures. LEDs use 85 percent less energy and last 22 times longer than incandescent bulbs. They also produce 90 percent less heat than incandescent bulbs. This makes them safer to operate and can cut home or building cooling costs.

LEDs and CFLs cost more at the store, but they cost less to operate (the second price tag) and are cheaper overall. They will save you money when you are paying for electricity and may help reduce the number of PV panels needed for your solar electric system! Review the table at the top of the next page comparing a 10 watt LED and 60 watt incandescent. Both provide the same brightness (lumens).

Light Emitting Diode (LED) & Incandescent Bulb Cost and Energy Use Comparison

	LED	Incandescent
Equivalent Light Output Wattage	10 watts	60 watts
Bulb Cost	$8.00	$0.75
Bulb Lifespan	25,000 hours	1,000 hours
Bulb Cost for 25,000 Hours	$8.00	$0.75 x 25 = $18.75 (takes 25 bulbs to get 25,000 hours)
Energy Used in kWh	25,000 hours of light at 10 watts = 250,000 watt-hours. 250,000 ÷ 1,000 watts =250 kilowatt-hours (kWh)	25,000 hours of light at 60 watts = 1,500,000 watt-hours. 1,500,000 ÷ 1,000 watts =1,500 kilowatt-hours (kWh)
Utility Electricity Cost for 25,000 hours of light at $0.1235 / kWh	250 kWh x $0.1235 = $30.88	1,500 kWh x $0.1235 = $185.25
Store Purchase Cost + Electricity/ Operation Cost = Total Cost	$8.00 + $30.88 =$38.88	$18.75 + $185.25 =$207.50*

* *Add the "value" of the time it takes to replace burned-out incandescent bulbs 24 times.*

A more visual representation of the calculations above is provided in the graphic on the next page (only shown over a period of 20 years instead of the life of a LED bulb). This graphic is borrowed from the Clean Energy Resource Teams' Right Light Guide (mncerts.org/lighting/guide). LEDs can replace incandescent bulbs for most of a building's lighting

Cost Over 20 Years	Bulb(s) / Energy	Pros (+) and Cons (-)
LED	1 bulb in 20 years **$35 total cost**	+ Saves 85% of energy use over incandescent + Lasts 25 times longer than incandescent + Great for dimmed, recessed, or enclosed fixtures + Performs well in cold temperatures - Higher bulb cost
CFL	3 bulbs in 20 years **$54 total cost**	+ Saves 75% of energy use over incandescent + Lasts 10 times longer than incandescent - Recessed & enclosed fixtures reduce bulb life - Performs poorly in cold temperatures - Contains mercury (recycling required)
Incandescent	Bulb & Replacement Cost / Energy Cost 22 bulbs in 20 years **$284 total cost**	

Note: Cost comparison is based on a 20-year life and takes into account power consumption, hours of use per day, residential electric cost, bulb cost, and replacement cost. For detailed cost calculations and a full pro/con list, visit http://Lighting.MnCERTs.org.

needs. Larger, agricultural-based buildings can be retrofitted to use LED, or T-8 or T-5 fluorescent tube lighting.

With all the new technology, lighting selection may seem more difficult. Different amounts of light are needed for different uses. The way the light appears in color is a matter of preference. Consumers will need to shift from thinking about lighting in terms of only watts and bulb type (i.e., 60 W incandescent) to considering brightness and light appearance instead to ensure satisfaction. Lumen is the measure of brightness. Higher lumen output produces brighter light. Color temperature in Kelvins (K) is the measure of light appearance. A warm, yellow light is described as 2,700-3,000 K (closely matching an incandescent) and a cool, blue light is described as 5,000-6,500 K.

Lighting conservation measures of course include turning-off lights when not needed and using natural daylight whenever possible, but can include so much more. The Home Energy Guide offers many tips for using the appropriate style of lighting (e.g., task lighting), timers, dimmer switches, and motion sensors. It also offers bulb selection and disposal guidance.

Electronics

A 2010 study of residential plug-in devices in Minnesota suggests that consumer electronics, audio-visual entertainment, and portable space conditioning devices account for 15 to 25 percent of the total electrical load in Minnesota homes.

Note: Prioritize building envelope and space conditioning equipment improvements to minimize use of portable space conditioning devices like portable heaters and humidifiers.

Television, computer, and audio devices and their peripheral equipment (e.g., printers, DVRs) comprise 31, 21, and 5 percent, respectively, of the household total plug-in device electrical use. About 500 kWh per year could be saved through low-cost or no-cost measures, including 300 kWh per year of savings just from adjusting power management settings on desktop computers for maximum efficiency.

About 20 percent of a Minnesota household's total plug-in device electrical use can be attributed to standby power. Simply unplugging unused electronics, otherwise known as "energy vampires" or "phantom loads," can save as much as 10 percent on your electricity bill. Even though a cell phone charger uses only 0.26 watts on average when not charging, a cable box uses about 18 watts and one with DVR capabilities uses about 43 watts when the TV and these devices are "off." When the average American household has 25 consumer electronics, these phantom loads can add-up to a significant amount of an energy bill. When replacing electronics, choose ENERGY STAR devices, because they have lower standby power usage and generally lower energy use for all functions.

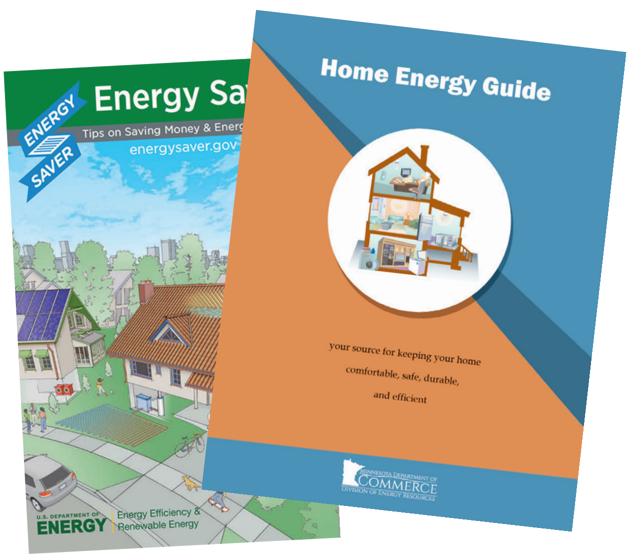
Understanding household plug-in loads can inform the electricity saving opportunities at businesses and farms, too. If a business is open 40 hours per week, then there are 128 non-business hours to drastically reduce standby power. In particular, households, businesses and farms can stay ahead of phantom loads by using smart power strips on TVs/computers and peripheral equipment and putting equipment like printers on timers.

Additionally, farms can see up to 85% electricity savings by adding timers to tractor block heaters. The energy savings from running the engine block heater unnecessarily will usually pay for the timer in 1 to 3 months.

Other efficiency measures for the farm include modifying irrigation systems by switching from high- and medium- to low-pressure sprinkler systems and using variable speed drives for pumps, fans, and other equipment. A farm can reduce electricity use by as much as 35 percent with variable speed drives alone. If energy and water resources are a concern, planting crops with lower water requirements reduces water use and the electricity needed for pumping. Converting to drip irrigation or a linear/pivot system also saves both energy and water.

Key Themes

Conserve where you can and buy energy efficient fixtures, appliances, and machinery. Look for ENERGY STAR labels and compare the bright yellow EnergyGuide labels.



Resource Guides

The Minnesota Department of Commerce and U.S. Department of Energy have booklets with numerous tips on how to save money and energy.

- Home Energy Guide: your source for keeping your home comfortable, safe, durable, and efficient: http://mncerts.org/home-energy-guide
- Energy Saver: Tips on Saving Energy & Money at Home: http://energy.gov/articles/updated-energy-saver-guide-helps-you-save-energy-and-money-home
- CERTs Right Light Guide: Understand bulb types, brightness, color, and cost: http://mncerts.org/lighting/guide

Get an Energy Audit

If you hire a business to conduct an energy use assessment, select one that has trained and certified employees.

- BPI (Building Performance Institute) and RESNET (Residential Energy Services Network) are two certification programs for homes that use HERS (Home Energy Rating System).
- The Minnesota Building Performance Association is another great resource for finding qualified home energy auditors (www.mbpa.us/find-professional-location)
- RETAP (www.pca.state.mn.us/retap) and Energy Smart (mnenergysmart.com) are two programs in Minnesota that provide energy audits.
- You may be able to tap into your utility company for free or low-cost assessments, so be sure to inquire.
- Farms should hire someone who can perform an American Society of Agricultural and Biological Engineers Standard 612 type audit, preferably a Professional Engineer or Certified Energy Manager if the farm may want to pursue USDA funding, like Rural Energy for America Program (REAP - www.rd.usda.gov).

A blower door test measures the amount of leakage in a home during an energy audit.

Additional Resources

Clean Energy Resource Teams. (2016). Right Light Guide for General Use Bulbs. Available online also at http://www.cleanenergyresourceteams.org/lighting/guide

Energy Center of Wisconsin. (2010). Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes: A Technical and Behavioral Field Assessment. Report number: 257-1. Retrieved September 12, 2015 from http://www.seventhwave.org/publications/electricity-savings-opportunities-home-electronics-and-other-plug-devices-minnesota

Energy Trust of Oregon. (2010, April). Reduce Irrigation Energy Costs. Retrieved September 12, 2015, from http://energytrust.org/library/forms/PE_BRO_Irrigation.pdf

Minnesota Department of Commerce, Division of Energy Resources. (2015). Home Energy Guide: your source for keeping your home comfortable, safe, durable, and efficient. Document Version February 2015. Available online also at http://www.mn.gov/commerce/energy/consumers/resources/Consumer-Guides/index.jsp

Energy Information Administration. (2009). Residential Energy Consumption Survey. Retrieved September 14, 2015 from http://www.eia.gov/consumption/residential/data/2009/

Energy Information Administration. (2013, March). Today in Energy: Heating and cooling no longer majority of U.S. home energy use. Retrieved September 14, 2015 from http://www.eia.gov/todayinenergy/detail.cfm?id=10271&src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-f1

US Census Bureau. (2013). 2009-2013 5-Year American Community Survey (Table B25040 House Heating Fuel). Retrieved September 14, 2015, from http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_13_5YR_B25040&prodType=table

Sustainable Agriculture Research and Education (SARE). (2008, February). Clean Energy Farming: Cutting Costs, Improving Efficiencies, Harnessing Renewables. Retrieved August 27, 2015, from http://www.sare.org/Learning-Center/Bulletins/Clean-Energy-FarmingU.S. Energy Information Administration. (2013, August). State fact sheets on household energy use: Wisconsin. Retrieved September 12, 2015 from http://www.eia.gov/consumption/residential/reports/2009/state_briefs/

U.S. Environmental Protection Agency. (2014, October). Are Energy Vampires Sucking You Dry? Retrieved September 12, 2015, from http://energy.gov/articles/are-energy-vampires-sucking-you-dry

U.S. Environmental Protection Agency. (2015). All Certified Products. Retrieved September 12, 2015, from http://www.energystar.gov/products/certified-products

U.S. Environmental Protection Agency. (2015). Clothes Dryers for Consumers. Retrieved November 20, 2015, from https://www.energystar.gov/products/appliances/clothes_dryers

U.S. Environmental Protection Agency. (2015). Light Bulbs for Consumers. Retrieved September 12, 2015, from http://www.energystar.gov/products/certified-products/detail/light-bulbs

Wisconsin Public Service. (2015). Tractor Heater Timers. Retrieved September 12, 2015, from http://www.wisconsinpublicservice.com/business/farm_tractor.aspx

E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Lissa Pawlisch.

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. Costs
7. Installation
8. Electricity Use Worksheet

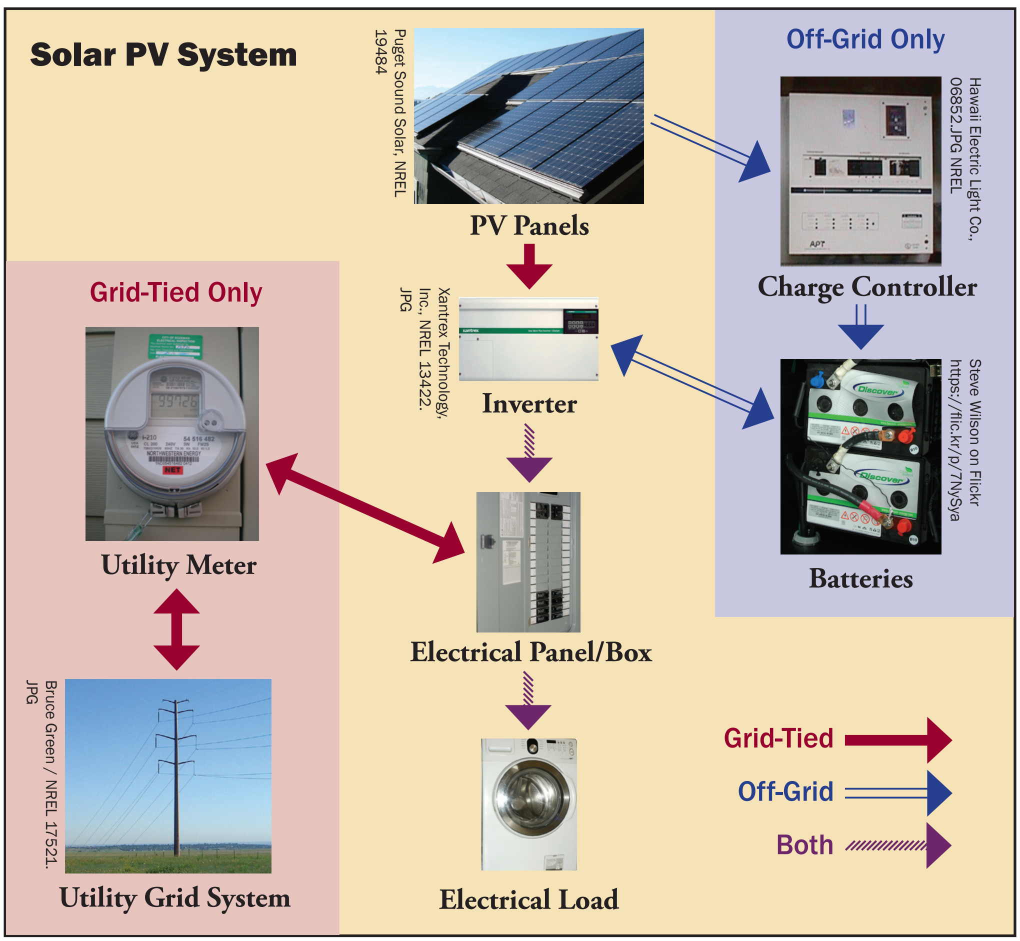
STEP 4: SYSTEM COMPONENTS

Solar Electric System Options

Each solar electric system is designed based on the electrical load, whether it is connected to the utility grid, and whether it includes batteries. The term "grid" refers to a utility company's system of transmission and distribution lines that carry and deliver electricity to your home, farm, or business. Grid-tied systems are connected to the utility power grid. They are also called grid-connected systems.

Grid-connected systems without batteries are currently the most common system type, and as such are the focus of this guide. PV panels produce electricity when the sun is shining during the day. At night, electricity comes from the utility grid. If during the day the building or equipment needs more electricity than the PV panels are producing, electricity is provided by the utility grid. If the PV panels are producing more electricity than needed, the extra electricity is fed into the utility grid. If there is a daytime power outage, the PV system automatically shuts down (does not supply electricity) for utility worker safety.

There are also off-grid systems that rely on batteries and multimodal systems that are battery and grid interactive. These are not the focus of this guide, but if you would like other resources please visit Home Power Magazine (homepower.com) or talk with your local installer about your other options.



Photovoltaic (PV) Materials

Photovoltaic (PV) materials are the electricity producing component of a solar electric system. PV materials are made of solar "cells." When the sun's light energy (not heat energy) hits and is absorbed by the cells, electrons are released and flow as electricity. The greater the amount and intensity of the sunlight, the more electricity generated. PV materials generate direct current (DC) electricity. Commercially available PV materials include crystalline silicon panels and thin-film materials that are both made in various sizes with various wattages of electrical output, though crystalline silicon panels are the most widely used in Minnesota.

Crystalline silicon flat-plate panels range in size and electrical output. They can be used for a variety of applications. Those typically placed on home rooftops range from about two-to-three feet wide by four-to-five feet long with a three-inch thickness. Electrical output ranges from 175 to 300 watts.

On partly cloudy days, PV materials will produce about 80 percent of their capacity. Extremely overcast days may reduce electricity output to 30 percent of capacity. PV materials are relatively unaffected by severe weather and temperatures, although like most electronic devices, they operate more efficiently at cooler temperatures. Because they are typically a dark color and face the sun at an angle, snow slides off or melts quickly. PV materials are designed to resist hail damage (one name-brand panel is tested to withstand one-inch hail at 51 mph). They typically come with a 25-year power output warranty, but most will produce electricity 30-plus years.

Tracking Systems

If your building does not have a south-facing roof or surface (or you cannot use PV on or as structures), panels can be ground-mounted or pole-mounted in a yard or field. Pole-mounted panels can be in a fixed south-facing position or placed on tracking devices. Like sunflowers, tracking devices follow the sun's skypath. A single-axis tracker follows the sun from east to west. A dual-axis tracker follows the sun from east to west and adjusts for seasonal sun angles. Trackers increase system cost, but can increase power production by 20 to 30 percent. Trackers also increase the number of moving parts on a system, and more moving parts can mean more maintenance. For the more hands-on homeowner or building manager, adjustable rooftop and ground mounting structures are available for making seasonal sun angle adjustments.

Photovoltaic Material Types	
Crystalline Silicon	**Single-Crystalline Silicon** Also called Monocrystalline • Made from a single, large silicon crystal • Most commonly used • 15-20%+ efficient: currently the most efficient material for converting sunlight into electricity • Costs more per watt than multi-crystalline; less than thin-film
Crystalline Silicon	**Multi-Crystalline Silicon** Also called Polycrystalline • Made from silicon blocks with many, small crystals • 10-15% efficient • Costs less per watt than single-crystalline and thin-film
Thin-Film	**Thin-Film Types** Amorphous silicon, and non-silicon materials such as Copper Indium Gallium Selenide (CIGS), and Cadmium Telluride • 6-10% efficient • Currently costs more per watt than both crystalline silicon types

PV Panel Performance

Manufacturers will provide a minimum warrantied power rating (in watts) that may be called peak power or peak tolerance rating. Many panels are tested under either Standard Test Conditions (STC) or PVUSA Test Conditions (PTC). The main difference is the testing temperatures. A PTC rating is deemed a more realistic rating. If the panels you are considering have a STC rating, actual performance may be 85-90 percent of stated wattage output. Be sure to also compare efficiency ratings.

System Performance

If you are sizing your own complete system, you can use the rated wattage output (referred to as nameplate DC rating) to estimate the number of panels you will need to meet your targeted electrical load. Actual output of electricity will depend on factors such as roof orientation, tilt angle, and overall system efficiencies. Because there are inefficiencies in the remaining components, multiply the PV panel nameplate DC rating by 77 percent (a conservative de-rate factor used in NREL's PV Watts on-line tool) for an estimate of the amount of electricity that will actually reach your electrical load. For example: a 230 watt DC Nameplate rating x .77 = approximately 177 watts of actual electrical power that will reach your electrical load.

Balance-of-System (BOS)

Balance-of-System (BOS) is a term that refers to the remaining components that accompany PV panels. BOS includes an inverter, meter(s), safety equipment (disconnect switches, etc.), and potentially batteries and a charge controller. It also includes conduit, cables, and combiner boxes.

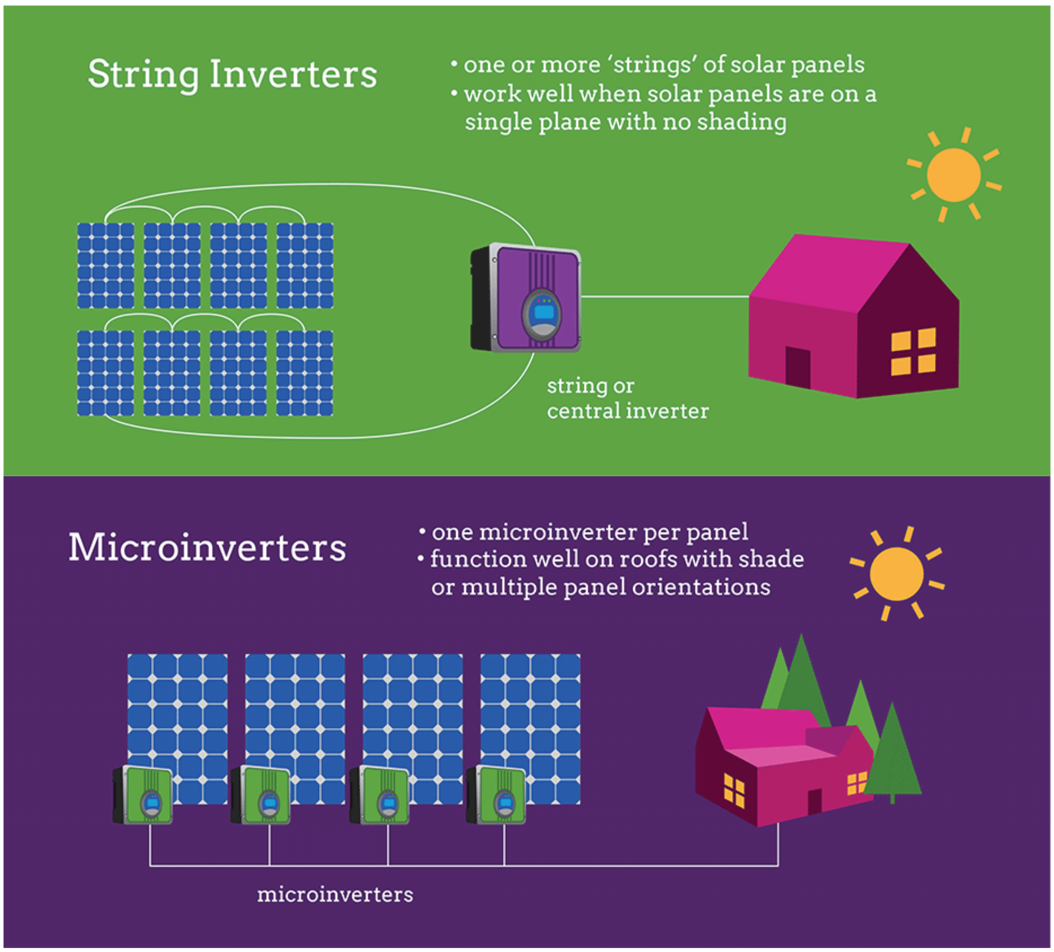
Inverter

An Inverter converts and conditions electricity. All PV materials/panels produce DC electricity, which can be used for DC-powered appliances, and camping and boating-related equipment, etc. Most appliances, electronics, and machinery require alternating current (AC) electricity, and an inverter converts the PV-generated DC into AC electricity. Inverters also "condition" the PV-generated electricity to match the qualities of the utility grid-produced electricity in order to properly power the electrical load.

There are two commonly used types of inverters: string inverters and microinverters. String inverters are the most widely used inverter system worldwide and are central inverters that serve entire PV systems. They work well when systems are sited for no shading. Microinverters work well where there might be potential panel shading, as they are attached to each individual PV panel instead of using a central inverter for the whole system. They are more expensive, but they can make system expansion easier and less expensive.

When it comes to installation, keep in mind that all grid-tied inverters must be Underwriter's Laboratories (UL)-certified. In addition, inverters should be accessible, weather-protected, and kept out of direct sun. Inverters can be up to 98 percent efficient and last up to 20 years. Warranties are typically for 10 years.

All solar electric system components must be matched to work together as a system. If you plan on adding more PV panels at a later date, consider either sizing your inverter for the future system or consider using microinverters. It may be less expensive to consider these alternatives at the beginning than it would be to upgrade to a larger inverter and the accompanying equipment changes that would also be required down the road.



Source: EnergySage, the online solar marketplace. Learn more at https://www.energysage.com/solar/101/string-inverters-microinverters-power-optimizers

Meters

Meters track the amount and "direction" of electrical flow in grid-tied systems (off-grid systems often have meters to track battery charge levels, etc.). When the sun is shining, the PV system generates electricity. If your building or machinery does not use all of the electricity being generated at any one time, it is fed into the utility's grid. When this occurs, you are credited at either a retail or wholesale rate from the utility. The retail rate is the rate you pay for electricity from the utility. The wholesale rate is a lower rate the utility pays for electricity it buys on the wholesale market.

How is electricity from a grid-tied system tracked? Typically, a special Net Meter, or bi-directional meter, is provided and installed by the utility company once a grid-tied system installation is completed. This digital meter "spins" forward when you are using electricity from the grid and "spins" backward when you are generating excess PV-generated electricity that is fed into the grid. If at the end of a month's billing period you used more electricity than your PV system generated, you are billed for the net amount you use. If your PV system generated more than you used, you receive a financial or energy (kWh) credit for the excess energy produced.

In some instances the utility company may also install a production meter to record the solar energy produced (not the net of production and usage). This is often used when the customer receives a production incentive payment so as to allow the utility to calculate the incentive amount.

All utilities in Minnesota are required to allow you to connect a net metering system <40 kW in size as long as you follow all of the standard interconnection procedures. In Xcel, Minnesota Power, and Otter Tail territory, customers can net meter systems up to 1 MW as long as the system does not exceed 120% of the onsite load. Your installer will be able to navigate this process with you. It is always a best practice to contact your utility company to ask for their current interconnection and net metering requirements.

Safety Equipment

Safety equipment protects owners, utility workers, and system equipment. Safety equipment includes AC and DC disconnect switches, grounding equipment, and surge protection. This equipment is very important for protecting people and system components from power surges, lightning strikes, ground faults, and equipment malfunctions. Automatic and manual disconnect switches are required in Minnesota. Disconnect switches shut down the system so it can be worked on safely whether for routine maintenance or repairs. Switches also prevent the system from sending power to the grid and endangering utility workers while they conduct repairs.

Systems with Batteries

Batteries store electricity. Off-grid buildings require batteries as part of the solar electric system. Electricity is stored and used from the battery bank, which is sized to provide electricity for the full electrical load for two or three days. Grid-tied buildings with battery back-up typically have a small battery bank used to store electricity for use during utility power outages.

When batteries are part of a solar electric system, a charge controller, also called a regulator, is required. It is connected between the PV panels and the batteries. A charge controller regulates and optimizes electrical flow from the panels to the batteries, keeps batteries fully charged, and prevents battery overcharging. It also prevents batteries from being excessively discharged, which can damage or ruin them. Charge controllers must be properly matched to the overall solar electric system for proper function. Charge controllers can be up to 98 percent efficient and are typically warrantied for up to five years.

Inverters and charge controllers can be combined into one piece of equipment. In this combined system the inverter converts solar-generated DC power (stored in the batteries) to AC so that it can be used by appliances.

Batteries can lower the overall efficiency of a solar electric system because they only release a percentage (80-95 percent) of the electricity that is fed into them. Batteries need periodic maintenance, and have safety considerations. They may last from seven to ten-plus years before requiring replacement. Their lifespan depends on factors such as number of discharges and the temperature at which they are stored.

Component and System Certifications

No matter what type of solar electric system you are installing make sure to purchase and use quality, certified components.

PV panels:

- Underwriter's Laboratory (UL) 1703 safety standard.
- Inverters and Charge Controllers: UL 1741.

Organizations that test and certify system components:

- Florida Solar Energy Center (FSEC): www.fsec.ucf.edu
- Go Solar California: www.gosolarcalifornia.org

Ground-mounted solar PV tracker system installation in Spicer, MN. CC BY-NC 2.0 Clean Energy Resource Teams www.flickr.com/photos/mncerts/sets/72157632141554770

Additional Resources

Frietas, Christopher. (2009/2010 Dec./Jan.). Inverter Basics. Home Power, 134, 88-94.

McCabe, J. (ed.). (2010, Fall/Winter). All About Photovoltaic Systems. Solar Today: Getting Started (Bonus Issue), 16-19.

National Renewable Energy Laboratory (produced) for U.S. Department of Energy. (2002, Sept.). Battery Power for Your Residential Solar Electric System. DOE/GO-102002-1608.

National Renewable Energy Laboratory (produced) for U.S. Department of Energy. (2009, January). Own Your Power! A Consumer Guide to Solar Electricity for the Home. DOE/GO-102009-2656.

Sanchez, Justine and Brad Burritt. (2009, Feb./Mar.). Charge Controller Buyer's Guide. Home Power, 129, 72-77.

Sanchez, Justine. (2009/2010, Dec./Jan.). 2010 PV Module Guide. Home Power, 134, 50-61.

Sanchez, Justine. (2011, Aug./Sept.). PV Systems Simplified. Home Power, 144, 70-78.

U.S. Dept. of Energy. (2011, Feb.). Connecting Your System to the Electricity Grid. Retrieved February 16, 2011, from http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10520

U.S. Dept. of Energy. (2011, Feb.). Meters and Instrumentation for Grid-Connected Systems. Retrieved February 16, 2011, from http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10560

U.S. Dept. of Energy. (2011, Feb.). Power Conditioning Equipment for Grid-Connected Systems. Retrieved February 16, 2011, from http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10540

U.S. Dept. of Energy. (2011, Feb.). Types of Solar Cells. Retrieved September 28, 2015, from http://energy.gov/energysaver/small-solar-electric-systems

UNIVERSITY OF MINNESOTA
EXTENSION

E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Lissa Pawlisch.

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. **System Sizing**
6. Costs
7. Installation
8. Electricity Use Worksheet

STEP 5: SYSTEM SIZING

The size of your solar electric system depends on:

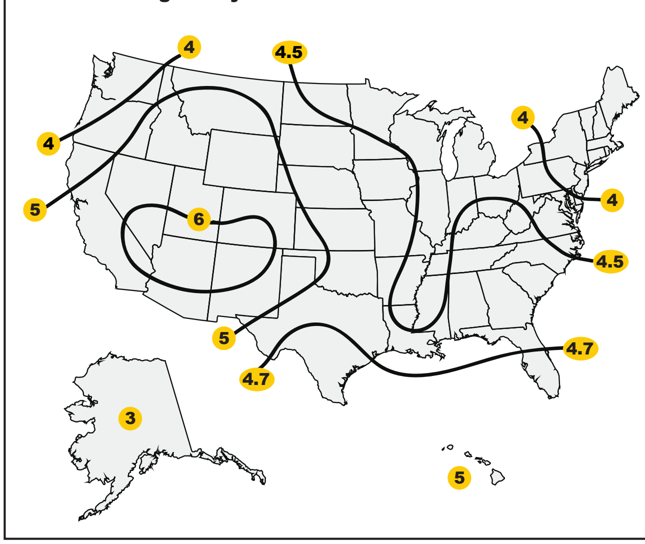
- How much electricity is used and the percentage of solar electricity to be generated
- Type of PV material used (crystalline silicon or thin-film)
- Roof or other PV material mounting surface orientation, tilt, area, and condition
- Local solar resource (solar radiation) and peak (direct) hours of sunlight
- Budget

You or a system installer can review your utility bills to determine how much electricity you use–typically shown in kilowatt-hours (kWh). If the information is not on your bill, contact your electricity provider and ask for your average monthly use in kWh.

One method for approximating system size is using **Daily Peak Sun Hours**:

1. Determine your average monthly electricity use in kWh
2. Divide by 30 for average use per day
3. Find the Peak Sun Hours for your location on the map; peak sun hours are the hours of direct sunlight that fall on a PV panel (not total hours of daylight)
4. Divide the answer calculated in #2 by your Peak Sun Hours; #4's answer is a rough estimate of the solar electric system size you will need (in kW) for 100% of your electricity

Annual Average Daily Peak Sun Hours



Example:

1. A Minnesota home's monthly average electricity use is 800 kWh/month
2. 800 kWh ÷ 30 = 26.67 kWh average per day
3. St. Paul is near the diagram's "4.5" line = 4.5 annual average peak sun hours per day
4. 26.67 ÷ 4.5 = 5.9 kW PV system would be needed to produce 100 percent of this home's electricity

NOTE: This method provides a rough estimate and should not be used to size a system. The actual system will most likely be larger due to many system-related factors.

For more accurate sizing, use the worksheet below. It takes conservation and efficiency measures and system component inefficiencies into account.

Solar Electric PV Panel/System Worksheet *Based on a South-Facing PV Module at a Fixed Tilt (Latitude Angle)*		
Steps	Example: Home in Saint Paul, Minnesota	Your Home/Building
1. Average monthly electricity used in kilowatt-hours (kWh).	800 kWh/month	
2. Multiply by 1,000 to convert to watt-hours used per month.	800 X 1,000 = 800,000 watt-hours/month	
3. Divide by 30 for total average watt-hours used per day.	800,000 ÷ 30 = 26,667 watt-hours/day	
4. Subtract daily watt-hours eliminated through energy conservation and efficiency.	26,667 – 2,667* = 24,000 watt-hours/day	
5. Multiply by the percent of electricity you want provided by the sun.**	For 50%: 24,000 X .50 = 12,000 watt-hours/day	
6. Divide by the average monthly solar radiation for your city or the city nearest you. Find in **Table A**. (on next page)	12,000 ÷ **4.5 kWh/m²/day** = 2,667 watts	
7. Multiply by 1.2 to account for system inefficiencies (wire losses, etc.)	2,667 X 1.2 = 3,200 watts	
8. Divide by 1,000 for the size of the overall system in kilowatts (kW). Will be used to approximate system cost.	3,200 ÷ 1,000 = **3.2 kW** PV array/ "system" size	
9. Divide #7's answer by the Peak/Max Power (in watts) of the PV panel you will install. (270 watts is a typical average)	3,200 watts ÷ 270 watts = 11.8 (12) panels	
10. Round up to a whole number. This is the number of PV panels needed to provide electricity based on the selected criteria.	**12**, 270-watt PV panels (12 x 270=3,240 watts) or **11**, 270-watt panels (11 x 270=2,970 watts)	

* Example of potential 10% energy savings in watt-hours/day. Re-run the calculation after you have implemented conservation and efficiency measures.

**Omit this step if you wish to provide 100 percent of electricity; carry value from #4 down to #6.

Worksheet Notes:

1. Minnesota homes use an average of 800 kWh/month of electricity.
2. 1 kilowatt-hour (kWh) = 1,000 watt-hours
3. 365 days/year divided by 12 months = 30 average days in one month.
4. Energy conservation and efficiency measures can reduce the size of your system. Estimate 10% savings can be accomplished before installing a system.
5. PV panels can be added to a system over time.
6. The solar radiation value used to rate panels is 1 kW/m2 and thus the results are in watts.
7. The amount of PV-produced electricity decreases as it flows through wires, the inverter, and other system components. NREL's PV Watts on-line tool addresses this using a de-rate factor.
8. Converts watts back to kilowatts (the units used to describe a system's "size").
9. If you know what PV panel you will use, divide Box 7's watts by the Peak Power (in watts) of the panel to determine the # of panels needed. Do you have enough space on your roof?

After the number of panels is determined, the remaining balance of system components (inverter, etc.) can be sized accordingly. While the kW output calculated in Step 8 above is specific to the PV panels/array, the kW number is also referred to/used as the "system size."

Find your city or city nearest your site for your average daily Solar Radiation (Solar Resource):

Table A: Solar Radiation for Flat-Plate Collectors/ Panels (south-facing, fixed tilt at latitude angle)	
Minnesota Cities	$kWh/m^2/day$
Duluth	5.0
International Falls	4.8
Minneapolis	4.7
Rochester	4.8
St. Cloud	4.7

Source: U.S. DOE/National Renewable Energy Laboratory (NREL): http://rredc.nrel.gov/solar/pubs/redbook/

Five Minnesota cities have National Solar Radiation Data Base collection stations. The NREL web link provides adjusted panel angles and tracking system data.

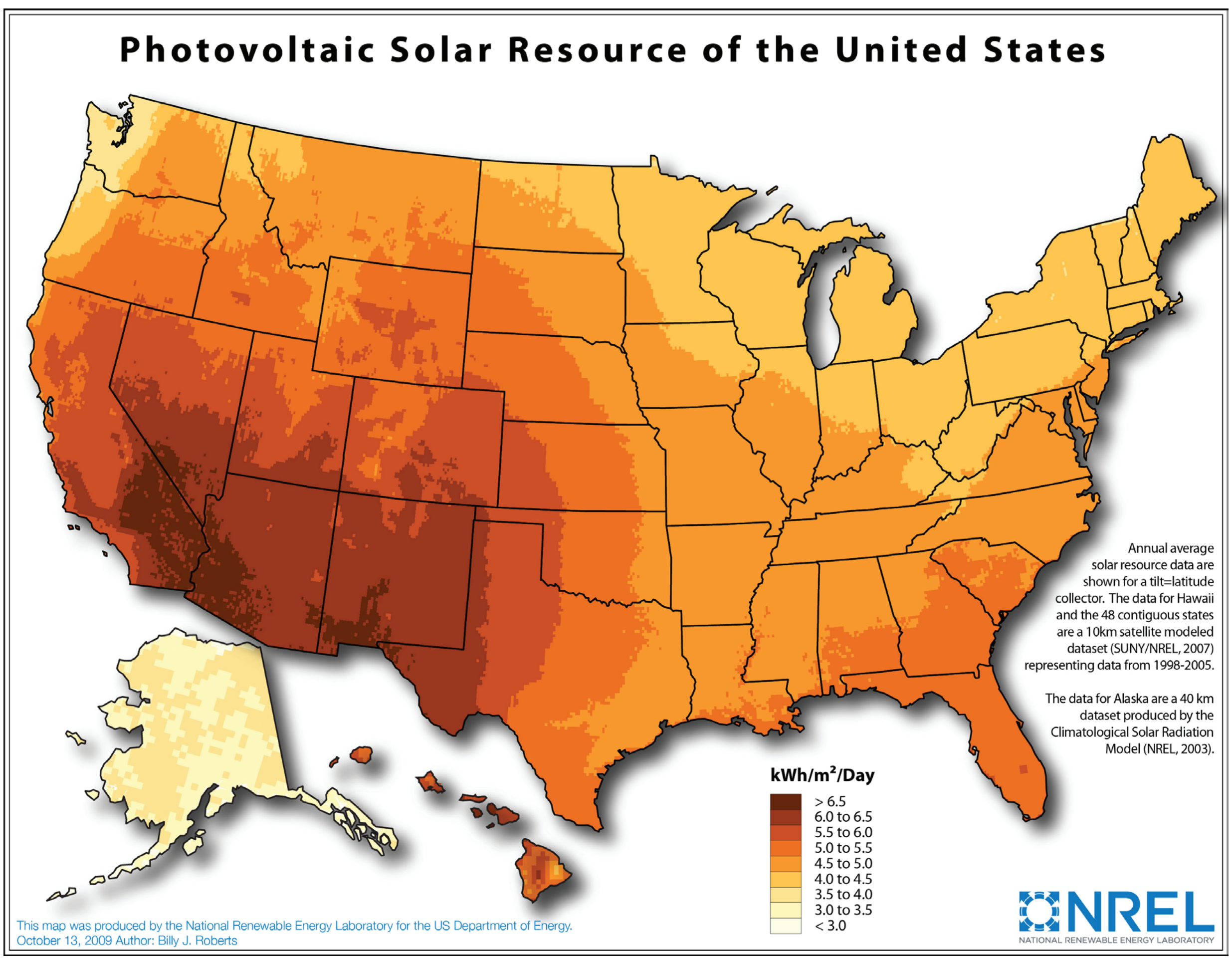
If your city is not listed in the table or is not near the listed cities, find your solar resource/radiation number from the map below. If printed/copied in black and white, access the map at http://www.nrel.gov/gis/solar.html.

Computer/On-Line Sizing Tools allow you to consider a combination of PV system options for specific locations using your address or zip code. Know how much electricity you use in one year (in kWh) and the approximate PV system size you are considering before you access the free programs described below.

- The Minnesota Solar Suitability App shows solar energy potential for every square meter of the state, provides basic system size and cost information, and helps you walk through next steps: http://mn.gov/solarapp
- PV Watts is an on-line calculator that provides energy production and cost savings estimates for grid-tied systems: pvwatts.nrel.gov
- My Solar Estimator estimates solar electric as well as wind and solar hot water system sizes: www.solar-estimate.org

Whether you use pencil and paper or a computer, these exercises provide a sense of what system size will work for you. A consultant or installer can provide a more detailed analysis and can advise on what will work best for your particular needs.

Are you interested in solar electricity because you want to reduce your environmental footprint? To determine the amount of greenhouse gases you are not emitting into the atmosphere by installing a solar electric system, use Option 1 (insert the kWh provided by the solar electric system) with the U.S. EPA's Greenhouse Calculator: www.epa.gov/cleanenergy/energy-resources/calculator.html.



Courtesy of NREL, http://www.nrel.gov/gis/solar.html / www.nrel.gov/gis/images/solar/national_photovoltaic_2009-01.jpg

Additional Resources

McCabe, J. (ed.). (2010, Fall/Winter). All About Photovoltaic Systems. Solar Today: Getting Started (Bonus Issue), 16-19.

National Renewable Energy Laboratory (produced) for the U.S. Department of Energy. (2002, August). How to Size a Grid-Connected Solar Electricity System. DOE/GO-102002-1607.

National Renewable Energy Laboratory (produced) for the U.S. Department of Energy. (1997, March). Photovoltaics: Basic Design Principles and Components. DOE/GO-10097-337.

University of Minnesota Extension
Montana State University Extension
Western SARE Sustainable Agriculture Research & Education
University of Wyoming Extension

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Lissa Pawlisch.

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. **Costs**
7. Installation
8. Electricity Use Worksheet

STEP 6: COSTS

As a general rule of thumb, an installed, grid-tied residential solar electric system without batteries costs approximately $4,000 to $7,000 per kilowatt (kW). Using watt units, $4 to $7 per watt. Larger systems typically cost less per installed kilowatt. An "installed kW" price includes the purchase and installation costs. Using the Saint Paul home system sizing worksheet example from Step 4 on System Sizing, a 3.2 kW system that provides 50 percent of the home's electricity would cost about $16,500. (3.2 kW x $5,500 = $16,500).

Note: Be prepared to pay or finance the full purchase price because some incentives that lower the final cost are received after the system is installed.

Incentives that Lower Costs

There are a variety of federal, state, and utility incentives for energy efficiency and renewable energy. These incentives vary by state and in the length of time they are available. The Department of Energy's Database of State Incentives for Renewables and Efficiency (DSIRE) — http://dsireusa.org — keeps track of tax credits, rebates and other incentives available to reduce your system's final cost.

Estimating Cost Savings and Simple Payback for a Net-Metered System

First, calculate the yearly cost savings of your PV system using the formula: (PV system size) x (Energy Production Factor) x (Electricity Rate) = $/year saved

For the St. Paul example:

- PV system size: 3.2 kW
- Energy Production Factor: 4.6 kWh/m2/Day (find in Step 4: System Sizing's Table A: Minneapolis' (Year) average or the NREL map, both on Page 3) x 365 days/year = 1,679 kWh/kW-year
- Electricity (utility) Rate: $0.10 per kWh

3.2 kW x 1,679 kWh/kW-year x $0.10/kWh = $ 537 saved per year

Simple Payback is calculated by dividing the system price by the amount saved per year. Examples below use the Saint Paul home numbers.

Without Incentives: Cost $16,500 ÷ $537 saved per year = 31-year simple payback

Many solar systems will be eligible for various incentives that can shorten this payback period.

First, apply utility-specific Rebates. Several Minnesota utilities offer solar energy rebates (Austin, Brainerd, Marshall, Minnesota Power, Moorhead, New Ulm, Owatonna, Rochester, Shakopee). See an up-to-date list of current utility-specific solar rebates and the program details at: www.dsireusa.org. Any customer served by a utility with a current rebate should contact the utility directly for eligibility and availability for the rebate program.

Second, apply any available Federal incentives. Solar projects are eligible for an Income Tax Credit of 30 percent of system cost (after utility/local rebates) through December 31, 2019 (starting January 1, 2020 incentive amounts will step down).

$16,500 x 30 percent = $4,950 tax credit. Therefore, $16,500-$4,950 = $11,500. System Final (Net) Cost: $11,500 ÷ $537 saved per year = 21-year simple payback.

With Production Incentives

- Minnesota's largest utility, Xcel Energy no longer offers a solar energy rebate, but rather a production incentive (which does not need to be applied before the tax credit). You can learn more about this Solar*Rewards program at http://mncerts.org/solarrewards.
- In addition, customers of Xcel Energy, Minnesota Power, and Otter Tail Power are all eligible for the Made-in-Minnesota production incentive program. The production incentives are allocated via a lottery system, with roughly half of the available incentive dollars allocated to residential customers and the other half allocated to commercial customers. The program has $15 million available per year for each of 10 years until 2023. Incentive amounts vary by manufacturer, and at present there are four eligible manufacturers: tenKsolar, Silicon Energy, itek Energy, and Heliene. Read more about the program and stay up to date on incentive amounts at the Minnesota Department of Commerce site: mn.gov/commerce/industries/energy/solar/mim.

For example, our 3.2 kW system that produced 1,679 kWh/kW-year would receive an additional 0.25/kWh produced if installed a Heliene system and received a Made-in-Minnesota incentive through the lottery. That would amount to:

3.2 kW * 1,679 kWh/kW-year * $0.25/kWh = $1,343.20 saved per year.

The Made-in-Minnesota incentives are in addition to the $537 / year saved on your utility bill. In total your simple payback would now be:

System cost: $16,500 ÷ ($537+$1,343.20) saved per year = 8.77 simple payback (the MiM incentive only last for 10 years).

NOTE: Payback times decrease when electricity costs increase. Some conservation and efficiency measures (that can reduce PV system size) also qualify for a tax credit. Visit the DSIRE website for complete and up-to-date information: http://dsireusa.org.

PV System Financing

There are a variety of financing options for solar electric systems:

- Center for Energy and Environment (CEE) Solar Financing: www.mncee.org/Find-Programs/Solar/
- Neighborhood Energy Connection (NEC) Solar Financing: thenec.org/home-and-energy-loans
- USDA Rural Energy for America Program (REAP): www.rd.usda.gov
- Bank Loan
- Home refinance — roll into a mortgage payment
- Construction loan
- Home equity loan
- Minnesota Housing Finance Agency Fix-Up Fund (allows for solar). See program details and eligibility: http://bit.ly/mnhousingfixup
- Some PV system companies provide financing
- For businesses, Property Assessed Clean Energy (PACE) financing is also an option. Learn more here: http://mncerts.org/pace

4 kW solar PV installation on a Edina, MN home. Photo by Karl Schwingel, Innovative Power Systems. Used with permission.

Additional Resources

Department of Energy's Database of State Incentives for Renewables and Efficiency (DSIRE). (2011, February). *Residential Renewable Energy Tax Credit*; Residential Alternative Energy System Tax Credit; and Northwestern Energy-USB Renewable Energy Fund. Retrieved May 19, 2011 from http://dsireusa.org/incentives/index.cfm?getRE=1?re=undefined&ee=1&spv=0&st=0&srp=1&state=MT

(National Renewable Energy Laboratory Engineer and Montana-based NABCEP-certified PV system installers, personal communication regarding current PV system purchase and installation costs, April 12, 2011).

Solarbuzz: Solar Market Research and Analysis. (2011). *Solar Electricity Prices*. Retrieved April 11, 2011, from http://www.solarbuzz.com/facts-and-figures/retail-price-environment/solar-electricity-prices

U.S. Dept. of Energy. (2011, Feb.). *Estimating Energy Cost Savings for a Net-Metered Photovoltaic System*. Retrieved March 11, 2011, from http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10860

UNIVERSITY OF MINNESOTA EXTENSION

E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger. Updated by Lissa Pawlisch.

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. Costs
7. **Installation**
8. Electricity Use Worksheet

STEP 7: INSTALLATION

Pre-Installation Considerations

Before installing a solar electric system, your solar installer will check local building codes, subdivision covenants, and zoning ordinances or regulations and any private easements. They will also contact your local electrical or building inspector to determine requirements. The National Electric Code (NEC) Article 690 provides requirements for designing and installing a safe, reliable and code-compliant solar electric system. Using NEC criteria will ensure local code official approval. Check whether a building permit is required if installing a system on an existing building.

Review the covenants and contact the homeowner's association (HOA) board or the management company if you live in an area with a homeowner's association. You may need to educate local building code officials and local representatives if you are the first in your area to install a renewable energy system. Contact your utility company to see what it requires to interconnect your system. Systems in Minnesota will need to comply with a series of inverter safety requirements developed by Underwriter's Laboratory (UL 1741).

Other installation issues might include: historic district guidelines and/or restrictions and future shading. Will any trees on your property or nearby property grow and shade the system panels? Be sure to communicate with neighbors about your plans and determine if they might plant trees or add a second story to a home that may shade your panels. Some government jurisdictions have solar access zoning regulations that prevent the blocking of the sun required for operation of any solar energy system. Minnesota law (Minnesota Statute 500.30) allows the creation of easements to protect solar and wind energy rights. This requires negotiation with neighboring property owners.

9 kW of solar installed in 2009 & 2012 on a Blaine, MN home. Photo by Sam Villella. Used with permission.

24.5 kW solar PV installation on a Welch, MN farm. Photo by Solar Connection Inc. Used with permission.

Who Will Install Your System?

Proper installation of your solar electric system will ensure maximum electrical output. Hiring a qualified company or contractor is recommended because proper installation entails numerous considerations and requires attention to safety (roof work, electrical hook-ups, etc.). Some manufacturers will extend a system's warranty if installed by one of their trained contractors. Some utility rebates will only be given if a system is installed by a trained and certified professional. Protect yourself and feel confident you are hiring a qualified professional by asking questions about experience, licensing, certifications, and customer service.

Experience

Does the company or individual contractor have experience installing and providing maintenance for the type of system you want installed? Do they warranty their installation work? Do they provide system commissioning? Ask for the contact information of other customers, and if possible, take time to see those systems and ask the owners about their experience with the system and the level of customer service received.

Licenses

Some states require a contractor to be licensed. Minnesota solar PV systems and their components are considered electrical equipment under the State Electric Code. Thus, a licensed electrician is required to connect grid-tied systems to the utility's grid. All electrical contractors and electricians must be licensed by the State Board of Electricity.

Insurance

Be sure to ask about and see confirmation of liability and workman's compensation insurance. Have they taken safety training?

Certifications

Many installers take specialized training and exams to receive certifications. The North American Board of Certified Energy Practitioners (NABCEP) is one group that tests and certifies solar electric and other renewable energy system professionals. The Clean Energy Project Builder website lists companies in Minnesota with NABCEP-certified professionals: cleanenergyprojectbuilder.org/nabcep-pv.

Trade organizations

Ask the company or installer if he/she is a member of a trade organization such as the Minnesota Solar Energy Industries Association (MnSEIA) and/or the Minnesota Renewable Energy Society (MRES). Are they a member of the Better Business Bureau (BBB)?

System Monitoring

Many companies now offer a system monitoring service that allows them/you to monitor the system through a web-based computer program. Ask your installer about what tool(s) they offer for you to be able to monitor your own systems output in an on-going, and ideally real-time way.

Where Can You Find an Installer?

The Clean Energy Project Builder website (cleanenergyprojectbuilder.org) provides a list of solar energy installers searchable by zip code. It lists companies, provides a company profile, lists relevant certifications and memberships, and in some instances references projects.

Comparing Bids

Get bids from more than one company and compare. Have bids specify the system type, size, electricity output, and maintenance requirements in addition to cost.

- Ask the installer if he/she installs packaged systems and whether the system or the individual components are UL certified
- Because different PV panels generate different amounts of electricity, ask for the maximum generating capacity (measured in DC watts or kilowatts) under a Standard set of Test Conditions (STC) or under PVUSA Test Conditions (PTC); Or, ask the electricity output of the system at the inverter
- Ask for an estimate of the amount of electricity the system will produce on an annual basis in units of kilowatt-hours (kWh) that will actually reach your electrical load
- Ask how the panels will be attached to the roof/what type of mounting system will be used
- Ask about whole system or individual component warranties; Some solar rebates require a minimum system warranty; Installers may offer longer warranties
- Ask that the bid include the following costs: installation, initial set-up and commissioning, all hardware, required National Electric Code (NEC) signage, permits, sales tax, and warranties

Post-Installation Considerations

Maintenance

Solar electric systems are low maintenance generally with no moving parts (apart from trackers), but like any electronic equipment, they do require routine, periodic attention for maximizing performance. System performance can now be monitored in a variety of ways. Qualified solar companies and contractors may also conduct system inspections and perform maintenance tasks. Ask your system installer what is required or recommended and be sure to read the owner's manual. Companies may provide a yearly maintenance checklist specific to your system, and it is recommended you hire a licensed and/or certified contractor for necessary maintenance.

System Monitoring

It is important to know your system is operating efficiently and producing the amount of electricity intended. Monitoring devices allow system owners to view production at any time and to view historical production for comparison over time. For example, inverters are equipped with a display that shows current and lifetime power production.

Web-based monitoring/data-logging systems allow you to access information from your own computer or anywhere internet access is available. The information can include equipment performance, how much electricity was sent to the utility grid, how much money was saved, and the amount of greenhouse gases not emitted.

Additional Resources

Community Associations Institute. Solar rights and Easements by State. Retrieved September 29, 2015, from http://www.caionline.org/govt/Pages/SolarRightsandEasementsbyState.aspx.

Minnesota Department of Labor and Industry. (2014). Solar Photovoltaic (PV) Systems Questions and Answers. Retrieved September 29, 2015, from http://www.dli.mn.gov/CCLD/PDF/solarFAQ.pdf.

National Renewable Energy Laboratory (produced) for U.S. Department of Energy. (2009, January). Own Your Power! A Consumer Guide to Solar Electricity for the Home. DOE/GO-102009-265

U.S. Dept. of Energy. (2010, Oct.). Community Solar Access. Retrieved February 8, 2011, from http://www.energysavers.gov/renewable_energy/solar/index.cfm/mytopic=50013

U.S. Dept. of Energy. (2011, Feb.). Installing and Maintaining a Small Solar Electric System. Retrieved February 16, 2011, from http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10820

U.S. Dept. of Energy. (2011, Feb.). Local Codes and Requirements for Small Renewable Energy Systems. Retrieved February 16, 2011, from http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=10690

University of Minnesota Extension · Montana State University Extension · Western SARE Sustainable Agriculture Research & Education · University of Wyoming Extension

UNIVERSITY OF MINNESOTA
EXTENSION

E3A: Solar Electricity for the Home, Farm, and Business

By Susan Bilo, Sarah Hamlen, Mike Vogel, Milton Geiger.

Steps in the Solar Electricity Series

1. Introduction
2. Building and Site Assessment
3. Conservation and Efficiency
4. System Components
5. System Sizing
6. Costs
7. Installation
8. **Electricity Use Worksheet**

STEP 8: ELECTRICITY USE WORKSHEET

Electricity Use Worksheet

Address: ______________ Calculated by: ______________ Date: ______________

Electrical Device	* Wattage (Volts x Amps = Watts)	X	# of Hours Used Per Day (when used)	X	# of Days Used Per Year	=	Watt-hours Used Per Year	Divide by 1,000 = kWh	Kilowatt-hours (kWh) Used Per Year
Example: Flat Screen TV	120 watts	X	2	X	269	=	64,560	64,560 / 1,000	64.56 kWh
Example: Dishwasher (not using the drying feature)	1200 watts	X	1	X	104	=	124,800	124,800 / 1,000	124.8 kWh
		X		X		=		/ 1,000	
		X		X		=		/ 1,000	
		X		X		=		/ 1,000	
		X		X		=		/ 1,000	
		X		X		=		/ 1,000	
		X		X		=		/ 1,000	

Electrical Device	Wattage	X	Hours Used/Day	X	Days Used/Year	=	Watt-hours	÷1,000 =	KWh Used/Year
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
		X		X		=		____ 1,000	
Total kilowatt-hours (kWh) Used Per Year									
Divide by 12 for Average KWh Used Per Month Use this number for the Solar System Sizing Exercises in Factsheet 5.									

* An electrical device has a metal plate/sticker showing **wattage** on or near the back or side. If not shown, use the amperes (amps) number times the voltage to get wattage.
Most U.S. appliances use 120 volts. Larger appliances (electric clothes dryers and cooktops) use 240 volts.

- **Refrigerators**: Because they cycle on and off to maintain a set temperature, divide the total time the refrigerator is plugged in by 3.

University of Minnesota Extension
Montana State University Extension
Western SARE Sustainable Agriculture Research & Education
University of Wyoming Extension