The Montana Consumer Guide to Grid-Interactive Solar Photovoltaic Systems

Incorporating On-site PV Electricity Generation for Residential and Small-Business Consumers

April 2026

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The Consumer Guide focuses on grid-interactive solar photovoltaic (PV) systems. It begins with the essentials , emphasizing the importance of implementing energy efficiency measures before installing a solar system. Key topics include estimating the appropriate size of a solar array and selecting a qualified installer.

The early sections of the publication provide a thorough explanation of NorthWestern Energy's solar interconnection process and net metering standards. They also provide key steps, with examples, to help customers make informed decisions about solar energy. NorthWestern Energy resources, along with helpful web links, are included.

The latter section of the guide provides a more detailed exploration of solar technology. For those who want to delve deeper, it discusses the various components and processes involved in solar PV production. Additionally, the final pages include information on warranties, consumer safety considerations, and definitions relevant to solar energy and electrical systems.

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The Essentials

Optimizing Home Efficiency Before Going Solar

Improving your home's energy efficiency before installing solar isn't just a smart add on—it's one of the most effective ways to maximize the value of your future PV system. By reducing wasted energy and tightening up your home's overall performance, you can lower the size of the solar array you need, cut long term utility costs, and ensure your panels deliver the strongest return on investment. A few strategic upgrades now can make your home truly solar ready and set the foundation for decades of clean, reliable power.

Home Energy Assessment

The best place to begin is with a home energy assessment. This evaluation gives you a clear picture of how your home currently uses energy and where improvements will make the biggest difference. If you're a NorthWestern Energy customer, you may qualify for a free in home or virtual Energy Check. During this visit, an energy specialist examines your insulation, heating and cooling sys-systems, lighting, appliances, and areas where air may be leaking. They provide personalized recommendations and may even offer free or discounted efficiency products such as LED bulbs, smart thermostats, or weather stripping.

This simple step helps you understand your home's baseline and identify the most cost effective upgrades before moving forward with solar. Learn more and submit your request for an assessment at **Energy Check**.

Sealing Air Leaks and Insulation Improvements

Once you know where your home is losing energy, sealing air leaks and improving insulation is often the next logical step. Many homes lose significant amounts of heated or cooled air through gaps around windows, doors, attics, and crawl spaces. By tightening these areas and adding insulation where needed, your home maintains a more stable temperature with far less effort from your heating and cooling system. These improvements typically deliver quick payback and immediately reduce your overall energy use.

HVAC Upgrades

Upgrading your heating, cooling, and ventilation systems can also make a substantial difference. Older HVAC systems often consume far more energy than necessary. Replacing them with high efficiency models, adding a smart thermostat, or ensuring your ductwork is properly sealed and sized can dramatically reduce your energy load. Even routine maintenance, such as changing filters regularly, helps your system run more efficiently and prepares your home for a right sized solar installation.

NorthWestern Energy Home Rebates

NorthWestern Energy also offers a variety of **rebates** that can help lower the cost of making your home more energy efficient or replacing older appliances, making it even easier to take the next step toward reducing your energy use.

Combined Efficiency and Solar Example

To see how these steps can impact your solar investment, consider a simple example. A homeowner using about 1,200 kilowatt hours of electricity each month might initially need a 10 kilowatt solar system to offset most of their usage. After making a few efficiency improvements—such as adding attic insulation, upgrading to a heat pump, switching to LED lighting, and installing a smart thermostat—their energy use drops by roughly 25 percent.

With monthly consumption reduced to around 900 kilowatt hours, the homeowner now needs only a 7.5 kilowatt solar system. This reduction can save thousands of dollars in installation costs while lowering utility bills even before the solar panels are installed.

Non-utility Efficiency and Conservation Incentives

In addition to utility based programs, Montana residents and businesses have access to a wide range of energy efficiency and conservation incentives that can help reduce upfront costs. Many of these offerings—such as rebates, tax credits, and low cost upgrade programs—are listed in the Database of State Incentives for Renewables and Efficiency (DSIRE). DSIRE™ has tools to help understand the specifics of various tax credits/deductions, incentives, and loans. The site is written and organized in a practical format and provides links to resources with more detailed information. DSIRE™ is accessible at **dsireusa.org**. Consumers can access Montana incentives and tax information by clicking on the "MT" section on the site's home map.

Choosing a Solar Installer

Selecting a solar installer is one of the most important decisions you'll make on your path to going solar. A knowledgeable, reputable installer will help you understand your options, design a system that fits your home's energy needs, and guide you through permitting, incentives, and installation with confidence. Taking the time to compare providers, review credentials, and understand what each installer offers ensures you'll end up with a system that performs well, lasts for decades, and delivers the long term savings you're expecting.

NorthWestern Energy provides a list of approved renewable energy installers who have met the program's requirements. You can **view the full list here** to help make your selection process easier

The PVWatts® Calculator

The PVWatts® Calculator is a simple, user friendly online tool that estimates how much electricity a solar PV system can produce. By entering your location, basic system design details, and optional economic information, the tool calculates expected energy output and the approximate value of that production. It also applies standard assumptions for factors such as shading, system losses, and inverter efficiency.

PVWatts® gives consumers a quick way to compare different system sizes and configurations before receiving a site specific assessment from a solar contractor. This baseline estimate can help set realistic expectations and reduce the risk of being oversold on system size or features that may not be necessary.

The PVWatts® Calculator is available at pvwatts.nrel.gov. To get started, simply enter your address or zip code, and the tool will guide you through the remaining steps.

Applying for Interconnection

Once you've selected a solar installer, the next step is to begin the interconnection application process. This is the formal approval required to connect your solar energy system to NorthWestern Energy's electric grid. Your installer will typically guide you through the paperwork and technical requirements, but it's helpful to understand the purpose of this step: ensuring your system is safely designed, properly sized, and compatible with the grid. Completing the interconnection application early keeps your project on track and helps avoid delays as you move closer to installing and activating your solar system.

NorthWestern Energy has a formal interconnection protocol with well-defined requirements, instructions, and resources. Following is a summary of the mandatory application and interconnection procedures.

Interconnection Request and Permit Process

For systems up to 50 kilowatts (kW), customers need to complete and submit a ***Level One Small Generator Facility Interconnect Request***. There is a $200 processing fee that must accompany the Request. The submission includes applicant information, system size and specifications, and the net metering agreement. The complete terms and conditions for electrical net metering are detailed in ***Rule 16 (Electrical Net Metering)***.

NorthWestern Energy's documents and requirements for interconnection and net metered solar systems are available for viewing and download. To access these resources, visit **Net Metering and Private Generation**.

Upon receipt of the Request, NorthWestern Energy dates and time stamps the document, and it is placed in the queue for review using the criteria in ***Rule 17 (Interconnection Procedures for Small Generator Facilities Other Than Qualifying Facilities – Section 5***). Timelines and conditions for systems approved or denied are detailed in ***Rule 17***.

Choosing the right Annual Settle-up month is important. Applicants are encouraged to examine their electrical usage patterns and renewable energy system output to make an informed decision. The available Annual Settle-up months are January, April, July, and October. You chose your Annual Settle-up month when completing the Interconnection Request, Exhibit A, Required Net Meter Application Information.

The Annual Settle-up month is a crucial part of net metering, and it's important to understand how it works. At the Annual Settle-up month any remaining unused kilowatt-hour credit accumulated during the previous 12 months will be granted to NorthWestern Energy without compensation to you, the customer. NorthWestern Energy allows consumers to change their cycle date once after installation.

In tandem with the Interconnection Request, the customer must obtain applicable local and/or state building/electrical permits. Like the interconnection application, the contractor helps facilitate the permitting process. The provisions, steps, and cost for solar PV permitting differ throughout the State; however, only licensed electricians or registered electrical contractors can secure electrical permits.

Concerning electrical permitting and interconnection, the completed PV system must first be inspected and approved by the permit authority's electrical inspector (local or State) before NorthWestern Energy will connect the system to the grid. In addition, NorthWestern technicians verify the presence and compliance of the utility-required external disconnect switch (EDS).

Enjoying the Benefits of Solar

Once your solar system is installed and connected, you can begin enjoying the long term benefits of producing your own clean energy. Solar panels generate electricity for your home throughout the day, reducing the amount of power you need from the grid and lowering your monthly bills. When your system produces more energy than you use, NorthWestern Energy's net metering program allows that excess electricity to flow back to the grid, earning you credits that help offset the energy you draw at night or on cloudy days.

Understanding how this process works helps you make the most of your solar investment and enjoy the full value of your renewable energy system for years to come.

Net Metering

Net metering lets you get full value from the energy your solar system produces by turning any extra electricity into credits on your NorthWestern Energy bill. When your panels generate more power than your home needs—often during sunny afternoons—that extra energy flows back to the grid, and you earn credits automatically. Later, when your home uses more electricity than your panels produce, such as in the evening or on cloudy days, those credits are applied to help reduce your charges. This means your bill reflects the give and take between what your system produces and what your home uses, making it easy to see the monthly benefits of your solar investment.

Understanding Your Net Metering Bill

Imagine your solar system produces more electricity than your home uses during a sunny month. With net metering, that extra energy doesn't go to waste—it becomes a credit on your NorthWestern Energy bill.

Here's a simple example:

- Your home used: **600 kWh** and Your solar system produced: **750 kWh**
- Extra energy sent to the grid: **150 kWh**

Because you produced more than you used, your bill for that month would show zero kilowatt hours charged, and you would see a 150 kWh credit carried forward. That credit stays on your account and is automatically applied in future months when your home uses more electricity than your panels produce.

- Your home used: 900 kWh and Your solar system produced: **400 kWh**
- **Shortfall:** 500 kWh

Your earlier 150 kWh credit would be applied first, reducing the amount you need to buy from the grid. You would only be billed for the remaining 350 kWh. This makes your bill lower because you're using the credits you earned during sunnier months.

When you have an excess energy balance, the balance will be noted on your statement in the **Important Account Information** section. When there is no excess energy balance, you will be billed the actual kilowatt-hours (kWh) and kilowatts (kW) consumed based on your energy usage. You can find the net energy billed amount on page 2 of your statement. When there is no excess energy balance, there is no excess energy balance to report on your bill.

Energy Storage Systems (ESS)

As a final consideration, some customers choose to add supplemental power sources—such as batteries or backup generators—to their grid connected solar PV systems. While only a small percentage of installations include storage today, it can provide added peace of mind during power outages by keeping essential devices running when the grid is down.

In Montana, energy storage systems must meet safety and installation requirements outlined in the National Electrical Code (NEC), International Fire Code (IFC), and International Building Code (IBC). These standards cover both electrical and structural elements to ensure systems are installed safely and operate reliably.

Battery storage is typically designed to support critical loads, such as refrigeration, medical devices, or home heating controls. Because solar panels may not produce enough electricity during an outage, especially at night or during storms, batteries supply the stored energy needed to keep those essential circuits powered.

The cost and complexity of adding storage can vary widely depending on the size of the backup system and the specific loads a customer wants to support. In many cases, battery systems represent a significant additional investment.

Most modern residential systems use pre-engineered lithium ion battery products that are matched to the home's solar array and backup needs. Lithium ion technology continues to evolve rapidly, with ongoing improvements in performance, safety, and cost expected in the coming years.

Making a Well-Informed Solar Decision

Analysis Steps and Key Formulas

A productive solar system depends on how well it captures sunlight, converts it into usable electricity, and supports your home's energy needs. Ultimately, each customer must decide what type of system to install, how large it should be, and which features matter most.

The following guide outlines a clear, three step process to help you make those decisions with confidence.

Step One: Understanding Your Electricity Use and Choosing a Target Offset

1. **Review Your Electricity Use –** The average Montana household uses about 9,000 kWh of electricity per year. To understand your own usage patterns, review one to two years of past electric bills. NorthWestern Energy customers can access two years of usage data by creating a **My Energy Account**.
2. **Identify Efficiency and Conservation Opportunities –** Before sizing a solar system, consider ways to reduce your energy use. This may include upgrading to efficient lighting, replacing older appliances, or adopting simple conservation habits such as turning off unused lights.
3. **Select Your Target kWh Offset –** Using the information from 1 and 2, determine how much of your annual electricity use you want your solar system to offset. Many net metered customers aim to offset **25–75%** of their yearly consumption.

Step One Example:
A homeowner uses 11,700 kWh per year. After completing an energy audit and making efficiency upgrades, they reduce their usage by 1,000 kWh, bringing annual consumption to 10,700 kWh. If they choose to offset 50%, the target becomes: 10,700 kWh × 50% = 5,350 kWh per year, this becomes the required annual output of the PV system.

Step Two: Sizing the System Based on Site Characteristics

Siting factors—such as roof space, shading, and orientation—play a major role in determining system size and performance. Ignoring these early can lead to design challenges later.

1. **Estimate System Size Using Montana's Average Production –** In Montana, a fixed mount, south facing PV system typically produces about 1,300 kWh per installed kilowatt each year. This is a general estimate; actual output varies based on orientation, shading, panel efficiency, and location. For a more precise estimate, the **PVWatts® Calculator** is a reliable and easy to use tool.
2. **Evaluate Space and Siting Constraints –** Once you know the desired system size, assess whether your property can accommodate it. Typical space needs:
   a. Crystalline panels: 75–125 sq. ft. per kW
   b. Thin film panels: 125–300 sq. ft. per kW

A qualified solar contractor should provide a detailed assessment of available space, shading issues, and solutions.

Step Two Example:
To generate 5,350 kWh annually, the homeowner divides the target output by Montana's average production: 5,350 ÷ 1,300 = 4.1 kW system. Their roof has enough south facing space for a 4.1 kW array, but a nearby tree causes partial shading. Options may include trimming the tree, downsizing the system, or using micro inverters or power optimizers to reduce shading losses.

Step Three: Determining the System Cost and Payback

Many customers evaluate solar based on economic value, though environmental benefits, resilience during outages, and interest in renewable technology also play a role.

1. **Identify the Total System Cost (TSC) –** Request a detailed, itemized bid from your contractor. A complete bid should include:
   a. Equipment
   b. Design and labor
   c. Permits
   d. Structural or electrical modifications
   e. Optional maintenance agreements
2. **Calculate the Annual Production Value (APV) –** To estimate the value of the electricity your system will produce, multiply the system's annual output (APO) by the current NorthWestern Energy kWh rate. Current rates can be found at **Rates & Tariffs**.
3. **Determine Simple Payback –** Simple Payback = Total System Cost (TSC) ÷ Annual Production Value (APV) This provides a basic estimate of how many years it will take for the system to pay for itself.

Step Three Example:

- System size: 4.1 kW
- Annual output: 4.1 × 1,300 = 5,330 kWh
- Total system cost: $12,900 (including a $700 maintenance agreement)
- Electricity value: 5,330 kWh × $0.15 = $799.50
- Simple payback: $12,900 ÷ $799.50 = 16.13 years

***Note: The 15¢/kWh rate is for example purposes only. Customers should verify current rates with NorthWestern Energy*.**

NorthWestern Energy Resources

Interconnection and Net Metering
Phone: (406) 497-4165
E-mail: **northwesternenergynetmeter@northwestern.com**
Website: **Net Metering and Private Generation**

Energy Efficiency, Renewable Programs and Qualified PV Installer Information
Phone: (800) 823-5995
E-mail: **e+programs@northwestern.com**
Website: **NorthWesternEnergy.com/EE**

NorthWestern Energy Customer Service
Phone: (888) 467-2669
Website: **Contact Us**

In-Depth: Solar Technology, Components and Operation

The History and Science of Solar Photovoltaic (PV) Power

In 1839, French physicist Edmund Becquerel found that exposure of certain materials to sunlight resulted in a small electrical current. Albert Einstein described the science of this interaction - for that, he won the Nobel Prize for Physics. His research and writings on the "photoelectric effect" form the basis of modern photovoltaics.

Bell Laboratories built the first photovoltaic (PV) module, and NASA used the technology in the 1960s space programs. Land-based, structural PV prototypes followed, and systems became available to consumers. The cost of the first PV modules was high, but due to incentives, market transformation, and production improvements, the price for PV systems steadily dropped.

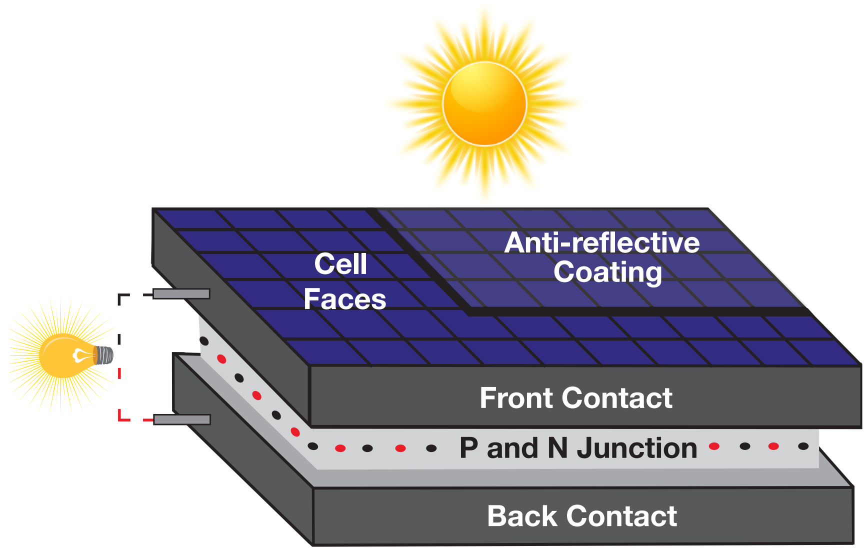
Today's prices for PV modules are approximately 30-50% of those ten years ago. To a lesser degree, component costs have also decreased. Montana has an established, reputable solar contractor community- the number of solar (only) and general electrical contractors who perform and maintain PV systems has steadily increased and serves most of the State's geographic areas.

How PV Works

As described by Einstein, sunlight contains energy. When it contacts the PV cell, integrated materials within the cell (typically silicon) enable the light energy to produce an electrical field near the top surface of the cell. This electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the cell connects to an electrical load.

Solar PV Building Blocks (Cell, Module, Array)

There are between 60 and 72 solar cells in a residential or small commercial solar module (also called a panel). Residential modules are usually 60 cell designs.



Solar Photovoltaic Process
60-Cell Solar Module (Expanded View)

Each cell has a voltage of between 0.5 and 0.6 volts and produces approximately 200 to 250 mA (milliamps) per square inch. The cells electrically connect and form the solar module, and modules wired together comprise the solar array.

The modules used for non-utility applications are rectangular with outside dimensions of approximately 39" x 65" for a 60 cell module and 39" x 78" for a 72 cell module.

The average weight of a 60 cell module is between 40-50 pounds, and 72 cell modules weigh between 50-65 pounds each. Based on the cell composition, design, and cell count, the electrical output per module is between 175-450 watts.

The solar array is the entire cluster of modules grouped on the roof of a structure or a ground mounted pole. The array has a maximum system power capacity rating, listed in watts or kilowatts (one thousand watts). This rating is also called the "peak output."

The maximum capacity rating is the production benchmark. This figure represents the output of the array when operating at full power. Production is highest when the sun is providing the greatest amount of light. When the sun is blocked or not directly striking the panels or in conditions such as extreme temperature, the system's output will not reach rated capacity.

The Three Objectives of a PV System

The three main objectives of a grid-interactive photovoltaic system are to capture, direct, and use the generated power safely and efficiently. The third objective, which focuses on the safe and efficient use of generated power, primarily addresses interconnection and net metering, as referenced on pages two and three in the first section.

The following sections of the guide will explore the first two objectives: capturing and directing solar energy. This includes key components, variables, and options related to solar array performance, safety, and production.

Capturing the Sunlight

Approximately 95% of residential and small-scale commercial PV systems use modules that contain silicon. The most common silicon module has recently transitioned from monocrystalline (mono) to polycrystalline (poly). The longevity and performance characteristics of the two silicon types have narrowed to the point where features such as cost, warranties, and aesthetics are factors in choosing a specific product. Following is a general overview of crystalline modules. Consumers should examine module specification sheets in detail before deciding on which type they select.

Monocrystalline cells typically have the highest efficiency rates (15-23%), and they are the most space-efficient per produced watt. Solar panel efficiency defines how well a panel converts solar energy (sunlight) into electrical energy. It is expressed in a percentage—a panel rated at 20% efficiency converts 20% of the sunlight reaching the panel's surface into usable electricity.

Monocrystalline panels are manufactured using single-crystal, high purity silicon formed into an ingot and then cut into wafers (which results in minor silicon waste). The cells have a black hue and rounded edges. Research shows that mono modules outperform poly modules in higher temperatures and low-light conditions. The primary disadvantage of them is a higher cost per module.

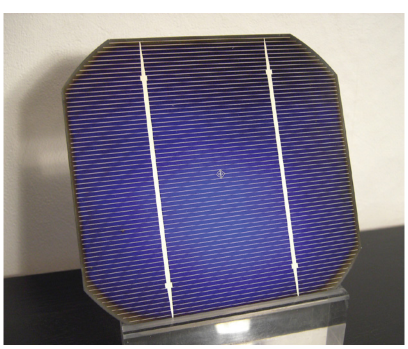
Polycrystalline cells are between 15-21% efficient, which translates into higher space requirements than a monocrystalline array of the same capacity. They are manufactured through pouring raw silicon into a square mold and then cutting the silicon into square wafers. This process is more straightforward and less costly than the method used to produce monocrystalline cells.

Polycrystalline cells have a blue tint, sometimes striated face, and square cells. The panels usually cost less than mono.

Solar dealers and contractors typically offer both types of crystalline modules. Depending on the specific installation, a contractor might recommend either type. From a performance perspective, the critical factors are the output and efficiency ratings. High-quality UL® listed panels include ratings based on real-world conditions. These ratings account for fluctuating ambient temperatures and panel aging.

Crystalline Module Performance in Montana's Environment

In Montana, where the PV industry has been viable for approximately 25 years, the most frequent system problems and warranty replacements involve faulty electronic components and issues such as wiring degradation within the array. PV module defects and breakage issues are rare.



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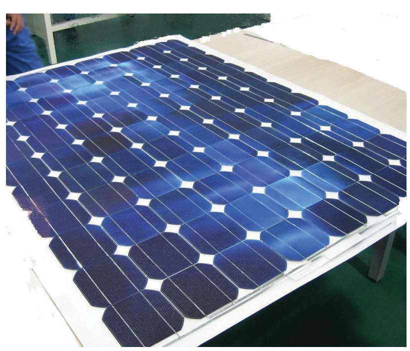


Module

Array

Montana solar contractors report that both mono and poly modules have demonstrated the ability to withstand the State's weather patterns, including "four seasons" extremes, as well as hail and heavy snow episodes. The most common damage to modules is from ice and snow buildup at the bottom of an array, where freeze/thaw cycles can cause module cracks and breakage.

Amorphous (Thin-Film) Modules

Thin-film (amorphous) modules make up between 3-5% of the solar PV market in the United States. Sales are hard to quantify because the thin-film label also identifies crystalline-based products with a compact or non-traditional design or composition.

Thin-film modules are manufactured through a process whereby the photovoltaic elements of the module are adhered to a substrate such as glass, instead of using the complex methods used to manufacture crystalline modules.

The efficiency ratings of thin-film technologies are between 6-11% (or roughly 30-50% of crystalline modules). This efficiency factor translates into the need for two to three times the roof space to produce a similar amount of power compared to a crystalline array.

A survey of thin-film modules also suggests shorter warranty periods and less favorable performance curves as the modules age. There are also amorphous designs that do not have traditional frames around the outside of the module, leading to extra costs when customizing the required support structure.

On the plus side, thin-film modules work well in niche designs and applications and perform well in higher temperatures and low light conditions. In Montana, thin-film modules exist on several small commercial jobs and show favorable performance results.

Thin-film is a technology that continues to evolve, and it has steady support from the solar industry. Some professionals consider new coatings that use proprietary photovoltaic compounds as the next breakthrough in the industry.

New Technologies

The solar PV industry continuously improves solar PV cell and module efficiencies. In the last five years, the average power capacity of a conventional 60 cell residential module has increased from approximately 250 to 450 watts.

At the forefront of the new, more powerful modules are Passivated Emitter and Rear Cell (PERC) modules and bi-facial designs, which capture direct sunlight and ambient and reflected light. They improve efficiency by minimizing cell shading and maximizing available light through proprietary design and construction.

Most Montana solar PV contractors are knowledgeable about contemporary solar products and system components. Guidance on the advantages of one module type and design over another for a particular installation is a service a contractor should provide to consumers.

Array Mounting

It's not acceptable to attach solar modules directly to a structure without proper racking, or worse, to lean them on the side of a building or place them on the ground. Appropriate mounting components and techniques are essential for production, structural integrity, and safety. Engineered module racking is designed to match the structure or pole it attaches to. Racking functions as the structural "backbone" of the array and is crucial to the system's electrical safety.

This section of the publication will address the three options for mounting (roof, ground, pole) and then overview array racks and variables.

Roof Mounts

Modules do not attach directly to the roof surface; instead, the contractor first attaches the array framework or "racking" to the structure. The modules are then attached to the racking.

The National Electrical Code (NEC) and State of Montana building codes govern the regulations for placing the racking and modules. These standards ensure the array's electrical and mechanical compliance and allow for proper airflow and temperature regulation. Modules require roof clearance to prevent high heat conditions that can cause decreased production and lead to electrical failures.

In most cases, the solar contractor mounts the racking and modules with a minor offset but at an equal angle with the roof. There are engineered systems that change the angle or orientation of the modules compared to the roof. These are reliable and can boost performance but add cost to the system.

When considering a roof mount, there are some essential factors that the consumer should analyze. They are:

1. What is the condition of the roof? The module lifespan will likely exceed that of most roof coverings. How will this impact future re-roofing? If the roof covering needs repair or replacement, should this be completed before the installation?
2. What is the composition of the roof covering? As a rule, wood shake or tile roofs are harder to mount racking on and seal. If the existing roof covering is suspect, consult with a roofing contractor familiar with solar PV mounts.
3. What are the tilt angle and orientation of the roof? Also, is there available space for the desired system size?
4. Are there existing obstructions impacting the roof that will result in shading? Inventory vent pipes, chimneys, adjacent trees and structures, and wires. Can obstacles be moved or, in the case of trees, be trimmed?
5. Can the structure support the load increases of the array? The building permit process includes roof load calculations.
6. Can the system be installed and maintained safely? Is there adequate access to and around the proposed array? Does the system allow for access around the modules in the event of an emergency? Building and fire codes require access to the array for emergencies.
7. Are there zoning requirements that could influence a rooftop installation? Evaluate adjacent properties and their impact on the system. Include trees that could affect PV production as they grow. Some jurisdictions have solar access statutes that address inter-neighborhood regulations.

Ground mounts

Ground mounted arrays have rows of single height modules, with secure foundations. They are popular in rural residences, agriculture, and dedicated commercial assemblies - or other locations with minimal shade and open space.

An advantage of ground mounted systems is their design, which allows optimal tilt and orientation. Also, they have adequate airflow and accessible components for installation and maintenance.

In urban areas, public accessibility and vandalism can be a problem. Other challenges are overgrown vegetation, drifting snow, and inter-row shading when there is more than one module row.

The National Electrical Code and State building codes have regulations for ground mounted solar. The solar contractor must comply with the Code standards, including the security of electrical wiring and components. Compliant ground mounted arrays safeguard humans, pets, and livestock.

Single pole Mounts

A single pole system regularly includes a large diameter (6”-8”) steel pole, engineered for mounting at a considerable depth in the ground, with concrete footings.

In a single pole system, the entire array attaches to the pole at the desired tilt angle and orientation. The pole can be quite tall, especially when adding ground and safety clearances required in the NEC.

Single pole systems take up less square footage than ground mounts. As a result, they work in both urban and rural settings. Some designs also include a tilt mechanism that allows for seasonal modifications based on the sun's altitude. The cost of the pole, excavation, and footings add to the overall cost of the system. Often a crane or lift is required to place the pole. Maintenance of single pole systems can be problematic in some cases. The height of the array can require a mechanical lift and the associated costs.

Like ground mounts, achieving optimum tilt and orientation and avoiding shading will optimize production. Some single pole systems incorporate unique designs that owners find pleasing.

When considering a ground or pole mount, there are some factors that the consumer should deliberate. They are:

1. What is the likelihood of vandalism or access by children, pets, and livestock?
2. What are the additional costs of the ground or pole mount footings, materials, and labor? How will the solar contractor assure cost-effective maintenance?
3. Will the ground or pole mount be installed in a location where there could be future modifications, such as outbuildings or roads?
4. Is it feasible to connect the PV electricity to existing electrical circuitry?
5. Are there zoning or subdivision requirements that affect the installation? Check restrictions relative to "edge of property"rules.
6. Can trimming of vegetation and environmental factors such as drifting snow and flooding be resolved?

Mounting Racks

Just as there are options for solar modules, the racking attached to the roof or pole is available in various designs, materials, and mounting choices.

The primary factor a consumer should examine with the solar contractor is the rack's compatibility with the modules. Essential elements include the roof or pole type, rack composition, NEC compliance, and aesthetics. The contractor should also offer a warranty for both materials and workmanship.

Structural Attachments

The racking attaches directly to the roof or pole. The attachment method and hardware vary based on the roof covering or substructure type. One of the failure points can be a roof leak due to faulty penetrations. Building inspectors in Montana are diligent regarding structural loading requirements for solar PV systems. In most cases, roof mounting issues are workable; however, consumers shouldn't expect a rubber stamp when permitting the array.

Fixed Versus Adjustable Racks

Fixed racks are permanently mounted to a structure or pole framework and are stationary. Most contractors use what is called a "top-down" rail system. This design contains four components:

1. Feet, called "standoffs" mounted to the roof's substructure (Customarily, the rafter system).
2. Aluminum rails fastened to the standoffs.
3. End clips that secure the modules to the racking.
4. Junction or mid-clips that join two modules to the mounting rail.

Top-down systems come in various designs and mount at the same pitch as the roof, with a gap between the racking/module and the roof's surface. The primary problem with top-down systems is the limited airflow underneath the array and limited access to the rear of the modules. Accessible quick-connect electrical links minimize access problems.

When solar modules cost more, contractors commonly employed components, including manually adjustable racks, to increase the production and ROI of arrays. Today, adjustable racks are used less – instead, contractors recommend fixed arrays containing more modules.

Adjustable racks are still available to consumers, and they will increase production and provide maintenance access and optimal airflow. The racking can be difficult to install – with smaller tolerances for rafter spacing and layout options. Seasonal adjustments require contractor labor costs, reducing the extra production benefits resulting from the adjusted array.

Array Standoffs Attached to the Roof's Substructure

Rails/Racking Attached to the Standoffs

Modules Attached to the Racking

Tracking Systems

Solar tracking systems, like manually adjustable racking, were popular when solar modules were high priced. These trackers, designed for pole and ground mounts, through passive or electrically powered technology, allow the array to track the sun's path. Manufacturers advertise a 10-25% increase in production over fixed systems.

There are two types of solar PV trackers. The most popular trackers for non-utility applications are single-axis units aligned at a static position north and south but track the sun from east to west (sunrise to sunset).

As the name suggests, dual-axis trackers have mechanisms to allow the solar modules to move in both an east-west and north-south pattern as the day progresses. Dual-axis trackers work well in northern locations where the sun is low in the winter sky and higher during the summer months.

Passive trackers rely on chemicals that move the tracker based on thermal reactions, but some consumers have experienced problems with adjustments and performance. Active trackers use motors, gears, and hydraulics, which need maintenance.

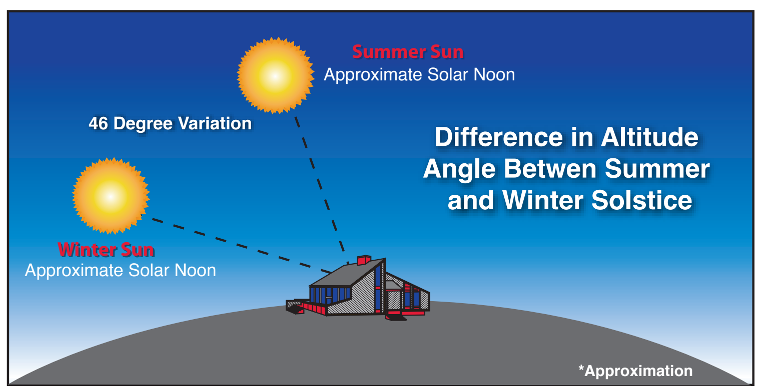
Residential tracker performance has improved, and several consumer models are available. In some applications, they remain popular, most notably in utility-scale or off-grid systems. Also, some consumers enjoy watching the array track the sun throughout the day. Consumers should be aware that not all contractors are familiar with tracking system installation and service. A performance and maintenance warranty is a critical request when purchasing trackers.

Capturing the Available Power - "Siting" the PV System

For the consumer, determining where to mount a PV array is as crucial as the system components. Without adequate sunlight, even the most efficient and expensive array will not perform up to expectations.

The main goal of the system mounting (commonly called siting) is to have the array positioned to capture the maximum amount of light energy throughout the day. When the sun's rays are perpendicular to the array, power production is best. Excluding obstructions, the two factors that impact the percentage of sunlight that hits the modules' front surface are orientation and angle (tilt).

The direction and angle of the PV array directly relate to the sun's position in the sky and rely upon the sun's azimuth and altitude.



Azimuth is the sun's location on a horizontal plane, east to west, as it moves throughout the day. Altitude is the height of the sun in the sky. Azimuth changes throughout the day, and as important, is seasonal, which accounts for the longest day of the year on June 21st (summer solstice) and the shortest day on December 21st (winter solstice).

Orientation (the direction the array points) corresponds to the azimuth. The optimum orientation is "solar south," which has an azimuth of 180 degrees, but this is not always possible. The good news is that an array mounted within 30 degrees of solar south still produces about 90% of an array mounted directly at solar south. On some installations, modules are purposely sited on southeast and southwest surfaces to complement a south-facing array.

The tilt or angle of the array depends on a location's specific latitude. Montana's average latitude is 47 degrees North, which roughly splits the State in half. The northern border is at 49 degrees North, and most of the State's southern border is at 45 degrees North.
In theory, the desired angle or tilt of the array for year-round production will match the latitude at the installation site. A steeper angle would favor winter production (because the sun is lower on the horizon), and a flatter angle would increase summer production.

Most residential roofs have between a 4/12 and 8/12 pitch, or equal to a tilt angle of between 18 and 35 degrees. As discussed earlier, when modules were costly, adjustable racking (roof) or trackers (ground or pole mounts) were popular, but now the standard practice is to use additional modules.

Finally, relative to the sun's azimuth and altitude, the term "solar window" is helpful to understand. This term defines the optimal hours for southerly facing array production. Adjusted for the four seasons, the hours from 9:00 am. - 3:00 pm. represent the ideal year-round time for solar production.

Contractor Solar Site Assessment

Shading impacts many residential sites, and evaluation by sight alone requires observation over an entire year. Fortunately, reputable solar contractors will provide the consumer with an accurate site analysis using equipment and software designed for PV installations.

There are several proprietary site analysis instruments that solar PV contractors use for site assessments. These devices can determine the impacts of shading and potential gains if obstacles are removed or minimized. They also provide projected monthly power output data and other relevant information.

Professionals recommend that consumers request a more thorough site assessment than a remote analysis, cursory walk-through, or general production estimate. A complete on-site review is suggested to evaluate specifics such as roof surface and structural integrity, disconnect locations, and the capacity and condition of the home's electrical service

Converting and Directing PV Produced Power

Photovoltaic cells produce direct current (DC). With a grid-interactive system, the conversion to alternating current (AC) occurs between the module or array's output circuit and structure's electrical service. An electronic device called an inverter performs this. There can be other electrical interactions within the system; for example, a system with energy storage that channels some of the DC electricity to the batteries.

Balance of System (BOS) Components

The industry term for the wiring and components supporting the PV array is the balance of system (BOS). Depending on the specific design, the BOS components can include; wiring, connectors, combiner boxes, disconnects, rapid shutdown devices, and the system inverter(s). If installing a system on NorthWestern Energy's distribution system, an external disconnect switch (EDS) is required for utility personnel safety.

An understanding of inverter types, functions, and applicability to siting variables is essential for the consumer. In the complete PV system, inverters are second only to modules in cost, and incorrect selection and installation of an inverter can lead to production and safety impacts.

What are Inverters?

America's electrical infrastructure relies on 60-Hertz (Hz) alternating current (AC) power. This hertz value includes the power delivered via the utility grid and the electrical parameters of appliances, lights, and other loads used by consumers.

Because solar cells produce DC power, conversion from DC to AC, called "inversion" in proper electrical terms, is required for grid-interactive systems.

In a grid-interactive system, the essential component in the PV system is the inverter(s). Inverter sizing must meet or exceed the peak output of the array in a string or central inverter system or the production of one or two individual modules in a micro-inverter design.
For use in a grid-interactive system, the inverter must be listed for grid-interactive use. Grid-interactive inverters have supplementary functions, including the integration of utility and solar electricity. NorthWestern Energy requires consumers to use UL® listed, IEEE compliant inverters to ensure the reliability of the electrical grid and safety of utility workers.

There are two distinct types of grid-interactive inverters used in the PV industry - string and micro-inverters. Both apply to residential and small commercial installations.

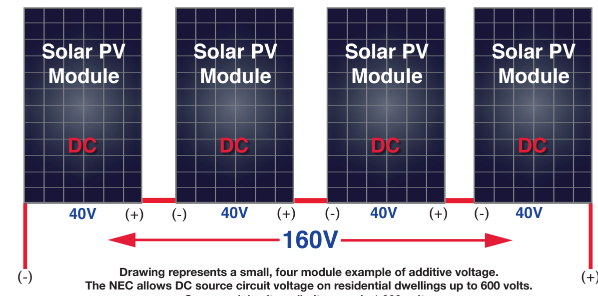
String Inverters

In small-scale applications, the most common inverter type used is a string inverter. Modules connect in a series configuration, and the DC power produced by the modules flows into the inverter at a single point. In a series wiring design, voltages are additive, resulting in up to the NEC threshold of 600 volts direct current (Vdc) voltage to the inverter (residential systems). After conversion, the output to the structure or grid is usually 120/240 volts alternating current (Vac.)

The advantages of string inverter systems are the cost and single component to operate and service. There are various inverter sizes to match the power rating between the array and inverter. Approximately 70% of Montana solar arrays incorporate string inverters.

In a string inverter configuration, the primary disadvantage is that the poorest performing module directly impacts overall system performance. Several factors can contribute to decreased system performance, including; a manufacturing defect in a single module or partial shading from nearby structures, trees, or snow on the array.

PV String Inverter System (Grid Interactive)
Additive Voltage (Series Wiring)



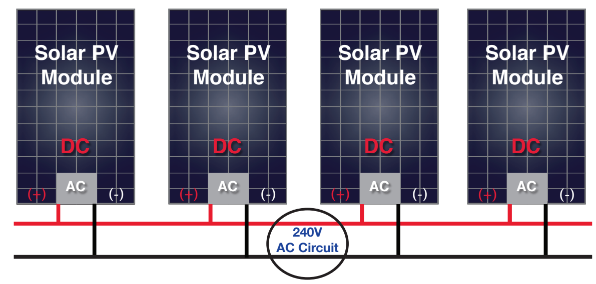
Drawing represents a small, four module example of additive voltage.
The NEC allows DC source circuit voltage on residential dwellings up to 600 volts.
Commercial voltage limit exceeds 1,000 volts.

Micro-inverters

Micro-inverters are distinct from string inverters. They perform the DC-AC conversion at or "attached" to the module and have a parallel wiring design. The voltage remains constant, but the amperage (current) increases as each module connects within the array. AC flows from the array to the PV electrical components and utility point of connection.

The primary benefit of micro-inverter systems is that poor performance in a single module (due to module failure or shading) does not impact the array's production to the same degree that occurs in a string inverter system.

PV Micro-Inverter System (Grid Interactive)
Additive Amperage (Parallel Wiring)



Drawing represents a small, four module example with micro-inverters.
With this type of grid-interactive system, the amperage from module to module is additive and the voltage remains constant.

Manufacturers suggest that using a micro-inverter can increase annual electricity production between 10-30%, depending on the site. Micro-inverters are popular with some home and business owners because the addition of modules later is possible without the need to buy additional, expensive equipment or up size a string inverter. The primary disadvantage with them is a higher initial cost, and in some cases, access for repairs and maintenance can be difficult.

AC Modules

Modules that have factory integrated micro-inverters are known as AC modules. These modules prevent the installer from performing two separate mechanical and electrical tasks when installing and wiring the module and micro-inverter. Manufacturers of AC modules suggest a 20-40% time-savings for the panel installation.

Several reputable module manufacturers now offer AC modules. They are sometimes advertised as a "plug and play" component; however, a licensed electrician must complete portions of the installation, including wiring the AC circuit and connecting to the consumer's electrical system.

Some manufacturers label AC modules, with integrated micro-inverters, as "smart modules." Simultaneously, other manufacturers who produce modules with built-in DC optimizers also use the same smart module classification for their products.

Consumers should consult the module specifications for a particular product. The term smart module is a marketing rather than a technical designation.

DC Power Optimizers

Unlike micro-inverters, which do not require a string inverter, DC power optimizers are paired with a string inverter but operate at the module level. When modules produce electricity, the optimizers isolate and condition the voltage at each module before directing the power to the string inverter.

Optimizers minimize string power loss due to shading or other problems. Without them, the connected modules can only produce electricity at the level of the lowest output module on the string.

Solar PV contractors favor using power optimizers when designing string inverter systems where not all modules are on the same roof plane or face the same direction. This use allows for increased productivity throughout the day as the sun tracks across the sky.

As a rule, power optimizers cost approximately 50-60% of micro-inverters. A primary disadvantage with power optimizers, compared to micro-inverters, is if the consumer wanted to increase the size of their array in the future, the inverter might require upgrading.

String Inverters (Positive Comparisons to Micro-Inverters)

1. String inverters cost less per total array capacity.
2. String inverters have been tested and improved. Common failure points have been fixed.
3. A string inverter mounts at ground level (usually next to the main electrical supply), supporting operation and maintenance.
4. String inverter systems typically have lower voltage loss due to the wire and component size.
5. There are various string inverter designs and features available to consumers, including system monitoring and feedback.

Micro-inverters (Positive Comparisons to String Inverters)

1. Failure of one micro-inverter only impacts the module it services. A string inverter failure affects the entire system. Likewise, shading or damage to a single module in a micro-inverter array has a minimal overall impact.
2. For non-conventional applications where modules are placed on surfaces with different orientations, micro-inverter modules are more productive and can be orientated individually, rather than collectively.
3. It's common to add future modules without the cost of purchasing a larger-sized, costly inverter.
4. Individual power point tracking assures the optimum performance of each panel. With a string inverter, this is a more difficult task and can add costs if done at the module level.
5. Micro-inverters shut the system down at module level in an emergency or utility disruption. String inverters need additional electrical safeguards to offer the same level of safety.

A Note on Wiring

Depending on whether the consumer decides on a string inverter or micro-inverter system, the array's wiring scheme varies. Compliant wiring methods are essential for safety purposes - PV systems have high voltages.

Grid-interactive string inverters connect in a series configuration. The positive wire from one module connects to the next negative lead until they combine at the inverter. DC voltages exist up to the NEC limit of 600 Vdc (at the inverter) on residential installations. The NEC allows up to 1,000 Vdc for roof mounted commercial systems.

Grid interactive micro-inverters or AC modules connect in a parallel configuration. The positive wire from each module connects to the next module's positive lead. Amperage increases with each module's connection, but the voltage remains constant.

Rapid System Shutdown (RSS)

Solar PV systems are power production units regulated by the National Electrical Code (NEC), and the State of Montana adopts the NEC and enforces the Code through both local and State compliance networks.

Beginning in the 2014 edition, the NEC placed requirements in the Code for the rapid shutdown of PV systems in the event of an emergency. Without a rapid system shutdown (RSS) mechanism in place, even if the utility electricity is disconnected, energized circuits from the PV array are possible.

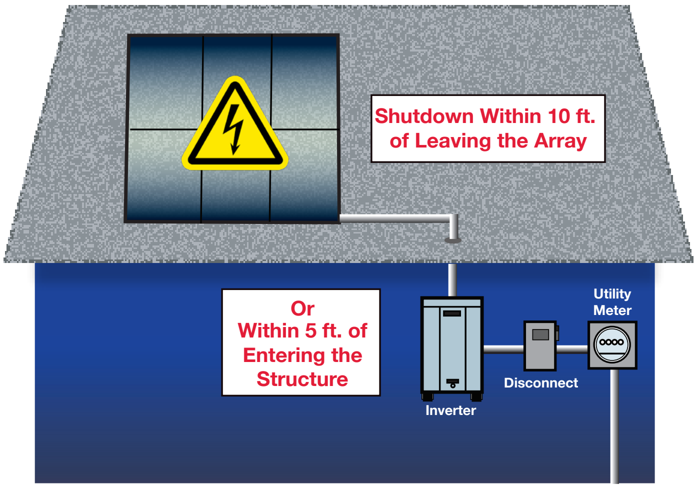
The NEC doesn't require RSS for ground or pole mount systems. Also, arrays with either micro-inverters or power optimizers meet the requirements for rapid shutdown without supplemental controls.

The NEC further modified RSS parameters in the 2017 NEC - with criteria for a more stringent shutdown. Although the 2017 shutdown parameters didn't change in the 2020 NEC, there were reductions made to the number of rapid shutdown switches allowed for RSS initiation (from six to one). Also, in the 2020 NEC, the Code introduced the concept of a UL-listed "PV Hazard Control System" – meaning all RSS components are tested and listed as a unit.

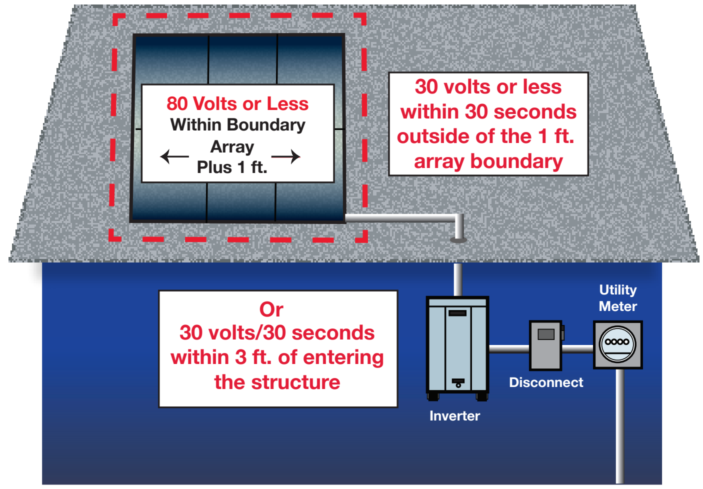
It's necessary to ensure the solar contractor includes RSS in the design and bid for a system. RSS components can add cost and should be included upfront in contractor bids.

The specifics of RSS are beyond this publication; however, the two illustrations below highlight the 2014 and 2017/2020 shutdown parameters.

Rapid System Shutdown (RSS)
2014 NEC Requirements



Rapid System Shutdown (RSS)
2017/2020 NEC Requirements



Important Information to Know

System Warranties

The PV system warranty is all-important, can be challenging to understand, and might contain fine print. The system's primary components (modules, inverter, etc.) have separate warranties, and the contractor's installation and maintenance warranty, if offered, is independent of the manufacturer.

At the contractor level, there usually is a several year warranty on parts and labor. In this case, even if the manufacturer's component failure is covered, the contractor will often repair or replace the component with no labor charge.

After the contractor's "parts and labor" contract expires, the manufacturer component warranty doesn't always include labor charges. A survey of manufacturer component warranties follows.

Modules Warranties

Most UL® listed modules have a warranty of between 20-25 years. The warranty is based on power output (customarily 80% output for the life of the warranty or pro-rated per year of the warranty).

Module warranties cover electrical performance and damage from normal environmental conditions but do not cover vandalism or misuse. Module failure is rare because there are no moving parts in the design; however, electrical circuitry problems can happen.

Consumers opting for micro-inverters or AC panels should research the details of the module warranty. Because some modules have integral micro-inverters, there can be coverage variables.

Inverter Warranties

Surveyed Montana solar contractors agree the point of failure in a grid-interactive PV system is often the inverter. Inverters have electronics and complex circuitry that can fail. A broken or defective inverter can be both a performance issue and a safety concern.

String (central) inverters are usually warrantied from 5-10 years, although manufacturers suggest that a well-installed inverter has a life expectancy of up to 20 years. Various manufacturers advertise micro-inverter warranties at 25 years.

Energy Storage System and Battery Warranties

Battery warranties vary between manufacturers and are often limited or pro-rated. Limited warranties are not due to inept manufacturers or contractors; instead, they are based on variables such as charge/discharge cycles (use patterns) and factors including compliance with manufacturer ESS installation protocol.

Reputable companies will provide some level of warranty protection for the initial years of battery life - principally to cover manufacturing defects.

Questions to Ask the Contractor Relative to Warranties (All Components)

1. Does the installation contract include a parts and labor warranty from the contractor separate from the manufacturer warranty?
2. In the case of a component failure, is the consumer "on their own" after the contractor's parts and labor warranty expires (but while still under manufacturer warranties)?
3. For manufacturer warranties, what is covered, and to what degree? Examples include; troubleshooting, removing, and replacing components and shipping costs.
4. What guarantee is available if the manufacturer discontinues the component while the warranty is in place?

Interconnection Safety - NWE's Required External Disconnect (EDS)

A grid-interactive PV system connected to NorthWestern Energy's grid requires a lockable, accessible external disconnect switch (EDS). The EDS must be within ten feet of the utility meter and marked as the utility disconnect.

The EDS's primary purpose is to prevent back-feeding to the utility grid when NorthWestern Energy personnel need to provide emergency services or perform maintenance to the distribution lines connected to a consumer's PV system. NorthWestern Energy service workers can manually activate and place a lock on the disconnect device. The EDS is supplemental to the preventative controls designed within the inverter and required NEC disconnects.

If the system design includes locating the EDS farther than ten feet away from the utility meter, prior permission from NorthWestern Energy is required. If the utility grants an alternative EDS placement, a weather-resistant placard at the meter, indicating the EDS location, is necessary.

Consumer Safety Considerations

Even smaller PV systems have the potential to cause serious injury to people or structures if installed improperly. The DC voltage "on the roof" to the inverter is often three-five times 120 Vac household voltage. Other components and connections, if not designed and installed correctly, can be hazardous.

Montana Statute requires a licensed electrician to perform the work on circuits that are 90 volts and above; thus, all grid-interactive systems require State licensed electricians. Some established, reputable solar contractors in Montana do not have an electrician on staff but sub-contract the electrical part of the installation to a licensed electrician.

When in operation, the consumer is liable for their PV system's safety and integrity - until then, the contractor is primarily responsible for the crew and public safety. Before hiring a solar contractor, the consumer should request proof of liability insurance, workmen's compensation insurance (for employees), and copies of structural and electrical permits. If in doubt, consumer protection groups suggest contacting insurance providers to ensure the contractor's proof of insurance is valid.

Definitions

- **Alternating Current (AC**) - The flow of electricity that constantly changes direction between positive and negative sides. Almost all power produced by electric utilities in the United States moves in current that changes direction at a rate of 60 times per second.
- **Ampere (Amp)** - The unit of measure that indicates how much electricity flows through a conductor. For example, a 1,200-watt, 120-volt hair dryer uses 10 amperes of electric current (amps = watts/volts).
- **Circuit** - One or more conductors through which electricity flows.
- **Direct Current (DC)**- The flow of electricity that flows continuously in one direction. Solar PV produced electricity is DC at the cell level.
- **Interconnection** - The linkage of electrical lines between two utilities, or between a utility and an end-user, enabling power to be moved in either direction.

- **Insolation** - The solar power density incident on a surface of stated area and orientation. It is commonly expressed as average irradiance in watts per square meter (W/m2) or kilowatt-hours per square meter per day (kWh/m2/day).
- **Inverter** - A device that converts direct current electricity to alternating current either for customer consumption or to supply power to an electricity grid.
- **Irradiance** - The direct, diffuse, and reflected solar radiation that strikes a surface. Usually expressed in kilowatts per square meter. Irradiance multiplied by time equals insolation.
- **Kilowatt (kW)** - 1,000 watts - A unit of measure of the amount of electricity needed to operate given equipment. For example, a one kW system provides enough power to illuminate 10 light bulbs at 100 watts each. (volts x amps = watts)
- **Kilowatt-hour (kWh)** - One kilowatt of electricity supplied or consumed for one hour. For example, a one kW system, if operating at full capacity for 5 hours, will produce 5 kWh of electricity.
- **Maximum Power Point (MPP)** - The point on the current-voltage (I-V) curve of a module, under illumination, where the product of current (amperage) and voltage is maximum.
- **National Electrical Code (NEC)** - Contains guidelines for all types of electrical installations. The 1984 and later editions of the NEC contain Article 690, “Solar Photovoltaic Systems” which should be followed when installing a PV system. The NEC is adopted by the State of Montana under the Department of Labor and Industry.
- **Peak Sun Hours** - The equivalent number of hours per day when solar irradiance averages 1,000 w/m2. For example, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance for six hours been 1,000 w/m2.
- **Solar Resource** - The amount of solar insolation a site receives, usually measured in kWh/m2/day, which is equivalent to the number of peak sun hours.
- **String** - A number of photovoltaic modules or panels interconnected electrically in series to produce the operating voltage required by the load.
- **Utility Grid** - The interconnection of electricity generation plants through the transmission and distribution lines to customers. The grid also refers to the interconnection of utilities through the electric transmission and distribution systems.
- **Utility Interactive Inverter** – An inverter that can function only when tied to the utility grid, and uses the prevailing line-voltage frequency on the utility line as a control parameter to ensure that the PV systems output is fully synchronized with the utility power
- **Volt (V)** - The amount of force required to drive a steady current of one ampere through a resistance of one ohm. Electrical systems in most homes and offices use 120 volts. (volts = watts/amps) (volts = amperes x resistance)
- **Watt (W**) - Electric measurement of power at a single point in time, as either capacity or demand. For example, light bulbs are classified by wattage.