RENEWABLE ENERGY

Selecting a solar electric system for a commercial building rooftop

FACT SHEET

BIOMASS

SOLAR

WIND

Contact Focus on Energy℠ to learn about renewable energy options for your home, business or organization. Full program details, applications for awards and eligibility requirements are available from the Renewable Energy Information Center. Call 800.762.7077 or visit focusonenergy.com.

CREDIT: CHRIS JURIK, GE HEALTH CARE

Photo 1: **The 135kW solar electric system mounted on the flat roof of the GE Health Care building in Waukesha, Wisconsin, is held in place by ballasted racks. No penetration of the roof membrane was needed.**

The rooftops of commercial buildings offer huge opportunities for generating solar power. Wal-Mart alone owns enough roof area to locate 2,000 megawatts of solar panels (or modules). Today, Wal-Mart, along with Kohl's, General Electric and Google, is installing solar electric modules on store rooftops in California. And Kohl's is installing a few systems in Wisconsin.

Rapidly increasing demand has stimulated development of economical solar electric (also known as PV, or photovoltaic) technologies. As a result, equipment costs have begun to decrease. Leading solar module manufacturers have promised to reduce system costs 50 percent by 2012. It is possible that Wisconsin solar power systems will cost less than conventional power within the next five to ten years.

SOLAR ORIENTATION FOR PEAK POWER PRODUCTION

Solar electric system production depends largely on two factors: the size of the system and the orientation of the solar modules. In Wisconsin, the ideal orientation for solar electric modules is due south and tilted about 25° to 45°. However, modules do not need to face due south in order to produce significant power (see Figure 1).
Electricity use reaches its peak in Wisconsin on hot summer days between 1 p.m. and 5 p.m. Locating modules to face about 40° west of due south with a tilt angle of about 35° maximizes power production during the utility's peak period. In this case, total annual production would be reduced by about 4 percent, but during the utility summer afternoon peak, production would increase by about 6 percent and utility peak coincidence is increased by about 12 percent.

Solar electric systems can also be rotated to better offset the building's peak consumption periods to reduce demand charges or its time-of-use time-of-day electric rate. As sites have differing power usage patterns and electric rate schedules, optimal array orientations are best developed on a case-by-case basis.

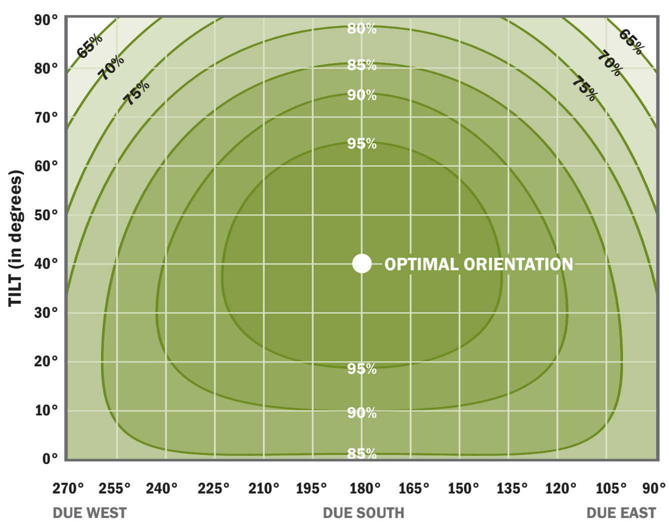
FLUSH-MOUNTED MODULES ON A SOUTH-FACING SLOPED ROOF

Flush mounting standard modules on a south-facing sloped roof is the most economical alternative based on electricity generated per dollar of system cost (see Photo 2). This is because rack costs are reduced and orientation is optimal. Attaching solar modules onto a standing-seam metal roof can further reduce mounting costs. However, as the roof slope falls below a three-in-twelve pitch (3:12) or 15°, production drops off and snow is more likely to accumulate.

COURTESY OF H&H SOLAR ELECTRIC

Photo 2: **The Aldo Leopold Center in Reedsburg, Wisconsin, expects to get 110 percent of its electricity from the 39.6kW solar electric system that is flush mounted on its sloping roof. Connected to the electric grid, the system will produce extra electricity in the summer which can then be drawn back from the grid during the darker winter months.**

FIGURE 1: **THE EFFECT OF DIFFERENT MODULE ORIENTATIONS ON SOLAR POWER PRODUCTION WHEN COMPARED TO AN OPTIMALLY SITED SYSTEM FOR MADISON, WI**



THE OPTIMAL ORIENTATION IS A 40° TILT FACING DUE SOUTH

The window for generating significant solar power is quite large. Fixed arrays of modules facing within 45° of due south and tilting within 25° of the site's optimal tilt angle produce 90 percent of the output of an optimally oriented system. As a rule of thumb for Wisconsin, the optimal tilt angle is the site's latitude minus 6°. The figure applies to systems located at roughly the same latitude across Wisconsin. For sites in far northern Wisconsin, the bulls-eye will shift roughly 4° to the north.

Source: based on the work of Larry Krom, "Photovoltaics for Wisconsin Commercial Buildings," who used PVFORM 3.3 simulations using TMY-2 data.

RACK-MOUNTED MODULES ON A FLAT ROOF

The most common method of mounting solar electric arrays on a flat rooftop in Wisconsin is the use of ballasted roof racks (see Photo 3). The module racks are attached to large, shallow pans that are filled with roof ballast or concrete blocks to hold them in place by weight. Ballasted racks require no roof penetrations and less construction coordination than roof-integrated racks. The racks typically orient the modules to face due south with a tilt angle of 20° to 30°.

Parallel rows of rack mounted modules must be spaced to avoid shading the next row. For example, to limit shading to periods when the sun is less than 10° above the horizon, rows of racks should be spaced apart by 1.9 or 2.7 times the width of the rack for modules tilting at 20° and 30°, respectively. Even properly sited parallel rows of racks will cause self shading that reduces power generation by about two percent during early morning and late afternoon hours.

Ballasted rack-mounted systems typically cost 10 percent to 20 percent more than flush-mounted systems due to additional rack, assembly and labor costs.

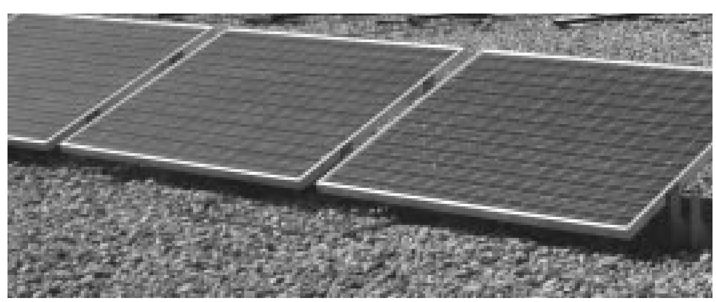


PHOTO: NIELS WOLTER, FOCUS ON ENERGY

Photo 3: **Roofing ballast fills trays to which these solar electric panels are attached, anchoring the installation. The ballasted trays blend in with the surrounding roofing.**

COURTESY OF SIKA SARNAFIL

Photo 4: **Thin film solar electric modules installed directly to the surface of this roof provide 325 kilowatts of electricity for the Coca Cola bottling plant in Los Angeles, California.**

FLUSH MOUNTING SYSTEMS ON A HORIZONTAL ROOF

Solar arrays can be installed flat on a horizontal roof. A flush-mounted system should be considered if the roof cannot support the weight of a rack mounted solar electric array plus the additional wind and snow loading.

Solar arrays for horizontal roofs come in two kinds: those where the thin film solar modules are integrated into EPDM (ethylene-diene-propylene-monomer) or TPO (thermoplastic polyolefin) roofing membranes, and those where crystalline modules, sometimes integrated into "tiles," sit on top of existing roofing.

Thin Film Modules

The EPDM and TPO integrated thin film systems can be installed as new or replacement roofing (see Photo 4). These systems typically use a thin film solar module that has half the conversion efficiency of the standard crystalline module and thus requires twice the module area per system kilowatt (see Figure 3). Module suppliers can provide information about how failed modules are replaced.

Crystalline Modules

Solar tile arrays can be placed on an existing roofing substrate. Some brands of tiles provide insulation, weatherproofing and a reflective surface to further reduce building heating and cooling costs. Tiles are typically made using a crystalline solar electric material with a high-strength glass covering, but they are not designed to be walked upon (see Photo 5).

COMPARING BALLASTED-RACK AND FLUSH-MOUNTED SYSTEMS ON HORIZONTAL ROOFS

Power Production

Due to their orientation and potential for accumulating snow, solar modules mounted horizontally will produce about 20 percent to 30 percent less power than south-facing modules with a 30° tilt. However, their installed cost will likely be significantly less than a rack mounted system.

FIGURE 2: **EFFECT ON MODULE TILT ANGLE AND SNOW COVER ON PRODUCTION**

MODULE SLOPE DEGREES	MODULE SLOPE RISE/RUN	PERCENT MAXIMUM PRODUCTION WITHOUT SNOW COVER	ESTIMATED PRODUCTION LOST DUE TO SNOW COVER*	PERCENT MAXIMUM PRODUCTION WITH SNOW COVER
45.0°	12/12	99%	1%	98%
40.0°	10/12	99%	1%	98%
33.5°	8/12	100%	2%	98%
26.5°	6/12	99%	2%	97%
20.0°		97%	3%	94%
14.0°	3/12	94%	4%	90%
0.0°	0/12	85%	12%	75%

*Snow-cover estimates are for areas outside the Lake Superior snow belt.

Source: Created with data from PV Watts Milwaukee, WI

Snow accumulation on modules is a reality in Wisconsin. This table summarizes electricity production, with variables of slope and snow cover, from a non-shaded, south-facing system located in Milwaukee.

FIGURE 3: **ESTIMATED ROOF AREA AND LOAD REQUIREMENTS FOR SOLAR ELECTRIC INSTALLATIONS**

TYPE	SQ. FT./kW OF MODULE	LOAD: LBS./SQ. FT.
Flush-mounted on south-facing roof, crystalline modules	100	Less than 4
Rack-mounted on a flat roof, crystalline modules	250	About 15
Flush-mounted on a flat roof, thin film modules	200	About 1
Flush-mounted on a flat roof crystalline modules	100	Less than 4

Different methods of mounting the solar electric modules result in different roof load and area requirements. Loading estimates include the weight of the solar electric modules and racks, as well as the effects of wind, snow and ice. Exact roof-area requirements depend on many factors, including module efficiency, rooftop mechanical equipment and module size.

COURTESY OF DOE/NREL, CREDIT: SPIRE SOLAR CHICAGO

Photo 5: **This 130kW solar electric tile system is located atop the Art Institute of Chicago.**

Focus on Energy recommends calculating the cost per kilowatt hour (kWh) generated for different types of racks. The flush-mounted option should be considered if it costs 20 percent less than the ballasted rack-mounted option. For example, a rack-mounted system that costs $9 per watt and a flush-mounted system that costs $7.20 per watt will have a similar costs per kilowatt hour generated. However, the flush-mounted system may also reduce roofing expenses, which would make it the more economical choice.

Roof Loading

Flush-mounted flat-roof systems weigh less and experience less wind and snow loading than ballasted-rack systems. For these reasons, flush-mounted systems are suited to a wider variety of flat-roofed buildings.

Visibility

The presence of solar modules indicates a commitment to cutting-edge renewable energy technology. If solar electric systems are easily visible from the ground or from neighboring buildings, they offer great opportunities for community education and public relations (see Photo 6). Flush-mounted horizontal roof arrays are rarely visible, and rack-mounted systems are generally only visible when located near the southern edge of the roof. For businesses wishing to fully display their systems, other solar module mounting options may be preferable, such as solar awnings, pole-mounted solar flags, or solar systems integrated into curtain walls or window glazing.

CREDIT: NIELS WOLTER, FOCUS ON ENERGY

Photo 6: **The solar electric system installed on the roof of the Wisconsin Energy Conservation Corporation building in Madison, Wisconsin, is close enough to the edge to be viewed easily from the parking lot and entrance.**

MORE INFORMATION

Focus on Energy

Learn more about solar technologies and other renewable energy choices and available program financial incentives.
focusonenergy.com/renewableenergy

Focus on Energy offers a variety of information, fact sheets and case studies to help you learn more about solar electric and other renewable energy systems. Here are a few facts sheets to start with:

- Grid-Connected Solar Electric Systems
- Focus on Energy Guide to Solar Electric Systems
- The Benefits and Costs of Large Commercial Solar Energy Systems
- Commercial Building Rooftops Ready for Solar Electric Systems
- Solar Electricity in Architecture
- Flying a Solar Flag: Pole-Mounted Renewable Electricity

focusonenergy.com/reliterature