Solar Ready Building Design Guidelines

Solar Ready Building Design Guidelines for the Twin Cities, Minnesota

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Author:
Lunning Wende Associates, Inc.
275 4th Street East, Suite 620, Saint Paul, Minnesota 55101-1684
651-221-0915 • www.lunningwende.com

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This page should reference three documents

- Solar Ready Buildings Planning Guide: by NREL
- Solar Ready Building Guideline Specification Minneapolis / Saint Paul: by Lunning Wende Associates, Inc.
- Outline Building Specification, “Solar Ready Construction Requirements”: by Lunning Wende Associates, Inc.

Is there a notice similar to the NREL document?

Are there printed copies available, and where?

Where will electronic copies be available?

- Local Solar Cities site
- We would like to have these available on the Lunning Wende website
- At the state building code website
- Other

Table of Contents

Overview and Introduction

What is a solar ready building? A building that is “designed and constructed to enable installation of solar photovoltaic and heating systems at some time after the building is completed.” These guidelines provide a cost effective way to plan for solar installations before a building is built in order to make certain modifications that will facilitate the installations in the future.

These documents present solar ready building guidelines that are tailored to the Twin Cities region specifically and the Midwest/Minnesota in general. They are a regional supplement to the “Solar Ready Buildings Planning Guide”, Technical Report NREL/TP-7A2-46078 dated December 2009, developed by The National Renewable Energy Laboratory based in Golden, Colorado. These guidelines encompass two documents:

“Solar Ready Design Guidelines for the Twin Cities, Minnesota”
These guidelines include recommendations related to solar system siting, roof orientation, structural load profiles, visual appearance, co-location issues with HVAC equipment, type of roof, location on roof, conduit locations and racking alternates. This is to be used during the planning and design phases of the project.

“Solar Ready Construction Specifications”
This is a model specification for solar ready construction and is to be included in the Project Specification document. This is an editable “prompt option” document in Word format.

The Design Guidelines and Construction Specifications are companion documents to be used together. Starting with the Design Guidelines in the initial stages of project planning and the finalization of building design, the Owner and Building Team make decisions informing the construction process. The Construction Specifications, along with the Drawings and other specification sections, document these decisions so that Solar Ready systems can be easily incorporated during the construction process.

The design guideline /specifications addresses two specific building types:
Urban-sized new single family and duplex construction with pitched roofs, and;
Flat-roof structures one to four stories that could be multi-family housing, commercial/office or mixed-use buildings. Taken together, these two building types comprise the vast majority of new construction in the Twin Cities region.

The audience for these documents includes:
Public Agencies; State (i.e. Minnesota Housing Finance Agency), County and City Municipalities
Neighborhood Organizations, District Councils, and Community Development Corporations
Non-profit and for profit development community
Owners, Architects, Builders and Contractors

These guidelines and specifications are funded by U.S. DOE’s Solar America Cities program.

About These Guidelines

These guidelines address specific site planning, building form, space planning, roofing, and mechanical and electrical issues to be considered in the design of solar ready buildings.

The guidelines are intended as a checklist of the “solar ready” decision-making process from site selection to the beginning of construction. Building owners, developers, and builders review a clear process outlining decision-making, timing of decisions, and responsibilities for each issue.

The guidelines are to be used as a starting point to incorporate solar ready construction into the building planning process. Guideline users are referred to the National Renewable Energy Laboratory’s Solar Ready Building Planning Guide (NREL/TP-7A2-46078) and Solar Thermal & Photovoltaic Systems (NREL/TP-550-41085) for a thorough explanation of these issues.

Although these guidelines focus primarily on new construction, many of the issues are similar for renovating existing buildings.

About the specifications:

The Solar Ready Construction Requirements establish responsibilities and procedures for implementing these requirements during the construction phase of the building process.

The specifications are intended to be modified for specific projects and can, therefore, be used for new construction and renovations.

Climate, Location, and Sunlight

Benefiting from solar energy requires maximizing available sunlight

To accomplish this, one needs to start with an evaluation of the amount of sunlight that is available at the geographic location under consideration.

While, even on cloudy days, some solar energy is available; more clear days means more solar energy

Although the Twin Cities of Minnesota are renowned for their climatological extremes, the percentage of available sunshine is relatively consistent throughout the year. Annually, the sky is clear to partly cloudy 58% of daylight hours. Only November and December are cloudy more than 50% of the time. Daylight hours are clear to partly cloudy more than 60% from May to September.[1]

A location's position relative to the Earth's equator has important consequences for the amount of solar energy that is available seasonally

The Twin Cities are situated at Latitude 44º 57' / Longitude 93º 16' and Elevation 837 feet above Sea Level.

At noon, the incident angle of the sun for a horizontal surface is about 21.5º on December 21 and about 68.5º on June 21. On March 21 and September 21, the sun angle is about 45.5º.

From early-November through late-January, the sun angle at the Twin Cities' latitude is very low, the sun is above the horizon less than 9 hours per day, and more than half of the days are overcast. Therefore, the contribution of solar energy during the late fall/early winter months is minimal. For the remainder of the year— as the sun angle increases to its maximum of 70º, ample daylight is available, and 63% of days are clear to partly cloudy— solar energy is ample.[2]

The amount of solar energy, or "insolation," is measured in British thermal units (btu) per day per square foot of surface area (btu/day/sq.ft.). Using this measurement, calculations have been made for insolation at many geographic locations so that it is possible to estimate the amount of solar energy available at a given location and time of year.

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1 Minnesota Climatology Working Group, State Climatology Office – DNR Waters & University of Minnesota. 30 years of data, from 1971-2000.

Website: http://climate.umn.edu/doc/twin_cities/twin_cities.htm

2 Architectural Graphic Standards, 10th ed., John Ray Hoke, Jr., Ed., 2000. John Wiley & Sons, Inc., New York.

The Twin Cities have the following average insolation values:

In January, 464 btu/day/sq.ft. are available on horizontal surfaces and 768 btu/day/sq.ft. are available on vertical surfaces.
In July, 1,970 btu/day/sq.ft. are available on horizontal surfaces and 1,071 btu/day/sq.ft. are available on vertical surfaces.
The annual daily average is 1,172 btu/day/sq.ft.for horizontal surfaces and 996 btu/day/sq.ft for vertical surfaces.

While the Twin Cities has significantly more solar energy available during the summer than during the winter, this locale's annual average daily insolation compares favorably with that of other locations. The combined daily annual average insolation for horizontal and vertical surfaces at selected American cities is:

Denver	2,904 btu/day/sq.ft.
Los Angeles	2,753 btu/day/sq.ft.
Miami	2,415 btu/day/sq.ft.
Minneapolis/Saint Paul	2,168 btu/day/sq.ft.
Nashville	2,163 btu/day/sq.ft.
Washington	2,122 btu/day/sq.ft.
New York City	1,950 btu/day/sq.ft.
Seattle	1,913 btu/day/sq.ft.[3]

In conclusion, a Twin Cities building incorporating solar energy systems would experience:

Beneficial contributions from solar energy
Greater contributions on horizontal surfaces in the summer and on vertical surfaces in the winter
Significantly more benefit in the spring through the fall seasons than during the winter season

3 J.D. Balcomb et al., Passive Solar Design Handbook, Vol. 3, 1983. American Solar Energy Society, Inc., Boulder.

Solar Model

Budget Allowance for Solar Ready Construction

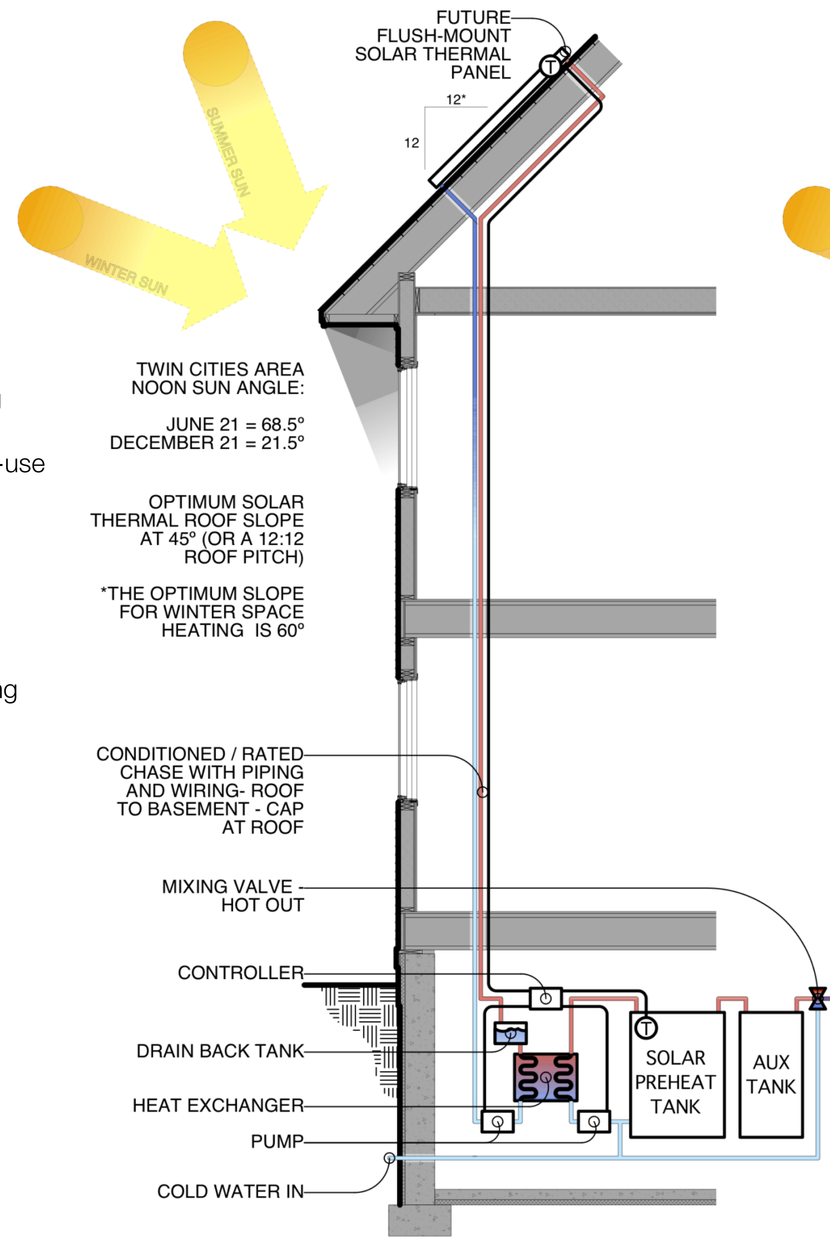
$1,000 for a two-story residential building

$5,000 to $7,500 for a three-story mixed-use building

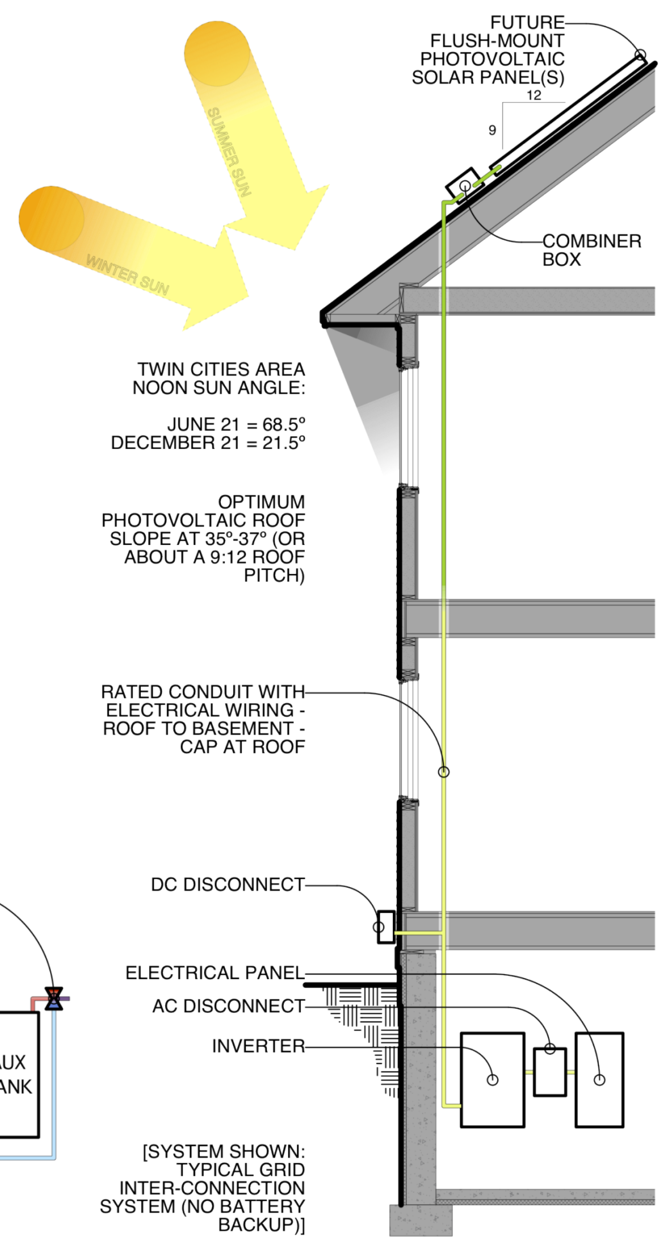
Estimated Cost for Retro-fitting Existing Structures to Incorporate Solar Ready Requirements

$5,000± for a two-story residential building

$20-30,000 for a three story mixed-use building



Example Solar Thermal Setup



Example Photovoltaic Setup

Site Planning

To define the site requirements for Photovoltaic and/or Solar Thermal System, the following documentation will be needed:

Site Survey showing topography and site features for the property and surroundings.
Documentation of regulatory requirements.

City Plat and Ordinance Variations

Starting Point: Decades-old decisions by cities and their surveyors have significant impacts on future solar access.

Rules of Thumb: Select a site with good potential for solar access.
Update community plans to minimize shading of solar arrays.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
In evaluating the potential for Solar Ready Construction, consider the size and orientation of the prospective building sites and the impacts of existing buildings and vegetation (both on-site and on adjacent sites) on solar access.	Same.	Determine if sufficient solar access is available prior to purchasing the building site.	Before purchasing the building site.	Owner with assistance of Architect or Builder and/or Solar Consultant.

Planning for Solar Access

Starting Point: Solar access depends on workable relationships between neighbors.

Rules of Thumb: Plan for a lengthy decision-making process if agreements between property owners are needed.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
In developed or developing neighborhoods, achieving and maintaining solar access may require agreements or easements with neighboring property owners regarding heights of future buildings and landscaping. Access to sunlight is not a protected property right; forethought and proactive steps are needed to ensure long-term viability of a solar resource.	Same.	Work neighbors and other interested parties to find mutually beneficial solutions. Minnesota statutes enable local jurisdictions to address solar access through the use of solar easements. Check with local officials on whether a solar easement can be acquired from adjacent property owners and filed with the city.	In some cases, prior to purchasing the building site and early in the Building Planning Process.	Owner with assistance of Architect or Builder and Attorney.

City Regulatory Issues

Starting Point: Obtain copies of relevant regulations; read them.
Some neighborhoods have design and/or historic district guidelines; all neighborhoods care about the appearance of buildings.

Rule of Thumb: Avoid surprises: review plans with city officials early and often; prepare memos of the meetings.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
A solar-ready building needs to anticipate the eventual installation of a solar system. The addition of solar generation to a building may require conditional use permits or design review with city agencies or city commissions. Some cities will limit the installation of solar systems on the front of the building. A solar ready building will, if possible, minimize or eliminate the need for additional permits or review through initial design. For examples of how to apply solar zoning best practices, review "Model Sustainable Development Ordinances" - Minnesota Pollution Control Agency, 2008. Minneapolis has accepted zoning standards for solar installation and other Minnesota municipalities are considering solar zoning standards. Review development association covenants for restrictions that may need to be addressed. While the solar array may not be part of the initial phase of construction, inform interested parties of this possibility and illustrate with suitable graphics.	Solar thermal systems have some design differences, primarily related to the optimal pitch of such systems in Minnesota (see roof planning), that could affect aesthetic considerations differently than PV systems.	Maintain a relationship with the city agencies with jurisdiction. Understand the regulatory requirements for putting a solar system on the building and address these in the design and construction of the solar-ready building so as to minimize the regulatory process at the time of solar system installation. Include city agencies' decision-making process in the project schedule. Communicate with neighboring property owners and community groups about the building plans and the potential for Solar Ready Construction.	Throughout the Building Planning Process.	Owner with assistance of Architect or Builder.

Building Form Planning

To define the building form requirements for Photovoltaic and/or Solar Thermal System, the following documentation will be needed:

Dimensioned Site Plan with roof plan and location of solar array; show adjacent properties, buildings and vegetation.

Building Elevations

Building Section through solar array, show relationship to adjacent properties.

Three-dimensional representations may be useful.

Site & Plan Organization

Starting Point: Think of the area for the solar array as an essential space in the building's program.

Rules of Thumb: In general, 100-150 square feet of roof area is needed for 0.8-1.0kW of solar modules depending on racking technology. A moderate-sized single-family residential sized solar thermal system has approximately 65 square feet of solar collector area and may need 100 square feet of roof area.

A contiguous rectangle of the required size works best.

Like a kitchen, the solar array has a size and function to be included early in the building's design process.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Site the building and arrange the building plan with solar access as a design criteria so that the location of the solar array is an integral element of the building design, not an afterthought	Same.	Determine the size of the solar array, optimize its location on the site, and evaluate building plan options with this in mind to minimize the length of the electrical feed.	An initial step in the Building Planning Process.	Architect or Builder with input from Solar Consultant.
The location of the solar array on the roof has consequences for the location of and distance to the inverter, the electrical meter, and for the routing of the solar electric feed.	The location of the solar array on the roof has consequences for the location of and distance to the storage tanks and for the routing of the pipes from the array to the tanks.	Develop the early building plan and proximity diagrams with this relationship in mind.		

Building Massing

Starting Point: Individual actions on private property affect the common good of the neighborhood.

Rule of Thumb: Change happens… and trees grow; it's best to plan for that eventuality.
Strategically place trees and select tree species to shade south and west windows without shading the solar array.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Plan the building form— building height, roof projections, etc.— so that the roof area reserved for the solar array can receive a maximum amount to sun exposure. The solar array needs to be located so that neighboring building and maturing trees do not cast shadows on this area. Mass the building to anticipate the solar access potential for neighboring properties by minimizing the shades cast by the proposed building and landscape.	Same.	A solar system is a 30 – 40 year investment. Consider potential alterations on properties between the proposed solar array and the sun, including new buildings as allowed under zoning for the area and the growth of trees. Investigate developing a solar access easement with adjacent property owners. Examine whether zoning permits take into consideration solar access – some cities do give solar access weight when reviewing conditional use or variance applications.	An initial step in the Building Planning Process.	Architect or Builder and Attorney.

Orientation

Starting Point: What will the neighbors think?

Rule of Thumb: Keep in mind solar is just one aspect of a building's design.
South orientation is necessary in almost all cases, but solar tilt is somewhat forgiving.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Orient the building form so that the solar array can be installed to receive the maximum exposure to the sun and to integrate the array unobtrusively with other building elements. PV systems can be integrated easily into a variety of building forms with minimal effort, but conscious decisions about orientation and tilt should be considered in the design process.	Thermal systems frequently need a steeper pitch than PV systems in Minnesota to optimize the solar resource. For some building types, integration with building form can be somewhat more difficult.	By considering the orientation of the array early in the planning process, it can be integrated into the building form.	An initial step in the Building Planning Process.	Architect or Builder.

Roof Form

Starting Point: Solar plays an important functional role and roof form is aesthetically important to the overall building expression.

Rule of Thumb: Solar array installation is simpler when parallel with the roof plane.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Optimize the performance of the solar array while integrating it with the roof form (See Roof Planning). Flat roofs are relatively straightforward, mainly requiring adequate distance between the space for the array and the roof edge. Pitched roofs pose more challenges for aesthetic considerations, but can be addressed with fairly minimal changes at most.	Same for flat roofs. On pitched roofs, integrating solar thermal systems with roof form to address aesthetic issues is challenging for pitched roofs less than 35-40 degrees.	Consider the appearance and view of the solar array.	An initial step in the Building Planning Process.	Architect or Builder.

Space Planning

To define the space planning requirements for Photovoltaic and/or Solar Thermal System, the following documentation will be needed:

Dimensioned Floor Plans of all levels.

Space for Inverters & Disconnects

Rules of Thumb: Organizing the system's equipment so that wiring runs in straight vertical and horizontal lines

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Provide wall space approximately 3' by 3' for the inverter and an AC disconnect as close as possible to the solar array and next to the main service panel. A clear floor area 3' wide is required in front of the equipment. Some systems also include an outside DC disconnect and combiner box adjacent to the inverter. Additional wall space maybe required for these.	Not applicable.	An inverter generates heat, so it is best to locate it in a cool, well-ventilated space. In Minnesota, inverters are generally located in basements in a location having a direct vertical connection to the solar array.	During the Building Planning Process.	Architect or Builder with input from a Solar Consultant.

Distance from Solar Array to Inverter

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Locate the inverter and main service panel directly below the roof location for the solar array.	Not applicable.	Locating the inverter directly below the solar array makes installation easier and reduces costs.	During the Building Planning Process.	Architect or Builder with input from a Solar Consultant.

Space for Heated Water Storage Tank

Rule of Thumb: For every foot of pipe distance, a solar thermal system looses 17 BTUs.
For freeze protection keep pipe runs sloping downward and shorter than 20 feet, wherever possible.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Not applicable.	Determine the maximum size of the heated water tank based on the system requirements, establish its location, and provide sufficient floor space to accommodate it. For a single family residential installation, plan for storage tanks with a capacity of 80-120 gallons.	Develop a schematic plan for the solar thermal systems, so that all of the components can be accommodated.	Early in the Building Planning Process so that sufficient space can be coordinated with other planning decisions.	Architect or Builder with input from a Solar Consultant.

Space for Preheat Tank, Pumps, Controller, Heat Exchanger, Drain-Back Tank and Additional Plumbing

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Not applicable.	Determine the size and location for the required components and verify that sufficient space is designated for their future installation.	Develop a schematic plan for the solar thermal systems, so that all of the components can be accommodated.	Early in the Building Planning Process so that sufficient space can be coordinated with other planning decisions.	Architect or Builder with input from a Solar Consultant.

Chase from Solar Array to Mechanical Space for Piping

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Not applicable.	Provide a vertical conditioned, fire-rated chase from the roof to the location for the tanks. The supply and return water piping is to be located in this chase, in addition to any control wiring.	Locate the continuous shaft in the building floor plans to minimize the distance between the solar array and the storage tanks.	Early in the Building Planning Process so that the chase can be integrated into the floor plans and related to the future solar array location.	Architect or Builder.

Roof Planning

To define the roof requirements for Photovoltaic and/or Solar Thermal System, the following documentation will be needed:

Dimensioned Roof Plan - showing size, slope, parapets, obstructions and other features.

Location and size of the area with solar access on the Roof Plan.

Structural design for the roof that addresses the loads imposed by the future solar array.

Description of roofing materials and system.

Area

Starting Point: How large does the roof area need to be to support a solar array of the "desired" capacity?

Rules of Thumb: In general, residential PV systems need between 200 and 400 square feet of roof area, and thermal systems need approximately 100 square feet. Commercial or multi-family systems can be much larger if solar access is adequate.

A contiguous area is best.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Designate the location of the roof that has unobstructed solar access and maintain this area free of obstructions or building and mechanical systems that would shade the area. The size of the solar system will not be known until the system is installed at some future date. Maximizing the roof space that will be available for the solar collector will provide for flexibility and ease of installation.	Same for most issues. For single-family or duplex residential buildings less roof space is needed for solar thermal than for PV systems, and minor shading will have only a minor impact on system performance. Commercial thermal systems may, however, require as much space as a PV system if the thermal load in the building is large.	Inform all trades of the location of the solar array and the intention for this area. Provide specifications for leaving the area open and unshaded.	Beginning of the Construction Process.	Architect or Builder with assistance of Contractor.

Materials

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
For flat roofs, membrane roofing is preferred. Built up roofing systems can be accommodated, however these roofing systems must cure for 2-3 years prior to installing the solar array. Ballasted roofing systems are not acceptable. For sloped roofs, standing seam metal roofing is preferred and asphalt roofing can easily be accommodated. Tile roofs are not acceptable.	Same.	Determine roofing materials by balancing function, aesthetics, and costs. A solar system has a longer life than many types of roofing, and must be removed and reinstalled when the roof must be replaced.	Early in the Design Process.	Architect or Builder.

Roof Pitch

Starting Point: What is the best angle for a fixed position solar array in Minnesota?

Rules of Thumb: The ideal pitch for a PV system in Minnesota is between 35-37°. A solar thermal system typically needs a pitch of between 40-50 degrees to maximize the usable solar system output.

On flat roofs a rack system will always be used - the solar installer will balance between the pitch of the panel and the distance between rows to best utilize available roof area.

A shallower pitch favors the summer sun, when the more solar exposure is best. For a PV system pitch less than 30° but greater than 15 degrees, there is only a minimal loss of annual solar power generation. Snow shedding will likely be a bigger issue with shallower sloped roofs. On pitched roofs, plan for solar panels to be installed close to the roof and at the same angle as roof, when at all practical.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Plan the building so that a suitable, contiguous flat or properly sloped roof plane facing south or southwest is available. On pitched roofs, always plan for a system that will be flush-mounted. While a 35-37° pitch is ideal, roofs between 25-45° will absorb at least 95% of available solar energy.	On pitched roofs, flush mounting thermal systems ideally requires a steeper pitched roof (more than 40 degrees). A pitch lower than 40 degrees starts to result in summer capture of heat that exceeds the capacity of the storage tank, except for commercial buildings with very large water heating loads.	Determining the pitch of the roof requires a balancing of functional and aesthetic elements. A 12:12 pitch provides the greatest number of options for easy installation of a solar system. Planning for a thermal system on a pitched roof that is not going to be flush mounted requires much more attention to roof structure so as to accommodate wind loads and raises many more aesthetic issues.	Early in the Design Process.	Architect or Builder with assistance of Contractor.

Obstructions

Starting Point: Can vents, chimneys, gables, etc. be in the area of the solar array?

Rules of Thumb: Ideally, no vents are in this area, since they can conflict with solar modules and impede the performance of both.
Shading significantly reduces performance of PV systems. Even small shading elements, such as the shade of a power or telephone line, an antenna, or a utility pole can significantly reduce output from the system.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Obstructions on the roof that can interfere with the placement of the solar array—such as, plumbing and exhaust vents—or that can cast shadows—such as, chimneys, rooftop equipment, or gables—should be kept clear of the area. Obstructions should ideally be located on the north side of a pitched roof. Potential roof shading elements should be located twice as far away from the solar array area as these elements are tall. Shading 10% (or even less) of a PV panel will reduce output by much more than 10%, and may essentially shut the panel production down. Consideration is needed even for shadows of utility poles and overhead wires.	Thermal systems are also affected by shading, but are forgiving of partial shade – 10% shading reduces output by 10%.	Solar ready construction requires close attention to the location of plumbing and mechanical equipment in the building. Therefore, the location of the future solar collection system must be clearly described in the earliest stages of developing the building's floor plans.	Coordinating the locations of plumbing and mechanical systems with the solar array area needs to occur as the floor plans are being developed. Establishing the final location of vents occurs during construction.	Architect or Builder. Contractor, Plumbing, Mechanical, & Roofing Subcontractors.

Structure

Starting Point: How is the roof structure different on a solar-ready building?

Rules of Thumb: Designing the building to allow systems to be mounted flush (parallel to the roof pitch) greatly simplifies structural issues.
On flat roof systems, a ballasted system could impart 25 psf or more of ballast weight to counteract the uplift. A good source that can be used to find information on the performance and exact weight of various solar thermal systems is: http://www.solar-rating.org/
The NREL "Solar Ready Buildings Planning Guide" has useful technical references related to structure.

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Solar PV collection systems add approximately 3-5 pounds per square foot (psf) to the dead load of a roof system (approximately the same weight as a layer of shingles). Depending on the configuration (flush mounted or pitched at a steeper angle than the roof), a solar system can also increase the wind and snowdrift loading that the roof structure must withstand. Ballasted systems can add significantly more dead load often in the range of 20-30 psf, which is roughly double the typical dead load for a roof.	Solar Thermal collection systems add approximately 6 psf to the dead load of a roof system. Depending on the configuration, (flush-mount or pitched more steeply than the roof) a solar system can also increase the wind and snowdrift loading that the roof structure must withstand. On sloped roofs with a pitch of 12: 12 or greater, flush mounted solar arrays perform optimally. On roofs pitched lower 9:12, non-flush mounted systems may be needed and may require additional structural support.	During initial construction the cost of structuring the roof to support a solar array is very modest since even a ballasted system will only increase the overall roof load by about a third. The cost of restructuring an existing roof to put on a solar system can be prohibitive; the restructuring costs may make the installation infeasible. See page 5 of these Guidelines for a cost comparison of Solar Ready versus Retrofitting for Solar Construction.	During Building Planning Process after the scope of the future solar array is established.	Architect or Builder with input from Structural Engineer. The Structural Engineer should note the drawings to make clear how framing was designed for future arrays.
For systems that are not flush-mounted to the roof, wind uplift pressure needs to be taken into account. The roof structure needs to be designed to resist these pressures.	Same.	Consideration should be given to either designing the roof for an additional 20-30 psf dead load, or designing the framing to support vertical pipe stand-offs extending above the roof and placed at the time of construction to support a future array.		
Obstructions such as non-flush mount solar arrays can cause drifting snow, which adds significant loads to roof structures in Minnesota. With the addition of solar panels, snow loading needs to be carefully considered in the initial structural design.	Same.	Designing the roof pitch to allow flush mount systems will greatly ease eventual installation.		

Access

	Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
	In a flat roof application, a stairway with roof access is sufficient. (Refer to Section 1009.11 of the International Building Code.) Guardrails at the roof edge may also be needed. (Refer to Section 1013.5 of the International Building Code.)	Same.	Since climbing on snow and ice covered sloped roofs is not recommended under any circumstances, a special snow rake may be used on roofs that can be reached from the ground. For solar arrays on second story or inaccessible roofs, building owners should plan for snow to slide off of the panels. The fall zone where this sliding snow will land should be planned taking this into consideration.	Early in the Building Planning Process, as the floor plans are being developed.	

Mounting Systems

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
On pitched roofs use standing seam metal roofs: S-5 clips are attached to the raised seam, so no additional penetrations are needed at the time of solar system installation. The standing seam roof itself must, however, be attached to the structure well enough to withstand additional loads imposed by the solar system. Composite asphalt shingle roofs: While stand-off brackets bolted to structural members is ideal, mounting systems for retrofit applications can be secured directly to the roof surface. Care should be taken to seal roof penetrations. Flat roofs: Curb mounts can be pre-installed, however ballasted systems that hold solar panels in place are commonly used. Ballasted racks avoid roof penetrations, but may require pads to protect the roof from damage.	Same.	Consider mounting options during the Design Process. Review mounting options with Solar Consultant and solar panel manufacturer. If the solar array system is designed appropriate mounts can be pre-installed. This offers the advantage of the preparatory roof work being covered under the roofing warranty. The disadvantage is that pre-installed mounts may limit panel and mounting choices when the system is ultimately installed. Moreover, the amounts have negative aesthetic impacts until the system is installed (see "Solar Ready Buildings Planning Guideline," page 14, for illustrations and more discussion).	During Building Planning Process after the scope of the future solar array is established.	Architect or Builder with input from Solar Consultant and Structural Engineer.

Roof Warranty

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
In some instances, the preparation of the roof for Solar Ready Construction creates out of the ordinary roofing conditions.	Same.	Verify the warranty provided by the roof manufacturer and installer includes provisions for Solar Ready Construction.	During the roof specification and roofer selection process.	Architect or Builder.

Mechanical & Electrical System Planning

To define the mechanical and electrical requirements for Photovoltaic and/or Solar Thermal System, the following documentation will be needed:

Schematic and/or riser diagrams of the proposed systems.
Refer to the electrical installation guidelines in "Expedited Permit Process for PV Systems," Solar America Board of Codes and Standards, Brooks Engineering, May 2009. Available at www.SolarABCS.org

Empty metal conduit from roof to main service panel

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
A 2" minimum metal conduit is needed to house the wiring connecting the solar array to the main service panel. Note: Diameter of the conduit is dependent on the size of the system.	Not applicable.	Installing an empty conduit before finish materials are in place allows it to be efficiently located and reduces costs.	Project Planning- prior to Construction Start	Architect or Builder with input from Solar Consultant and/or Electrician

Electrical panel space for power input breaker

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Provide sufficient space in the electrical panel for a power input breaker. Governed by NEC 690.64(B), the sum of the ratings of over current protection devices in all circuits supplying power to an electrical panel must not exceed 120% of the bus bar rating.	Not applicable.	Providing electrical panel space during the initial construction reduces the amount of re-working needed when the system is installed.	Project Planning- prior to Construction Start	Architect or Builder with input from Electrician

Space in breaker box for the solar electric feed

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Provide sufficient room in the breaker box for the solar electric feed breaker. Requirements will depend on the size of the solar system.	Not applicable.	Providing space in the breaker box eliminates the need to install an additional box when the system is installed.	Project Planning- prior to Construction Start	Architect or Builder with input from Engineer and/or Electrician

Production Meter

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Provide space for a production meter to be metered off the AC system and located adjacent to Electrical Panel. Xcel Energy requires a production meter for the Solar Rewards Program and Minnesota Renewable Energy Credit.	Not applicable.	Providing space for this meter during construction simplifies the installation process.	Project Planning- prior to Construction Start and during Construction.	Architect or Builder with input from Engineer and/or Electrician

Ground solar electrical system

Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
Provide for a ground wire meeting the requirements of UL 467. [Some systems may be self grounded]	Same.	Grounding the system assures protection once it is installed.	Project Planning- prior to Construction Start	Architect or Builder with input from Electrician

Pipes from roof to tank location

	Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Responsibility:
	Not applicable.	Install 3/4" copper supply and return water pipes from the roof to the location of the water storage tanks. These pipes need to be accessible from the roof at the time of system installation.	Installing these pipes during building rough-in, rather than at the time of the thermal system installation, is a significant cost savings.	Project Planning- prior to Construction Start	Architect or Builder with input from Solar Consultant and/or Plumber

Insulate and cap pipes

	Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Decision Assistance:
	Not applicable.	Install "loose" caps at both ends of pipes and pre-formed, foam insulation on entire length of piping.	Capping the pipes keeps them clean until they are put into service. Insulating the pipes conserves energy while in service.	Project Planning- prior to Construction Start	Architect or Builder with input from Plumber

Sensor wire parallel to water pipes

	Photovoltaic Systems:	Solar Thermal Systems:	Decision Making:	Decision Points:	Decision Assistance:
	Not applicable.	A sensor wire is needed to connect the solar array to the system monitor.	Installing this low voltage wire during building rough-in simplifies the process.	Project Planning- prior to Construction Start	Architect or Builder with input from Electrician