Solar Ready Building Design Guidelines

Solar Ready Building Design Guidelines for the Twin Cities, Minnesota

Solar Ready Building Design Guidelines

September 2010

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

Project Coordinator:
CR Planning, Inc.
2634 Vincent Avenue North, Minneapolis, Minnesota 55411
612-588-4904 • www.crplanning.com

Prepared for:

The Minneapolis Saint Paul Solar Cities Program

Funded by:
Solar America Communities
National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Subcontract No. AEJ-0-40331-01 under
Prime Contract No. DE-AC36-08GO28308

Table of Contents

Overview and Introduction

Solar energy systems are becoming more common in Minnesota. Home owners and businesses are more interested than ever in seeing how their buildings can use solar energy. Local and State elected and appointed officials have adopted policies to promote solar energy. Solar energy is overwhelmingly viewed in a positive light by the general public. But obstacles remain to the creation of a sustainable solar energy market and the routine incorporation of solar energy systems into Minnesota buildings and infrastructure.

What is "solar ready"? What is a solar ready building? The National Renewable Energy Lab defines a solar ready building as being designed and built "to enable installation of solar photovoltaic and heating systems at some time after the building is constructed" (*Solar Ready Buildings Planning Guide*, 2009). At the most basic level, solar ready buildings are designed and built to easily incorporate a solar energy system. Ideally a solar system can be installed in a solar ready building without having to change the roof structure, without having to open walls for piping or electric cable, or without having to create a location for electric components, storage tanks, or other necessary components of the system. The three basic components of a solar ready building include:

1) A place on the roof of the building that has unrestricted solar access, is free of obstructions such as rooftop equipment or plumbing vents, and is structurally designed to accommodate the weight, wind, and drift loads that the system might impose;
2) A internal chase or other means for connecting the solar system to the building's mechanical or electrical system;
3) Space within the building that is readily available for the installation of controls and components, such as electric invertors and hot water storage tanks.

Why "solar ready"? One of the major barriers to the installation of solar energy systems is the traditional design of our building stock. Existing buildings were not, understandably, built for easy solar energy retrofits. Roof structure, building orientation, choices about the location of mechanical systems and building design elements often make installation of solar energy systems much more complicated and expensive than it needs to be. Even new buildings need substantial improvements to take full advantage of the building's solar resource. A few fairly simple changes to the way that we design and build our buildings can significantly ease the solar retro-fit process, making installation more predictable and less costly.

The "solar ready buildings" idea treats buildings as infrastructure, multi-generational investments that consider not only today's markets, but provide flexibility to meet the next generation's needs. By ensuring that solar systems can be installed easily, the solar ready building will allow the owner to invest in solar energy at any point in the future. The U.S. Department of Energy reports that solar energy has started to be cost competitive with retail electric service in some parts of the country, and that retail cost parity will become widespread in some electric markets by 2016. Solar energy will likely be cost competitive in Minnesota at the retail level (what homes and businesses pay for energy) within the next decade and possibly even sooner. While solar energy has not reached for most Minnesota electric customers, the added consumer value of having "green power" is driving new markets for solar energy even in our State.

What kinds of solar systems? Solar energy systems include active and passive systems, solar electric, solar hot water, and solar space heating systems. The Solar Ready Building Guidelines are directed at the solar technology options readily available to consumers in Minnesota today including solar water heating (SWH) and solar electric (photovoltaic or PV). Whether you build solar into your homes and buildings from the outset or design as solar ready for installation at a later point, designers and builders need to understand how to tailor to a building project accommodate solar. The basic options covered in this guide include solar water heating (SWH) and solar electric (photovoltaic or PV) and are described below.

- ✓ ***Solar water heating (SWH)*** systems are de-signed to heat domestic hot water. In Minnesota's climate, a SHW system can be designed to supply 75% of a household's hot water. SWH systems typically consist of collectors, a control-ler, a well insulated storage tank, and freeze protection. SWH sys-tems are both reliable and economical, with a positive cash flow, especially when incorporated into the upfront cost of the building or home. Some manufacturers have developed packaged systems and streamlined installation processes that make it easy to incorporate SWH into your building schedules.
- ✓ ***Solar electric (photovoltaic or PV)*** systems are made up of modules containing PV cells that generate direct current (DC) electricity when exposed to sunlight. An inverter converts the DC power to the alternating current (AC) electricity. PV systems have been tested to rigorous standards by public and private organizations. They have no moving parts, require almost no maintenance, and last for decades. The price of PV has declined substantially just in the past year (2010) as the market has expanded. Moreover, rebates and incentives are widely available in many parts of the state. See the Database of State Incentives for Renewables and Efficiency (DSIRE) at www.dsireusa.org for a comprehensive list of efficiency and solar incentives available in your location.

  Today's PV systems come in a range of efficiencies and configurations. PV systems with modules that are mounted on roofs are still the most common, but building integrated photovoltaic (BIPV) systems are gaining in popularity. In a BIPV system, the modules do double duty—they generate electricity AND can replace traditional building materials such as roof shingles and window awnings. BIPV is, however, a choice best made during construction rather than afterwards. This guide for solar ready buildings does not address BIPV except to the extent that the technology utilize the same roof space, chase, and utility space.

This guide is designed to help Minnesota architects, engineers, contractors and their clients understand and plan for future solar PV and SHW systems.

Using the Solar Ready Guide. The Solar Ready Buildings Guide presents solar ready building guidelines that are tailored to the Twin Cities region specifically and the Midwest/Minnesota in general. The guidelines 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.

What type of building is covered by the Guidelines? The design guideline /specifications address two specific building types:

1. Urban-sized new single family and duplex construction with pitched roofs, and;
2. 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.

Other building types can be designed as solar ready, but the design process is usually more complex and is thus not directly addressed in these documents. The basic principles of solar ready design are, however, the same for all building types – designing for a rooftop solar area, maintaining a direct chase or connection to the buildings mechanical and electric systems, and space in the utility area for mechanical and storage components.

The audience for these documents includes:
- ✓ Public Agencies; State (i.e. Minnesota Housing Finance Agency), counties and cities
- ✓ Neighborhood organizations, District Councils, and Community Development Corporations
- ✓ Non-profit and for profit development community
- ✓ Owners, architects, builders and contractors

Minnesota's Solar Resource

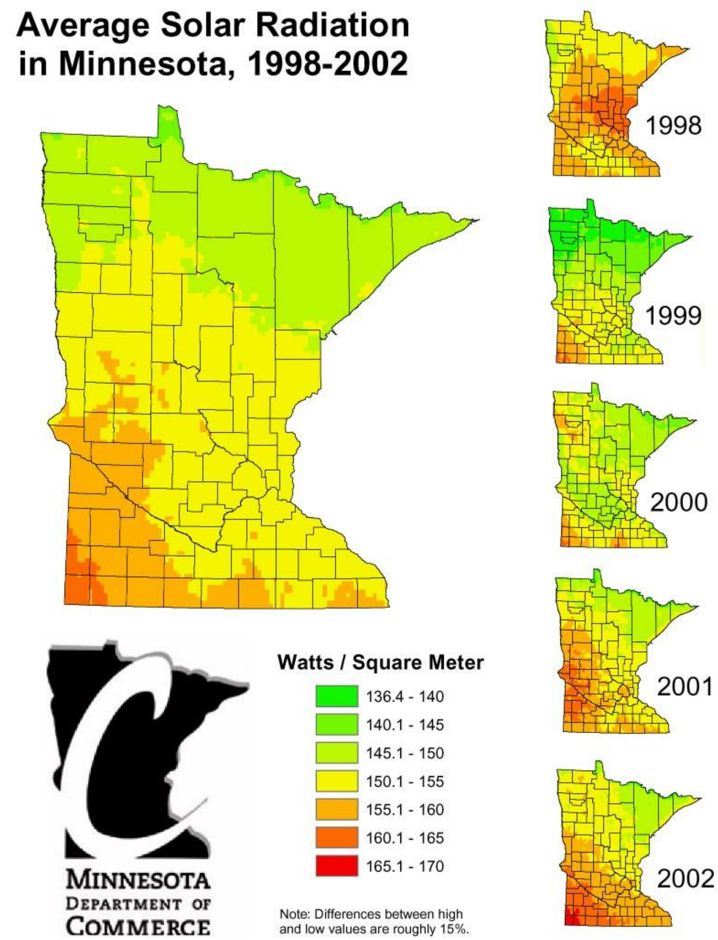
Minnesota has an excellent solar resource. Although the Twin Cities are renowned for their climatological extremes, the percentage of available sunshine is relatively consistent throughout the year. The sky is clear to partly cloudy 58% of daylight hours. Only November and December are cloudy more than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

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. The solar resource during the late fall/early winter months is minimal. For the remainder of the year— as the sun angle increases to its maximum of 70°, 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.

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 other 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]



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

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 guide addresses only those issues for making a building “solar ready”; the guide is not intended to be a specification for solar installations. Many aspects of installing a solar system can only be addressed at the time of actual installation, such as sizing system components, calculating the capacity of the system, and even the most appropriate mounting systems for solar collectors.

Thus, 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 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. Additional technical information related to solar electric systems can be found in the Expedited Permit Process for PV Systems (Solar America Board for Codes and Standards, New Mexico State University). Addition information on solar ready buildings for northern climates can also be found in Building a Solar Ready Home (Canadian Solar Industries Association).

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

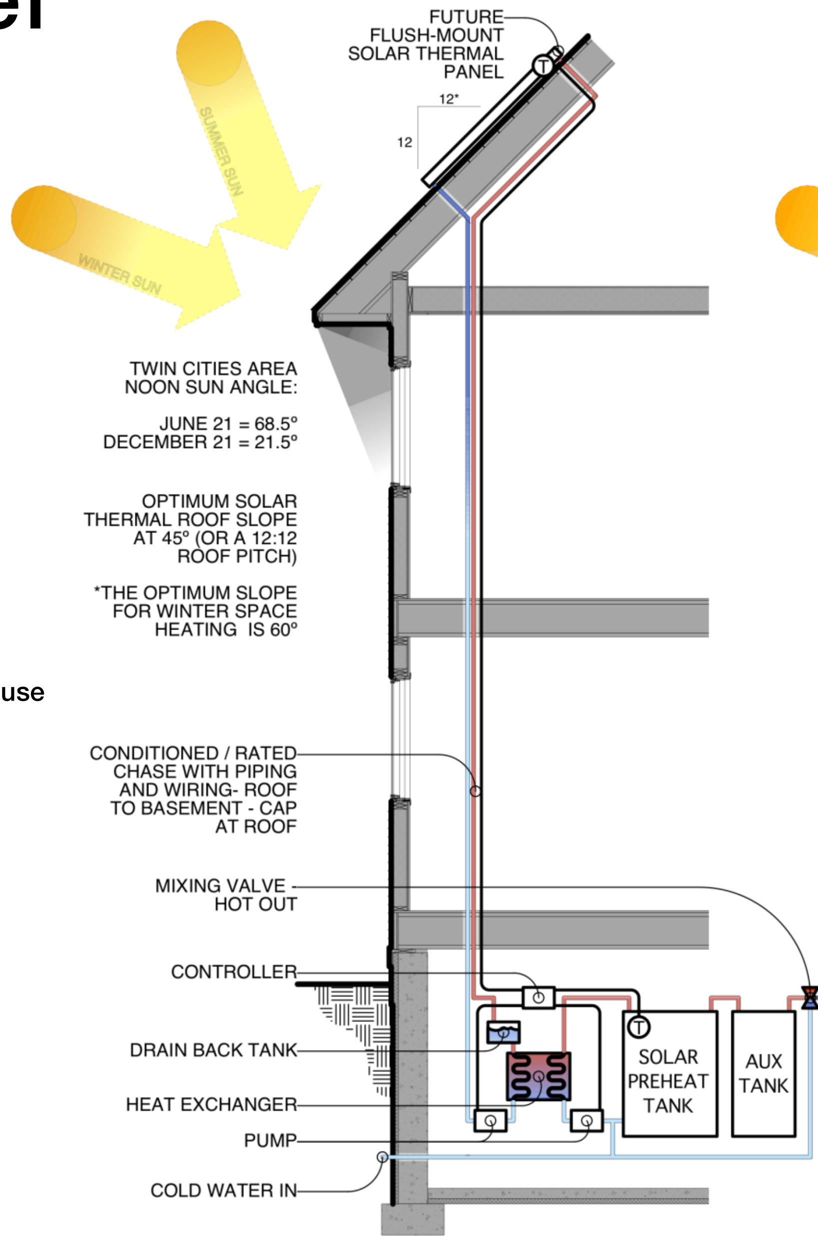
About the specifications:

- ✓ The Solar Ready Construction Specification establishes 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.

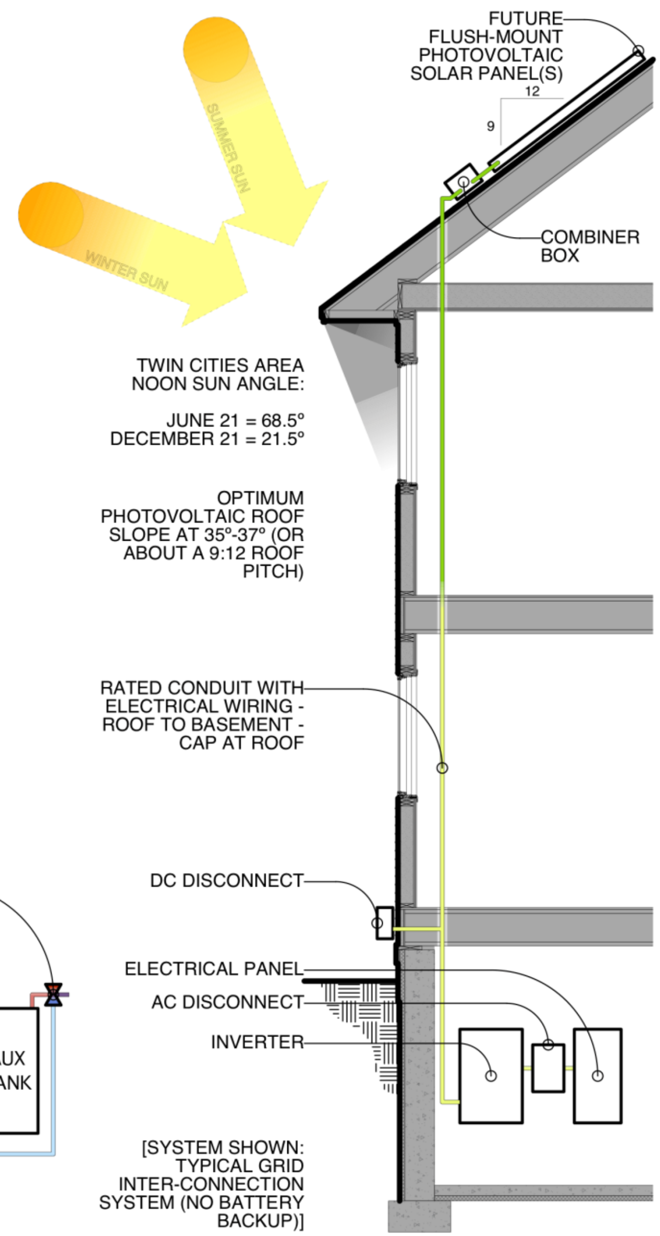
Solar Model

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.

- Neighborhoods may 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.

- For examples of solar zoning best practices, review Minnesota's *Model Ordinances for Sustainable Development* , Minnesota Pollution Control Agency, 2008.

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. An increasing number of Minnesota cites, including Minneapolis and Saint Paul, have adopted solar zoning standards or are considering such 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. Communicate with neighboring property owners and community groups about the building plans and the potential issues associated with the eventual installation of a solar system.	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, but shading and structural considerations weight more heavily.
- Like a kitchen, the solar array has a size and function to be included early in the building's design process, not added after the fact.

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 protect the solar access potential on neighboring properties. Minimize shading by the proposed building and landscape.	Same.	A solar system is a 30 – 40 year investment. Consider potential alterations on properties to the south of the proposed solar array, including new buildings as allowed under the applicable zoning district and the growth of trees. Investigate applying a solar access easement with adjacent property owners. Check whether zoning permits take solar access into consideration – some cities 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 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 require conscious and proactive decisions in the design process about solar orientation and tilt.	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: Organize 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. Systems may require an outside DC disconnect and combiner box adjacent to the inverter. These components will also need wall space.	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, but shading and structural considerations must take precedence.

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 balancing functional and aesthetic elements. A 12:12 pitch provides the greatest number of options for easy installation of a solar system. Planning for a non-flush-mount solar system on a pitched roof 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. For information on the performance and exact weight of various solar thermal systems go to: 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 2.5 – 3 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.		
Non-flush mount solar arrays, like other wind obstructions, can cause drifting snow on the roof. The additional 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 using standing seam metal roofs, S-5 clips are attached to the raised seam. 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. On composite asphalt shingle roofs, stand-off brackets bolted to structural members is ideal if the system will be installed soon after construction. Otherwise, retrofit mounting systems can be secured directly to the roof surface. In either case, take care to seal roof penetrations. On flat roofs, curb mounts can be pre-installed. However, ballasted systems are more common, making pre-installed mounts irrelevant. Ballasted racks avoid roof penetrations, but may require pads to protect the roof from damage. Some self-ballasting systems now being manufactured may make flat roof installations even easier, and mount more irrelevant.	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 NREL's "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. The minimum diameter of the conduit is dependent on the size of the system, which will not be known until installation.	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. Insulate the pipes with a minimum of R-4 insulation with a temperature rating of at least 180 degrees C.	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