Planning Improvements

Step 3, PL 3-A
Building Code Improvements

Develop a solar-ready buildings checklist for new construction

A new construction checklist guides a developer, architect or other interested party through the components of building design required to prepare a building for future solar installation. At the most basic level, the checklist would include recommended best practices by providing guidelines for solar-ready building design to minimize the costs of future photovoltaic (PV) or solar hot water retrofitting and installation, while maximizing potential system efficiency. The checklist would apply to site selection, building design and building construction.

Basic components of a solar-ready building checklist include requirements for: 1) a place on the roof that has unrestricted solar access, is free of obstructions and can structurally accommodate the additional load; 2) means to connect the solar system to the building's electrical system (called a "chase"); and 3) space for the installation of system controls and components.

A basic checklist may incorporate the following general solar guidelines:

- Minimize shading from trees and neighboring buildings.
- Identify potential placement of future solar arrays.
- Optimize south-facing roof (if sloped) and maximizing open area.
- Specify appropriate roof construction.
- Record roof specifications on drawings.

It may also outline electrical specifications, such as:

- Location of electrical panel for interconnection.
- Specification of panel capacity.
- Layout of inverter and other system components.
- Verification of interconnection restrictions for the building location.
- Requirements for running electrical conduit from the proposed solar collector locations to panels.

Other early design requirements or considerations may include:

- Orientation of the building.
- Evaluating a site for solar access.

Examples

The Twin Cities, Minnesota, Solar Ready Guidelines

The Twin Cities have released two location-specific documents for use by public agencies, community organizations, the nonprofit and for-profit development communities, and owners, architects, builders and contractors. The Solar Ready Building Design Guidelines explain the concept of solar-ready buildings and outline guidance for designing and building a solar-ready structure through site planning, building form, space planning, roofing, and mechanical and electrical design. The Solar Ready Construction Specifications provides a methodology for achieving solar-ready buildings by establishing responsibilities for the contractor and procedures for implementation. The guidelines were based on a more detailed guidance document developed by the National Renewable Energy Laboratory (NREL).

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- Solar Ready Building Design Guidelines: https://mn.gov/commerce/energy/images/Solar-Ready-Building.pdf
- Solar Ready Construction Specifications: https://mn.gov/commerce/energy/images/Solar-Ready-Construction.pdf
- NREL Solar Buildings Planning Guide: http://www.nrel.gov/docs/fy10osti/46078.pdf

City of Boston, Massachusetts: Department of Neighborhood Development Solar Ready Guidelines
Boston's solar-ready guidelines require new affordable-housing developments to limit roof obstructions and avoid roof designs that would complicate future solar installations. The solar ready standard has been in place since 2007 for all affordable housing projects developed by the Department of Neighborhood Development.
www.cityofboston.gov/dnd/PDFs/D_2010_DND_DESIGN_STANDARDS-112010.pdf

Energy Trust of Oregon, Solar Ready Installation Requirements
The Energy Trust of Oregon, a utility-funded nonprofit, developed solar-ready installation guidelines for solar access, solar electric and solar hot-water systems. The installation requirements are connected to the Energy Trust of Oregon's solar assessment and planning incentive program. New buildings or major retrofits in Oregon which seek to be solar ready will qualify for subsidized technical assistance from the Energy Trust to achieve solar readiness. The most recent guidance document was released in July 2013.
http://energytrust.org/library/forms/sle_rq_solarreadyreq.pdf

Sample: Solar ready building design guidelines

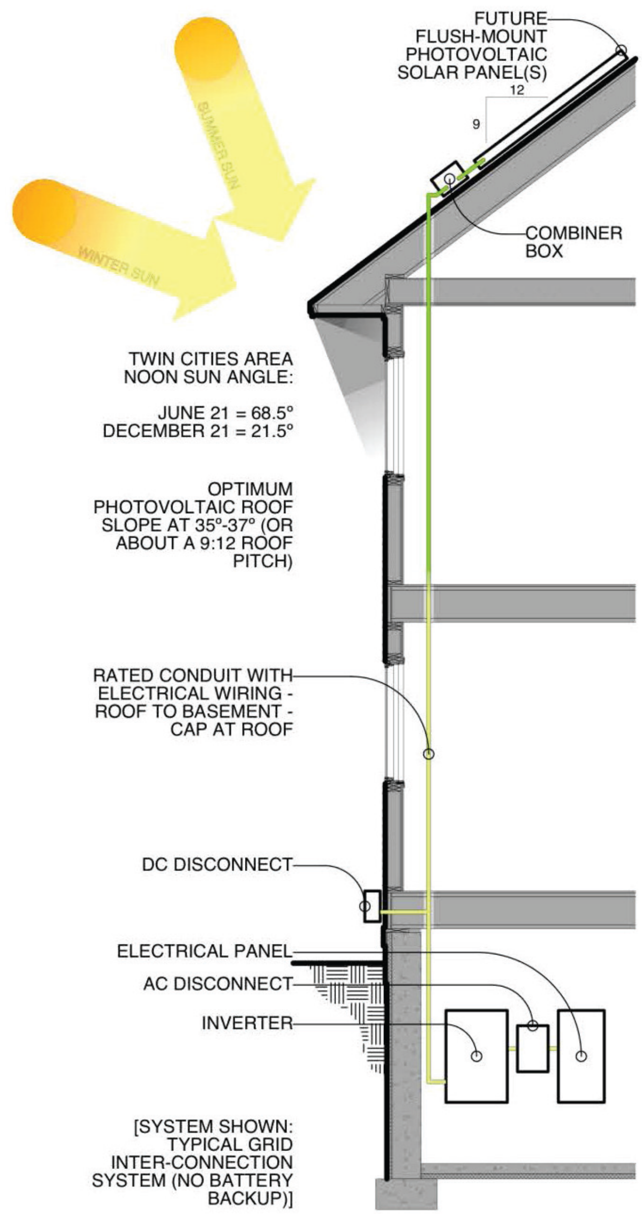
(Source: The Twin Cities, Minnesota, Solar Ready Guidelines. https://mn.gov/commerce/energy/images/Solar-Ready-Building.pdf)

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 of each issue.

The guidelines are a starting point to incorporate solar-ready construction into the building-planning process. Guidelines users are referred to the National Renewable Energy Laboratory's *Solar Ready Building Planning Guide* (NREL/TP-7A2-46708) 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).

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



Example Photovoltaic Setup

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.

Site Planning

To define the site requirements for PV systems, the following documentation will be needed:

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

City Planned Ordinance Variations

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

Rule of Thumb: Select a site with good potential for solar access.

- Update community plans to minimize shading of solar arrays.

Photovoltaic 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.	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.

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

Photovoltaic Systems	Decision Making	Decision Points	Responsibility
In developed or developing neighborhoods, achieving and maintaining solar access may require agreements 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.	Work with neighbors and other interested parties to find mutually beneficial solutions.	In some cases, prior to purchasing the building site and early in the building planning process.	Owner with the 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.

Photovoltaic 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. Review development association covenants and design guidelines 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.	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 the assistance of architect or builder.

Building Form Planning

Starting Point: Solar access depends on workable relationships between neighbors.
Rule of Thumb: Plan for a lengthy decision-making process if agreements between property owners are needed.

Photovoltaic Systems	Decision Making	Decision Points	Responsibility
In developed or developing neighborhoods, achieving and maintaining solar access may require agreements 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.	Work with neighbors and other interested parties to find mutually beneficial solutions.	In some cases, prior to purchasing the building site and early in the building planning process.	Owner with the assistance of architect or builder and attorney.

Building Form Planning

To define the building form requirements for a photovoltaic 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 and 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 contiguous rectangle of the required size works best, but shading and structural considerations weigh 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	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. 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.	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. Develop the early building plan and proximity diagrams with this relationship in mind.	An initial step in the building planning process.	Architect or builder with input from solar consultant.

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	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 buildings 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.	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	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.	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	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.	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 a photovoltaic system, the following documentation will be needed:

- Dimensioned Floor Plans of all levels.

Space for Inverters and Disconnects

Rule of Thumb: Organize the system's equipment so that wiring runs in straight vertical and horizontal lines.

Photovoltaic 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.	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	Decision Making	Decision Points	Responsibility
Locate the inverter and main service panel directly below the roof location for the solar array.	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.

Roof Planning

To define the roof requirements for a photovoltaic 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?

Rule of Thumb: In general, residential PV systems need between 200 and 400 square feet of roof area. 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	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.	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	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 two to three 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.	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 my location?

Photovoltaic 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 degree pitch is ideal, roofs between 25–45 degree will absorb at least 95 percent of available solar energy.	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 nonflush-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	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 percent (or even	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 and roofing subcontractors.

less) of a PV panel will reduce output by much more than 10 percent, and may essentially shut the panel production down. Consideration is needed even for shadows of utility poles and overhead wires.			

Structure

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

Rules of Thumb: Designing the building to allow the system to be mounted flush (parallel to the roof pitch) greatly simplifies structural issues.

- On flat roof systems, a ballasted system could impart 25psf or more of ballast weight to counteract the uplift. For information on the performance and exact weight of various solar thermal systems, go to www.solarrating.org.
- The NREL "Solar Ready Buildings Planning Guide" has useful technical references related to structure.

Photovoltaic 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 (if applicable). 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. 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. Non-flush mount solar arrays, like other wind obstructions, can cause drifting snow (if applicable) on the roof. The additional snow (if applicable) loading needs to be carefully considered in the initial structural design.	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. 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 standoffs extending above the roof and placed at the time of construction to support a future array. Designing the roof pitch to allow flush mount systems will greatly ease eventual installation.	During the 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.

Access

Photovoltaic 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.)	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. (Only if applicable based on your geography)	Early in the Building Planning Process, as the floor plans are being developed.	Architect or Builder. Contractor, Plumbing, Mechanical, & Roofing Subcontractors.

Mounting Systems

Photovoltaic 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.	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 preinstalled. This offers the advantage of the preparatory roof work being covered under the roofing warranty. The disadvantage is that preinstalled 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	Decision Making	Decision Points	Responsibility
In some instances, the preparation of the roof for solar-ready construction creates out of the ordinary roofing conditions.	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 and Electrical System Planning

To define the mechanical and electrical requirements for a photovoltaic system, the following documentation will be needed:

- Schematic 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	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.	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	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 percent of the bus bar rating.	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	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.	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.