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Mr. Will Boudra
Forest City Hawaii

Dear Mr. Boudra:

This report presents guidelines for designing and building new houses that are Solar Ready. Following Solar Ready guidelines will streamline the process of equipping these houses with photovoltaic (PV) systems in the future. I hope these will be useful in your plans for including PV in Forest City's new construction.

Please feel free to contact me or Andy Rosenthal with any questions or comments on this report.

Sincerely,

Corey Asbill
Photovoltaic Engineer

Recommendations for Building Solar Ready Houses
Photovoltaic Systems

Executive Summary

Builders considering adding photovoltaic (PV) systems to new houses after initial construction is completed can save time and money by following new house Solar Ready design guidelines. Solar Ready houses are designed and built with integrated electrical and mechanical features that streamline the integration of PV systems.

Solar Ready design guidelines are straightforward and impact house design in the following general areas:

- Roof pitch and orientation
- Layout of roof vents, chimneys, etc., to prevent shading
- Roof load bearing specification
- Designated roof mounting points for PV array
- Installation of electrical conduit from main electrical panel location to roof
- Specification of main service panel and circuit breakers
- Space near the main electrical panel for PV inverters and other equipment

Early consideration of these few requirements will ensure the seamless integration of future photovoltaic systems.

1.0 Complete List of Solar Ready design guidelines

Below is the complete list of areas and concerns that must be addressed to configure a Solar Ready house:

- Site and solar resource evaluation
- Roof/array pitch and roof/array orientation
- Roof structure designed to support additional weight of PV array
- Location of roof vents, chimneys, etc., in relationship to PV array
- Location of PV array in relationship to inverter and point of interconnection *with the existing utility service*
- Roof integrated mounting points for PV array
- Specifications and routing of electrical conduit from roof to PV dc disconnect
- Prepare the main electrical panel for PV
- Provide location and adequate spacing for photovoltaic equipment near main electrical panel
- Design for proper panel and main disconnect ratings on the main electrical panel
- Prepare for photovoltaic back-fed circuit breaker in main electrical panel
- Photovoltaic Solar Ready component labeling

The following sections describe each of these requirements in detail. This information is intended as a guide in cases where the PV system design has not been determined. In cases where the design of the future PV system is already known, some of these recommendations can be changed to more specifically and effectively accommodate the system installation. For example, when the type and model of PV modules are known, specific direct current (dc) wiring and disconnects can be sized and installed in advance.

2.0 Descriptions of recommended design guidelines

2.1 Site and solar resource evaluation:

When designing a PV Solar Ready house, a basic design requirement will be to perform a site evaluation of the house's location and orientation to the existing solar resource. This evaluation should take into account the relationship of the house to the path of the sun throughout the year. The location of any existing (or future) foliage that may shade the photovoltaic array should also be considered. It is recommended that the house's landscape design avoid tall trees and other objects that may eventually cast a shadow on the photovoltaic array. Areas to the east, south, and west of the house should be carefully landscaped to avoid shading the array during the corresponding portions of the day.

2.2 Roof/array pitch and roof/array orientation:

Another basic design requirement will be to determine the pitch and orientation of both the roof and the photovoltaic array. The roof surface where the PV array is to be located will, in an ideal case, be oriented directly toward the solar resource. This is generally to the south in the northern hemisphere. Where possible, the pitch of the roof plus the tilt of the array should be slightly less than or equal to the local latitude to provide optimal year round performance.

2.3 Roof structure designed to support additional weight of PV array:

When building a Photovoltaic Solar Ready house, the structural integrity of the roof should be examined to determine that it will carry the added weight of the photovoltaic system and the mounting components. The additional weight of the system will vary greatly depending upon the photovoltaic modules and mounting system used. In general, the roof below the photovoltaic array should be designed to support at least an additional 5 lbs/sq ft of dead weight.

2.4 Location of roof vents, chimneys, etc., in relationship to PV array:

When designing the layout and location of roof protrusions, special consideration should be given to the location of roof vents, chimneys, gables, or other obstructions that could cast shadows upon the photovoltaic array. The roof design should allow ample clearance for the anticipated photovoltaic array as well as eliminate any shading obstructions along the projected solar path. In general, in the northern hemisphere, any roof protrusions should be located to the north of the planned array location and, depending upon the

orientation of the roof surface, other protrusions should be limited to those locations that will limit the amount of shading during the year.

2.5 Location of PV array in relationship to inverter and point of interconnection:

To minimize losses associated with the transmission of dc energy, the distance between PV array output and the inverter should be kept to a minimum. For instance, if the inverter and main electrical panel are to be located in a garage or utility room, a logical location for the PV array would be on the appropriate roof surface directly above the garage or utility room location. This also serves to minimize the amount of electrical supplies, conduit, wire, etc., necessary to complete the connection between the PV array and the inverter.

2.6 Roof integrated mounting points for PV array:

One of the more time consuming tasks associated with the installation of roof mounted photovoltaic arrays is the integration of rack and module mounting systems. Traditionally, an installer will spend a number of hours planning the location and layout of the various mounting points for the photovoltaic array. The difficulty arises mainly due to the problems associated with locating the position of roof truss structures below the existing roof membrane.

The information provided in this section assumes the photovoltaic modules will be mounted above the roof surface using a traditional rack/module combination with anchors mounted directly to the roof trusses. There are a number of commercially available roof integrated or shingle style modules that can be mounted without the use of the underlying truss structure for support.

Two different roof mounting suggestions are presented along with their associated advantages and disadvantages.

One solution is to integrate rack mounting feet directly into the roof construction. This technique consists of attaching mounting feet directly to the roof truss structure along with the associated weatherproofing provisions. The advantage of this approach is that an installer is not required to penetrate the roofing surface, thereby decreasing the possibility of compromising the roof's integrity. The disadvantage is that the installer must adapt any racking system to the layout and spacing of the various mounting points. Also, the integration of these pre-installed mounting points may detract from the house's appearance as well as represent a potential trip hazard.

A second solution is to physically identify the various locations of the underlying roof truss structures. This could be achieved by referring to detailed as-built drawings to locate physical markers into the exterior roofing surface. These markers will provide the installer with the precise location of the underlying roof trusses. The advantage is that very little change is required from the traditional roofing techniques. The disadvantage is that the installer will still need to penetrate the roofing membrane during array

installation and, thus, be responsible for providing adequate weatherproofing of all roof penetrations.

2.7 Specifications and routing of dc conduit from roof to dc disconnect location:

A metal conduit is necessary to bring the dc wiring from the PV array output to the location of the dc combiner panel or dc disconnect (depending on the design of the PV system). The size of this conduit should be no smaller than 1" to accommodate the dc wiring.

If the house has an accessible attic space, it is recommended that the conduit be terminated within the attic area to allow for future installation flexibility. The installer will then route the conduit through the attic to the appropriate location before penetrating the roof surface. If the attic is inaccessible, the conduit penetration should be located in a place on the roof as near the anticipated PV array output as possible to minimize the amount of exposed wiring between the PV modules and the input to the conduit.

If the house has a flat roof the dc wiring conduit can be terminated on the inside of a parapet wall or, if necessary, up through the ceiling and roof surface at the appropriate location.

The opposite end of this conduit should be in a location where it can be easily connected to any future component: dc disconnect, dc combiner. Both ends of the conduit should be capped off to keep out water and pests.

2.8 Location and adequate spacing for photovoltaic equipment near main electrical panel:

Adequate space should be available in a readily accessible location for a dc disconnect, inverter, ac disconnect and, if applicable, PV system renewable energy credit (REC) meter and utility required ac disconnect will be mounted. The dimensions required for the location for the PV equipment will largely depend upon the PV system design and equipment choices. In general, a residential PV system consisting of the equipment mentioned above will require four to five horizontal feet of wall space with adequate clearance above and below the mounting locations.

The requirement and location for an additional ac disconnect and PV REC meter is determined by the requirements of the local jurisdiction as well as the local electric company. If this equipment must be located within site of the main electrical disconnect on the exterior of the building, it is recommended that the house design allow two to three feet of space.

2.9 Design for proper bus bar and main disconnect ratings on the main service panel:

The *National Electrical Code* imposes requirements on the size of a PV system that can be added to a specified size of existing electrical service.

For instance, a 100-amp main circuit breaker rating along with a 100-amp panel rating will accommodate up to 20 amps of ac current, which would allow PV systems up to 3.8kW in size. If the future photovoltaic system will produce more than 20% of the main circuit breaker's rating, then the size of the main electrical panel should be increased, in accordance with NEC 690.64(B).

An example of this would be if the main electrical panel rating was 225 amps and the main circuit breaker was rated at 200 amps, the PV circuit breaker could be sized up to 70 amps. Seventy amps is the highest allowable total value for all the PV circuit breakers in the panel. This 70 amps would support a system of up to 13kW in size.

2.10 Considerations for photovoltaic circuit breaker in main disconnect panel:

If the size of the PV system is unknown, a location (within the main disconnect panel) for the circuit breaker should be labeled as "Future Circuit Breaker From PV System" and left vacant for the installer to specify and connect. *This breaker position must be located at the opposite end of the panel from the main utility breaker.* This circuit breaker location should allow for a 240-volt breaker which, in turn, will allow the option of a 120-volt system to be installed if this is desired.

2.11 Photovoltaic Solar Ready component labeling:

Proper labeling of the pre-installed components will ensure that a future PV system installation will properly take advantage of the various features of the Solar Ready house. A label detailing specific PV system output limitations is recommended for the main service panel. This label should detail the current limitations and voltage level required to meet the various electrical standards, *NEC*, and local requirements. The PV circuit breaker location should also be labeled as such. It is also recommended that the dc conduit be labeled with appropriate wire size ranges and conduit fill capacities briefly detailed as well.