PROCEDURES FOR SOLAR ELECTRIC (PHOTOVOLTAIC abbreviated as PV) SYSTEM DESIGN AND INSTALLATION

SECTION 2: BACKGROUND ON PV SYSTEMS FOR BUILDERS AND DEVELOPERS

2.1 Benefits of including PV as a standard feature or option.

There are several areas of benefit of incorporating a PV system in residential developments:

1. **Price stability.** With all the uncertainty surrounding utility power in the past months and years, consumers are actively looking for ways to reduce their exposure to energy price fluctuations. For example, during the summer of 2000, because of power shortages due to heat waves, homeowners in the San Diego region experienced electric bills up to three times the normal level. This understandably infuriated homeowners in that region and made them much more interested in taking measures to reduce the impact of a similar event happening in the future. PV power is unique in its ability to produce electricity at each property with a free fuel source, the sun.
2. **Bill reduction.** The primary purposes of the PV system are usually to produce electricity to lower the amount of energy purchased from the local utility company. To maximize the benefit of the PV system, measures must be taken to reduce overall energy usage. Installing energy efficient appliances, insulating and sealing homes properly, and ensuring that the HVAC system is properly installed are all important first steps when considering PV as a home feature. Proper procedures for these measures are outlined in the Air Sealing, Insulation, and HVAC statements of work provided by the Building Industry Institute in Sacramento, California (http://www.thebii.org/Scopes_of_Work/scopes_of_work.html). If these measures are applied in the initial building process, a PV system can effectively lower the electricity usage of the home by half or more. This provides substantial monthly savings, can stabilize the homeowner's long-term electricity costs, and can protect the homeowner from future electricity rate hikes. Some financial institutions are now considering this greater affordability, qualifying homeowners for larger mortgages.
3. **Environmental benefits.** PV power does not pollute the environment. Many consumers are motivated by the idea of providing themselves, their children and grandchildren with a cleaner environment. The idea of providing a significant portion of a home's electricity needs with clean solar energy can be a very compelling concept for many home buyers.
4. **Power reliability and security.** Power outages are becoming more frequent during winter cold weather, summer heat waves, storms, and natural disasters and can disrupt power for hours or days. Many consumers when presented with the option of being able to continue to have power during these disruptions are quite willing to pay for this feature.
5. **Value and comfort.** There are operational benefits, such as the cooling effects of the solar array. When mounted on the roof, the attic does not get as hot, reducing cooling costs. If mounted as a trellis or shade structure, the solar array can serve the dual purpose of producing electricity and providing shade.
6. **Builder differentiation and technical advantage.** Builders and developers can leverage their decision to offer PV systems in their developments to get free publicity and public goodwill as a result of their "vision". They can market themselves as more high tech, more environmentally concerned, more beneficial to their customers than their competition. And buyers may be more inclined to buy when they see how their social and environmental conscience can be satisfied when compared to another development that does not offer the PV option. If this is done in an attractive and high tech approach, it will help differentiate this housing community from other neighboring sub-divisions. Developments based on these principles in the past have proven to be very successful with high consumer demand.

2.2 Typical System Designs and Options

2.2.1. Typical System Components:

a. solar modules: There are a variety of PV products available on the market today. The most common product is a PV module that is 5-to-25 square feet in size and weighs about 3-4 lbs./ft^2. Often sets of four or more smaller modules are framed or attached together by struts in what is called a panel. This panel is typically around 20-35 square feet in area for ease of handling on a roof. This allows some assembly and wiring functions to be done on the ground or in the contractor's shop.

b. balance of system equipment: This includes mounting systems and wiring systems used to integrate the solar modules into the structural and electrical systems of the home.
c. dc-ac inverter: This is the device that takes the dc power from the solar array and battery (if used) and converts it into standard ac power used by the house appliances.
d. house interface: This includes meters to provide indication of system performance. Some meters even indicate home energy usage.
e. other components:
    1. batteries and battery enclosures (optional)
    2. uninterruptible subpanels for special house circuits (optional)
    3. utility-required disconnects (depending on local utility)

2.2.2. PV Electrical System Types

There are two general types of electrical designs for PV power systems for homes; systems that interact with the utility power grid and have no battery backup capability; and systems that interact and include battery backup as well.

2.2.2.1. Grid-Interactive Only (no Battery Backup)
This type of system only operates when the utility is available. Since utility outages are rare, this system will normally provide the greatest amount of bill savings to the customer. However, in the event of an outage, the system is designed to shut down until utility power is restored.

2.2.2.2. Grid-Interactive With Battery Backup
This type of system incorporates energy storage in the form of a battery to keep special circuits in the house operating during a utility outage. When an outage occurs the unit disconnects from the utility and powers specific circuits in the home. These special circuits are wired from a separate subpanel that is separate from the rest of the electrical circuits. If the outage occurs during daylight hours, the PV array is able to assist the battery in supplying the house loads. If the outage occurs at night, the battery supplies the load. The amount of time these separate loads can operate depends on how much power they consume and the amount of energy stored in the battery system. Typical backup battery systems provide from 4kWh to 8kWh of energy storage. This means that the battery will operate a one kW load for 4 to 8 hours. A one kW load is the average usage for a home when not running an air conditioner.

2.2.3. Mounting Options

There are several ways to mount a PV system at a residence.

a. Roof mount

The most common mounting method is roof mounting. The PV array is mounted above and parallel to the roof surface with a standoff of several inches for cooling purposes. Particular attention must be paid to the roof structure and the weather sealing of the penetrations in the roof.

Figure 1 Roof Mounted PV System

Proper roof mounting can be labor intensive. It is typical to have one roof mount for every 120 Watts of PV modules. For new construction, the roof mounts are usually mounted as soon as the roof decking is applied. The crew in charge of laying out the array mounting system normally installs the brackets. The roofing contractor can then flash around these mounts as they install the roof. A simple installation detail and a sample of the roof bracket is often all that is needed for a roofing contractor to provide an estimate of the cost of flashing the roof mounts.

Masonry roofs are often structurally designed near the limit of their weight-bearing capacity. In this case, the roof structure must either be enhanced to handle the additional weight of the PV system or the masonry roof transitioned to composition shingles in the area where the PV array is to be mounted. By transitioning to a lighter roofing product, there is no need to reinforce the roof structure since the composite shingles and PV array usually weigh less than the removed masonry product.

b. Patio Cover

An alternative to roof mounting is to mount the system as a shade structure. A shade mount may be a patio cover or deck shade trellis type of installation where the roof of the shade structure is the PV array. These shade systems can support small-to-large PV systems.

The construction costs of the patio cover would be little different with a PV system than for a standard patio cover. This is especially true if the PV array is mounted in the same plane as shade roof. If the PV array is mounted at a steeper angle than a typical shade structure, additional structural enhancements may be necessary to handle the additional wind loads. The weight of the PV array is 3-to-5 lbs./ft^2, which is well within structural limits of most patio covers. The avoided cost of installing roof brackets and the associated labor could be counted toward the cost of fully constructed patio cover. The overall cost of this option will likely be higher than roof mounting, but the value of the shade often offsets the additional costs.

Figure 2 Patio Cover or Deck Shade

c. Building-Integrated PV Array

Another type of PV system uses building-integrated PV modules that can substitute for or replace some roofing product with a similar PV product. Examples of this include roof slates (similar to masonry roofing) and standing seam metal roofing products. Special attention must be paid to the installation of these products to ensure that they are installed properly and carry the appropriate fire ratings. The dimensional tolerances are critical with these products since they replace actual roofing products and may result in a leaky roof if installation guidelines are not carefully followed.

2.3 Estimating System Output

PV systems produce power in proportion to the brightness of sunlight striking the solar array surface. The intensity of light on a surface varies throughout a day, and is not exactly consistent day to day, so the actual output of a solar power system will vary with sunlight. There are other factors that effect the output of a solar power system. These factors need to be understood so that the developer and the customer have realistic expectations of overall system output and economic benefits under variable weather conditions over time.

Figure 3 Building-Integrated Installation

The estimates here do not include any reduction in output due to shading of the array. Even a small amount of shading of part of the array can substantially reduce the output of the array. Every effort should be applied to ensure that the array is not shaded by chimneys, vents, roof hips, or other roof features.

2.3.1. Factors Effecting Output

Standard Test Conditions

Solar modules produce DC electricity. The DC output of solar modules is rated by manufactures under Standard Test Conditions (STC). These conditions are easily recreated in a factory, and allow for consistent comparisons of products between manufacturers, but need to be modified to estimate output under common operating conditions in sunlight. STC conditions are: solar cell temperature = 25 ^oC; solar irradiance (intensity) = 1000 w/m^2 (often referred to as peak sunlight intensity, comparable to clear summer noon time intensity); and solar spectrum as filtered by passing through 1.5 thicknesses of atmosphere (ASTM Standard Spectrum). Under these STC conditions a manufacturer may rate a particular solar module output at 100 watts of power, and call the product a “100-watt solar module”.

Temperature

When operating on a roof, a solar module will heat up substantially, reaching inner temperatures of 50-70 ^oC, which in turn reduce the overall output power of the module. A typical temperature reduction factor recommended by the CEC is 89% or 0.89. So the 100-watt module will typically operate at about 89 watts in the middle of a hot day, under full sunlight conditions.

Dirt and dust

Dirt and dust can accumulate on the solar module surface, blocking some of the sunlight and reducing output. Although typical dirt and dust is cleaned off during every rainy season, it is more realistic to estimate system output taking into account at least some reduction due to dust. A typical dust reduction factor to use is 93% or 0.93. So the 100-watt module, operating hot on a roof with some dust may typically operate at about 83 watts (.89 x .93 = .83).

DC to AC conversion losses

The DC power generated by the solar module must pass through an inverter to be converted into common household AC power. The inverter is not 100% efficient in this conversion, and some power is lost in the process, as well as small losses in the wires from the rooftop array down to the inverter and out to the house panel. Modern inverters commonly used in residential PV power systems have peak efficiencies of 92-94% indicated by their manufacturers, but these again are measured under well-controlled factory conditions. Actual field conditions usually result in overall DC to AC conversion efficiencies of about 82-89%, using 86% or 0.86 as a compromise. So the 100-watt module output, reduced by heat and dust and AC conversion will translate into about 71 watts of AC power delivered to the house panel during the middle of a clear day (.89 x .93 x .86 = .71).

	Flat	4:12	7:12	12:12	21:12	Vertical
South	0.89	0.97	1.00	0.97	0.89	0.58
SSE,SSW	0.89	0.97	0.99	0.96	0.88	0.59
SE, SW	0.89	0.95	0.96	0.93	0.85	0.60
ESE,WSW	0.89	0.92	0.91	0.87	0.79	0.57
E, W	0.89	0.88	0.84	0.78	0.70	0.52

Table 1: Orientation Factors for Various Roof Pitches and Directions

Sun angle and house orientation

During the course of a day, the angle of sunlight striking the solar module will of course change, and this will directly effect the power output. The output from the 100 watt module discussed above will rise from zero gradually during dawn hours, and increase with the sun angle to its peak output at midday, and then gradually decrease into the afternoon and back down to zero at night.

The pitch of the roof will affect the angle of the sun with respect to the solar module surface, as will the East-West orientation of the roof. These effects are summarized in the table, showing that an array on a 7:12-pitch roof facing due South in Southern California for example gives the greatest output (correction factor of 1.00), while an East facing roof at that same pitch would yield about 84% of the annual energy of the South facing roof.

CITY	kWh/kWstc
Arcata	1092
Shasta	1345
San Francisco	1379
Sacramento	1455
Fresno	1505
Santa Maria	1422
Barstow	1646
Los Angeles	1406
San Diego	1406

Table 2: Annual Energy Production by City per kW_{STC} array rating

2.3.2. Estimating System Energy Output

Table 2 is intended to give a conservative estimate of the annual energy expected from a typical PV power system, taking into account the various factors discussed above.

These values are for annual kWh produced from a one kilowatt (1kW) STC DC array, as a simple and easy guide. If the system includes battery backup the output may be reduced further by as much as 10% due to battery effects.

Example: A 4 kW_{STC} solar array (as specified under STC conditions) located in the Los Angeles area at a 4:12 pitch and facing due southeast will produce about 5343 kWh of electric energy annually (1406 kWh/kW x 0.95 x 4 kW = 5343 kWh). The annual typical consumption in that area is about 7300 kWh annually (CEC), meaning such a solar power system could produce around 75% of the total energy needed by such a typical home. And if energy efficiency measures were taken by the builder to reduce the overall electrical consumption of the home, the percentage could approach 100%. Net metering has recently been extended to time-of-use customers yielding an additional value of 30-40% for the PV electricity generated by the system. With this net time-of-use metering, this example homeowner would cover almost all of their electric bill and only have to pay the monthly metering charge.

2.4. Typical Prices

Packaged system price varies by manufacturer and typically goes down as quantity of installations goes up. Systems with battery backup are somewhat more expensive than non-battery systems. Systems with large solar arrays are relatively lower in price per watt of power and kWh of energy than smaller systems because the fixed cost of the inverter and other fixed installation costs is spread over more solar modules. Installation costs are very sensitive to specific house model layout and roofing type. Some approximate costs are presented below to serve as very rough guidelines.

Small 1 kW systems cost about $6,000 to $8,000 while larger 4 kW systems cost approximately $20,000 to $25,000. Systems with battery backup can add $2,000 to $5,000 to these costs. Engineering, project management, and installation costs can vary from $1,500 for simple small systems to $3,000 for complex larger systems. These estimated costs are prior to any incentives or buy-downs to reduce costs.

2.5. Incentives to Reduce Costs

Substantial incentives are in place from the CEC and several local utilities and municipalities throughout California to reduce these system costs to the builder. The CEC rebates are calculated by multiplying $3.00 times the adjusted peak DC power from the system in watts (up to a maximum of 50% of the system cost). This is available for all Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) customers. Some municipal utilities in cities such as Sacramento, Los Angeles, Palo Alto, and Roseville provide the same or even higher incentives.

The peak STC DC power rating of the array is reduced by a temperature factor and the inverter peak efficiency (this is the published peak efficiency from the inverter manufacturer, and not the lower field efficiency value presented previously). Examples are presented below:

Sample California Rebate Calculations

Solar Array (STC rating)		Temperature Derating		Inverter Peak Efficiency		CEC Rebate Rate		Rebate
1.2 kW	X	0.89	X	0.93*	X	$3.00/watt	=	$2,980
4.0 kW	X	0.89	X	0.96**	X	$3.00/watt	=	$10,250

* Example peak efficiency of a small 1 kW inverter. ** Example peak efficiency of a larger 5 kW inverter.

This level of rebate can reduce the cost of systems by 30% or more and result in much more favorable economics for the builder. This means that a builder can incorporate a basic 1.2 kW solar power system for as little as $3,000-$5,000. If the system is included as a standard feature in some models, this small increment in home cost may be very attractive when compared to the resulting reduction in monthly utility bill.

2.6. Estimating Economic and Environmental Benefit

One of the key benefits of residential solar power systems is lower electric utility bills resulting from reduced electricity supply from the electrical grid due to the displacement of energy that the solar system produces. The energy savings to a homeowner can be estimated by simply multiplying the annual energy in kWh that a solar electric power system might produce times the utility electric energy rate. These rates vary by local utility, and are likely to increase from their current values under utility restructuring. Estimated energy savings from a small and large solar electric system in Southern California are presented below to illustrate the kinds of savings that can be had by owners.

Sample Annual Electric Utility Bill Savings

Solar Array (STC)	Estimated Annual Energy	Utility Electric Energy Rate		
		$0.10 /kWh	$0.15 /kWh	$0.20 /kWh
1.2 kW	1687 kWh	$168.70	$224.93	$337.40
4.0 kW	5624 kWh	$562.40	$843.60	$1,124.80

The environmental benefits of generating clean renewable solar power can also be estimated and presented to customers to encourage them to purchase. One compelling fact is the amount of CO2 production that is deferred because their electricity is not generated by polluting power stations. This can also be translated into the equivalent size of forest that is needed to absorb from the atmosphere the CO2 that would have been produced if their electricity had been produced by a polluting power station. An example of these factors is presented below.

Solar Array (STC rating)	Tons of CO_2 Deferred Over Lifetime Of System*	Equivalent Forest Area
1.2 kW	30 tons	1/2 acre
4.0 kW	100 tons	1 1/2 acres

* System life assumed to be 20 years, warranty period of solar modules.

2.7. SUPPLIER QUALIFICATIONS

When choosing a supplier and specifying a PV system, the following are a series of general guidelines to help guide the decision-making process.

2.7.1. Pre-Engineered Systems

When a builder considers an HVAC for a home, they do not buy a compressor from one manufacturer and an air handler from another company, a reversing valve from a third company and then put these pieces together. The equipment manufacturers have engineered a package system that is designed to work together. Each model of a home may need a slightly different unit based on the size and layout, but those variations have been designed into the product. In the same way, the PV system should be engineered to work together as a unit accounting for variations in system size for different homes.

Since the PV industry is in the early stages of development, there are a number of PV system integration firms that undertake the project management, engineering design, assembly, and installation of PV systems. There is a wide range of competency levels among these system integrators. Unless the builder is familiar enough with the technology to recognize whether the system integrator is competent, it is much safer to stay with a firm that provides pre-engineered systems. At the time of the release of this protocol, no company has received National Evaluation Services (NEC) or

International Conference of Building Officials (ICBO) Evaluation Services reports on their engineered systems, but several were beginning to investigate this feature for their products. Although the NES or ICBO report may not guarantee that the product is the best on the market, it will make for a smoother approval process by the local building officials.

2.7.2. Warranties

There are several types of warranties that come with a system or can be purchased in addition to a standard warranty. These include (1) product warranties covering defects in manufacture; (2) system warranties covering proper operation of equipment for a specific time period (typically 5 or 10 years); and, (3) annual energy performance warranties covering the guaranteed output of the PV system.

Product warranties
It is common these days to see warranties on PV modules of 20 or more years. Although this is impressive and indicates the level of confidence manufacturers place in the longevity of their products, there are many other components in these systems that may not have the same life expectancy. Inverters may have one-year, five year, or even ten year warranties. This must be considered when reviewing the cost of inverters and other system components.

System warranties
It is equally important to look for entire system-level warranties of five years or more. This indicates that the manufacturer has taken many other operational issues into account. Since these systems generate electrical power, it is helpful to have system performance included as part of the warranty. For instance, a typical system-level warranty might state that the system is guaranteed to produce two kilowatts (2 kW) of AC power at PVUSA Test Conditions (PTC) (PTC is $1kW/m^2$ irradiance, 1 m/s windspeed, 20^oC ambient temperature) in the fifth year of operation. The equipment to perform this test is expensive, but the fact that a company would know enough to specify this type of warranty is an indication that they are confident in their system design.

Annual energy performance warranties
Although there are very few companies selling systems with this type of warranty, an energy performance warranty guaranties that the system will perform consistently over a period of time. This is particularly helpful in ensuring that the customer receives the bill savings that they expect. Adequate metering to verify the system power output and energy generation is necessary to help the system owner understand whether the system is operating properly, or has warranty-related performance issues. With an adequate meter, the customer can readily identify when the system is malfunctioning.

2.7.3. Company Reputation (years in business, previous projects)

Like any company with which a builder does business, the reputation of the PV company is a critical piece of the decision-making process. The size of the company, number of years in business, number of previous projects completed, are all important issues that are appropriate to review before choosing a company's products. Although price is often the strongest single consideration in reviewing proposals, the other less tangible considerations often add up to a similar level of importance with cost. Fortunately, there are several companies with very strong financial and historical records in this field. It is recommended that you research the background and history of the prospective vendor thoroughly.

2.8. OVERALL PROJECT COORDINATION

Once the decision is made to incorporate PV into the housing product, several issues must then be addressed.

2.8.1. Utility Considerations

The utility company plays a very important role in this process. The issues related to installing multiple solar generators in close proximity to one another must be reviewed by the serving utility to ensure that they will not have adverse effects on the local distribution system. If PV is sold as a standard feature, there will often be instances where the whole neighborhood is exporting power. Fortunately, PV has the most developed set of utility interconnection standards in this field known as "distributed generation." However, utilities are generally cautious with these types of installations since most utilities have very little experience interconnecting PV systems. The key point is to involve the serving utility as early as possible in the subdivision design.

Another utility-related consideration is metering requirements. In California, as in many other states, there is a legislative mandate requiring utility companies to "net-meter" a certain amount of PV systems. Net metering refers to the ability to use a standard house utility meter to measure the flow of electricity in and out (yes, out!) of the home. Even a 500-Watt PV system on a sunny day may generate more electricity than a home consumes at any given time. California law allows customers to carry-over excess energy from month-to-month with an annual true up and payment of the electrical bill for any net consumption over the whole year. The net metering law does not require the utility to compensate the customer for excess electricity at the end of that 12-month period. For more information about this and other consumer-related PV issues, download the document, *Buying a Photovoltaic Solar Electric System: A Consumers Guide*, from the California Energy Commission's website at http://www.energy.ca.gov/reports/500-99-008.PDF or call them at 1-800-555-7794 (Renewable Energy Call Center) to receive a copy by mail.

2.8.2. Procurement

Once the supplier and PV system have been chosen, the systems must be procured and delivered. Since the equipment is very expensive, it is often best to deliver it to a facility that has some level of security. PV modules have been the target of theft and vandalism, so a completed home with a lockable garage should be considered a minimum level of security. The contractor's shop might be the most preferable option; however, this is not always in a location convenient to the job site.

2.8.3. Trades Involved and Sequence of Installation

Coordination of trades is always a challenge in home building. The PV system installation often involves two or more subcontractors. Two trades that are typically involved are the roofing contractor installing and flashing the roof mounts, and the electrical contractor or PV system integrator installing the PV modules, electrical wiring, and equipment. The electrical wiring inside the home can be installed concurrent with the rough electrical. Roof mounts can be installed as soon as the roof decking is put on. A key issue to coordinate is location of other roof penetrations such as chimneys, and plumbing and furnace vents. The higher the vent, the farther away from the PV array the penetration must be. This especially true of vents on the south, east, or west sides of the PV array since these obstructions often cause power loss due to shading. Even seemingly insignificant amounts of shading can substantially reduce the system output. Coordination of these penetrations means that the plumbing and HVAC contractors must be aware and potentially coordinate with the PV installation, even though they may have no role in the installation of the PV equipment.

Most PV system designs include some level of prewiring off the roof that is often done by the electrical contractor. Once the PV modules have been panelized and wired, they must be tested to verify that they are wired properly. After the contractor verifies that they have been wired properly, the panels can be lifted to the roof (or whatever other location is chosen), installed in the brackets, and connected to the wiring system. From that point on, the installation sequence may vary slightly from one manufacturer to another depending on the manufacturers installation procedure, but the remaining work is electrical by nature.

2.8.4. Acceptance of Systems (performance evaluation)

It is typically the job of the general contractor to verify that the system has been installed according to the manufacturers procedures. A sample checkout procedure is provided at the end of this document; its purpose is to ensure that the system will work as it was intended to work and provides the customer with a properly operating system. Obtaining extremely accurate performance is difficult and requires expensive test equipment. Fortunately, it is not necessary to define the performance with extreme accuracy. A system can be checked with some fairly simple test equipment to verify proper installation and performance. A key to keeping the system testing simple and quick is to do the tests on cloudless days. This eliminates the unavoidable fluctuations that occur on partly cloudy days. The PV System Installation Checklist that accompanies this protocol has a detailed System Acceptance Test.

2.8.5. Customer Education

Previous sections of this document discuss the choice, installation, and performance issues of PV systems. Of similar importance are the issues of interfacing with the customer and ongoing maintenance for the equipment. As with other major systems in a home, it is essential that the homeowner be given a complete set of documentation on the system. This should include system manual and copies of relevant drawings for whatever system maintenance might be required in the future. The key component of the system providing feedback to the customer is the metering. Without proper metering the customer will never know whether the system is operating properly or not. A simple meter, registering the power output of the PV system and recording the energy delivered to the house, can provide the customer with the satisfaction that they can monitor the performance of the system.

Education is critical so that the customer understands that the output of the system fluctuates with the amount of available sunlight on the PV array. It is helpful to instruct the owner that the maximum power output of most properly installed PV systems occurs near midday on sunny days in the spring and fall. This education is necessary to keep homeowners from calling and complaining in the middle of the winter when maximum output is impossible. The meter is also a way of proving to the customer that the equipment is properly installed. Often, the customer's primary indication of whether they feel the system is operating properly on not is their monthly electric bill. If the customer suddenly begins using more electricity, they may see an increase in their bill and blame it on poor PV system performance. A meter can arbitrate between the builder and the customer by showing that the system performs as advertised.

One of the attractive attributes of PV system is lack of maintenance needed due to the fact that it is a semi-conductor product with no moving parts. However, even electrical systems need to be maintained from time to time. With proper metering, an informed customer can easily determine if their system is operating properly or not. It is important that the customer have contact information for contractors that can perform system maintenance in their area. Although many areas do not have full-time PV contractors, it is always helpful to provide a list of two or three local contractors that offer PV maintenance services. Along with the information on local contractors, the system warranty information should be provided so that customer clearly understands what is and is not covered by their warranty and over what time periods.

2.9. REFERENCES

1999 National Electrical Code (NEC) Article 690 and Article 702.
Emerging Renewables Buy-Down Program Information: http://www.energy.ca.gov/greengrid
  Buying a Photovoltaic Solar Electric System: A Consumers Guide: http://www.energy.ca.gov/reports/500-99-008.PDF
  Clean Power Estimator: http://www.energy.ca.gov/cleanpower/index.html
  List of Certified PV Modules: http://www.energy.ca.gov/greengrid/certified_pv_modules.html
  List of Certified Inverters: http://www.energy.ca.gov/greengrid/certified_inverters.html
  California Energy Commission, 1516 9th Street, Sacramento, CA 95814-5512, 800-555-7794 (Renewable Energy Call Center)
UL Standard 1703, Standard for Flat-plate Photovoltaic Modules and Panels
UL Standard 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems
IEEE Standard 929-2000, Recommended Practice for Utility Interface of Photovoltaic (PV) Systems
IEEE Standard 1262-1995, Recommended Practice for Qualification of Photovoltaic (PV) Modules