Wealth Creation in Rural Communities

# Harnessing the Sun as an Alternative Energy Resource:

## Economic and Social Impacts of PV Use in Electricity Production

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## Wealth Creation in Rural America

This report is part of the Wealth Creation in Rural America initiative, funded by the Ford Foundation. The aim of the initiative is to help low-wealth rural areas overcome their isolation and integrate into regional economies in ways that increase their own-ership and influence over various kinds of wealth. The initiative has produced nine previous papers, which can be found at http://www.yellowwood.org/wealthcreation.aspx. The goal of this report is to advance the initiative's broad aim of creating a comprehensive framework of community ownership and wealth control models that enhance the social, ecological, and economic well-being of rural areas.

## Author

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# Introduction

The need for alternative energy sources is becoming increasingly apparent for a host of reasons: saving the environment for future generations, decreasing home energy to afford warmth and comfort in the winter, decreasing dependence on foreign oil for national security and other national interests, allowing suburban residents to continue working five-day weeks, or elevating the standard of living for impoverished families in America. It's clear that a paradigm shift is necessary if Americans are to sustain their standards of living through their use of energy.

Photovoltaics (PV), or using the energy from the sun to create electricity, can provide an exceptional amount of electricity while decreasing fossil fuel demand and having zero negative direct effects on the environment. The U.S. receives far more energy from the sun in one day over its total land area than it consumes. How do we best capture and utilize this resource? Here, the current state of the PV technology industry and PV workforce training and demand are examined, followed by a case study of a successful workforce development program.

# One Size Does Not Fit All (or Fit All Needs): Economic Impacts

PV technology currently uses systems that require heavy subsidization with rebates and incentives to realize financial returns. Further, the range of electric utility rates across the nation makes PV systems extremely economically feasible in some locations and not in others. FindSolar's My Solar Estimator[1] offers a quick estimate of the cost of a PV system and the estimated return based upon an individual's electricity consumption. The estimator is easily configurable for many different PV systems and options.

The Solar Estimator first asks for the user's location in order to calculate costs based on the solar irradiance (a measure of energy from the sun usually in watts per square meter) in the specified location. The user is then asked to indicate the utility company used and one of three measures of electricity consumption: annual electric bill in dollars, annual kilowatts hours of electricity used, or seasonal electric bill. With this information the system calculates PV system size, estimated purchase cost, and savings and benefits from a PV system purchase, including return on investment and number of years to breakeven.

As an illustration, let's look at a residence that uses 8000 kWh annually in State College, Pennsylvania, and a similar one in Richmond, California. The electric utilities used were Allegheny Power (Pennsylvania) with an average per kilowatt-hr rate of $0.07/kWh and Pacific Gas & Electric (California) with an average rate of $0.1647/kWh. (Both rates are from September 2008.)

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1. My Solar Estimator. *FindSolar*. Accessed on September 24, 2008 <http://www.findsolar.com/index.php?page=rightforme>

The payback period for the Pennsylvania system is 28–47 years with no property value appreciation. The period for the California system is only 5–10 years. With property value appreciation, the periods become 21–40 years and less than 1–3 years for the Pennsylvania and California systems, respectively. These major differences in payback periods occur for a number of reasons, all of which must be carefully considered when determining the financial feasibility for a PV installation.

One major factor is location-specific. Due to solar irradiance in California, the recommended system size is smaller and lower cost, since fewer panels must be installed to cover the same portion of electricity consumption. A second major factor is the price per kWh of electricity. The monthly electric bill in California is more than twice that in Pennsylvania, and thus monthly savings from the system differ greatly. This situation alone can double the payback period of a similarly sized system. Third, the increase in property values due to PV system installation is assumed to be greater in California because the system savings will be greater there, assuming current rate trends are maintained. For the system in Pennsylvania, the upper threshold of the property value increase is $7,775, while it is $23,781 in California.

Both systems are eligible for a federal tax credit of up to $2,000. The incentive-based difference between the two systems may be found at the state level. The expected California state rebate for the proposed system is $4,750. These two credits bring the already less expensive California system down from $24,210 to $17,460. At the moment, the Pennsylvania system, when used in concert with the aforementioned utility, does not qualify for other rebates or incentives beyond the federal tax credit. This brings the cost of the 3.57 kW Pennsylvania system down to $30,130. Different rebates and potential cost savings programs may be found in both states and should be investigated on a case-by-case basis.[2]

In summary, the system in Pennsylvania is more expensive because: (1) the lower solar irradiance requires a bigger system that is more expensive to install; (2) there are very few incentives/rebates for the larger system, which does not help subsidize the financial burden; and (3) purchase of the system will not result in a large property value increase, since the savings will be minimal due to the relatively inexpensive utility rate of $0.07 /kWh. (There's more information about these FindSolar results in the Appendix.)

## COST REDUCTION AND INCREASED BENEFITS

The conversation about alternative energy today includes talk about incentives, which are available for photovoltaics at the utility, state, and national levels.

2. The incentive calculator for California can be found at the California Solar Initiative website: http://www.gosolarcalifornia.ca.gov/. Other programs in Pennsylvania exist, such as the Solar Energy Buy-Back Program: http://www.theenergyco-op.com/solarpower.htm.

These incentives and rebates can be leveraged against the cost of installing solar systems—and should be included in the decision-making process when evaluating the financial feasibility of a system purchase. The different types of utility rates and metering options as well as buy-back programs should also be considered. Here, we look at the different types of incentive programs as well as utility rates and metering options. Please note that the following information generally applies only to grid-tied PV systems.

## FORMS OF INCENTIVES

There are three basic forms of PV incentives: federal/state tax credits, state or utility subsidy programs, and performance-based incentives or feed-in tariffs. The best source of information on state and federal incentives is the Database of State Incentives for Renewables & Efficiency[3] (DSIRE). This collaborative project between the North Carolina Solar Center and the Interstate Renewable Energy Council is funded by the U.S. Department of Energy. Users of DSIRE may click on any state in the nation or a federal tab, which then provides a list of all incentives in the targeted area with links to explanations.

Incentives are available for various groups such as governments, non-profits, utilities, small-scale generation, businesses, industries, and residences. Some programs offer a one-time rebate/credit. The Residential Solar and Fuel Cell Tax Credit[4] provides $2,000 for solar-electric and water systems and $500 per 0.5 kW for fuel cells. Other programs offer system loans. New Jersey's PSE&G Utility Solar Loan Program offers a 40–60% loan of the cost of the PV system for 10 years at an interest rate of 6.5%. The loan can be repaid in cash or with the signing over of Solar Renewable Energy Certificates (SRECs). After the loan is paid off, the customer has full rights to their SRECs and can sell them at the market value.

Production-based programs that reward an owner/customer per kWh also exist. The NC (North Carolina) GreenPower Production Incentive[5] rewards PV owners by paying them $0.15/kWh from the program and an additional $0.04/kWh from their utility under a power purchase agreement, totaling $0.19/kWh. Another example of this type of incentive is California's Feed-In Tariff [6], which allows customer-generators to sell their generated electricity to the grid at market-based prices.

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3. Database of State Incentives for Renewables & Efficiency (DSIRE), accessed September 30, 2008. North Carolina Solar Center.
4. Residential Solar and Fuel Cell Tax Credit. DSIRE, Accessed August 1 and September 30, 2008. <http://www.dsireusa.org/library/includes/incentive2.cfm?incentive_code=us37f&state=federal&currentpageid=1&ee=1&re=1>
5. NC GreenPower Production Incentive. DSIRE, accessed January 14 and September 30, 2008. <http://www.dsireusa.org/library/includes/incentive2.cfm?incentive_code=nc05f&state=nc&currentpageid=1&re=1&ee=1>.
6. California Feed-In Tariff. DSIRE, Accessed February 28 and September 30, 2008. <http://www.dsireusa.org/library/includes/incentive2.cfm?incentive_code=ca167f&state=ca&currentpageid=1&re=1&ee=1>.

# Job Creation and Support: Social Impacts

The solar industry, specifically photovoltaics, has a great capacity to create and support jobs in manufacturing, education, design, sales, installation, maintenance, auditing, and many other categories. In short, the PV industry has the potential to employ thousands of individuals.

A number of different organizations have done workforce calculations for the photovoltaic and renewable energy industries.[7, 8, 9] The consensus is that there are and will continue to be jobs and job opportunities in varying industry sectors. To capture these opportunities, states have created incentive programs focused on industry growth. There are three such programs in four states located within the Appalachian region. Virginia and West Virginia have the Solar Manufacturing Incentive Grant (SMIG) Program[10]. This program offers a maximum of $4.5 million per year paid at $0.75 per Watt, decreasing over the course of six years, for panels sold in a calendar year. North Carolina has the Green Business Fund [11] to encourage the development and commercialization of "promising" renewable energy and green building technologies. This program provides grants up to $100,000 to businesses with fewer than 100 employees. New York also has similar programs, such as the NYSERDA Renewable, Clean Energy, and Energy Efficient Product Manufacturing and Incentive Program[12] that provide phased payments to manufacturers looking to develop or expand facilities to produce eligible products.

Despite the potential for growth in the industry and numerous training institutions, employers are having trouble finding qualified workers. In California[13] —an example of an already established and successful solar industry—two out of three employers indicate difficulty finding entry-level employees while three out of four mention difficulty finding experienced employees.

*According to the American Solar Energy Society's report,* Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century, *there were 450,000 jobs in renewable energy in 2006. In Navigant Consulting's report,* Economic Impacts of Extending Federal Solar Tax Credits, *an industry analysis conservatively predicted 2,150 MW of PV installations in 2016 with the current tax credit and 24.2 job-years per MW installed. The Solar Energy Industries Association and the Prometheus Institute report,* U.S. Solar Industry: Year in Review, *predicted that there would be 62,000 new jobs in the solar energy industry by 2015.*

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7. R. Bezdek (2007), *Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century*. Boulder, CO: American Solar Energy Society.

8. Navigant Consulting, Inc. (2008), *Economic Impacts of Extending Federal Solar Tax Credits*. Solar Energy Research and Education Foundation. Burlington, MA: Navigant Consulting.

9. *2007 US Solar Industry: Year in Review*. Solar Energy Industries Association and the Prometheus Institute, September 30, 2008. <http://seia.org/galleries/pdf/Year_in_Review_2007.pdf>

10. Solar Manufacturing Incentive Grant (SMIG) Program. DSIRE, accessed November 12, 2007; October 1, 2008. <http://www.dsireusa.org/library/includes/incentive2.cfm?incentive_code=va08f&state=va&currentpageid=1&re=1&ee=1>.

11. North Carolina Green Business Fund. DSIRE, accessed April 3 and October 1, 2008. <http://www.dsireusa.org/library/includes/incentive2.cfm?incentive_code=nc47f&state=nc&currentpageid=1&re=1&ee=1>

12. NYSERDA - Renewable, Clean Energy, and Energy Efficient Product manufacturing and Incentive Program. DSIRE, accessed September 10, 2007; October 1, 2008. <http://www.dsireusa.org/library/includes/incentive2.cfm?incentive_code=ny41f&state=ny&currentpageid=1&re=1&ee=1>

13. *California's Solar Industry & Workforce Study Key Findings, 2008. Centers of Excellence*. California Community Colleges, accessed October 10, 2008. <http://coeccc.net/solar/>

When employers in California were asked to describe the preferred educational background of employees, 58% indicated that installers should have primarily work experience and no degree. However, when asked about their interest in community college programs, 88% were interested in a certificate program for entry-level installers and 83% cited interest in a 2-year degree program. Clearly, those community colleges that offer long- and short-term educational programs with on-the-job training will be able to provide the number and quality of workers needed by this growth industry.

*Countless job opportunities exist in the PV industry. The broad job categories include manufacturing parts, assembling the panels, installing the panels, and maintaining and repairing the systems. These broad categories can be broken down into smaller jobs carried out by many different skilled laborers, such as roofers, electricians, and sheet metal workers. PV system utilization is the most labor-intensive technology of all other renewables per MW installed.*

## Training

### JOB OPPORTUNITY ➠ NECESSARY TRAINING

Countless job opportunities exist in the PV industry. The broad job categories include manufacturing parts, assembling the panels, installing the panels, and maintaining and repairing the systems. These broad categories can be broken down into smaller jobs carried out by many different skilled laborers, such as roofers, electricians, and sheet metal workers. PV system utilization is the most labor-intensive technology of all other renewables per MW installed.[14]

The implementation of these systems requires sales people capable of communicating the benefits of PV use as well as performing energy audits to identify opportunities to increase energy efficiency (a valuable step before moving forward with a PV system). Calculations must be performed to determine system feasibility, financing options, and potential gains. The system can then be carefully designed on a site-by-site basis to ensure productivity and efficiency. Once designed, the system must be properly installed by well-trained individuals knowledgeable about general construction practices, structural roofing requirements, and electricity. Finally, the system may need to be maintained, potentially creating system maintenance positions. Let's take a look at the different post-manufacturing and assembly jobs, focusing primarily on the needs for and skills of a system installer since this step is exceptionally complex and can be quite dangerous.

**General Building Practices.** Prospective laborers in the PV industry must first learn all about basic building and construction. Skills needed include basic math, blueprint reading, carpentry, hand and power tool operation, and construction-site awareness/safety. These skills can be obtained via a few different routes, such as high school "shop"-type classes, on-the-job training for young apprentices, or pre-apprenticeship training programs such as RichmondBUILD.

14. *Community Jobs in the Green Economy*. Apollo Alliance and Urban Habitat. Accessed June 20, 2008 <http://www.apolloalliance.org/downloads/resources_community_jobs_in_the_green_economy.pdf>.

**Photovoltaic System Implementation.** Photovoltaic system implementation involves marketing and sales, siting and designing, installation, and maintenance; all of which utilize different skill sets. The person who sells a system is often not the person who installs it on the roof. While some individuals may be capable of attaining all the skills and knowledge needed to educate, design, install, and maintain a system, training individuals to perform specific tasks and developing an integrated approach can be achieved faster and with less investment in human capital.

**Marketing and Sales.** Selling a PV system is no simple task. Anything with large initial capital costs and extended payback periods is a tough sell. Many factors must be considered to determine customer needs and desires, final component price, total installed system cost, and final rate of return to the customer. The person or team responsible for marketing and selling systems must know the local market, including incentives and metering practices, available technology and specific benefits related to each technology, and differences between stand-alone and grid-tied systems (including the purpose and feasibility of each). The team typically includes one person who helps the customer determine their specific system goals and which technologies would be the most suitable, and a project estimator who is familiar with proposed technologies and the costs of materials and manpower to implement them.

Different marketing approaches can be used to gain customer recognition and interest, including face-to-face, telephone, mail, Internet, press, radio, or TV advertising. Effective marketing usually involves a careful balance of marketing mediums and commitments that would be best determined by someone familiar with and experienced in both marketing strategy and PV products.

It's also possible to attract business through certifications and search databases. Websites such as the North American Board of Certified Energy Practitioners[15] appear at the top of a Google search when looking for solar installers. This website provides a map interface to search for installers who have completed the necessary steps to receive a NABCEP certification. Getting on this list is a sure-fire way to increase your market presence.

**Siting and Designing.** Properly determining the location and size of a PV system is not a simple task. Many factors must be taken into consideration. It should be noted that grid-tied systems are slightly easier to design and implement, as the utility grid functions as a large, relatively inexhaustible, back-up power generator.

Designing a system involves a site survey and shading analysis, sizing and balancing of components, mounting and building integration, as well as

15. Find Certified Installers. North American Board of Certified Energy Practitioners, accessed August 26, 2008. <http://www.nabcep.org/map.cfm?normalflag=yes>.

## RichmondBUILD

*The RichmondBUILD Pre-apprenticeship Construction Skills and Green Jobs Training Academy was first developed to create employment and career opportunities for Richmond residents and to implement a violence-reduction strategy in the community. Established in 2007, it quickly become a model of an effective and broad public / private partnership focused on developing talent and skills in the construction and renewable energy fields.*

*The 14-week intensive program includes training in safety, first aid / CPR, power tools, framing, sheet rock, basic electrical, roofing, scaffolding, basic plumbing, basic welding, eco literacy, energy efficiency and solar installation training.*

*To date, RichmondBUILD graduates have a 90% placement rate with an average wage of $18.33/hour.*

*For more information, visit: http://www.ci.richmond.ca.us/index.aspx?nid=1243* financial/incentive considerations.[16, 17] The site survey and shading analysis are necessary to ensure maximum solar irradiance and minimal shading of the panels. This includes determining the orientation of the panels relative to solar noon. Generally, south-facing panels are preferred; however, many considerations can result in a non-south orientation. The mounting angle from horizontal (horizontal is sometimes preferred) depends upon time of year and site latitude. For example, if the system is mounted on a seasonal residence, such as a summerhouse, fall hunting shack, or winter ski cabin, the system should be optimized for maximum production during time of use. Also, if the system is grid-tied and in a region with varying electricity rate structures based upon peak utility rates, a system could be oriented for maximum production during peak utility rates. This of course depends upon whether the system is utilizing an energy storage system.

In the shading analysis, the duration and type of shading that will fall on the mounted array are determined using a variety of methods, including a site plan and sun path diagram, sun path diagram on acetate, or a shading analyzer such as a digital camera and accompanying software or the Solar Pathfinder. These tools allow the designer to determine the shadow outline for a given site. This outline must be analyzed with a full year in mind, taking into account the varying angles of the sun, growth of new flora, stages of coniferous and deciduous trees, as well as new construction.

The sizing and balancing of components differs for each system. Proper system size is determined by a series of decisions and types of information: stand-alone or grid-tied, energy demand, load separation, percent of load to be covered by PV, energy storage, and seasonal demand. Components in a given PV system may include the PV cells themselves, batteries or another storage mechanism, a charge controller, an inverter, a back-up generator, and a system control mechanism—all have very precise yet varying specifications that must be in perfect balance for the system to function efficiently.

**Installation.** The physical installation of the PV system has three basic phases: mounting system and roof considerations; module fixing and external wiring; and internal wiring and component set-up, such as inverters, charge controllers, and batteries. Note that installation basics described here pertain primarily to an additive, grid-tied PV system. This means that the panels are attached as a super-structure and function solely to produce electricity. They are not used for weatherproofing, heat insulation, or sun shading. Furthermore, the system utilizes a grid-tied inverter and thus does not utilize charge controllers or batter banks—both of which further complicate installation procedures.

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16. R. Messenger and J. Ventre (2000), *Photovoltaic Systems Engineering*. Boca Raton, FL: CRC P.

17. *Planning and Installing Photovoltaic Systems: A Guide for Installers, Architects and Engineers.* Detroit, MI: Earthscan/James & James, 2008.

Many considerations and techniques are involved in properly mounting an array to a roof. There are many different roof shapes, such as ridge, mansard, mono-pitched, and flat. There are also different types of roof construction, such as rafter, collar beam, truss, or flat. To further increase the number of considerations, there are numerous roofing materials such as tiles, concrete, shingles, sheets, slate, corrugated panels, flat panels, liquid plastics, etc. Proper mounting of the rails requires an understanding of the roof material and possibly consultation with a structural engineer when dealing with loading and/or making changes to a truss roof. Roof penetrations must be carefully executed, especially when dealing with steel or flat roofs due to the difficulty in maintaining a waterproof seal.

Load considerations include wind-related pushing and pulling, the weight of the modules and rails, and snow. The gap between the modules and the roof may not be overly large or the modules excessively close to the edge of the roof so that wind can be easily caught beneath the panels. However, the gap must be sufficient to allow adequate ventilation for cooling and not trap leaves and debris that would prevent rain shedding.

Due to the intended longevity of PV systems, corrosion resistance is also a large concern when considering mounting hardware. It is important to use high-quality aluminum and/or stainless hardware and compatible metals. For example, do not use brass screws on galvanized rails, hooks, or clips. Also, UV-resistant equipment such as conduit, junction boxes, and wire ties must be used.

Special care must be taken when dealing with DC installations, specifically solar. The moment the panel comes out of the box it is “live”, producing DC current and voltage. The more panels that are plugged together in series, the more voltage is produced. Residential installations can be upwards of 600 volts while commercial/industrial systems can reach 1,000 volts. The combiner box, which takes the series wired strings and combines them into parallel arrays in order to increase the current, can be exceptionally dangerous if proper wiring techniques and devices are not used.

Due to the intrinsically live nature of PV arrays certain wiring procedures and devices must be used. DC current can produce a permanent arc so the installation must be grounded and fault- and short-circuit-proof. Only cable connectors, fuses/circuit breakers, and disconnect switches specifically rated for DC current should be used. It is also important to use the DC disconnects for load switching, as disconnecting module cables or working with the DC main cable under load can be hazardous. Furthermore, polarity and energy flow direction must be correct when dealing with circuit-breaking devices to ensure proper functionality and protection.

# Maintenance and Troubleshooting

Photovoltaic systems, especially grid-tied, are designed to be a “set it and forget it technology,” sitting on your roof quietly producing power and decreasing your electricity bill. However, maintenance procedures should be periodically carried out to maximize system performance and minimize potential hazards and downtimes. See the Appendix for periodic maintenance, upkeep, and troubleshooting suggestions.

## TRAINING INSTITUTIONS

Employment in the photovoltaic industry requires different skills and abilities. Similarly, an individual can take numerous avenues receive training necessary to participate within the green sector. Installing photovoltaics is a multidisciplinary. multifaceted task that involves roof sealing, structural engineering, electrical wiring, and data collection and analysis. For this reason, certificate programs, such as those offered by community colleges and NABCEP, focus primarily on the mechanics of installation and design. Next, we look at solar and renewable education as offered via trade unions and organizations, community college degrees and certification programs, universities, and workforce development organizations such as Solar Richmond. (See the Appendix for examples of programs discussed here.)

## TRADE UNIONS

The National Electrical Contractors Association (NECA) in collaboration with the International Brotherhood of Electrical Workers (IBEW) and its National Joint Apprenticeship & Training Committee (NJATC) offer solar training and workshops in addition to and within its traditional training programs.

The NJATC offers a few different courses related to PV systems.

Via this training, union electricians learn to deal with any electrical system, including photovoltaics, and the highest quality and workmanship levels. The core training of a union electrician can take over four years and includes much information not directly related to PV or green construction.

## COMMUNITY COLLEGES

Numerous certificate and degree programs in community colleges focus on renewable energy and PV installation. For example, Owens Community College in Toledo, Ohio, offers a 40-hour PV training course open to anyone interested in PV installation. The program includes: system sizing and construction, codes and standards, siting and design, battery safety, interconnection safety, troubleshooting, and maintenance. It concludes with discussion about the requirements for taking the entry level NABCEP certification exam. AOS and

### INSTALLING GRID-CONNECTED PHOTOVOLTAIC SYSTEMS

***Cost:*** *$495*

***Duration:*** *3.5 day(s)*

***Description:*** *Goal is to develop “system knowledgeable” professionals who can ensure the safety and quality of PV system installations. Course format includes both classroom instruction and a high level of participant-interactive exercises. Exercises involve complete step-by-step process of designing, installing, and commissioning grid-connected PV systems, and develop working knowledge of PV systems and equipment.*

### PHOTOVOLTAIC SYSTEMS

***Cost:*** *$550*

***Duration:*** *4 day(s)*

***Description:*** *Course provides overview of photovoltaic systems; open to contractors, journeymen, instructors and apprentices. Topics include an overview of PV systems and applications, solar resource and site assessments, system design and installation, and operations and maintenance.*

### SOLAR PHOTOVOLTAIC SYSTEMS FOR CONTRACTORS

***Cost:*** *$250*

***Duration:*** *2 day(s)*

***Description:*** *16-hour course targeted to electrical contractors and journeymen and focused on business opportunities in solar photovoltaic (PV) system installations. Topics include overview of PV systems and equipment; markets and applications; customer development and site surveys; requirements for contracting and installing PV systems; taking advantage of financial incentives and achieving industry certifications; and other resources.*

AAS degree programs are offered by community colleges. These include the Photovoltaic Installation Certificate program at Hudson Valley Community College; the Energy Management Technician program with a Renewable Energy Technician option at Lane Community College; and the Renewable Energy Technology program with either a solar thermal or photovoltaic specialty at Red Rocks Community College. All of these programs involve at least some level of renewable energy theory and construction skills.

## HIGHER EDUCATION INSTITUTIONS

Universities across the nation are consistently adding renewable energy classes and programs to their catalogues. Some universities offer continuing education (CE) credit courses while others are now offering full degrees either related to or specifically about renewable energy. For example, the University of Central Florida and its Florida Solar Energy Center (FSEC) offers a 40-hour continuing education course entitled "Installing Photovoltaic Systems". This course is open to contractors, electricians, utility supervisors, and engineers interested in PV installation. It is has a classroom section as well as a hands-on lab component and covers the basics of PV installation for both grid-tied and independent systems. Attendees receive a certificate of completion from the FSEC at the end of the week.

North Carolina State University also offers a five-day continuing education credit course for architects, builders, electricians, businesspersons, engineers and students, entitled "Renewable Energy Technologies (IV)". Upon completion attendees are prepped for the optional NABCEP entry-level PV installer's exam and students receive credit towards their degree program. Other universities have also started renewable Bachelor of Science degree programs, such as those available at The Pennsylvania State University (Energy Engineering) and the Oregon Institute of Technology (Renewable Energy Engineering). These are intended to be four-year degree programs that include a core education based upon the natural sciences and engineering principles.

## WORKFORCE DEVELOPMENT ORGANIZATIONS

Several organizations now focus specifically on providing pathways out of poverty through green construction and photovoltaics. Solar Richmond[18], in Richmond California, is a green-collar job training organization that provides a two-week solar installation-training program in collaboration with its partners, RichmondBUILD and GRID Alternatives. Training begins with individuals receiving basic construction training through RichmondBUILD and ends with the two-week PV-specific training.

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18. "What We Do." *Solar Richmond*. Accessed September 2, 2008 <http://www.solarrichmond.org/id47.html>

While workforce development organizations may not have the furthest reach or greatest number of participants, their impact is immediately felt for at least two reasons. First, their target audience is generally underprivileged individuals who greatly benefit from the training and work experience. So far, Solar Richmond has placed sixteen individuals into the workforce and installed over fifty kilowatts of photovoltaics on low-income properties. Second, they provide low-cost solar installations with free labor for qualified low-income homeowners. This allows more money to remain within the community while helping its members by decreasing their utility bills.

## WORKFORCE SAFETY

Photovoltaic systems differ from traditional residential electrical systems primarily by operating with direct current (dc) as opposed to alternating current (ac). This may make the system unfamiliar to some contractors and especially to the average homeowner/do-it-yourselfer. The systems are energized immediately upon exposure to light and may have numerous energy sources. A brief elaboration of considerations for safe and effective PV systems may be found in the Appendix.

Typical electrical systems are installed by electricians who are extensively trained in the practical application of safe electrical practices required by local and national codes. Non-contractor PV engineers often do not possess detailed knowledge of these practices. Thus, either a team of specialized individuals designs and installs the system or one highly trained individual oversees the entire project. This training is generally only available to those individuals with practical electrical experience as well as additional PV system education.

## LICENSING, ACCREDITATION AND CERTIFICATION

According to the National Electrical Contractors Association, due to the high voltage present in PV systems, they should only be installed and serviced by fully trained and licensed electricians. Roofers will argue that due to the penetrations often necessary to properly secure an array, only someone trained in maintaining a weatherproof barrier should mount the system. Furthermore, due to the inefficient operation of an improperly installed system, rebate programs such as those in California require that the system be installed and certified according to certain guidelines. Some rebate programs, such as the Power Saver Program[19] offered by Austin Energy in Austin, Texas, could require that the system be installed by a NABCEP certified installer. California's Solar Initiative program also recommends that NABCEP installers install the PV systems.

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19. Registered Installer Requirements. *Energy Efficiency*. Austin Energy. Accessed September 2, 2008 <http://www.austinenergy.com/energy%20efficiency/programs/rebates/solar%20rebates/installerresources.htm>

The Interstate Renewable Energy Council (IREC) provides Institute for Sustainable Power Quality[20] (ISPQ) accreditation as a third party for renewable energy courses. This standard was developed by the Institute for Sustainable Power (ISP). Some of the key points of its accreditation program may be found in the Appendix. The task analysis used by IREC is the PV Task Analysis[21] designed by NABCEP (see Appendix for the complete Task Analysis). The analysis outlines the skills and abilities that an individual must possess in order to safely and completely install and maintain a PV system. These tasks are targeted to the system installer rather than the designer, however. Therefore, further education beyond all tasks covered in this analysis is necessary to be a full PV integrator. A listing of accredited programs is available on the IREC website.[22]

Certification and accreditation are voluntary at this time since a PV installer license is not required by national law. This does not mean that program accreditation or individual certification is not valuable or useful. Electrical licenses are only recognized at the state level. While a nationally recognized PV license is unlikely in the immediate future, third-party accreditation is a valuable tool for determining the quality of education offered by a specific program or institution.

## Solar Richmond (Richmond, CA): A Case Study

Solar Richmond, in Richmond, California, has been created to provide community members with pathways out of poverty. In partnership with RichmondBUILD, the Solar Living Institute, and Grid Alternatives, this program educates students in general construction practices as well as PV installation. Its goals include creating 100 new green-collar jobs, installing 50 solar systems for low-income homeowners and a total installed capacity of 5 MW by 2010.

The program has five basic thrusts.

**1. Solar Installation Training**

- A two-week long, PV-specific training program is offered in addition to construction training received from RichmondBUILD.

**2. Low-Income Solar**

- Grid Alternatives helps to facilitate the provision of low-cost PV installations for qualified low-income homeowners.

### SOLAR RICHMOND:

*Successfully Creating Employment and Business Opportunities in Renewable Energy*

*Solar Richmond, in partnership with RichmondBUILD, the Solar Living Institute, and Grid Alternatives, educates students in general construction practices as well as PV installation. Its goals include creating 100 new green-collar jobs, installing 50 solar systems for low-income homeowners and a total installed capacity of 5 MW by 2010.*

*The program has five main thrusts:*

- *Solar Installation Training*
- *Low-Income Solar*
- *Advocacy and Policy*
- *Solar Promotion*
- *Internship Program*

*For more information: http://www.solarrichmond.org/id47.html*

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20. ISPQ Training Accreditation. *IREC Programs*. Interstate Renewable Energy Council. Accessed September 11, 2008 <http://www.irecusa.org/index.php?id=25>

21. PV Task Analysis. North American Board of Certified Energy Practitioners. Accessed September 11, 2008 <http://www.nabcep.org/pvtaskanalysis.cfm>.

22. This page contains a listing and further links to the ISPQ-accredited programs and individuals: http://www.irecusa.org/index.php?id=91

- The system is installed at no cost to the homeowners through free labor provided by Solar Richmond members.
- In addition to the low-cost system, homeowners receive deferred low-interest loans through the City of Richmond Redevelopment Agency, which require payment only upon the sale of the home.
- The PV system also creates substantial savings on the homeowner's electric bill due to the effectiveness of PV in California.

**3. Advocacy and Policy**

- Work with the city officials to help create policy that brings the advantages of the green economy to Richmond.
- Secure no-permit costs for all Richmond residents.
- Secure favorable loans specifically for low-income homeowners.
- Work to get the City Council to pass a resolution to install 200kW of PV on City Hall.

**4. Solar Promotion**

- Participate in Richmond's annual Earth Day
- Provide Richmond Solar Homes Tours, which are part of the annual ASES national tour.

**5. Internship Program**

- Provide immediate, paid opportunities for graduates to receive further on-the-job training
- Ten-week paid internships are available with local solar companies and bridge training to permanent employment.

As of August 2008, sixteen graduates had been placed into the workforce. Some were very successful, while others stayed briefly and then moved on. In order to continue finding jobs for graduates, an internship program was created. The paid internship program gives solar companies the opportunity to work with the graduates in the field. This allows the less articulate population coming from the program to compete with college and university graduates for the same positions. The interns' pay comes from donations made to the Solar Richmond program. In addition to providing the 10-week internship, Solar Richmond assigns a case manager to help individuals stay focused and on track. The case manager also helps graduates prepare resumes and compete in the growing green-collar job market.

It should be noted that the Solar Richmond program is not completely financially self-sufficient. The systems being installed at residential locations are almost zero cost due to funding, donations, and partnerships. The homeowners are unable to afford the systems and the labor is free as part of the training. This means that the installers from the program are not paid for their work (unless they are involved in the paid internship program) and herefore are not receiving income. It is not until a graduate finishes the program and is hired by a PV integrator that the program comes full circle and provides a sustainable living wage for the participants. Further, this particular program does not completely train individuals for PV work—it is simply a start. The 2-week PV training is far from being as detailed and technically advanced as a longer-term degree or trade school program. However, program graduates receive significant practical application skills through on-the-job training.

## Summing Up

This examination of the photovoltaic industry and corresponding educational institutions uncovered a few key findings. The industry is evolving so rapidly that it very difficult to determine current best practices as newly honed programs are developed almost daily. However, certain elements have proven successful.

**Importance of System Location and Type.** The location and type of the PV system is important, but not for the obvious reasons. While the power of the incident sun on a given location does change, it does not determine whether PV will work in that location. The most important factors are electricity cost and types of incentives available. In areas such as California, for example, where electric rates can be over twenty cents per kilowatt-hour, PV is far more feasible than in locations that utilize inexpensive coal generation (environmental costs aside). A grid-tied system will most likely be the most effective way to implement PV with current technology because the grid can function as an always available, super-efficient battery with no installation cost, no maintenance, and no degradation from cycling. A grid-tied system is only effective as a money-saving versus environment-saving device when net-metering is available. Also, time-of-use metering can further increase system-related benefits.

**Incentives.** When identifying and assessing incentives, it is apparent that local incentives are currently the most effective in decreasing the cost of installing a PV system. However, these high-paying incentives only exist in limited locations across the nation. To maximize their utility, production-based incentives such as feed-in tariffs should be used to reward the system for its positive environmental impact over its useful lifetime.

**Workforce Training.** When examining potential training programs and institutions for the PV workforce, different strengths and weaknesses emerge. For individuals tasked with installing a system, practical experience is critical—this is where community colleges, technical schools, and programs such as Solar Richmond shine. However, these programs do not always go into as much depth and are not as technical as those to which university degrees are attached—and such training can be necessary for system design and engineering. Further, programs that include energy efficiency and other renewable energy education maximize the marketability of graduates.

The duration of a program can also be a good measure of the level of training and experience to be received by graduates. A weekend or single-week course may be an effective way to introduce PV installation to someone without previous experience but it will certainly not produce a fully competent system integrator. An individual capable of designing and installing a system by themselves will need years of extensive training and an aptitude for such tasks. Use of blended crews, as occurs with Solar Richmond, allows for low-cost system integration while maintaining high-quality installations. An ideal team would include a university-trained system engineer, community college-educated project managers and foremen, trade-union master electricians, and workforce development organization trained laborers.

Finally, programs should target at-risk individuals for training, low-income areas for system implementation, and proper locality to maximize system effectiveness and incentives. In addition, a quality measure of individuals and programs should be done through the development of national certification and accreditation processes, similar to that found in electrical licensing (which is still only at the state level), and university accreditation.

# Appendix A1

## FINDSOLAR.COM SOLAR ESTIMATOR RESULTS FOR THE 8,000 KWH PENNSYLVANIA SYSTEM

Building Type: .......... Residential

State & County: .......... PA—Centre

Utility: .......... Allegheny

Utility Type: .......... Investor-Owned Utility

*Assumed Average* Electric Rate: .......... $0.07/kWh
Please check against your bill

*Assumed* Average *Monthly* Electricity Usage: .......... 667 kWh/Month
Please check against your bill

Your Average *Monthly* Electricity Bill: .......... $47/Month
(Assumed rate x average monthly usage)

Tiered Rates Apply: .......... Yes

Time-of-Use Metering Offered: .......... Yes

Net-Metering Available: .......... Yes

**ESTIMATED SYSTEM SIZE**
The system size best for your situation will vary based upon product, building, geographic and other variables. We encourage you to work with a Solar Pro who can better estimate the system size best for your situation. We estimate your building will need a system sized between 2.86 kW and 4.28 kW of peak power. This estimate assumes the mid-point of this range.
Solar Rating: .......... **Good**
4.21 kWh/sq-m/day

Solar System Capacity Required: .......... 3.57 kW of peak power (DC watts)

Roof Area Needed: .......... 357 sq. ft.

**ESTIMATED SYSTEM COST**
This is only an estimate based upon many assumptions. Installation costs can vary considerably. We encourage you to work with a Solar Pro who can provide you with a more detailed cost estimate. We estimate that a 3.57 kW peak power system will cost between $25,704 and $38,556. This estimate assumes the mid-point of this cost range.

Assumed Installation cost: .......... $32,130
(before rebates, incentives or tax credits). assuming $ per watt DC

Expected Allegheny Utility Rebate: .......... ($ 0 )

Expected PA State Rebate: .......... ($ 0 )
State incentive does not apply to this utility

PA State Tax Credit/Deduction .......... ($ 0 )

Federal Tax Credit: .......... ($2,000)
(Installation type: Residential)

Income Tax on Tax Credit: .......... $ 0

**YOUR ESTIMATED NET COST: .......... $ 30,130**

Monthly Payment (6.5% APR, 30 years): .......... $190

**SAVINGS & BENEFITS**
**Increase in Property Value: .......... $4,600–$7,775**

Exempt from Property Tax: .......... No

Accelerated (5 yr) Depreciation: .......... No
(Installation type: Residential)

First-Year Utility Savings: ........................................................................... **$230–$389**
Since this is not a business application, these savings are in after tax dollars. So, your realized savings may actually be higher!

**Average Monthly Utility Savings:** ................................................................. **$32–$54**
(over 25-year expected life of system)

**Average Annual Utility Savings:** ............................................................... **$386–$652**
(over 25-year expected life of system)

**25-year Utility Savings:** .................................................................. **$9,651–$16,312**

**Return on Investment (ROI):** ........................................................................... **72%**
(with *Solar System* avg. cost set as asset value)

**Return on Investment (ROI):** .................................................................... **85%–97%**
(with system cost less *property* appreciation set as asset value)

**Internal Rate of Return (IRR):** ...................................................................... **0%–0%**

**Years to Breakeven:** ............................................................................ **21–40 years**
(I*ncludes* property value appreciation)

**Years to Breakeven:** ............................................................................ **28–47 years**
(Assuming *no* property value appreciation)

**Greenhouse Gas (CO2) Saved:** .................................................................... **82.0 tons**
*over 25-year system life* **164,000 auto miles**

# Appendix A2

## FINDSOLAR.COM SOLAR ESTIMATOR RESULTS FOR THE 8,000 KWH CALIFORNIA SYSTEM

Building Type: ........ Residential

State & County: ........ CA–Contra Costa

Utility: ........ Southern California Edison Co

Utility Type: ........ Investor-Owned Utility

*Assumed Average* Electric Rate: ........ $0.1738/kWh
Please check against your bill

*Assumed* Average *Monthly* Electricity Usage: ........ 667 kWh/Month
Please check against your bill

Your Average *Monthly* Electricity Bill: ........ $116/Month
(Assumed rate x average monthly usage)

Tiered Rates Apply: ........ Yes—See Notes, below!

Time-of-Use Metering Offered: ........ Yes—See Notes, below!

Net-Metering Available: ........ Yes—See Notes, below!

**ESTIMATED SYSTEM SIZE**
The system size best for your situation will vary based upon product, building, geographic and other variables. We encourage you to work with a Solar Pro who can better estimate the system size best for your situation. We estimate your building will need a system sized between 2.15 kW and 3.23 kW of peak power. This estimate assumes the mid-point of this range.

Solar Rating: ........ **Great**
5.66 kWh/sq-m/day

Solar System Capacity Required: ........ 2.69 kW of peak power (DC watts)

Roof Area Needed: ........ 269 sq. ft.

**ESTIMATED SYSTEM COST**
This is only an estimate based upon many assumptions. Installation costs can vary considerably. We encourage you to work with a Solar Pro who can provide you with a more detailed cost estimate. We estimate that a 2.69 kW peak power system will cost between $19,368 and $29,052. This estimate assumes the mid-point of this cost range.

Assumed Installation cost: ........ **$24,210**
(before rebates, incentives or tax credits). assuming $ per watt DC

Expected Southern California Edison Co. Utility Rebate: ........ ($ 0 )
(Limited to not exceed state max. incentive amount)

Expected CA State Rebate ........ ($4,750)
For updates Click Here
($2.18/watt installed)
(Maximum: $220,000)

CA State Tax Credit/Deduction ........ ($ 0 )

Federal Tax Credit: ........ ($2,000)
(Installation type: Residential)

Income Tax on Tax Credit: ........ $ 0

**YOUR ESTIMATED NET COST:** ........ **$17,460**

Monthly Payment (6.5% APR, 30 years): ........ $110

**SAVINGS & BENEFITS**
**Increase in Property Value:** ........ **$12,060–$23,781**

Exempt from Property Tax: ........ YES

Accelerated (5 yr.) Depreciation: ................................................................................ No
(Installation type: Residential )

First-year Utility Savings: ............................................................................ $603–$1,189
Since this is not a business application, these savings are in after tax dollars. So, your realized savings may actually be higher!

**Average Monthly Utility Savings:** ............................................................... **$84–$166**
(over 25-year expected life of system)

**Average Annual Utility Savings:** ....................................................... **$1,012– $1,996**
(over 25-year expected life of system)

**25-year Utility Savings:** ................................................................. **$25,303–$49,895**

**Return on Investment (ROI):** .......................................................................... **359%**
(with *Solar System* avg. cost set as asset value)

**Return on Investment (ROI): ............................................................ 1,160%–991%**
(with system cost less *Property* appreciation set as asset value)

**Internal Rate of Return (IRR):** .................................................................... **7%–15%**

**Years to Breakeven:** ................................................................................ **< 1–3 years**
(*Includes* property value appreciation)

**Years to Breakeven:** .................................................................................. **5–10 years**
(Assuming *no* property value appreciation)

**Greenhouse Gas (CO2) Saved:** .................................................................... **82.0 tons**
over 25-year system life **164,000 auto mi**

# Appendix A3

## THE INTERSTATE RENEWABLE ENERGY COUNCIL (IREC) "CONNECTING TO THE GRID" PROJECT: STATE AND UTILITY NET-METERING RULES, REGULATIONS AND PROGRAMS (UPDATED DECEMBER 2007)

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Arizona - Arizona Public Service | 100 kW / All customers | Solar, Wind, Biomass | 15 MW | Credited at retail rate to customer's next bill; granted to utility at end of calendar year | (Utility guidelines) | Arizona Public Service |
| Arizona - Salt River Project | 10 kW / Residential | Photovoltaics | None | Purchased monthly by utility at average monthly market price minus a price adjustment of $0.00017/kWh | (Utility guidelines) | Salt River Project |
| Arizona - Tucson Electric Power | 10 kW / Commercial, Residential | Photovoltaics, Wind | 500 kW peak aggregate | Credited to customer's next bill; granted to utility after January billing cycle | (Utility guidelines) | Tucson Electric Power |
| Arkansas | 25 kW for residential systems; 300 kW for non-residential systems | Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Microturbines | None | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| California | 1 MW (three biogas digesters up to 10 MW per unit may net meter) / Commercial, Industrial, Residential | Photovoltaics, Landfill Gas, Wind, Anaerobic Digestion, Fuel Cells | 2.5% of utility's peak demand | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities[23] |

23. In California, all utilities with the exception of Los Angeles Department of Water & Power (LADWP)—must offer net metering to customers with PV and wind-energy systems. (LADWP offers net metering voluntarily.) In addition, investor-owned utilities must offer net metering to customers with fuel cells and biomass-energy systems.

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Colorado | 2 MW / Commercial, Industrial, Residential | Solar, Landfill Gas, Wind, Biomass, Anaerobic Digestion, Small Hydro, Fuel Cells (Renewable Fuels) | None | Credited at retail rate to customer's next bill; at end of each calendar year, customer reimbursed for NEG at utility's average hourly incremental cost for the prior 12-month period | Yes | Colorado utilities serving 40,000 or more customers |
| Colorado - Delta-Montrose Electric Association | May not exceed customer's measured demand / Commercial, Residential | Photovoltaics, Wind, Biomass, Hydro | 1 MW | Granted to utility monthly | Yes | Delta-Montrose Electric Association |
| Colorado - Empire Electric Association | 10 kW / Commercial, Residential, Nonprofit, Schools, Agricultural, Institutional | Photovoltaics, Wind | 50 customers | Utility pays customer at a rate equal to the average cost of power from the utility's wholesale supplier for that year, excluding wholesale power sold to loads billed under the utility's SCS tariffs | Yes | Empire Electric Association |
| Colorado - Fort Collins Utilities | 10 kW / Residential | Photovoltaics, Wind | 25 customers | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | Fort Collins Utilities |
| Colorado - Gunnison County Electric | 10 kW / Commercial, Residential | Photovoltaics, Wind | 50 customers | Purchased by utility at wholesale rate | Yes | Gunnison County Electric |
| Colorado - Holy Cross Energy | 25 kW / Commercial, Industrial, Residential | Photovoltaics, Wind, Biomass, Hydro, Geothermal | None | Credited to customer's next bill at retail rate; purchased by utility at avoided-cost rate at end of calendar year | Yes | Holy Cross Energy |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Colorado - La Plata Electric Association | 25 kW / Commercial, Residential | Photovoltaics, Wind, Biomass, Hydro | 1% of utility's aggregate customer peak demand | Credited at avoided-cost rate to customer's next bill; utility pays customer for any unused NEG at beginning of each calendar year | Yes | La Plata Electric Association |
| Connecticut | 2 MW / All customers | Solar, Landfill Gas, Wind, Biomass, Fuel Cells, Municipal Solid Waste, Small Hydro, Tidal Energy, Wave Energy, Ocean Thermal | None | Credited to customer's next bill at retail rate; purchased by utility at avoided-cost rate at end of 12-month billing cycle | Yes | Investor-owned utilities |
| Delaware | 25 kW for residential systems; 2 MW for non-residential customers of DP&L; 500 kW for non-residential customers of DEC and municipal utilities | Solar, Wind, Biomass, Hydro, Fuel Cells | 1% of utility's aggregated customer monthly peak demand | Credited to customer's next bill at retail rate; at end of 12-month period, any remaining NEG is granted at the utility's avoided-cost rate to Delaware's Green Energy Fund | Yes (under revision) | All utilities (applies to cooperatives only if they choose to compete outside their limits) |
| District of Columbia | 100 kW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Tidal, Fuel Cells, CHP, Microturbines | None | Credited at retail rate to customer's next bill | Yes | All utilities |
| Florida - Florida Keys Electric Cooperative | 10 kW / Residential | Photovoltaics | None | Credited at retail rate to customer's next bill; purchased by utility at retail rate at end of 12-month period | Yes | Florida Keys Electric Cooperative |
| Florida - JEA | 10 kW / Residential | Photovoltaics, Wind | None | Credited at retail rate to customer's next bill | (Utility guidelines) | JEA |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Florida - Lakeland Electric | 500 kW for commercial systems; 10 kW for residential systems | Photovoltaics | None | Credited at retail rate to customer's next bill; indefinite carryover | (Utility guidelines) | Lakeland Electric |
| Florida - New Smyrna Beach Utilities | 10 kW / Commercial, Industrial, Residential | Photovoltaics | None | Credited at retail rate to customer's next bill | (Utility guidelines) | New Smyrna Beach Utilities |
| Florida - Tallahassee Electric Utility | 10 kW / Commercial, Residential | Photovoltaics | None | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | (Utility guidelines) | Tallahassee Electric Utility |
| Georgia | 100 kW for commercial systems; 10 kW for residential systems | Photovoltaics, Wind, Fuel Cells | 0.2% of a utility's annual peak demand | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| Hawaii | 50 kW / Commercial, Residential, Government | Photovoltaics, Wind, Biomass, Hydro | 0.5% of a utility's annual peak demand | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| Idaho - Idaho Power | 100 kW for large commercial and agricultural; 25 kW for residential and small commercial | Solar, Wind, Biomass, Hydro, Fuel Cells | 0.1% of utility's 2000 peak demand (in Idaho) | Credited to customer's next bill at utility's retail rate for residential and small commercial customers; credited at 85% of utility's avoided-cost rate for large commercial and agricultural customers | (Utility guidelines) | Idaho Power |
| Idaho - Rocky Mountain Power | 100 kW for large commercial and agricultural; 25 kW for residential and small commercial | Solar, Wind, Biomass, Hydro, Fuel Cells | 0.1% of utility's 2002 peak demand (in Idaho) | Credited to customer's next bill at utility's retail rate for residential and small commercial customers; credited at 85% of utility's avoided-cost rate for all other customers | (Utility guidelines) | Rocky Mountain Power |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Idaho - Avista Utilities | 25 kW / Commercial, Residential, Agricultural | Solar, Wind, Biomass, Hydro, Fuel Cells | 0.1% of utility's 1996 peak demand (in Idaho) | Credited to customer's next bill at utility's retail rate; granted to utility at beginning of calendar year with no compensation to customer | (Utility guidelines) | Avista Utilities |
| Illinois - Specific rules developing in Docket 07-0483, opened 9/18/07 | 2 MW All customers | Solar, wind, crops, anaerobic digestion of livestock or food processing waste, fuel cells, microturbines that use renewable fuels, hydro | 0.1% of utility's annual peak demand | 40 kW or less, 1:1 ratio<br>40kW to 2 MW, credited at provider's avoided cost of supply, or as negotiated within a power-purchase agreement.<br>Excess credits expire after 1 year. | (Utility guidelines) | All utilities, except munis and coops |
| Indiana | 10 kW / Residential, Schools | Photovoltaics, Wind, Small Hydro | 0.1% of a utility's most recent peak summer load | Credited at retail rate to customer's next bill | Yes | Investor-owned utilities |
| Iowa | 500 kW / Commercial, Industrial, Residential | Photovoltaics, Wind, Biomass, Hydro, Municipal Solid Waste | None | Credited at retail rate to customer's next bill | No | Investor-owned utilities |
| Kentucky | 15 kW / All customers | Photovoltaics | 0.1% of a utility's single-hour peak load during the previous year | Credited at retail rate to customer's next bill; indefinite carryover | No | Investor-owned utilities, cooperatives |
| Louisiana | 100 kW for commercial and agricultural systems; 25 kW for residential systems | Photovoltaics, Wind, Biomass, Hydro, Geothermal, Fuel Cells (Renewable Fuels), Microturbines (Renewable Fuels) | None | Credited at retail rate to customer's next bill; indefinite carryover | Yes | All utilities |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Louisiana - City of New Orleans | 100 kW for commercial systems; 25 kW for residential systems | Photovoltaics, Wind, Biomass, Hydro, Geothermal, Fuel Cells (Renewable Fuels), Microturbines (Renewable Fuels) | None | Credited at retail rate to customer's next bill; indefinite carryover | Yes | Entergy New Orleans (and any other jurisdictional utilities) |
| Maine | 100 kW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Municipal Solid Waste, CHP, Tidal Energy | None | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | No | All utilities |
| Maryland | 2 MW / Commercial, Residential, Schools, Government | Photovoltaics, Wind, Biomass | 1,500 MW | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| Massachusetts | 60 kW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, CHP, Fuel Cells, Municipal Solid Waste | None | Credited at average monthly market rate to customer's next bill | Yes | Investor-owned utilities |
| Michigan | 30 kW / Commercial, Industrial, Residential, Nonprofit, Schools, Government, Agricultural, Institutional | Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste | 0.1% of a utility's peak load or 100 kW (whichever is greater) | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | Various utilities (voluntary participation) |
| Minnesota | 40 kW / Commercial, Industrial, Residential | Photovoltaics, Wind, Biomass, Hydro, Municipal Solid Waste, CHP | None | Customer receives a check for NEG at the end of each month, calculated at the "average retail utility energy rate" | Yes | All utilities |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Missouri | 100 kW / All customers | Solar, Wind, Hydro | 5% of a utility's single-hour peak load during the previous year | Credited at avoided-cost rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| Montana | 50 kW / Commercial, Industrial, Residential | Photovoltaics, Wind, Hydro | None | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | Investor-owned utilities |
| Montana - Montana Electric Cooperatives | 10 kW / Commercial, Residential | Photovoltaics, Wind, Geothermal, Fuel Cells, Small Hydro | None | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | Most of MEC's 26 members |
| Nevada | 1 MW[24] / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal | 1% of a utility's peak capacity | Credited at retail rate to customer's next bill; indefinite carryover | Yes | Investor-owned utilities |
| New Hampshire | 100 kW / Commercial, Industrial, Residential | All renewables | 1% of a utility's annual peak demand | Credited at retail rate to customer's next bill; indefinite carryover | Yes | All utilities |
| New Jersey | 2 MW / Commercial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells (Renewable Fuels), Tidal Energy, Wave Energy | None | Credited at retail rate to customer's next bill; purchased by utility at avoided-cost rate at end of 12-month billing cycle | Yes | Investor-owned utilities |

24. In Nevada, utilities are permitted to charge certain fees on systems greater than 100 kW.

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| New Mexico | 80 MW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Municipal Solid Waste, CHP, Microturbines | None | Credited to customer's next bill at utility's avoided-cost rate or purchased by utility at avoided-cost rate monthly | Yes *(under development)* | Investor-owned utilities, cooperatives |
| New York | 10 kW for residential or farm-based solar; 400 kW for farm waste; 125 kW for farm-based wind; 25 kW for residential wind | Photovoltaics, Biomass, Wind | Solar: 0.1% of a utility's demand in 1996;[25] farm biogas: 0.4% of a utility's demand in 1996; wind: 0.2% of a utility's 2003 demand | Credited to customer's next bill at retail rate, except NEG from wind systems over 10 kW, which is credited to customer's next bill at the utility's avoided-cost rate. NEG purchased by utility at avoided-cost rate at end of 12-month billing cycle. | Yes | All utilities |
| North Carolina | 100 kW for non-residential systems; 20 kW for residential systems | Photovoltaics, Wind, Biomass, Hydro | 0.2% of a utility's North Carolina retail peak load for the previous year | Credited to customer's next bill at retail rate; granted to utility annually at beginning of each summer season[26] | Yes | Investor-owned utilities |

25. In December 2006, the New York Public Service Commission approved a request by Central Hudson Gas & Electric Corporation to raise the limit on aggregate net-metering capacity for PV systems in the utility's service territory. The PSC's decision increased Central Hudson's aggregate net-metering limit by 50% -- from 800 kW to 1,200 kW.

26. In North Carolina, customers are required to switch to a time-of-use tariff in order to net meter. This arrangement includes the separate carryover of on-peak NEG and off-peak NEG.

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| North Dakota | 100 kW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste, CHP | None | Purchased by utility at avoided-cost rate | No | Investor-owned utilities |
| Ohio | No limit specified (must be sized to match some or all of customer's load) / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Fuel Cells, Microturbines | 1% of a utility's peak demand | Credited at utility's unbundled generation rate to customer's next bill; customer may request refund of NEG credits accumulated over a 12-month period | Yes | All competitive utilities |
| Ohio - Yellow Springs Utilities | 25 kW / Commercial, Residential | Photovoltaics, Wind | None | Not addressed | (Utility guidelines) | Yellow Springs Utilities |
| Oklahoma | 100 kW or 25,000 kWh/year (whichever is less) / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste, CHP | None | Granted to utility monthly or credited to customer's next bill at utility's avoided-cost rate (varies by utility) | No | Investor-owned utilities, cooperatives regulated by OCC |
| Oregon | 2 MW for nonresidential systems; 25 kW for residential systems | Solar, Wind, Biomass, Hydro, Fuel Cells | None | Credited to customer's next bill at retail rate; credited to Oregon low-income assistance programs at end of each March billing cycle | Yes | Investor-owned utilities (PGE and PacifiCorp only) |
| Oregon - Ashland Electric | None / Commercial, Residential | Photovoltaics, Wind | None | Purchased by utility monthly at retail rate (1,000 kWh/month maximum) | (Utility guidelines) | Ashland Electric |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Pennsylvania | 5 MW for systems connected to microgrids or available for emergencies; 3 MW for nonresidential systems;<br>50 kW for residential systems | Solar, Wind, Biomass, Hydro, Fuel Cells, Municipal Solid Waste, CHP, Waste Coal, Other DG | None | Credited to customer's next bill at retail rate; PUC to address treatment of NEG remaining at end of 12-month period | Yes | Investor-owned utilities |
| Rhode Island | 1.65 MW for systems owned by cities, towns or the Narragansett Bay Commission; 1 MW for all other customers | Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Municipal Solid Waste, CHP | 5 MW (1 MW reserved for systems under 25 kW) | Credited at the utility's avoided cost rate on the customer's next bill. Reverts to utility at the end of a 12-month period. | (Utility guidelines) | Narragansett Electric |
| South Carolina Santee Cooper Net billing pilot | Residential only | Solar, Wind, Biomass, Micro-hydro | 20 kW | Generators paid between 3.2 and 5.7 cents per kWh, depending on whether power is received during non-peak or peak demand periods. This is somewhat less than Santee's residential rate of 7 cents/kWh | (Utility guidelines) | Santee Cooper |
| Tennessee TVA | All customers. | All | None | TVA buys renewable generation from its distributors for its Green Power Switch program. The rate is a flat 10 cents/kWh.<br>Dual metering must be used. | Yes | All TVA distributors |
| Texas | 50 kW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Tidal Energy, Wave Energy, Microturbines | None | Purchased by utility monthly at avoided-cost rate | Yes | Integrated IOUs that have not unbundled |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Texas - Austin Energy | 20 kW / Commercial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste | 1% of utility's load | Credited to customer's next bill | (Utility guidelines) | Austin Energy |
| Utah | 25 kW / Commercial, Industrial, Residential | Solar, Wind, Hydro, Fuel Cells | 0.1% of a utility's 2001 peak demand | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | Investor-owned utilities, cooperatives |
| Utah - City of St. George | 10 kW / All customers | Photovoltaics, Wind | None stated | Credited to customer's next bill at utility's avoided-cost rate; indefinite carryover | (Utility guidelines) | City of St. George |
| Utah - Murray City Power | 10 kW / All customers | Photovoltaics, Wind, Hydro | None stated | Credited to customer's next bill at utility's retail rate; granted to utility each April | (Utility guidelines) | Murray City Power |
| Vermont | 150 kW for farm systems; 15 kW for commercial and residential / Commercial, Residential, Agricultural | All renewables | 1% of a utility's 1996 peak demand or peak demand during most recent calendar year (whichever is greater) | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| Virginia | 500 kW for non-residential; 10 kW for residential | Solar, Wind, Biomass, Hydro, Geothermal, Tidal, Wave, Municipal Solid Waste | 1.0% of a utility's annual peak demand | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | Investor-owned utilities, cooperatives |

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Virgin Islands (U.S.) | 10 kW / Commercial, Residential | Photovoltaics, Wind | 5 MW on St. Croix; 10 MW on St. Thomas, St. John, Water Island and other territorial islands | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | U.S. Virgin Islands Water and Power Authority (WAPA) |
| Washington | 100 kW / Commercial, Industrial, Residential | Solar, Wind, Hydro, Biogas, Fuel Cells, CHP | 0.25% of a utility's 1996 peak load | Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle | Yes | All utilities |
| Washington - Grays Harbor PUD | 100 kW / Commercial, Industrial, Residential | Solar, Wind, Hydro, Biogas, Fuel Cells, CHP | 0.25% of utility's 1996 peak load | Credited at retail rate to customer's next bill; purchased by utility at 50% retail rate at end of 12-month billing cycle | Yes | Grays Harbor PUD |
| West Virginia | 25 kW / Commercial, Residential | Photovoltaics, Landfill Gas, Wind, Biomass, Fuel Cells, Hydro | 0.1% of a utility's total load participation | Credited to customer's next bill at utility's retail rate | Yes (utility tariffs only) | All utilities |
| Wisconsin | 20 kW[27] / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste, CHP | None | Varies by utility. Generally credited at retail rate for renewables; generally credited at avoided cost for non-renewables. | Yes | Investor-owned utilities, municipal utilities |

27. In January 2006, the Wisconsin Public Service Commission approved a proposal by We Energies to offer net metering to customers with wind turbines greater than 20 kW but no greater than 100 kW in capacity. This offer is available to the first 25 eligible applicants.

| Program | System Size Limit / Customer Classes Eligible | Eligible Technologies | Limit on Total Capacity | Treatment of Net Excess Generation (NEG) | Interconnection Standards for Net Metering | Utilities Involved |
|---|---|---|---|---|---|---|
| Wyoming | 25 kW / Commercial, Industrial, Residential | Solar, Wind, Biomass, Hydro | None | Credited at retail rate to customer's next bill; purchased by utility at avoided-cost rate at end of 12-month billing cycle | Yes | All utilities |

# Appendix A4

## SAMPLE OF TRAINING INSTITUTIONS

| Type | Location | Program Name | Duration | Audience | Size | Format |
|---|---|---|---|---|---|---|
| University Continuing Education | Florida Solar Energy Center at The University of Central Florida | Installing Photovoltaic Systems | 40 hrs | contractors, electricians, utilities, engineers | | Classroom/ Lab |
| Community College | Hudson Valley CC, School of Engineering and Industrial Technologies | Photovoltaic Installation Certificate | 21-credit hrs | journeyman, Student | | Classroom/ Lab |
| Community College | Owens CC, Workforce and Community Services | Photovoltaic Training | 40hrs | Anyone interested in PV installation | | Classroom/ Hands-on |
| Community College | Lane CC | Energy Management Technician, Renewable Energy Technician Option | 100-credit hrs | | | Classroom/ Lab/ Hands-on/ Co-op |
| Community College | RedRocks CC | Renewable Energy Technology under Construction Technology | 61-credit hrs | | | Classroom/ Internship |
| NABCEP | | Entry Level Certificat of Knowledge of PV Systems | | Anyone interested in PV installation | | |
| College Workshop | Farmingdale State College | Residential PV System Installation and Maintenance Workshop | 40 hrs | High school degree, Licensed Electricians, Electrical Contractors, Engineering Degree | | Classroom/ Lab |
| University Continuing Education | North Carolina State | Renewable Energy Technologies (IV): 5-Day Renewable Electric Generation with PV Systems | 3.5 CEUs | Architect, Builder, Electrician, Businessperson, Engineer, or Student | | Classroom |
| NGO | Solar Energy International | PV Design & Installation | 80 hrs | Anyone interested in PV installation | | Classroom/ Lab |
| University | The Pennsylvania State University | Energy Engineering | 131 credit hrs | Undergraduate Students | | Classroom/ Lab |
| University | Oregon Institute of Technology | Renewable Energy Engineering | 181 credit hrs | Undergraduate Students | | Classroom/ Lab |

| Location | Curriculum | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Natural Sciences (Chemistry/Physics) | Advanced Math (Calculus) | Engineering Mechanics | Business (Finance, Economics) | Sustainable Design | Energy Auditing | EE/HVAC/Lighting | Residential Wiring Commercial Wiring | PV Basics | Performance and Operating Characteristics of PV | Siting (shade analysis) | System Sizing and Design | Mounting | Grid-Tied | Battery-Backup |
| Florida Solar Energy Center at The University of Central Florida | | | | | | | | | X | X | X | X | X | X | X |
| Hudson Valley CC, School of Engineering and Industrial Technologies | | | | | | | | X X | X | X | X | X | X | | |
| Owens CC, Workforce and Community Services | | | | | | | | | X | X | X | X | | X | X |
| Lane CC | | | | | X | | X | | X | X | X | X | X | X | X |
| RedRocks CC | | | | | | X | | | X | X | | | X | | |
| | | | | | | | | | X | X | X | X | X | X | X |
| Farmingdale State College | | | | | X | | | | X | X | X | X | X | X | X |
| North Carolina State | | | | | | | | | X | X | X | X | | X | X |
| Solar Energy International | | | | X | X | X | X | | X | X | X | X | X | X | X |
| The Pennsylvania State University | X | X | X | X | X | X | | | X | | | | | | |
| Oregon Institute of Technology | X | X | X | X | X | X | | | X | X | X | X | | X | X |

| Location | Curriculum | | | | | | Results | | |
|---|---|---|---|---|---|---|---|---|---|
| | Code compliancy | Troubleshooting | Maintenance | Inspection | Customer Knowledge / Relations | Solar Thermal | Certificate | Degree | Etc |
| Florida Solar Energy Center at The University of Central Florida | X | X | X | X | | | certificate of completion from FSEC | | |
| Hudson Valley CC, School of Engineering and Industrial Technologies | | X | | | | | Can take NABCEP PV Cert. of Knowledge exam | AOS | |
| Owens CC, Workforce and Community Services | X | X | X | X | | | Discussion of NABCEP and GLREA | | |
| Lane CC | | | | | X | X | | AAS | |
| RedRocks CC | X | | | | | X | | AAS | |
| | X | X | X | X | | | NABCEP Entry Level Cert. | | |
| Farmingdale State College | X | X | X | X | | | Certificate | | |
| North Carolina State | X | | | | | | Optional NABCEP Entry Level | Credits towards their degree program | |
| Solar Energy International | X | X | X | | X | X | ISP / Can take NABCEP entry level | | |
| The Pennsylvania State University | | | | | | | | BS | |
| Oregon Institute of Technology | | | | | X | x | | BS | |

| Location | Notes | Partnerships/ Sponsors | Links |
|---|---|---|---|
| Florida Solar Energy Center at The University of Central Florida | Does not give NABCEP certification | | http://www.fsec.ucf.edu/en/education/cont_ed/pv/igcpvs/installers.php |
| Hudson Valley CC, School of Engineering and Industrial Technologies | | | https://www.hvcc.edu/catalog/programs/eit/pvc.html |
| Owens CC, Workforce and Community Services | | | https://www.owens.edu/workforce_cs/jan08_pg3.pdf - 3a |
| Lane CC | Get course descriptions | | http://www.lanecc.edu/collegecatalog/documents/CTenergymgmttech.pdf |
| RedRocks CC | Call for more course detail: Larry Snyder 303-914-6306 larry.snyder@rrcc.edu | | http://www.rrcc.edu/renewable/degrees.html |
| | | NABCEP | http://www.nabcep.org/learningobjectives.cfm |
| Farmingdale State College | | | http://info.lu.farmingdale.edu/depts/met/solar/ |
| North Carolina State | Check for previous workshop details | NABCEP | http://www.mckimmon.ncsu.edu/opd/course.cfm?cid=657&sid=3070 |
| Solar Energy International | | ISP / NABCEP | http://www.solarenergy.org/workshops/index.html |
| The Pennsylvania State University | | | http://bulletins.psu.edu/bulletins/bluebook/college_campus_details.cfm?id=24&program=eneng.htm |
| Oregon Institute of Technology | | | http://www.oit.edu/Default.aspx?DN=e9c7716c-42f5-40d1-8664-4ffb45e05d0f&Anc=e9c7716c-42f5-40d1-8664-4ffb45e05d0f&Pa=d5ae3145-535a-4bba-a64e-9dc8e6900e79 |

# Appendix A5

## Tables reproduced from *Planning and Installing Photovoltaic Systems: A Guide for Installers, Architects and Engineers.*

### PERIODIC MAINTENANCE AND UPKEEP CHECKLIST

| **Period** | **Inverter** | **Operating without and fault display?** |
|---|---|---|
| Monthly | Yield Check | Log the meter readings regularly (not necessary in systems with automatic recording and evaluation of operating data) |
| | PV array surface area | Heavy soiling?<br>Leaves, bird droppings, air pollution or other types of soiling?<br>Clean with copious amounts of water (use a water hose) and a gentle cleaning implement (a sponge), without using detergents<br>Do not brush, or wipe the modules with a dry cleaning implement to avoid scratching the surface<br>Are all modules still correctly fixed?<br>Is the generator surface area subject to any mechanical stress? (e.g. as a result of a warped roof structure) |
| Every six months | PV combiner/junction box (if present) | Are there any insects/is there humidity in the device? (if mounted outdoors)<br>If possible, check fuses |
| | Surge arresters | *Check after thunderstorms as well*<br>Surge voltage arrester intact (window white or red)? |
| | Cables | Look for charred spots, broken insulation and other kinds of damage (e.g. cables damaged by animals)<br>Check the fixing points |
| Every three to four years | Repeat the measurements as during commissioning | Only to be carried out by a trained professional |
| | Inverters in outdoor applications | Humidity may penetrate in spite of suitability for outdoor applications<br>Only to be controlled by a trained professional |
| If suspected | Modules | Peak output measurement by a trained professional |
| | PV combiner/junction box | Check string fuses |
| | AC protective equipment | Line circuit breakers, AC fuses and RCDs |

## FAULT TYPES AND THE CHECKS AND MEASURES TO DETECT THEM

| | Visual inspection | Multimeter measurement | Earthing resistance measurement | Input/ output check | Insulation resistance measurement | Over/ under voltage check | I-V curves | Inverter data readout check | Test the AC circuit | Grid analysis |
|---|---|---|---|---|---|---|---|---|---|---|
| **Fault type** | | | | | | | | | | |
| **PV modules** | | | | | | | | | | |
| Soiling | *X* | | | | | | | | | |
| Delamination | *X* | *X* | | | | | *X* | | | |
| Bypass diodes | | *X* | | | | | | *(X)* | | |
| Contact points | | *X* | | *X* | | | *X* | *(X)* | | |
| Moisture | *X* | *X* | | | *X* | | *X* | | | |
| Defective modules | *X* | *X* | | | *X* | | *X* | *(X)* | | |
| **Inverter** | | | | | | | | | | |
| Efficiency | | | | *X* | | | | *X* | *X* | *X* |
| Control characteristics | | | | *X* | | *X* | | *X* | *X* | *X* |
| Harmonic content | | | | | | | | | *X* | *X* |
| Line voltage disturbances | | | | | | | | *X* | *X* | *X* |
| **Installation** | | | | | | | | | | |
| Faulty fuse | *X* | *X* | | *X* | | | | | | |
| Defective string diode | | *X* | | *X* | | | *X* | | | |
| Short circuit/earth leakage | *X* | | | | *X* | | | | | |
| Defective surge voltage protectors | *X* | *X* | | | *X* | *X* | | | | |
| Increased earthing resistance | | | *X* | | | | | | | |

# Appendix A6

## SAFETY CONSIDERATIONS

The wiring used in PV systems must be properly selected for its intended use. Automotive or welding cabling cannot be used in PV systems despite their other dc applications. The wiring, due to its exposure to the harsh environment typical on a roof around PV modules, must be capable of dealing with excessive heat, moisture, and ultraviolet and infrared energy. It must be properly sheathed and/or rated for such uses. Proper ampacity and voltage requirements must be calculated and the wire and wiring devices will likely need to be derated for numerous reasons in a typical application.

Overcurrent protection in a dc system also differs from standard ac practices. All devices in the system must be protected from an overload, which results from sustained current beyond the rating of components, and a short circuit, which is caused by line-to-line or ground-to-line low resistance faults. An understanding of when to use fuses or circuit breakers that are designed for dc use is important.

System disconnects are also very important for the safety of the system especially when the public may come in contact with it. Allowing easy access to dc disconnects for each component in the system so that an individual, such as a firefighter in an emergency situation, can quickly remove power from the system or any of its components. Regular ac switches cannot generally be used unless specifically rated for dc applications and only if they are not to be used for load-break purposes. Many other factors that would likely only be recognized by a trained professional must also be taken into consideration. For example, do not install a disconnect on or around a battery compartment as a spark from the disconnecting action while under load could ignite explosive hydrogen gas released by the battery bank.

System and equipment grounding offers its own challenges with PV systems installed in the United States, which utilizes a grounded electrical grid. Proper ground-fault equipment must be used as well as surge and transient suppression for protection from electrical storms due to the likelihood of the system being the highest metallic structure in their vicinity.

## ISPQ ACCREDITATION KEY POINTS

- The program shall be designed to prepare individuals with knowledge and skills required for a professional trade with the curriculum content following and approved task analysis.
- Curriculum shall have sufficient prerequisites to ensure that graduates have a predictable level of expertise.
- Facilities shall be sufficient and safe for the training.

- The organization has appropriate financial resources and that administrative and management procedures and policies are in practice; and written policies shall ensure the competence, impartiality, and integrity of the program.
- The instruction is presented in an organized and sequential learning format.
- The learning management system should provide the necessary assessment and reporting capabilities to monitor and track the learning process.
- Instructor provides timely and specific feedback.
- Learning shall provide frequent and meaningful interaction among learners, between learners and instructional material and between learners and the instructors.
- Assessment should be and integral part of the leaning experience.
- Advertising of any type is prohibited within the educational content.

## NABCEP TASK ANALYSIS (APPROVED 10/18/06)

| **1. Working Safely with Photovoltaic Systems** | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***As part of safety considerations associated with installing and maintaining PV systems, any PV installer must be able to:*** | | |
| 1.1 Maintain safe work habits and clean, orderly work area | Cognitive, Psychomotor | Critical |
| 1.2 Demonstrate safe and proper use of required tools and equipment | Cognitive, Psychomotor | Critical |
| 1.3 Demonstrate safe and accepted practices for personnel protection | Cognitive, Psychomotor | Critical |
| 1.4 Demonstrate awareness of safety hazards and how to avoid them | Cognitive, Psychomotor | Critical |
| 1.5 Demonstrate proficiency in basic first aid and CPR | Cognitive, Psychomotor | Very Important |
| ***The installer must be able to identify electrical and non-electrical hazards associated with PV installations, and implement preventative and remedial measures to ensure personnel safety:*** | | |
| 1.6 Identify and implement appropriate codes and standards concerning installation, operation and maintenance of PV systems and equipment | Cognitive, Psychomotor | Critical |
| 1.7 Identify and implement appropriate codes and standards concerning worker and public safety | Cognitive, Psychomotor | Critical |
| 1.8 Identify personal safety hazards associated with PV installations | Cognitive, Psychomotor | Critical |
| 1.9 Identify environmental hazards associated with PV installations | Cognitive, Psychomotor | Very Important |

| 2. Conducting a Site Assessment | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***In conducting site surveys for PV systems, the installer shall be able to:*** | | |
| 2.1 Identify typical tools and equipment required for conducting site surveys for PV installations, and demonstrate proficiency in their use | Cognitive | Very Important |
| 2.2 Establish suitable location with proper orientation, sufficient area, adequate solar access and structural integrity for installing PV array | Cognitive | Very Important |
| 2.3 Establish suitable locations for installing inverters, control, batteries and other balance-of-system components | Cognitive | Very Important |
| 2.4 Diagram possible layouts and locations for array and equipment, including existing building or site features | Cognitive | Very Important |
| 2.5 Identify and assess any site-specific safety hazards or other issues associated with installation of system | Cognitive | Very Important |
| 2.6 Obtain and interpret solar radiation and temperature data for site for purposes of establishing performance expectations and use in electrical system calculations | Cognitive | Very Important |
| 2.7 Quantify the customer electrical load and energy use through review of utility bills, meter readings, measurements and/or customer interview, | Cognitive | Important |
| 2.8 Estimate and/or measure the peak load demand and average daily energy use for all loads directly connected to inverter-battery systems for purposes of sizing equipment, as applicable | Cognitive | Very Important |
| 2.9 Determine requirements for installing additional subpanels and interfacing PV system with utility service, and/or other generation sources as applicable | Cognitive | Very Important |
| 2.10 Identify opportunities for the use of energy efficient equipment/appliances, conservation and energy management practices, as applicable | Cognitive | Important |

| 3. Selecting a System Design | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***Based on results from a site survey, customer requirements and expectations, the installer shall be able to:*** | | |
| 3.1 Identify appropriate system designs/configurations based on customer needs, expectations and site conditions | Cognitive | Very Important |
| 3.2 Estimate sizing requirements for major components based on customer load, desired energy or peak power production, autonomy requirement, size and costs as applicable | Cognitive | Very Important |
| 3.3 Identify and select major components and balance of system equipment required for installation | Cognitive | Very Important |
| 3.4 Estimate time, materials and equipment required for installation, determine installation sequence to optimize use of time and materials | Cognitive | Important |

| 4. Adapting the Mechanical Design | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***In adapting a PV system mechanical design, the practitioner shall be able to:*** | | |
| 4.1 Identify a mechanical design, equipment to be used and installation plan that is consistent with the environmental, architectural, structural, code requirements and other conditions of the site | Cognitive | Critical |
| 4.2 Identify appropriate module/array layout, orientation and mounting method for ease of installation, electrical configuration and maintenance at the site | Cognitive | Critical |

| **5. Adapting the Electrical Design** | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***In adapting a PV system electrical design, the practitioner shall be able to:*** | | |
| 5.1 Determine the design currents for any part of a PV system electrical circuit | Cognitive | Critical |
| 5.2 Select appropriate conductor types and ratings for each electrical circuit in the system based on application | Cognitive | Critical |
| 5.3 Determine the derated ampacity of system conductors, and select appropriate sizes based on design currents | Cognitive | Critical |
| 5.4 Determine appropriate size, ratings and locations for all system overcurrent and disconnect devices | Cognitive | Critical |
| 5.5 Determine appropriate size, ratings and locations for grounding, surge suppression and associated equipment | Cognitive | Critical |
| 5.6 Determine voltage drop for any electrical circuit based on size and length of conductors | Cognitive | Very Important |
| 5.7 Verify that the array operating voltage range is within acceptable operating limits for power conditioning equipment, including inverters and controllers | Cognitive | Very Important |
| 5.8 Select an appropriate utility interconnection point, and determine the size, ratings and locations for overcurrent and disconnect devices. | Cognitive | Critical |

| **6. Installing Subsystems and Components at the Site** | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***As part of the PV system installation process, the practitioner shall be able to:*** | | |
| 6.1 Utilize drawings, schematics, instructions and recommended procedures in installing equipment | Cognitive | Critical |
| 6.2 Implement all applicable personnel safety and environmental protection measures | Cognitive | Critical |
| 6.3 Visually inspect and quick test PV modules | Psychomotor | Important |
| 6.4 Assemble modules, panels and support structures as specified by module manufacturer or design | Psychomotor | Very Important |
| 6.5 Install module array interconnect wiring, implement measures to disable array during installation | Psychomotor | Very Important |
| 6.6 Complete final assembly, structural attachment and weather sealing of array to building or other support mechanism | Psychomotor | Critical |
| 6.7 Install and provide required labels on inverters, controls, disconnects and overcurrent devices, surge suppression and grounding equipment, junction boxes, batteries and enclosures, conduit and other electrical hardware | Psychomotor | Critical |
| 6.8 Label, install and terminate electrical wiring; verify proper connections, voltages and phase/polarity relationships | Psychomotor | Critical |
| 6.9 Verify continuity and measure impedance of grounding system | Cognitive, Psychomotor | Very Important |
| 6.10 Program, adjust and/or configure inverters and controls for desired set points and operating modes | Cognitive | Critical |

| **7. Performing a System Checkout and Inspection** | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***After completing the installation of a PV system, as part of system commissioning, inspections and handoff to the owner/operator, the practitioner shall be able to:*** | | |
| 7.1 Visually inspect entire installation, identifying and resolving any deficiencies in materials or workmanship | Cognitive, Psychomotor | Very Important |
| 7.2 Check system mechanical installation for structural integrity and weather sealing | Cognitive, Psychomotor | Critical |
| 7.3 Check electrical installation for proper wiring practice, polarity, grounding and integrity of terminations | Cognitive, Psychomotor | Critical |
| 7.4 Activate system and verify overall system functionality and performance, compare with expectations | Cognitive, Psychomotor | Critical |
| 7.5 Demonstrate procedures for connecting and disconnecting the system and equipment from all sources | Cognitive, Psychomotor | Critical |
| 7.6 Identify and verify all required markings and labels for the system and equipment | Cognitive | Critical |
| 7.7 Identify and explain all safety issues associated with operation and maintenance of system | Cognitive | Very Important |
| 7.8 Identify what documentation is required to be provided to the PV system owner/operator by the installer | Cognitive | Very Important |

| **8. Maintaining and Troubleshooting a System** | | |
|---|---|---|
| ***Task/Skill:*** | ***Skill Type:*** | ***Priority/ Importance:*** |
| ***In maintaining and troubleshooting PV systems, the practitioner shall be able to:*** | | |
| 8.1 Identify tools and equipment required for maintaining and troubleshooting PV systems; demonstrate proficiency in their use | Cognitive, Psychomotor | Very Important |
| 8.2 Identify maintenance needs and implement service procedures for modules, arrays, batteries, power conditioning equipment, safety systems, structural and weather sealing systems, and balance of systems equipment | Cognitive, Psychomotor | Very Important |
| 8.3 Measure system performance and operating parameters, compare with specifications and expectations, and assess operating condition of system and equipment | Cognitive, Psychomotor | Very Important |
| 8.4 Perform diagnostic procedures and interpret results | Cognitive, Psychomotor | Very Important |
| 8.5 Identify performance and safety issues, and implement corrective measures | Cognitive, Psychomotor | Critical |
| 8.6 Verify and demonstrate complete functionality and performance of system, including start-up, shut-down, normal operation and emergency/bypass operation | Cognitive, Psychomotor | Critical |
| 8.7 Compile and maintain records of system operation, performance and maintenance | Cognitive | Very Important |