Connecting to the Grid

A Guide To
PV Interconnection Issues

Third Edition
2000

by

Chris Larsen
North Carolina Solar Center

Bill Brooks, P.E.
Endecon Engineering

Tom Starrs, J.D., Ph.D.
Kelso Starrs & Associates

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Interstate Renewable Energy Council's
PV4You Interconnection Project

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1. Introduction

1.1 Background

The past few years have seen many milestones in the development of streamlined, standardized requirements for utility interconnection of small-scale renewable generating facilities, particularly solar photovoltaic (PV) systems. Long-awaited technical standards from the Institute of Electrical and Electronics Engineers (IEEE Std 929-2000) and the Underwriters Laboratories (UL Std 1741) were approved. State-level enactment and implementation of interconnection requirements is at an all-time high and, for the first time, a bill was introduced in the U.S. Congress calling for the development and adoption of national uniform interconnection requirements for certain small-scale generators. Also, interconnection-related activity has moved beyond the realm of small-scale PV to encompass larger-scale PV systems and other distributed generating technologies.

Interconnection issues broadly cover all of the steps that are taken when a small scale renewable energy system is connected in parallel to the utility grid. Simply put, interconnection refers to the technical, contractual, and rates and metering issues that must be settled between the system owner and the utility and local permitting authorities before the system is connected to the grid.

In a sense there's nothing new here. Since the late 1970s when Public Utility Regulatory Policies Act of 1978 (PURPA) was enacted, the U.S. has seen thousands of industrial and commercial qualifying facility (QF) generation units come on-line. Why all of a sudden are we talking about interconnection when we've been doing it for years?

The one-word answer is *scale*.

> ***Interconnection topics***
>
> **Technical**
>
> - National standards: UL 1741, IEEE 929, NEC Article 690
> - Additional safety equipment
> - Testing
> - Power quality
> - Electrical permits
>
> **Contractual**
>
> - Liability insurance
> - Fees and charges
> - Length and complexity of agreement forms
> - Contractual procedures
>
> **Rates and Metering**
>
> - Net metering
> - Monthly or annual netting
> - Time-of-use metering

Many of the renewable distributed generation systems on the market today – photovoltaics, wind, small hydro, etc. – fall in the 1 – 250 kilowatt (kW) range. This is tiny compared to industrial cogeneration units, which are rarely under 100 megawatts (MW). This difference in scale has important implications for interconnection requirements. Whereas the developer of an industrial cogeneration facility can afford to have a professional engineer review the system design and an attorney review the utility contract, experience has shown that these sorts of non-equipment expenses can be deal killers for a residential customer looking to install a 1 kW PV system or a small business owner looking to install a 25 kW wind turbine. A recent NREL report documents these barriers in a series of interconnection case studies.[1]

Utilities are frequently cited as one of the primary reasons that customers have such difficulty installing interconnected systems. The utilities defend their sometimes onerous interconnection policies by explaining that they are required, by governing organizations such as utility commissions and boards, to uphold the safety and reliability of the grid. And, because many utilities have limited experience dealing with small customer-owned generation systems, there is a tendency for utilities to rely on their previous experience with larger systems and require additional safety equipment or to review interconnection proposals on a case-by-case in the absence of clear rules.

The Solar House at North Carolina State University: A Demonstration Interconnected Residential PV System.

All of this points to the need for interconnection standardization for smaller systems. Standardization benefits all concerned parties – equipment manufacturers, end users, utilities, and regulators. And, this is where recent state-level efforts have been directed. Section 6 summarizes this activity, which may serve as useful background for interested parties in states where the issues are currently being discussed, or as testimonial to encourage other states to begin the process.

1.2 This Guide

A great deal has been written on the subject of interconnection, so one of the goals of this guide is to distill and summarize the issues. Much of the interconnection discussion has come by way of net metering laws. While many of the policy debates around the country have suggested that interconnection issues are a subset of the net metering debate, in fact, net metering is just one of many interconnection issues. This guide attempts to cover that broader spectrum.

[1] R. Brent Alderfer, M. Monika Eldridge, and Thomas J. Starrs, *Making Connections: Case Studies of Interconnection Requirements and Their Impacts on Distributed Power Projects.* National Renewable Energy Laboratory, April 2000.

Comments from the first two editions of this guide have indicated that there is a diverse audience for this guide. The audience includes utility regulators, customer-generators, utility representatives, and equipment manufacturers. With this in mind, we have designed some sections to be of general interest and others to be of particular interest to certain audiences. The contents are organized as follows:

Sections 2 through 4 cover technical, contractual, and rates/metering issues, respectively. These sections will be of interest to all audiences. Section 3 contains tips for prospective system owners trying to find the right utility contact.

Section 5 is primarily intended for the system owner. This section addresses electrical inspectors, building codes, local covenants, and solar access laws.

Section 6 provides a state-by-state summary of interconnection rules and rules development activity. This section will be of most interest to regulators and utility personnel.

You can also visit the *Connecting to the Grid* website at www.irecusa.org/connect.htm, the most comprehensive website addressing interconnection issues. Content at this site includes:

- The *On-line Interconnection Library*, which gives you ready access to electronic versions of important technical and non-technical interconnection reports and papers. You can also find out how to access or order national standards.
- Archives of IREC's electronic *Interconnection Newsletter*. Here you can also subscribe for this monthly service, which covers the latest state and national interconnection activity.
- Up to date state-by-state and utility-by-utility interconnect information presented both in tabular summary format and in detail through individual state pages.
- Information about IREC's national *Interconnection Project*, including information on the Project's workshops for utilities and regulators.
- An electronic version of this Guide, which can be downloaded in .pdf format.

2. Technical Issues: Safety, Power Quality, and Codes

This section looks at the technical questions that are at the heart of interconnection issues. The goal is to demystify and familiarize, while not going into great detail. Where appropriate, references are given for readers who would like more explanation. Safety and power quality issues are discussed before turning to codes and standards.

2.1 Safety

Like any source of electricity, PV systems are potentially dangerous to both people and property, and much attention has been given to finding ways to reduce these inherent safety risks. Large industrial customers have been generating power on-site for as long as electricity has been used, but interconnecting PV and other small generation systems to operate in parallel with the grid at *residential* and *small commercial* locations is a very new trend.

While major safety issues relating to grid connection of generators at large industrial sites (typically co-generation systems) have largely been addressed, the safety requirements necessary for these large generators are not necessarily appropriate for small residential and commercial generation. For example, major safety equipment and periodic checks by utility personnel or professional engineers may be important for the safety of a large customer generation site, but these requirements may be unreasonable for small PV systems.

This is largely because safety features are integrated into the design and manufacturing process for the power conditioning system or inverter, which acts as the electronic interface between the customer's generating facility, the customer's loads, and the utility system. The integration of these safety features into the inverter has permitted the development of fail-safe designs that prevent the inverter from operating unless its protective functions are operating properly. The distinctive safety features of inverter-based generating facilities justify different treatment from large cogeneration systems, which typically use rotating generation equipment.

2.1.1 PV Power

Photovoltaic modules produce direct-current (DC) power. Depending on the system design, some utility-interconnected PV systems operate at DC voltages in excess of 300 volts before being inverted to standard alternating-current (AC). The potential fire hazard of DC at these voltages is greater than that of standard AC found in residences because it is more difficult to extinguish a DC arc than an AC arc at the same voltage. Many electricians and electrical inspectors do not regularly deal with DC circuits; however, proper wiring according to the National Electrical Code[2] (NEC) ensures that any hazards related to DC

[2] The National Electrical Code, which is published by the National Fire Protection Association, is

power are significantly reduced. In addition to the NEC, there are guides to the proper wiring of PV systems. One popular manual published and distributed by Sandia National Laboratories is *Photovoltaic Power Systems and the National Electrical Code: Suggested Practices* by John Wiles.

Not all grid-tied inverters require DC wiring. One recent PV product innovation is the *AC module,* which is a PV module with a microinverter built directly onto the back of the module so that AC power leaves the module.

2.1.2 Islanding

One of the most important safety issues for small customer-sited PV systems is a condition called *islanding*. Islanding is where a portion of the utility system that contains both loads and a generation source is isolated from the remainder of the utility system but remains energized. When this happens with a PV system, it is referred to as PV-supported islanding.

The safety concern is that utility power goes down (perhaps in the event of a major storm) and a PV system continues to supply power to a local area. While a utility can be sure that all of its own generation sources are either shut down or isolated from the area that needs work, an island created by a residential PV system is out of their control. There are a number of potentially undesirable results of islanding. The principal concern is that a utility line workers will come into contact with a line that is unexpectedly energized. Although line workers are trained to test all lines before working on them, and to either treat lines as live or ground them on both sides of the section on which they are working, this does not remove all safety concerns because there is a risk when these practices are not universally followed.

> *The safety concern is that utility power goes down (perhaps in the event of a major storm) and a PV system continues to supply power to a local area.*

Fortunately, although islanding is a very real condition, inverter technology is such that there is no chance of a PV-supported island stemming from a interconnected residential or small commercial systems with inverters with built-in anti-islanding safety features. Grid-tied inverters monitor the utility line and can shut themselves off as quickly as necessary (in 2 seconds or less) in the event that abnormalities occur on the utility system. At Sandia National Laboratories and Ascension Technology, extensive testing of inverters under a variety of laboratory-controlled worst-case conditions led to the development of the definition of a "non-islanding inverter." A good discussion of islanding and anti-islanding inverters is contained in the annexes to IEEE Std 929-2000 and in Greg Kern, et al., "Results of Sandia National Laboratories Grid-Tied Inverter Testing."

discussed in greater detail in subsection 2.4.1.

2.1.3 Manual Disconnect

An external manual lockable disconnect switch ("manual disconnect") in the interconnection context is a switch external to a building that can disconnect the generation source from the utility line. The requirement for a manual disconnect, stems from utility safe working practices that require disconnecting all sources of power before proceeding with certain types of line repair. Whether a manual disconnect for small PV systems with listed inverters should be required has been the source of considerable debate.

In strict safety terms, a manual disconnect is not necessary for most modern PV systems because of the inverter's built-in automatic disconnect features as discussed in the previous section. Also, in accordance with NEC Article 690, the inverter already must have a manual means of isolation from the grid. The manual disconnect issue then really refers to the need for an additional switch that is (1) external to the building, (2) lockable by utility personnel, and (3) offers a visible-break isolation from the grid. As such, a manual disconnect is an additional means of preventing an islanding situation. And, the key from the utility perspective is that the switch is accessible to utility personnel in the event of a power disruption when utility line workers are working on proximate distribution system lines.

> *"Utilities may choose to relax their requirement for a utility-interface disconnect switch when a PV system employs a non-islanding inverter. . . ."*
>
> – IEEE Std 929-2000

In addition, in many situations, utility line workers can provide redundant protection against islanding by removing a customer's meter from the meter socket. Still, many utilities require a separate, external manual disconnect. While the cost of installing such a switch is not large relative to the overall cost of a PV system, when compared to expected energy savings from the system, such a switch is relatively expensive. Also, for PV systems located on the top of tall buildings, such a switch becomes very expensive.

Some state-level net metering and interconnection rules require that the utility pay for the installation of a manual disconnect. As of spring 2000, New Mexico, New York, and Texas do require a manual external disconnect. In New Mexico, use of the meter is an optional alternative to a separate switch. The following states do not require a manual disconnect, at least for small systems: California, New Jersey, Washington, and Nevada. Some utilities, such as those owned by the New England Electric System (NEES), have established their own interconnection guidelines that do not require an external manual disconnect for small systems.

2.2 Power Quality

Power quality is another technical concern for utilities and customer-generators. Power quality is analogous to water quality. Just as municipal water suppliers and individual water wells must meet certain standards for bacteria and pollutant levels, utility power is consistently supplied at a certain voltage and frequency. In the U.S., residences receive alternating current (AC) power at 120/240 volts at 60 cycles per second (60 Hz), and commercial buildings typically receive either 120/240 volts or three-phase power depending on the size of the building and the types of loads in the building.

Power quality is important because electronic devices and appliances have been designed to receive power at or near these voltage and frequency parameters, and deviations may cause appliance malfunction or damage. Power quality problems can manifest themselves in lines on a TV screen or static noise on a radio, which is sometimes noticed when operating a microwave oven or hand mixer. Noise, in electrical terms, is any electrical energy that interferes with other electrical appliances. As with any electrical device, a PV inverter, which converts the DC power from the PV modules into usable AC power for a house, potentially can inject noise that can cause problems. In addition to simple voltage and frequency ranges, discussions of power quality include on harmonics, power factor, DC injection, and voltage flicker.[3]

Harmonics generically refers to distortions in the voltage and current waveforms. These distortions are caused by the overlapping of the standard waves at 60 Hz with waves at other frequencies. Specifically, a harmonic of a sinusoidal wave is an integral multiple of the frequency of the wave. Total harmonic distortion (THD) is summation of all the distortions at the various harmonic frequencies.

Power factor is a measure of “apparent power” that is generated when the voltage and current waveforms are out of synch. Power factor is the ratio of true electric power, as measured in watts, to the apparent power, as measured in kilovolt-amperes (kVA). The power factor can range from a low of zero when the current and voltage are completely out of synch to the optimal value of one when the current and voltage entirely in synch. The terms “leading” and “lagging” refer to whether the current wave is ahead of or behind the voltage wave. Although not strictly the case, power factor problems can be thought of as contributing to utility system inefficiencies.

DC injection occurs when an inverter passes unwanted DC current into the AC or output side of the inverter. **Voltage flicker** refers to short-lived spikes or dips in the line voltage. A common manifestation of voltage flicker is when your lights dim momentarily. The significance of voltage flicker is highly subjective, but limits have been established by IEEE. Grid-interactive inverters generally do not create DC injection or voltage flicker problems.

[3] For a more detailed discussion of power quality, see the annexes of IEEE Std 929-2000.

2.3 Lack of Uniform Standards and the Legacy of PURPA

Perhaps the number one interconnection barrier for small renewable systems has been the lack of *uniformity* in interconnection standards from utility to utility. This is a result of the traditional discretion given to utilities to deal with their own generation, transmission, and distribution systems. Even the Federal Energy Regulatory Commission (FERC), which oversees all U.S. electric utilities, has a strictly defined jurisdiction and has not addressed interconnection issues for small customer-owned renewable systems in any detail.[4]

To be more accurate, it is a problem of utilities not having any standards *at all* for small grid-tied generators. A recent survey showed that only a handful of large utilities have any small generator interconnection standards (Wan and Green, 1998). In the case where a utility has no PV or small generator standards, interconnection is addressed on either a case-by-case basis or through existing standards for large industrial cogeneration systems.

Specifically, the standards that are used in the absence of a specific small generator interconnection rules are the qualifying facility (QF) rules adopted under PURPA. Regulated electric utilities have filed documentation with FERC that outlines the legal and technical terms of their contracts with QFs, which are designed, built, and operated for the purpose of producing large amounts of electricity for use on site and for sale in wholesale markets. These large QFs are complex projects that require customized engineering, financial, and legal work. However, it is beyond the means of most prospective PV system owners to hire a professional engineer and attorney for the interconnection of a small grid-tied system that is intended simply to offset a portion of the PV owner's electricity use.

As highlighted above, these interconnection issues are a question of *scale*. It stands to reason that a system with a capacity that is orders of magnitude less than typical QFs should not be subject to the same technical requirements. And, there are reasons why many utilities themselves favor the adoption of uniform interconnection standards:

- As more and more PV systems are installed, it will become very costly and time consuming for utilities to conduct case-by-case analysis of each grid-tied system;
- If a utility wants to get into the PV market, it is in their interest to encourage PV by adopting simple, uniform standards; and
- Utilities that reject uniform national interconnection standards such as IEEE Std 929-2000 and UL Std 1741 run the risk of being seen as having illegitimate concerns.

Finally, it should be noted that there are different ways uniform standards might be adopted. Utilities can adopt new standards voluntarily or by mandate. As we are seeing around the country, more and more state utility commissions are mandating uniform rules.

[4] In 1998, MidAmerican Electric Company brought to FERC a challenge of the Iowa Utilities Board's 1983 net metering rule. This proceeding, however, did not address interconnection issues, and as of summer 2000, the case is still pending.

2.4 Codes and Standards (To the Rescue)

To address safety and power quality issues, national codes and safety organizations have set out to provide guidelines for equipment manufacture, operation, and installation. The major code and safety organizations that deal with photovoltaics are the National Fire Protection Association (NFPA), Underwriters Laboratories (UL) and Institute of Electrical and Electronics Engineers (IEEE). The following subsections discuss these three sets of standards, how the codes interact, and how the documents are being used.

National Fire Protection Association (NFPA)	1 Batterymarch Park Quincy, MA 02269-9101 Phone: (617) 770-3000, Fax: (617) 770-0700 Web: www.nfpa.org
Underwriters Laboratories (UL)	333 Pfingsten Road Northbrook, IL 60062-2096 Phone: (847) 272-8800, Fax: (847) 272-8129 Web: www.ul.com
Institute of Electrical and Electronics Engineers (IEEE)	445 Hoes Lane, P.O. Box 459 Piscataway, NJ 08855-0459 Phone: (800) 678-4333 Web: www.ieee.org

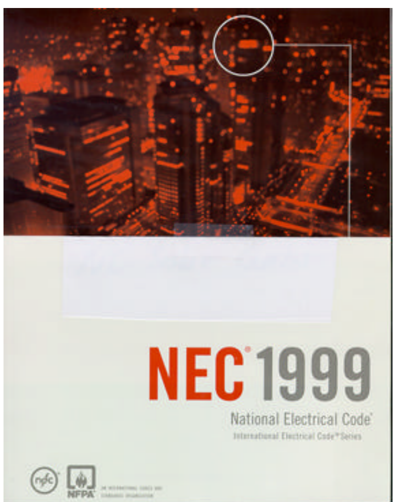
The U.S. Department of Energy's national laboratories are also actively involved in issues surrounding PV interconnection. The National Renewable Energy Laboratory (NREL) in Golden, Colorado and Sandia National Laboratories in Albuquerque, New Mexico work closely with the NFPA, IEEE, and UL on code issues and are frequently involved in equipment testing. The labs are not responsible for issuing or enforcing codes, but they do serve as valuable sources of information on PV and interconnection issues.

National Renewable Energy Laboratory	1617 Cole Boulevard, Golden, CO 80401 Phone: (303) 275-3000, Fax: (303) 275-4053 Web: www.nrel.gov
Sandia National Laboratories, Photovoltaic Systems Assistance Center	P.O. Box 5800, Division 6218, Albuquerque, NM 87185 Phone: (505) 844-8161, Fax: (505) 844-6541 Web: www.sandia.gov/Renewable_Energy/photovoltaic/pv.html

2.4.1 National Fire Protection Association

The National Fire Protection Association (NFPA) publishes the National Electrical Code (NEC) and is the foremost organization in the U.S. dealing with electrical equipment and wiring safety. The National Electrical Code is now 1,069 pages long, the most detailed of any NFPA code or standard. The scope of the NEC covers all buildings and property except for electric utility property. That is, the NEC applies to your home but not to the power lines or generators operated by your utility. With regard to photovoltaics, an entire section – Article 690 – deals with PV. Article 690, "Solar Photovoltaic Systems," mentions interconnection to the utility grid but focuses more on descriptions of components and proper system wiring. One key requirement in Article 690 is that all equipment must be listed by a recognized listing agency if a relevant listing exists. Listing agencies are discussed below in the Underwriters Laboratories section.

Article 690 references other relevant sections of the NEC. One of these is Article 705, "Interconnected Electric Power Production Sources." Although the scope of Article 705 covers all generation types, it is not frequently referenced in interconnection discussions.



1999 National Electrical Code, National Fire Protection Association

PV systems were first given the status of a special equipment article in the National Electrical Code in 1984. Revisions continue to be made to the article, but much of it has remained intact. (The NEC is updated on a three year cycle, with the 1999 edition being the most recent version.) To help system designers and installers with specific NEC issues, the Southwest Technology Development Institute at New Mexico State University and Sandia National Laboratories publish a guide to recommended practices based on the NEC (Wiles, 1996). This guide provides practical information on how to design and install safe, reliable, and code-compliant PV systems.

Building and electrical codes are often changed on the national level. At this level, agreement on changes in the codes is difficult because such changes are so far reaching in their impacts. Once a national code is changed, it is left to the discretion of state and local authorities to adopt the new changes. As an example, there are a few jurisdictions in the U.S. that adhere to the 1990 NEC even though three revisions have been issued subsequent to that version. In those jurisdictions it does not matter what is in the subsequent versions of the Code if it is different from the 1990 NEC. Although this is the exception rather than the rule, it is an example of local autonomy.

Local jurisdictions frequently impose stricter rules than the national codes require. One example is the requirement of sprinkler systems for fire protection in residences in certain jurisdictions. No national building code requires sprinkler systems for residences, but the local code supersedes the national code in this situation.

2.4.2 Institute of Electrical and Electronics Engineers

The Institute of Electrical and Electronics Engineers (IEEE) is a non-profit, technical professional association with a worldwide membership. Among its functions, IEEE has over 800 active technical standards and over 700 in development. In the 1980s, IEEE published ANSI/IEEE Std 929-1988, “IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems.” This standard addressed the basic issues of power quality, equipment protection, and safety. This document has been extensively revised and the current version, IEEE Std 929-2000, was approved by IEEE in January 2000 and replaces the 1988 version.

The standards that utilities adopt for their equipment and systems often originate from IEEE, and utilities usually are involved in the development of new IEEE standards, which helps to ensure that the standards meet utility concerns. Utilities however are not required to adopt IEEE standards unless a state public utility commission or FERC rules to that effect. Once a utility adopts an IEEE standard, equipment that is certified to meet the standard is acceptable.

> *It is the intent of IEEE Std 929-2000 to meet all legitimate utility concerns with safety and power quality so that there will be no need for additional requirements in developing utility-specific guidelines, especially for systems of 10 kW or less.*

It is the intent of IEEE Std 929-2000 to meet all legitimate utility concerns with safety and power quality so that there will be no need for *additional* requirements in developing utility-specific guidelines, especially for systems of 10 kW or less. The new 929 is also intended to be an informative document. While the standard itself is only about twelve pages, the annexes provide nearly twenty pages of background on technical issues such as islanding, distribution transformers, and manual disconnects.

At the time the original document was released in 1988, all commercially available U.S. manufactured inverters could be made to “run on” (power an island) for periods longer than two seconds under very controlled laboratory conditions. Although these conditions were extremely unlikely in the real world, they were still possible (Gulachenski, 1990). Inverters that meet the standards described in IEEE Std 929-2000 use more sophisticated means for assuring that under no real world or lab circumstances will they run on when utility power goes down. (Kern, 1997 and Kern et al., 1998).

IEEE 929 is not the only IEEE document relevant to PV systems or interconnection. A major effort underway is the development of a new standard that will address the interconnection of all small distributed generation. This new standard, IEEE P1547 is entitled “Draft Standard for Distributed Resources Interconnected with Electric Power Systems” and draws heavily from a variety of resources, including ANSI/IEEE Std 1001-1988 “Guide for Interfacing Dispersed Storage Generation Facilities with Electric Utility Systems,” which was withdrawn in 1996. Much of P1547 will also draw from the work that went into 929-2000. A more complete list of relevant standards is provided below.

2.4.3 Underwriters Laboratories

Underwriters Laboratories (UL) is a private, not-for-profit organization that has evaluated products, materials and systems in the interest of public safety since 1894. UL has become the leading safety testing and certification organization in the U.S., and its label is found on products ranging from toaster ovens to inverters to some office furniture. UL 1741 deals with inverters and the testing procedures for inverters.

Although UL writes the testing procedures, other organizations may do the actual testing and certification of specific products. In addition to the UL testing labs, Edison Testing Laboratories (ETL), the Canadian Standards Association (CSA), and Underwriters Laboratories Canada are widely recognized listing agencies.

UL Std 1741, “Static Inverters and Charge Controllers for use in Photovoltaic Power Systems,” was recently revised in conjunction with the work that was done on IEEE Std 929-2000. The test procedures proscribed by UL 1741 ensure that inverters meet the guidelines in IEEE 929. The UL 1741 listing thus conveniently assures the PV system owner that their inverter is in compliance with IEEE 929. A UL listing, however, does not make any assurances about the actual installation.

Until a few years ago, no listed inverters were available on the market. The cost of listing equipment in this relatively small market was too expensive for the companies manufacturing the equipment. There are now several listed inverters, and it is now quite possible to install a fully code-compliant PV system that most inspection jurisdictions will accept. You can call your inverter distributor or manufacturer to find out which models are listed as utility-interactive inverters, a special classification under UL Std 1741.

> *What if I have an inverter-based system, but I’m not using PV? Does UL 1741 apply?*

One question that frequently comes up is, “What if I have an inverter-based system, but I’m not using PV? Does UL 1741 apply?” The answer is yes largely because so many people have been asking. From the technical perspective, inverters that have different DC input power sources essentially go through the same processes to convert that power to AC. Because UL 1741 is an inverter document, it stands to reason that it should not matter whether a PV system, wind turbine, microturbine, or fuel cell is the power source. The May 1999 version of UL 1741 refers to PV specifically, but UL has already used this standard to test and list inverters for use with wind and fuel cell systems. And, the year 2000 version of UL 1741 is expected to have a formally expanded scope such that it applies to inverters generically, no matter the power source.

2.4.4 These Documents in Use

A grid-tied PV system that meets the National Electrical Code will also meet the requirements of both UL 1741 and IEEE 929. The 1999 NEC Article 690 requires the use of listed equipment, and any inverter that meets UL 1741 has been tested to the standards developed in IEEE 929.

A number of utility commissions and legislatures around the country already specify that the technical interconnection requirements for small scale PV systems and other distributed generation sources be based on the standards adopted by IEEE, NEC, and UL. This language is typically included in net metering rules. Those states that already reference IEEE, NEC, and UL for PV interconnection standards include California, Maryland, Nevada, New Jersey, Ohio, Rhode Island, Vermont, Virginia, and Washington.

Summary of PV and Interconnection-Related Technical Standards

Standard	Title
IEEE Std 928	Recommended Criteria for Terrestrial PV Power Systems
IEEE Std 929-2000	Recommended Practice for Utility Interface of PV Systems
IEEE Std 519-1992	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE Std 1262-1995	Recommended Practice for Qualification of Photovoltaic Modules
IEEE Std 1374-1998	Guide for Terrestrial Photovoltaic Power System Safety
IEEE Std P1479	Recommended Practice for the Evaluation of Photovoltaic Module Energy Production
UL Std 1741	Static Inverters and Charge Controllers for use in PV Power Systems
UL Std 1703	Flat-Plate Photovoltaic Modules and Panels
NFPA 70 Article 690 (NEC)	Solar Photovoltaic Systems
NFPA 70 Article 705 (NEC)	Interconnected Electric Power Production Sources

Standards Under Development or Discontinued

Standard	Title	Comment
IEEE Std P1547	Draft Standard for Distributed Resources Interconnected with Electric Power Systems	Expected completion 2001
IEEE Std 1001	Guide for Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems	Withdrawn
IEEE Std 1021	Recommended Practice for Utility Interconnection of Small Wind Energy Conversion Systems	Withdrawn
IEEE Std 1035	Recommended Practice: Test Procedure for Utility-Interconnected Static Power Converters	Withdrawn

There are a number of other IEEE and UL standards that address batteries for photovoltaic systems. These include IEEE 937, IEEE 1013-2000, IEEE 1145-1999, IEEE 1145-1999, and IEEE 1361.

3. Contractual Issues: Insurance, Fees, and Agreements

While trends suggest that the technical barriers to interconnection may soon be solved with the recent completion of IEEE Std 929-2000 and UL Std 1741, there still remain significant contractual barriers to interconnection. Among these are liability insurance requirements, fees and charges, and extensive paperwork.

3.1 Liability Issues

Liability insurance is required by most utilities that have interconnection standards for PV as a way to protect themselves and their employees should there be any accidents attributable to the operation of the customer's PV system. Most homeowners already have at least $100,000 of liability insurance through their standard homeowners insurance policies, so a requirement to provide this amount of coverage usually poses no further costs to the PV owner. In the first test of this issue, the New York Public Service Commission in 1998 rejected the proposal of several utilities that PV systems falling under the state's net metering law carry between $500,000 and $1,000,000 in liability insurance. The Commission concluded that $100,000 was sufficient.

In the first test of this issue, the New York Public Service Commission in 1998 rejected the proposal of several NY utilities that PV systems falling under the state's net metering rule have between $500,000 and $1,000,000 in liability insurance.

Indemnity is another liability-related issue that refers to security against or compensation for damage, loss, or injury. In the case of contracts between utilities and PV owners, utilities frequently require the PV owner or other customer generator to indemnify the utility for any potential damages as a result of operation of the PV system. Where there are liability insurance requirements, indemnification requirements are somewhat redundant. As part of its 1998 net metering ruling, the New York Public Service Commission ruled that indemnity requirements are not necessary for PV system owners because generic negligence and contract rules are sufficient.

Beyond the issue of limits of liability and indemnity, some utilities have sought to impose the requirement that they be listed as an "additional insured" on the customer generator's liability policy. In essence, what this means is that a utility would be protected under the system owner's policy in the event that the utility is sued in relation to the operation of the system. However, in most parts of the country, insurance companies have indicated that listing a utility as an additional insured is not even possible. In light of this, some utilities have dropped this requirement, and where state utility commissions have examined this, they have rejected this requirement.[5]

[5] For a more detailed discussion of liability issues related to interconnection, see Starrs and Harmon, "Allocating Risks: An Analysis Of Insurance Requirements For Small-Scale PV Systems."

3.2 Fees and Other Charges

There are a variety of fees that utilities may impose on owners of grid-tied PV systems. These fees include permitting fees,[6] interconnection-related fees and charges, metering charges, and standby charges. The imposition of even a modest fee can substantially alter the economics of grid-tied PV systems.

- *Interconnection-related fees and charges* include initial engineering and inspection fees for reviewing the system. Historically, utilities have conducted inspections of individual generating facilities, no matter how small in size, and have tended to charge the facility owners for these inspections. Fees for such inspections for even small PV systems have been reported as high as $900. It is expected, though, that such fees for inspections can be reduced with the more widespread recognition of relevant codes and standards such as NEC Article 690, IEEE 929, and UL 1741. For instance, utilities in the future may be comfortable simply checking that the components used in a particular facility are on an approved list of components that comply with appropriate codes and standards, rather than conducting a site visit in each case.

- *Metering charges* are typically imposed when a second meter is installed for a PV system. Such charges may range from $4–$8 per month. The first question is whether or not a second meter is needed at all. This will largely depend on whether your state has a net metering rule in place. If a second meter is required, the question is who should pay for the meter – the PV owner or the utility. This issue is still being considered in most states.

- *Standby charges* have been established by utilities for large customer generators. Utilities are required to have capacity in place to meet customer generator loads in the event that the customer's generation system goes down. It costs the utility to maintain this backup power, so large customer generators are required to pay standby charges. At issue is whether standby charges are necessary for small (<10 kW) customer generators. In a case involving Pacific Gas and Electric, the California Public Utility Commission ruled that standby charges would not be allowed for net metered customers. Since then, a number of other state laws have prohibited standby charges and other such charges for customers with small-scale PV systems. Typical standby charges for small PV systems can range from $2–$20 per month.

In light of the potentially detrimental economic impact of fees on customer generators, many state utility commissions that have ruled on interconnection (or on net metering) have placed limits or prohibitions on the imposition of additional fees by utilities.

[6] Permitting fees are discussed below in the section on Building Codes.

3.3 Standard Agreements and Procedures

3.3.1 Simplified Agreements

One of the most important interconnection issues is in the area of standardized agreement forms for customers interconnecting their PV systems. If the customer has to navigate and understand a stack of pages of fine print before they can move ahead with a system, even if the major technical and contractual rules are settled, they are less likely to move ahead. In other words, if a lawyer is needed to read and interpret the utility-required paperwork, costs go up and plans are abandoned.

Toward the end of simplification, the past three years have seen the development of a model one-page interconnection agreement that has gained support by customers, regulators and utilities alike. A copy of the *one-pager* is included in the Appendix. You can also download an electronic copy of this document from the IREC *Connecting to the Grid* site at www.irecusa.org/connect.htm.

This one-page agreement illustrates the importance of reliance on national standards: without getting into technical details, you can state in two lines of a document that systems must meet the requirements established by UL, IEEE, and the NEC.

A one-page agreement or modification thereof is now being used by utilities in Rhode Island, by Massachusetts Electric, Commonwealth Edison (Chicago), Connectiv (Delaware), and the City of Ashland Oregon. Its use is currently being considered in Virginia and North Carolina. Another model contract of five pages was developed for the California net metering law. This contract is also being used in New Mexico. You can download a copy of this document at the link above (www.irecusa.org/connect.htm).

3.3.2 Simplified Procedures and Contacting your Utility

A standard agreement, no matter how concise, needs to fit into a simplified procedural context. One of the frequent complaints of system owners looking to interconnect under net metering rules is that they (a) were not able to find a utility representative who was familiar with net metering and interconnection procedures or (b) encountered protracted delays in receiving the necessary paperwork or receiving approval once the paperwork was complete.

State regulatory commissions have sought to remedy this by establishing time limits for the various steps and requiring the utilities to designate a certain representative(s) to handle interconnection- or net metering-related queries. Ideally, information on the process would be available on utility websites and on state commission websites. This provision was recently incorporated into the Texas interconnection rules.

Still, most utilities do not have standard procedures for dealing with PV interconnection nor do most utilities have a designated individual to deal with requests. Not many utilities have *directly* used their control over interconnection rules and procedures to discourage PV systems or other customer generation; however, by failing to facilitate a simple process for small systems, many have discouraged it *indirectly*. In this case, it may make sense to try to look outside the utility for an agency that can provide some guidance. A good source of information is the utility commission public staff or the state utility consumer advocate group that represents consumer interests to the utility commission. Many states also have separate, specific consumer representative offices that are frequently located within the office of the attorney general. Your state energy office may know the right person to contact at your utility. Most state energy offices have staff who cover renewable energy and who may be able to provide leads.

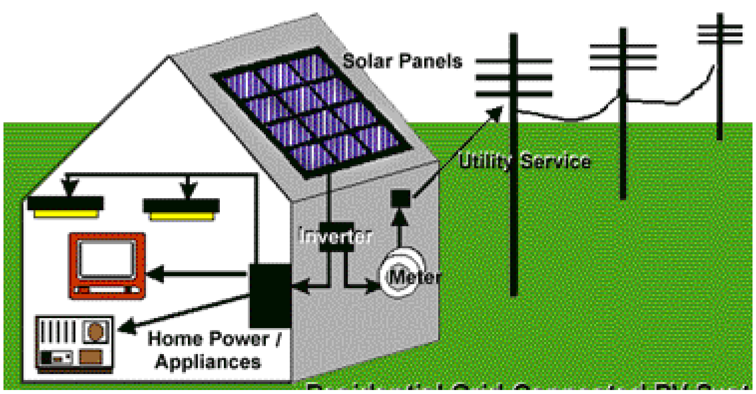
You can also check the web. Visit IREC's www.irecusa.org/connect.htm or the American Wind Energy Association's (AWEA) site at www.awea.org. Other sources of information on who to contact at your utility include the state and regional chapters of the American Solar Energy Society (ASES) and the Solar Energy Industries Association (SEIA). You can find the location of chapters and chapter contact information on the ASES (www.ases.org) and SEIA (www.seia.org) web pages.

4. Metering and Rates Issues

4.1 Net Metering

For those consumers who have their own electricity generating units, net metering allows for the flow of electricity both to and from the customer through a single, bi-directional meter. This arrangement is more advantageous to the customer than the two-meter arrangements that are more typically used for qualifying facilities authorized under PURPA. Under the most common two-meter arrangement, referred to as *net purchase and sale*, any electricity produced by a consumer that is not immediately used by the customer flows to the utility through the second meter. This excess generation flowing through the second meter is purchased by the utility at the utility's avoided cost, while the customer purchases any electricity off of the grid at the retail rate. There is usually a significant difference in the retail rate and the avoided cost. A typical retail rate might be 8.5¢/kWh, while the avoided cost rate may be 2.5¢/kWh.

With net metering, at times when the customer's generation exceeds her use, electricity from the customer to the utility offsets electricity consumed at another time. In effect, the customer is using the excess generation to offset electricity that would have been purchased at the retail rate. This may be thought of as analogous to the installation of compact florescent light bulbs or other efficiency devices that reduce total electricity consumption. Under most state rules, residential, commercial, and industrial customers are eligible for net metering, but some states restrict eligibility to particular customer classes.



Residential net metered PV system.

Net metering is also a low-cost and easily-administered way of promoting direct customer investment in renewable energy. One of the major advantages of net metering is its simplicity; most customers can use their existing meter without any additional regulation or equipment.

Arizona was the first state to implement net metering in 1981 when the Arizona Corporation Commission allowed net metering for qualifying facilities under 100 kW as an extension of PURPA. As of the spring of 2000, a total of thirty states have net metering, and net metering rules or laws are pending in at least four other states. In addition, some individual utilities offer net metering to small-scale generators on their own volition, in the absence of any statewide requirement. A list of states with net metering is provided in the Appendix.

4.2 Other Net Metering Issues

4.2.1 Annual vs. Monthly Netting

Recent net metering rules have called for month-to-month carry forward of any net excess generation or "annual netting." Under this provision, if over the period of a month, a customer generates more kWh than she uses, the excess kWh or "net excess generation" is carried over to the following month. In the event that there is excess generation carried over to the end of the year, any excess generation by the customer generator is granted to the utility with no payment to the customer generator.

The provision for annualized netting reflects the fact that some renewable energy resources are seasonal in nature. For example, a solar system may produce more energy than a household consumes in the summer months but may also produce less than what the household uses in the winter. Under this scenario the excess from the summer months would roll over to the winter months. The advantage to the utility of this type of arrangement is that not only is the utility granted any net excess generation at the end of the year, but the utility does not incur the administrative costs of paying the customer.

In states with month-to-month carry forward provisions, in the event that a customer-generator produces more than is consumed in a particular month, the customer is normally still required to pay the basic monthly customer charge.

4.2.2 Time-of-Use Metering and Smart Meters

Time-of-use (TOU) metering refers to a metering arrangement where customers pay differential electric rate based on the time of day that they are consuming electricity. Whereas the flat rate for residences may be 8.5¢/kWh, the time-of-use your rate for peak energy use may be 14¢/kWh and 3¢/kWh for off-peak. The question is how to make time-of-use measurements while net metering. TOU metering requires an electronic pulse meter which is fundamentally different from standard spinning electro-mechanical meters, and these TOU meters typically do not record energy flows in both directions.

There are two options for those who want to take advantage of both net metering and TOU metering. The first is to install a special electronic meter or *smart meter* that can measure energy flows in both directions and keep track of when those flows take place. However, these meters can cost up to $300 or more, and this would normally be an expense borne by the customer (assuming the utility allows you to have TOU metering with net metering). The other option – which was incorporated by New York state as part of its net metering rules – is to install a second meter (in addition to the TOU meter) that only measures net flows to the utility. This second meter, under the New York rules, is not a TOU meter, so the generation recorded on that second meter is allocated to the different rates based on expected PV output, which is based on meteorological data. The simplest approach, which has been adopted in a few states, is to simply not allow net metering customers to operate under a time-of-use rate.

5. Other Related Issues

5.1 Electrical Inspectors

In relation to interconnection, more attention is given to utilities than electrical inspectors because there are simply more issues in dealing with utilities; however, building and electrical inspectors have a very important role in ensuring that a grid-tied system goes on-line. Most people have heard the horror stories of a code compliant PV system not being approved by the electrical or building inspector because the inspector was unfamiliar with PV. Although these cases appear to be rare, this concern lingers. At the center of the issue is the fact that building inspectors have local autonomy. They are not bound to national codes and, in most cases, are not bound by state codes either.

Inspectors are not obligated to approve systems that are installed in compliance with the NEC if they are not comfortable with the system for any reason.

Most city or county inspection departments look to the National Electrical Code for guidance on most electrical inspection work. Since Article 690 of the NEC goes into detail on how PV systems should be wired for safety, any inspector can review this document and know what to look for in an installation. If the PV installation has not been installed to comply with the Code, the code official has full authority to prevent that system from being operated. And, inspectors are not obligated to approve systems that are installed in compliance with the NEC if they are not comfortable with the system for any reason. Until the code official is satisfied, the system could remain off-line indefinitely.

Most problems start by not properly briefing the code official on the installation. Showing concern to the code official about the issues they care about can help ensure a smoother inspection process. In most cases where inspectors are unfamiliar with photovoltaics, it is the job of the installer to explain the system to the inspector. One thing that electrical inspectors like to see are drawings and wiring diagrams. The installer should provide a complete set of simple plans in addition to the diagrams that come with the equipment.

5.2 Building Codes

Building codes are important because they address the physical safety of building structures. These codes are developed on the national level (1994 Uniform Building Code, 1994) to provide a consistent minimum standard by which local jurisdictions can evaluate the safety of their buildings. Building inspectors are concerned that the structural integrity of buildings are maintained and that the building will survive intact for many years with typical required maintenance. As this relates to PV, modules must be fastened in such a way that they will not blow off in a heavy wind or cause the roof to leak.

There are no significant barriers to engineering the structural integrity of a building for the mounting of PV systems. Problems have arisen when inspectors have required professional engineer stamps on drawings to ensure they are properly designed. The best way to mitigate this issue is by installing pre-engineered, packaged systems offered by several module manufacturers and large system integrators.

The development of innovative building-integrated PV systems that meet building codes has been ongoing for the last several years. These integrated approaches utilize construction techniques that have been proven in the use of large areas of glass in commercial construction. There are now commercially viable products, such as PV roofing materials and PV *curtain wall* products, where the displaced roofing material costs can improve the value of the PV system. Also, the mounting of systems on flat roofs has been greatly simplified and made more affordable through measures like ballasted roof mounting systems, which require no roof penetrations.

Installation of a ballasted roof mounted PV system for peak shaving at a textiles manufacturing plant.

One important issue under the topic of building codes is permitting fees. Permitting fees may be imposed by a municipality for PV systems where a building permit from the local building department is required. These fees are typically a percentage of the cost of the home improvement and thus can have a large impact on PV economics. One time permitting fees have been reported as high as $500. A key question is whether the PV system is a permanent part of the building structure or is removable and, therefore, considered personal property (Starrs et al., 1998). Prospective PV owners should look into whether permitting fees apply before proceeding with an installation.

5.3 Solar Access Rules and Local Covenants

Many states passed **solar access rules** in reaction to the oil crises of 1973–74 and 1979, but there has been relatively little activity in this area since then. The most common forms of solar access rules used throughout the U.S. are solar easements, covenant restrictions, and the granting of solar permits by a governing board. Of the fifty states, thirty-three have either explicit solar access provisions or have provisions for the creation of solar easements, with the latter being the most common solar access provision identified.

Like any other easement, **solar easements** allow the voluntary creation of a legally binding agreement between two parties with adjacent land whereby the “burdened” party agrees to never build or place any impediment that might infringe significantly on the solar radiation needed for the solar equipment of the "benefiting" party. Twenty-nine states have such provisions, most of which were created in the late 1970s and include the same or similar language.

Solar easements are legally binding once approved by the locally governing body—usually the county court—and run with the land no matter if land ownership changes hands. Rules typically require that (1) solar easements provide for the vertical and horizontal angles at which the easement extends over the real property subject to the solar easement, (2) the easement make clear provisions for the termination of the contract, and (3) the agreement spell out any compensation that might be due to the "burdened" party. Four states have gone further with their easement provisions and have allowed for the creation of wind easements. These states are Minnesota, Montana, New Mexico, and Wisconsin.

Local covenants refer to neighborhood- or development-imposed restrictions on what homeowners can do with their property. Many subdivisions and other planned communities across the U.S. have specific language that discourages or flatly prohibits the installation of solar panels. Often the reason is that a resident in the late 1970s or early 1980s put solar water heating panels on their roof without considering whether their neighbors would appreciate the aesthetic impacts, and unfortunately, most neighborhood or community officials do not understand the difference between a water heating panel and PV panel. If a neighborhood has a particularly restrictive covenant with respect to solar systems, it may be necessary to meet before the board that oversees the covenants.

Many subdivisions and other planned communities across the U.S. have specific language that discourages or flatly prohibits the installation of solar panels.

Seven states have statutory provisions that limit or prohibit the creation of covenants that restrict solar access. These states are Arizona, California, Colorado, Florida, Hawaii, Indiana, Iowa, Massachusetts, Nevada, Utah, and Wisconsin. Another positive trend is that communities across the U.S. are continually being set up with *requirements for solar energy* written into the established ordinances. Davis, California is an example community that has pioneered these types of ordinances. As more communities adopt these types of ordinances, other communities will have more models that exemplify the value and quality of incorporating solar energy provisions into their ordinances. And, in those communities where there are specific provisions supporting solar, interconnecting your system to the local utility will probably be much easier.

6. State-by-State Activity[7]

The previous sections are intended to lay out the issues and provide an understanding of how all the pieces fit together. This section of the guide, while in danger of becoming outdated, discusses what has *actually* been happening around the country and the interconnection trends that are developing.

6.1 Summary of Recent State-Level Activity

During 1999 and 2000, IEEE and UL approved their long-awaited updated technical standards for grid-connected PV systems – IEEE 929 and UL 1741. Sixteen states became actively engaged in the development of interconnection requirements for PV and other distributed technologies. Four states finalized their PV interconnection rules during this period, bringing the number of states that have adopted uniform, standardized requirements for PV systems to 10 (CA, DE, ME, MT, NV, NM, NY, RI, TX, and WA). While there are many more states that have yet to address these issues, much has been learned in the states that have moved ahead, and important trends have developed. Examples include the following.

- Although net metering laws passed in 1999 were far more specific about interconnection rules than earlier laws, the implementation of these laws has required substantial time and negotiating effort.

- Those states that have fully implemented interconnection rules have produced simplified contracts, usually based on the recently-finalized IEEE 929 and UL 1741.

- Some regulators expressed reluctance to act on PV interconnection standards while final approval of IEEE 929 was still pending. The approval of IEEE 929 in January 2000 is expected to encourage the adoption of standards in additional jurisdictions.

While most interconnection standards have been mandated in the context of net metering laws, many states are beginning to address interconnection issues independently from net metering. Also, the successful adoption of interconnection standards for PV technology has sparked a great deal of interest and activity in the development and adoption of uniform standards for other distributed resource (DR) technologies, including wind turbines, fuel cells, and microturbines. For instance, the scope of UL Std 1741 is being expanded to cover all inverter-based generating technologies, not just PV, and the IEEE P1547 working group is developing a standard for utility interconnection of all DR technologies, with a draft expected in 2001.

[7] This section was adapted from the paper "Utility Interconnection: Keep it Standardized, Stupid!" by Tom Starrs and Chris Larsen, presented at Solar 2000 in Madison, WI, June 2000.

Other major interconnection trends that are occurring include the following.

- ✧ The increasing visibility of other distributed resource technologies has focused attention on *interconnection study requirements*, which are intended to ensure that the existing distribution system can readily accommodate any power exported to the utility grid from the DR facility. Although interconnection studies have rarely been required for PV installations, technology-neutral study requirements may be enacted that require such studies for PV systems – typically at the customer's expense.

> *Some regulators expressed reluctance to act on PV interconnection standards while final approval of IEEE 929 was still pending. The approval of IEEE 929 in January 2000 is expected to encourage the adoption of standards in additional jurisdictions.*

- ✧ With the exception of interconnection study requirements, the most significant debates are no longer over technical issues; rather, more attention is being focused on contractual and economic issues. This includes the imposition of standby charges and the design of tariff rates for self-generating customers and others utilizing DR technologies.

- ✧ Utility efforts to block effective interconnection implementation in a number of states have included protective hardware beyond that called for in IEEE and UL standards; liability insurance requirements of $1 million or more; requirements that the utility be listed as an "additional insured" on customer insurance policies; and restrictions on the sale or transfer of customer-owned generating facilities.

- ✧ Inconsistent positions among some utilities (and even *within* some large utilities) have weakened overall utility opposition to standardized, simplified interconnection for PV.

- ✧ Other utilities, such as those owned by the New England Electric System (NEES), Commonwealth Edison in Chicago, and the Sacramento Municipal Utility District (SMUD), have provided valuable examples and constructive leadership on these issues.

6.2 Interconnection Progress: As Easy as 1-2-3?

The PV industry continues to lead other DR technologies in the development and adoption of uniform interconnection standards. However, a surge of interest in DR technologies – particularly fuel cells and microturbines – has started shifting interest away from PV and towards these other technologies. This section and the next two discuss both PV- and broader DR-related interconnection activity during the past two years.

It is important to emphasize that reaching the goal of simplifying and streamlining interconnection requirements requires more than just technical standards. In fact, streamlined interconnection requirements involve a three-step process.

(1) *Development* of technical standards by well-respected, independent standards-setting authorities such as the Institute of Electrical and Electronics Engineers (IEEE), the Underwriters Laboratories (UL), and the National Fire Protection Association (NFPA);

(2) *Adoption* of such standards, either by the utilities on their own volition or, more commonly, by governmental fiat (legislation or regulation); and

(3) *Implementation* of such standards, which includes approval of individual utility tariffs; preparation and dissemination of standardized interconnection agreements; dissemination of the relevant information to utility field personnel responsible for the interaction with the customer-generator; and actual experience.

The distinction between *approval* and *adoption* of technical standards deserves further explanation. The fact that the IEEE and others have developed and published standards in no way ensures that these standards will actually govern utility interconnection of a PV system or other DR facility. As discussed above, utilities historically have exercised a great deal of discretionary control over the requirements for interconnection into their networks, and are sometimes reluctant to give up this control in favor of generic standards.

However, policymakers have recognized that the development of viable mass markets for DR technologies will require uniform, simplified, “plug and play”-style interconnection standards. This is particularly true for small-scale installations such as residential PV systems where the cost of individually negotiating interconnection requirements and contractual terms and conditions is prohibitive.

Unfortunately, there are only a few states that can lay claim to having successfully completed the three-step interconnection process outlined above. One of them is California, where 1999 represented a real turning point in the implementation of the state’s net metering and interconnection requirements. At the beginning of the year, customers seeking utility approval for interconnection of residential PV systems were still reporting numerous difficulties with their local utilities. These difficulties included extensive delays in responding to interconnection requests; imposition of fees, charges, and other requirements expressly prohibited under the net metering law; lack of utility familiarity with PV system design and operation; and ambiguous or even contradictory statements regarding applicable requirements.

By the end of 1999, however, all three of California’s investor-owned utilities had embraced the technical standards called for in the law, adopted their interconnection agreements, and otherwise fully implemented the law. The result was a dramatic change in the interconnection experience residential customers were reporting, with customers citing few, if any, problems in obtaining a prompt response to their interconnection requests.

It is worth noting, however, that even in California, the full implementation of the net metering law and its interconnection standards required about four years. It also took the active involvement of the California Legislature, the California Public Utilities Commission, the California Energy Commission, the California Solar Energy Industries Association, and other stakeholders to overcome a variety of issues that arose during this period. This humbling testament to the challenges associated with overcoming barriers to interconnection should serve as a warning to those that expect state or federal PV initiatives to have an immediate effect on PV market development. In fact, it seems that getting interconnection requirements enacted is relatively simple compared to the more time-consuming and resource-intensive process of seeing these requirements effectively implemented.

6.3 State Activity: Development of PV Standards

Along with California, ten other states have at least completed step 2 – the process of adopting simplified, uniform interconnection standards for PV. These are Delaware, Maine, Maryland, Montana, Nevada, New Mexico, New York, Rhode Island, Texas, and Washington. In addition to these states, eight others are in the process of developing or finalizing similar standards, with more states just beginning to address these issues. These states are briefly discussed here. Arizona, California, Delaware, New York, and Texas are discussed separately in Section 6.4.

6.3.1 States With Uniform PV Interconnection Standards

The **Maine** Public Utilities Commission (MPUC) implemented interconnection rules for the state's net metering law in December 1998. The Maine process was driven in large part by individual PV system owners, and the PURPA preemption issue was at the center of debate. Utilities argued that the net metering law violates PURPA language regarding buy-back of electricity at avoided cost. In the end, the MPUC rejected arguments for federal jurisdiction over net metering. The interconnection rules cover all renewables up to 100 kW.

By the spring of 2000, nearly all of the **Maryland** utilities had filed their interconnection tariffs in accordance with the state's 1997 net metering law for residential and school PV systems up to 80 kW. Technical components of these tariff filings are based on IEEE and UL standards.

Net metering laws in **Montana, Nevada, and Washington** all include language specifying that technical interconnection requirements be based on national standards, and utilities have filed tariffs in accordance with the laws in all three states. *Montana's* rules cover solar, wind and hydro systems up to 50 kW; *Nevada's* rules cover solar and wind up to 10 kW; and *Washington's* rules cover solar, wind, hydro, and fuel cells up to 25 kW. The process for developing tariffs in these states was, for the most part, not contentious.

In September 1999, the **New Mexico** Public Regulatory Commission issued its final order on net metering after the January 1999 repeal of an earlier net metering ruling by the Commission. The final ruling, which lays out interconnection standards for Qualifying

Facilities (QFs) up to 10 kW, includes a standardized contract for the interconnection of systems to be net metered. Technologies covered include all renewables plus fuel cells, microturbines, and small cogeneration systems. Technical requirements are based entirely on applicable national standards, and utilities must use a Commission-developed five-page interconnection agreement.

Rhode Island's net metering rules for renewables and fuel cells up to 25 kW were established in 1998, and Rhode Island was the first state to adopt a simplified one-page interconnection agreement. Net metered systems must meet UL and IEEE standards and must be installed by a licensed electrician.

6.3.2 States Developing or Finalizing PV Interconnection Standards

As of May 2000, at least eight states are in the process of developing or finalizing their PV interconnection standards. These states are Florida, New Hampshire, New Jersey, North Carolina, Ohio, Oregon, Vermont, and Virginia. Several others, including Georgia, Hawaii, Massachusetts, Michigan, Utah, and Wisconsin, have started addressing interconnection issues.

Florida and North Carolina are following similar paths in dealing with interconnection standards. *Florida's* Public Service Commission has a docket open to address net metering and interconnection of PV systems up to 10 kW, and the *North Carolina* Utilities Commission has a docket open to address net metering and interconnection of renewable systems up to 100 kW. In both states there has been significant opposition by the utilities, and at the time of publication, many central issues remain unresolved.

Vermont's Public Service Board adopted interim interconnection standards for net metered renewable systems up to 15 kW in April 1999. The technical rules cover inverter-based systems as well as rotating generators, with the inverter rules based primarily on national standards. Final interconnection standards will be approved by the Board this year. The application for interconnection, which was based on an existing form, is also being reviewed with an eye toward simplification.

As of spring 2000, interconnection rules for **Oregon's** 1999 net metering law for solar, wind, fuel cell, and hydro systems up to 25 kW are nearly complete with the final step being incorporation of national standards into the state Building Code. Oregon's largest utilities have already filed interconnection tariffs that rely on national standards and simplified interconnection agreements.

New Hampshire's net metering law for solar, wind, and hydropower systems up to 25 kW was passed in 1997, but interconnection rules are yet to be developed as of this writing. The New Hampshire PUC hosted a series of interconnection workshops in 1999, and consensus was reached on many – but not all - issues. Much of the discussion centered on the issue of adding a surge withstand test requirement. The Commission is expected to have ruled by the end of 2000.

Electric restructuring laws in **New Jersey, Ohio, and Virginia** included net metering provisions with explicit language on interconnection. An important common feature in the draft rules is explicit reliance on national technical standards with prohibitions on additional technical requirements. *New Jersey's* draft rules, which cover solar and wind systems with a proposed size limit of 100 kW, include a provision for an annual aggregate net metering fiscal impact cap of $2,000,000 to protect service providers from excessive revenue losses. *Ohio's* rules, which were approved by the PUC in early 2000, cover solar, wind, biomass, landfill gas, hydro, microturbines, and fuel cells (with no system size limit). These rules were developed by the staff of the PUC in cooperation with renewables organizations and include interconnection provisions for DR systems up to 50 MW. What remains to be done in Ohio is for utilities to file net metering tariffs based on the rules. *Virginia's* net metering is limited to solar, wind, and hydro systems up to 25 kW, and to date the Virginia process has been very contentious, with strong utility opposition to proposed net metering and interconnection rules. By mid-2000, the commissions in New Jersey and Virginia are expected to have issued rules, and net metering tariffs will have been filed in Ohio.

6.3.3 Utilities with PV Rules

In addition to the states listed above, there are a handful of states where individual utilities have acted to develop interconnection rules in the absence of statewide rules. Massachusetts Electric has a one-page interconnection agreement for small scale renewables and is one of the easiest utilities in the country to work with on interconnection issues. Commonwealth Edison (ComEd) in Chicago recently developed a net metering program and a companion set of interconnection rules for PV systems. ComEd has also developed a net metering and interconnection brochure for its customers. Indianapolis Power and Light, Hawaiian Electric, and PECO Energy (Pennsylvania) have all also developed interconnection guidelines for PV systems.

6.4 State Activity: Development of Broader Standards

Most state interconnection requirements have been adopted in conjunction with the development of net metering laws. As a result, it is often the case that only facilities eligible for net metering can avail themselves of these simplified interconnection requirements. Because many net metering laws limit eligibility to small-scale facilities systems of no more than 10 – 100 kW, developers of larger-scale PV systems for commercial and industrial facilities are still subject to the utilities' traditional QF rules for interconnection.

Recently, the argument that larger PV systems should be eligible for uniform interconnection requirements has received a substantial boost from state efforts to adopt interconnection requirements for other distributed resource technologies. Although these proceedings have been driven primarily by fuel cell and microturbine industry representatives, the rules that have been developed equally apply to larger PV systems.

During 1999, the public utility commissions in two of the nation's most populous and influential states developed and adopted standardized interconnection requirements for DR facilities. The New York Public Service Commission enacted rules for facilities up to 300 kW, while the Public Utility Commission of Texas's rules apply to facilities up to 10 MW. A third state, Delaware, has moved forward Connectiv's (Delmarva Power) tariff filing that streamlines interconnection of systems up to 1 MW. Connectiv serves the majority of Delaware's customers and is the state's only investor-owned utility. Meanwhile, efforts are underway in Arizona and California to develop broader DR interconnection standards.

In short, policymakers have started acknowledging that the reasonable limitations on the size and type of technologies eligible for net metering are not appropriate limitations on the technologies eligible for standardized interconnection requirements.

The adoption of interconnection rules in these three states is a landmark in the evolution of interconnection requirements because the rules represent the first successful efforts to segregate the adoption of uniform, statewide interconnection standards from the adoption of net metering laws. The states of Arizona and California are following closely with working groups that are developing DR interconnection standards. In short, policymakers have started acknowledging that the reasonable limitations on the size and type of technologies eligible for net metering are not appropriate limitations on the technologies eligible for standardized interconnection requirements.

In 1999 the **Arizona** Corporation Commission (ACC) initiated a docket to establish interconnection standards for all distributed generation. Toward this end, the ACC established the Distributed Generation & Interconnections working group which, through three individual committees, developed recommendations to the Commission. As of the spring of 2000, the ACC has begun the formal rulemaking process to craft rules based on the working group recommendations, and a ruling is expected by the end of 2000. Once established, it is expected that specific technical rules will be based on system capacity breakpoints.

The **California** Public Utilities Commission (CPUC), in cooperation with the California Energy Commission and the Electricity Oversight Board, is moving ahead with the development of interconnection standards for distributed generation. Through a working group process similar to the format used in New York, California has developed a set of draft rules that will serve as the basis for a final CPUC ruling by the end of 2000.

The California DG rules do not have a system capacity limit, but the new rules will not impact PV systems up to 10 kW for which interconnection and net metering rules are already established. It is expected that the technical standards established in the California DG rules will closely match what is being developed by the Institute of Electrical and Electronics Engineers through the IEEE P1547 standards process.

A unique aspect of the California effort is the development of an interconnection screening process. Those systems that pass the screen are classified as a *simple interconnection* and require no further engineering review. Initial reaction to the screening process idea has been positive.

Delaware's interconnection rules for systems up to 1 MW have not received as much attention as those in New York and Texas. Filed by Connectiv, the state's only investor owned utility, the rules include technical interconnection guidelines for distributed generation up to 1 MW, with simplified standards for systems up to 25 kW. (Delaware's 1999 restructuring allows net metering for renewable facilities up to 25 kW.) The standards are broken into six categories:

- Renewables, inverter-based, up to 25 kW
- Renewables, rotating generator, up to 25 kW
- Non-renewable, inverter-based, up to 25 kW
- Non-renewable, rotating generator, up to 25 kW
- Any energy source, 25 kW to 1 MW, inverter-based
- Any energy source, 25 kW to 1 MW, rotating generator

The guidelines for inverter systems up to 25 kW are based on IEEE Std 929-2000 and UL Std 1741, and apply to all inverter-based generation sources – not just PV. Included in the Connectiv filing is a two-page interconnection application for systems up to 25 kW. A longer application form is used for larger systems. The Connectiv filing does not require installation of a manual external disconnect, but states that if no external disconnect is accessible to the utility, the utility can pull the customer's meter in the event that a visible disconnect is deemed necessary. The Delaware Division of the Public Advocate played an important role in the development of the new standards, and reaction from the renewables and distributed resources communities has been positive.

In December 1999, the **New York** Public Service Commission issued its final order on interconnection of small distributed generation units up to 300 kVA. The order was preceded by a year of collaborative work among stakeholders. Reaction to the rules from the renewables and distributed resources communities has been mixed.

The ruling, while defining standardized procedural rules and minimum technical requirements, allows utility discretion over final system design requirements based on the argument that "absent the utility's ability to protect its system on a case-by-case basis, the safety of the utility system may be compromised." Still, the Commission ruling notes that utilities will have to demonstrate the need for any specialized equipment and urges utilities to treat similar installations in a consistent manner. The Commission will closely monitor implementation and correct any unanticipated results.

Appendix B of the December 31, 1999 ruling outlines changes to the requirements for net metered PV systems (up to 10 kW), with technical guidelines that roughly follow the requirements in IEEE 929. The waveform testing requirements for these systems was dropped, but units must still be type-tested. In terms of other equipment, an external manual disconnect switch is required, and utilities may require a dedicated transformer if they can demonstrate a need to the Commission. As for testing, upon initial operation, owners must have a functional test of their systems performed, and utilities have the right to require periodic operational testing.

Work still to be done in New York includes the establishment of type-testing facilities, for which the Commission is working with the New York State Energy Research and Development Authority. Also, the Commission has opened up what is being referred to as the Phase II proceeding to examine cost-benefit issues associated with distributed resources in the state. This proceeding will be coordinated with another proceeding which will address standby charges for independent power producers.

Texas's December 1999 interconnection rules for distributed resources up to 10 MW have been favorably received by the DR community, which considers the Texas rules a model for other states to follow. The two new DR rules – 25.211 "Interconnection of On-Site Distributed Generation (DG)" and 25.212 "Technical Requirements for Interconnection and Parallel Operation of On-Site Distributed Generation" – cover procedural-contractual and technical requirements, respectively. Highlights of the Texas rules include:

- No pre-interconnection study fees for units up to 500 kW (under most circumstances) and limits on such fees for owners of larger systems;
- Time limits on pre-interconnection studies;
- Pre-certification provisions which will be specified in an ongoing proceeding;
- Technical provisions for interconnection to radial as well as network distribution systems;
- Mutual indemnification requirements instead of liability insurance requirements;
- Standardized interconnection applications (2-3 pages) and interconnection agreements (4-5 pages); and
- Designated dispute resolution procedures.

Work still to be done includes the development of pre-certification rules, i.e. who shall perform pre-certification tests and which standards shall apply, and the development of a Distributed Generation Interconnection Manual. A separate Commission proceeding was initiated in February 2000 to develop the manual and identify entities to perform pre-certification. It is expected that the pre-certification will be based on existing national standards such as IEEE 929, UL 1741, and the forthcoming IEEE P1547.

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Appendix

1. **Model One-Page Interconnection Agreement**
2. **State-by-State Net Metering Summary**

Interconnection Agreement for Solar, Wind, Hydroelectric and Fuel Cell Power Systems 25 kW Or Smaller

Section 1. Customer Information

Name: ____

Mailing Address: ____

City: ________________________, State _____ Zip Code: ____________

Street address (if different than above): ______________________________________

Daytime Phone: ____________________ Evening Phone: ____________________

Utility Customer Account Number (from utility bill): ______________________

Section 2. Generating Facility Information

System Type: Solar Wind Hydro Fuel Cell Generator Size (kW AC): _______

Inverter Manufacturer: ______________ Inverter Model: ________________

Inverter Serial Number: _____________ Inverter Power Rating: ________________

Inverter Location: ____________________________

Disconnect Type: Meter Removal Separate Manual Disconnect – Location: ____________

Section 3. Installation Information

Licensed Electrician: ___________________________ Contractor #: ___________

Mailing Address: ____

City: ________________________, State: _____, Zip Code:____________

Daytime Phone #: ____________________ Installation date: _____________

Section 4. Certifications

1. The generating facility's inverter meets the requirements of IEEE 929, "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems" and Underwriters Laboratories (UL) 1741, "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems"; and

Signed (Equipment Vendor): ____________________________ Date: _____________

Name (Printed) ______________________ Company: ________________________

2. The generating facility has been installed in compliance with the "Standards for Interconnection and Parallel Operation of Small-Scale, Customer-Owned Solar, Wind, Hydroelectric or Fuel Cell Powered Generating Facilities Up To 25 kW"; and with all applicable requirements of the National Electrical Code and the City of ____________ building and electrical codes.

Signed (Electrician): _________________________ Date: ______________

Name (printed) ______________________ Company: ________________________

3. The system has been installed to my satisfaction and I have been given system warranty information and an operation manual, and have been instructed in the operation of the system.

Signed (Owner): ____________________________ Date: _____________

Section 5. Utility and Building Division Inspection and Approval

1. Application Approved: ______________________ Date: ________________

2. System Inspection by: ______________________ Inspection Date: ____________

SUMMARY OF STATE NET METERING PROGRAMS (CURRENT)

State	Eligible Fuel Types	Eligible Customers	Limit on System Size	Limit on Overall Enrollment	Treatment of Net Excess Generation (NEG)(*)	Enacted	Citation / Reference
Arizona	Renewables & cogeneration	All customer classes	≤ 100 kW	None	NEG purchased at avoided cost	1981	AZ Corp. Comm. Decision No. 52345
California	Solar and Wind	Residential and small commercial customers	≤ 10 kW	0.1% of 1996 peak demand	Net metering customers are billed annually; excess generation is granted to the utility	1998	CA Public Utilities Code § 2827
Colorado	All resources	All customers	≤ 10 kW	None	NEG carried over month-to-month	1994	Public Service Co. of CO, Advice Letter 1265; Decision C96-901
Connecticut	Solar, wind, hydro, fuel cell, sustainable biomass	Residential only	No limit	None	Not specified	1998	CT Legislature, Public Act 98-28
Delaware	Renewables	All customer classes	≤ 25 kW	None	Not specified	1999	DE Legislature, S Amend 1 to HB 10
Idaho	Renewables & cogeneration	Idaho Power only; residential and small commercial customers	≤ 100 kW	None	NEG purchased at avoided cost	1980	ID PUC Orders No. 16025 (1980); 26750 (1997)
Illinois	Solar and wind	ComEd only; all customer classes	< 40 kW	0.1% of annual peak demand	NEG purchased at avoided cost	1999	Special billing experiment (effective 4/1/00)
Indiana	Renewables & cogeneration	All customer classes	≤ 1,000 kWh/month	None	No purchase of NEG; excess is granted to the utility.	1985	170 IN Admin Code § 4-4.1-7
Iowa	Renewables	All customer classes	No limit	None	NEG purchased at avoided cost	1983	IA Legislature & IA Utilities Board, Utilities Division Rules § 15.11(5)
Maine	Renewables, fuel cells & recycled municipal solid waste	All customer classes	≤ 100 kW	None	NEG carried over month-to-month; any residual NEG at end of 12-month period is eliminated w/o compensation	1998	Code Me. R. Ch. § 313 (1998); see also Order No. 98-621 (December 19, 1998).
Maryland	Solar only	Residential customers & schools	≤ 80 kW	0.2% of 1998 peak demand	NEG carried over to following month; otherwise not specified	1997	MD Legislature, Art. 78, Sec. 54M
Massachusetts	Renewables & cogeneration	All customer classes	≤ 60 kW	None	NEG purchased at avoided cost	1997	Mass. Gen. L. ch. 164, § 1G(g); Dept. of Tel. & Energy 97-111
Minnesota	Renewables & cogeneration	All customer classes	< 40 kW	None	NEG purchased at "average retail utility energy rate"	1983	Minn. Stat. § 261B.164(3)
Montana	Solar, wind or hydro	All customer classes	≤ 50 kW	None	NEG credited to following month; unused credit is granted to utility at end of 12-month period	1999	S.B. 409
Nevada	Solar and wind	All customer classes	≤ 10 kW	100 customers for each utility	Annualization allowed; no compensation required for NEG	1997	Nev. Rev. S. Ch. 704
New Hampshire	Solar, wind & hydro	All customer classes	≤ 25 kW	0.05% of annual peak	NEG carried over to following month	1998	NH Rev. Stat. §§362A:1-a & 362-A:9
New Jersey	Photovoltaic and wind	Residential and small commercial customers	No limit (100 kW limit proposed)	0.1% of peak **or** $2,000,000 annual financial impact	NEG credited to following month; unused credit is purchased at avoided cost.	1999	NJ Legislature, S.B. 7
New Mexico	Renewables & cogeneration	All customer classes	≤ 10 kW	None	At utility's option, customer is credited on the next bill for (1) purchase of NEG at utility's avoided cost; or (2) kilowatt-hour credit for NEG that carries over from month to month.	1999	NM PRC Order 2847 (9/7/99), amending previous Order from 11/30/98
New York	Solar only	Residential only	≤ 10 kW	0.1% of 1996 peak	NEG credited to following month; unused credit is purchased at avoided cost	1997	NY Public Service Law § 66-j
North Dakota	Renewables & cogeneration	All customer classes	≤ 100 kW	None	NEG purchased at avoided cost	1991	ND Admin. Code § 69-09-07-09
Ohio	Solar, wind, biomass, landfill gas, hydro, microturbines, or fuel cells	All customer classes	No limit	1.0% of peak demand for each retail electric provider	NEG purchased at unbundled generation rate, appears as credit on following bill	1999	S.B. 3 (effective 10/6/99)
Oklahoma	Renewables & cogeneration	All customer classes	≤ 100 kW and annual output ≤ 25,000 kWh	None	No purchase of NEG; excess is granted to the utility.	1990	OK Corp. Comm. Schedule QF-2
Oregon	Solar, wind, fuel cell and hydro	All customer classes	≤ 25 kW	No less than 0.5% of utility's historic single-hour peak load; beyond 0.5% eligibility can be limited by regulatory authority	NEG purchased at avoided cost or credited to following month; at end of annual period unused credits shall be granted to low-income assistance programs, credited to customer, or "dedicated to other use" as determined by regulatory authority	1999	H.B. 3219 (effective 9/1/99)
Pennsylvania	Renewables only (includes fuel cells)	All customer classes	≤ 10 kW	None	NEG granted to utility at end of month	1998	PA PUC, Miscellaneous Individual Utility Tariffs
Rhode Island	Renewables & fuel cells	All customer classes	≤ 25 kW	1 MW for Narragansett Electric	NEG credited to following month; unused credit is granted to utility at end of annual period	1998	RI PUC, Order, Docket No. 2710
Texas	Renewables only	All customer classes	≤ 50 kW	None	NEG purchased at avoided cost	1986	PUC of Texas, Substantive Rules, § 23.66(f)(4)
Vermont	Solar, wind, fuel cells using renewable fuel, anaerobic digestion	Residential, commercial, and agricultural customers	≤ 15 kW, except ≤ 100 kW for anaerobic digesters	1% of 1996 peak	NEG carried over month-to-month; any residual NEG at end of year is granted to the utility	1998	VT Legislature, H. 605

Virginia	Solar, wind, hydro, fuel cells	Residential and commercial customers	≤ 10 kW (residential); ≤ 25 kW (commercial)	0.1% of annual peak demand	Net metering customers are billed annually; excess generation is granted to the utility	1999	S.B. 1269 (effective by 7/1/2000)
Washington	Solar, wind, hydropower, and fuel cells	All customer classes	≤ 25 kW	0.1% of 1996 peak; "no less than" 50% of cap for renewables	NEG credited to following month; unused credit is granted to utility at end of annual period	1998	WA Legislature, House Bill 2773
Wisconsin	All Resource	All retail customers	≤ 20 kW	None	NEG purchased at retail rate for renewables, avoided cost for non-renewables	1993	WI PSC, Schedule PG-4

[*]Net excess generation occurs only when total generation exceeds total consumption over the entire billing period, i.e. the customer has more than offset his/her total electricity use and has a negative meter reading.

SUMMARY OF STATE NET METERING PROGRAMS (PROPOSED)

State	Eligible Fuel Types	Eligible Customers	Limit on System Size	Limit on Overall Enrollment	Treatment of Net Excess Generation (NEG)[*]	Enacted	Citation / Reference
District of Columbia (authorized)	Renewables, cogeneration, fuel cells, microturbines	Residential or commercial	≤ 100 kW	None	Customer-generator "may receive compensation based on the net metering rules established by the Commission."	Pending	Authorized by District of Columbia Enrolled Bill 13-284; requires further Commission action
Georgia (pending)	Solar, wind, hydro, biomass, fuel cells	All customer classes	≤ 100 kW	None	Net metering customers are billed annually; excess generation is granted to the utility	Pending	Senate Bill 433
Illinois (pending)	Solar or wind	All customer classes	≤ 40 kW	None	NEG credited to following month; unused credit is purchased at avoided cost	Pending	House Bill 2615, Senate Bill 0534 (companion bills)
North Carolina (pending)	Solar, wind, hydro, and biomass	All customer classes	≤ 10 kW (residential); ≤ 100 kW (non-residential)	1.0% of annual peak demand	NEG credited to following month; unused credit is eliminated at end of annual billing period (residential customers only)	Pending	NC Utilities Commission, Docket No. E-100, Sub 83 (November 18, 1998)
South Dakota (tabled)	Solar, wind, geothermal, biomass, hydro	All customer classes	≤ 100 kW (as amended)	None	NEG credited to following month; unused credit is purchased at avoided cost	Pending	House Bill 1232

[*]Net excess generation occurs only when total generation exceeds total consumption over the entire billing period, i.e. the customer has more than offset his/her total electricity use and has a negative meter reading.

North Carolina Solar Center
Box 7401, NC State University
Raleigh, NC 27695-7401
(919) 515-3480
(919) 515-5778 (fax)
www.ncsc.ncsu.edu

Interstate Renewable Energy Council
P.O. Box 1156
Latham, NY 12110-1156
(518) 458-6059
(phone & fax)
www.irecusa.org