Solar Boston Permitting Guide

A resource for building owners and solar installers

Fall 2010

City of Boston — Thomas M. Menino, Mayor

October 28, 2010

Dear Boston Residents and Business Owners,

I am pleased to present the *Solar Boston Permitting Guide*. This new resource will support residents, businesses and institutions interested in installing solar energy systems and will further Mayor Thomas M. Menino's goal of siting 25 megawatts of solar in Boston by 2015. In addition to assisting Bostonians looking to adopt solar technology, this guide provides critical information to solar installers about the permitting and interconnection policies of the City of Boston and our Solar Boston partner NSTAR.

Solar Boston, a program supported by the U.S. Department of Energy's Solar America Initiative, has worked within City government and our communities to increase the installation of solar power systems on Boston rooftops. This guide describes new, streamlined permitting rules for solar photovoltaic systems, particularly for residential photovoltaic installations on one-to-four family buildings. In conjunction with this guide, the Mayor filed an ordinance with City Council that will reduce solar permitting fees by up to 60%. These renewable energy initiatives will stimulate our local economy and provide jobs for Boston residents.

Since the Mayor's Climate Action Leadership Committee's April 2010 recommendations, the City of Boston has initiated new programs and policies needed to meet the committee's ambitious goals. This fall, the Renew Boston program began connecting residents and businesses with energy efficiency resources throughout the City. The Boston Housing Authority recently initiated the largest public housing energy efficiency project in our country's history. Reducing community-wide greenhouse gas emissions 25% by 2020, and a further 80% by 2050, will require Boston residents, businesses, institutions and community organizations to work collaboratively to find win-win solutions to our shared climate challenges.

The City of Boston looks forward to continuing our work on alternative energy and climate policy. We appreciate the efforts of all Bostonians in supporting these initiatives, and helping to make our climate action goals a reality.

Sincerely,

James W Hunt, III
Chief of Environmental and Energy Services

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Chapter 1. About the Solar Boston Program and this Guide

In June of 2007, the City of Boston became one of thirteen inaugural Solar America Cities under the U.S. Department of Energy's Solar America Initiative. The Solar Boston program works with local installers, business and residents to promote the development of a robust solar industry in the City of Boston. As part of Mayor Menino's Renew Boston Initiative, Solar Boston has worked to further the city's ambitious goal of siting 25 MW of solar capacity in Boston by the end of 2015.

Through the Solar Boston Initiative, the Mayor's Office of Energy and Environmental Services has worked to promote solar technology adoption by both residents and businesses as well as on public buildings. Since the inception of the program, solar capacity in Boston has increased fivefold and the number of installers working on Boston-based projects has grown significantly. The Solar Boston program has hosted workforce training events, served as an informational resource for residents, has sponsored outreach events promoting solar, and has tracked the growth of the city's solar market. Additionally, the Solar Boston Initiative has worked to encourage city departments to develop projects on municipal buildings. Since the start of the program, the city has developed nine solar projects on city properties totaling more than 500kW of capacity, with an additional 200kW in the project pipeline.

Mayor Menino launches the Solar Boston Initiative with former U.S. DOE Secretary Samuel Bodman, DOER Commissioner Phil Guidice and City of Boston Chief of Environmental and Energy Services Jim Hunt.

Soar Boston has worked to promote photovoltaic and solar hot water installations throughout the city. The program collaborated with the Boston Redevelopment Authority (BRA) to develop the Solar Boston Map (gis.cityofboston.gov/solarboston), an online Geographic Information System (GIS) based map that both tracks the city's solar installations and provides users with a high-level solar site assessment. The Solar Boston map is discussed in detail in Chapter 4 of this guide. Solar Boston has also worked to streamline the permitting and interconnection process for solar systems in the city. Solar Boston staff have worked with the Boston Inspectional Services Department (ISD) to adopt a nation-leading permitting fee structure and worked with ISD, the Landmarks Commission and the Fire Department to coordinate the city permitting process to ensure that solar installers can safely and efficiently work in the city.

The Solar Boston Permitting Guide was developed as a resource for residents, businesses and solar installers to help navigate the solar project development process. Chapter 2 of the guide discusses general background information on solar technologies. Chapter 3 discusses how property owners can evaluate whether solar makes sense for their buildings. Chapter 4 explains how Bostonians can use the Solar Boston map to further explore the solar potential of their homes or businesses. Chapter 5 details state and federal financial incentives that may be available to owners of solar systems and Chapter 6 details how to find a qualified solar installer. Chapter 7 describes the permitting and interconnection process for systems built in Boston and is intended to serve as a primary resource for solar installers working in the city.

Chapter 2. Solar Energy Technology Background

This section provides an overview of solar photovoltaic (PV) technologies and systems. The reader is encouraged to review the **Additional Resources** listed at the end of this section to delve deeper into many of the topics presented here as well as the **Glossary** at the end of this guide.

2.1 How Does a Photovoltaic System Work?

Photovoltaic systems convert sunlight directly into electricity. These systems allow building owners to generate some or all of their daily electrical energy demand either on their roof or somewhere on their property. The majority of solar PV systems are grid-tied, meaning they are directly connected to the power grid and do not require battery storage. Grid-tied PV systems will generate electrical power to supply part of a building's energy usage during the daylight hours, but will not produce power during a power outage or during non-daylight hours. Figure 2.1 depicts an illustration of a solar PV system interconnected to the grid.

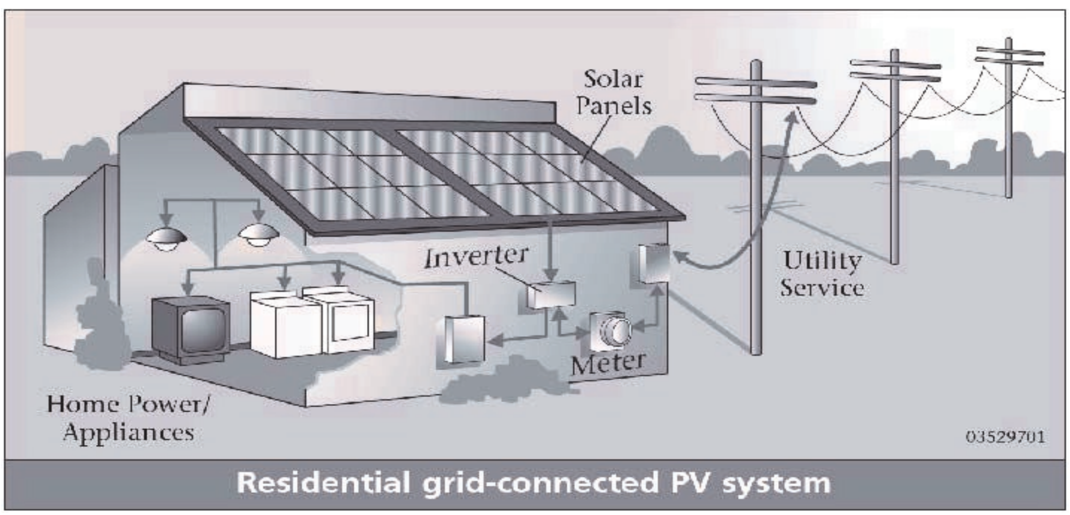

Figure 2.1: Residential Grid-Connected PV System. Source: A Consumer's Guide: Get Your Power from the Sun, US. Department of Energy, 2003

A solar PV system can provide power to a home or business, reducing the amount of power required from the utility; when the solar PV system power generation exceeds the power needs, surplus power can be fed back into the electricity grid, spinning the building's electricity meter backwards. The ability to export electricity into the grid and receive compensation from the utility is called **net-metering**. NSTAR has a special rate tariff for net-metered power system and will install a special utility meter that records the net power coming in from the utility and the surplus power flowing out from the solar PV system. For more information on net metering see Chapter 5 of this guide.

A solar PV system will not operate during a power outage unless the system includes a battery backup. During a power outage, photovoltaic systems can energize electric lines that the utility assumes is not energized, and create a shock hazard to personnel. Photovoltaic systems will shut off during grid power outages as a safety feature for utility personnel who might be working to restore power on nearby electric distribution lines. Photovoltaic systems can also be designed with battery backups to provide uninterruptible power supplies (UPS) that can operate selected circuits in a building for hours or days during a utility outage.

The basic building block of PV technology is the solar cell. Solar cells are typically six- to nine-inch wafers of silicon or other advanced materials with integrated circuitry. When sunlight hits a solar cell, the unique chemistry of the cell materials generates an electrical current. Multiple PV cells are connected to form a PV module, the smallest PV component sold commercially. A PV system connected or tied to the utility grid typically has the following components:

PV Array: A PV Array is made up of PV modules, which are collections of PV cells. The most common PV module is 5-to-25 square feet in size and weighs about 3-4 lbs/ft^2. Modules range in power output from about 10 to 300 watts (although higher wattages are available for utility-scale PV applications), with the power density ranging from about 5-to-18 watts per square foot.

DC to AC Inverter: An inverter is the device that takes the direct current (DC) power from the PV array and converts it into standard alternating current (AC) power used throughout a building. The inverter also creates an AC power stream that matches the frequency and quality of power from the electricity distribution grid. This power conversion process allows PV generated electricity to be exported onto the power grid.

Balance of System Equipment (BOS): BOS includes mounting systems and wiring systems used to integrate the solar modules into the structural and electrical systems of the building. The wiring systems include disconnects for the DC and AC sides of the inverter, ground-fault protection, and overcurrent protection devices, junction boxes and possibly circuit combiner boxes. (See Figure 2.2).

Figure 2.2. Typical Residential solar wiring. Source: Celentano Energy Services

Metering: Solar PV systems require special meters that record and display total electricity generated by the solar system. For a typical solar installation, the local utility will assist with the installation of a suitable bi-directional electricity meter that allow system owners to net-meter installations. Many installers are also offering Data Acquisition Systems (DAS) that can be accessed through a website interface. These metering systems allow system owners to track their PV system's production in real time and to determine if their system is functioning properly. The DAS for a 19.5 kW PV system on the Franklin D. Roosevelt Elementary School can be viewed here: Roosevelt School PV.

Batteries (optional): Batteries can provide energy storage or backup power in case of a power interruption or outage on the grid. Battery backup PV systems (Fig. 2.3) account for less than 5% of all installed solar PV systems.

The photovoltaic systems discussed in this guide are generally installed on the customer's side of the electricity meter, allowing the system to offset building electricity load. Many utilities and power generating companies are currently building multi-megawatt, utility-scale photovoltaic systems. These ground mounted, multi-acre PV systems generate power that is sold in the wholesale electricity market.

Fig. 2.3. A battery bank for an off-grid PV system on Georges Island in the Boston Harbor Islands.

2.2 Photovoltaic Technologies

Today's PV systems come in a range of efficiencies and configurations. Photovoltaic systems with modules that are mounted on top of existing roofing are the most common configuration, but building integrated photovoltaic (BIPV) systems are gaining in popularity. In a BIPV system, the solar modules both generate electricity and serve as a functional building architectural element. Roof shingles, building siding and windows can be replaced with BIPV systems.

2.3 Installation Methods

There are a number of methods for affixing PV arrays to buildings or mounting them in open spaces. Common PV array mounting methods for residential and commercial systems include:

- Integral mounting (rooftop) (Figure 2.4)
- Standoff mounting (rooftop) (Figure 2.5)
- Rack mounting (rooftop or ground)
- Ballasted mounting (rooftop or ground) (Figure 2.6)
- Pole mounting (ground) (Figure 2.7)

Large-scale flat roof commercial projects are often designed with fully engineered and certified systems, and many systems require no roof penetrations. For these systems, mounting hardware is either ballasted, interlocking or some combination of the two in order to withstand wind speeds as required by local building codes. Non-penetrating ballasted systems require adequate roof structural integrity in order to withstand the additional weight of the ballast (Fig. 2.6). Ballasted, interlocking systems often limit the maximum angle that the PV array can be

Figure 2.4 **Integral rooftop mounting system (attach directly to roof rafters) at the Boston Nature Center.**

Figure 2.5: Standoff mounting system for roof top (several inches off the roof surface allowing natural venting) Source: Unirac

Figure 2.6 Commercial ballasted PV system on the Roosevelt Elementary School.

Figure 2.7: Pole-mounted PV system at Logan Airport.

tilted in order to withstand design wind speeds. Non-penetrating mounting hardware can be installed on standing seam metal roofs with roof clips. Mounting hardware can also be mechanically attached to the roof and underlying structural members.

Installation of PV systems requires detailed structural analysis to ensure that the underlying building can safely support the added load of a PV system. In the City of Boston, structural drawings stamped by a Professional Engineer are required to obtain a building permit to construct PV systems.

2.4 Additional Reading Material and Resources

Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices , SAND2005-0342, February 2005, Sandia National Laboratories, Photovoltaic Systems Assistance Center, Albuquerque, NM 87185-0753. Also available in PDF format only from the Southwest Technology Development Institute, http://www.nmsu.edu/%7Etdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

A Guide to Photovoltaic System Design and Installation, California Energy Commission Consultant Report 500-01-020, June 2001 http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

Installing Photovoltaic Systems (Course Manual) , 2002, Florida Solar Energy Center, 1679 Clearlake Road, Cocoa, FL 32922-5703 http://www.fsec.ucf.edu

Home Power: The Hands-on Journal of Home-Made Power , Home Power, Inc., PO Box 520, Ashland, Oregon, www.homepower.com

Solar Ready Buildings Planning Guide, L. Lisell, T. Tetreault, and A. Watson, National Renewable Energy Laboratory, Technical Report NREL/TP-7A2-46078 December 2009

A Homebuilder's Guide to Going Solar, U.S. Department of Energy, December 2008, DOE/GO-102008-2744

Chapter 3. Is Solar Right for You?

While the cost of energy produced by PV systems continues to drop, PV energy still usually costs more on a kilowatt-hour per kilowatt-hour basis than energy from local utilities. However, many of the available state and federal incentives are designed to make power from PV systems cost-competitive with fossil-fuel generated electricity. Nonetheless, many reasons beyond cost exist for considering a PV system. Whether it is a commitment to more sustainable living, a hedge against rising electricity costs, or a way to offset peak demand, PV is an excellent choice for a growing number of building owners. Additionally, many consumers consider the following advantages of PV systems.

Modularity	A PV system can be designed for easy expansion. If power demand is likely to increase in future years, the ease and cost of increasing PV power supply should be considered.
Fuel Supply	Transmitting conventional electricity to the site and distributing it can be as or more expensive than the fuel itself. Solar energy runs on sunlight and, as a distributed generation technology, is delivered free of charge.
Environment	PV systems create virtually no pollution and generate no waste products when operating.
Peak Generation	Solar PV often offsets the need for electricity during expensive peak demand hours.
Maintenance	Any energy system requires maintenance, but experience shows that PV systems require less maintenance than most other alternatives.
Durability	Most of today's PV modules are based on a proven technology that has historically experienced little degradation over 15 years of operation.
Cost	For many applications, the advantages of PV systems offset their relatively high initial investment costs.

Furthermore, homeowners and businesses should consider solar if:

- The proposed building is already as energy-efficient as it can be
- The roof is new or in good condition (if considering a rooftop system)
- Or the proposed space (roof or land) gets sufficient sunlight during the sunny hours of the day (an average of six hours is recommended)

Decisions made during the design of a PV system affect the construction costs and return on investment. If a system is designed based on unrealistic requirements, the initial cost will be unnecessarily high. If less durable parts are specified, maintenance and replacement costs will increase over time. As a result, system life-cycle costs can easily double if inappropriate choices are made during system design. System designers should be experienced and knowledgeable of proper design techniques, code requirements, maintenance and implementation, and associated cost impacts. Chapter 6 of this guide discusses factors to consider when choosing a PV system installer

In addition, before installing a solar system, customers should discuss the following design, installation, and financing options with their prospective installers.

3.1 Efficiency First

Before considering a solar photovoltaic system for a building, energy-efficient measures should be incorporated first. Energy-efficiency is not only a cost-effective means of reducing carbon emissions but also reduces the optimal PV system size and installation cost. Weatherization and conservation represent "low hanging fruit" that enable customers to achieve both energy and dollar savings. Ultimately, implementing energy efficient measures are much more cost effective and less capital intensive than installing a solar PV system, and therefore should be done first or in concert with solar PV system installations.

The City of Boston's Renew Boston initiative assists local residents and businesses improve the energy efficiency of their buildings. Additionally, both NSTAR, the local electric utility, and National Grid, the local gas distribution company, offer residents and businesses comprehensive efficiency services. Frequently, these services include free energy audits and substantial grants and rebates for energy efficiency upgrades. For additional information regarding efficiency opportunities in Boston, contact Renew Boston (www.renewboston.org) or MassSAVE (www.masssave.org) to learn more.

3.2 Direct System Ownership or Power Purchase Agreements

While many PV system owners choose to directly purchase the solar installations on their properties, a number of innovative financing mechanisms have been developed to minimize the upfront costs of solar installations. Many Massachusetts project developers offer solar power purchase agreements (PPAs), through which developers own, finance, and install a solar array on a building owner's roof. Property owners agree to enter into a solar power energy contract with the developer, paying a monthly fee for the solar energy used by the household or business. Under this ownership structure, the PPA provider or project developer can monetize the federal and state tax credits and also receives other state incentives. Building owners can benefit from PPAs by signing long-term power supply contracts for on-site renewable energy. These contracts can serve to diversify the building's energy use portfolio and to hedge against future power price increases.

3.3 Solar PV System Site Considerations

Successful solar PV installations require good access to sunlight, minimal shading, and proper tilt and orientation. This requires suitable rooftop space and proper installation and mounting. The following discusses several key aspects that influence the suitability of solar sites.

Sunlight Intensity (Irradiance)

The output of a PV system is proportional to the intensity of the sunlight falling on the system. Greater amounts and duration of sunlight increase system performance, though solar systems can generate electricity even on cloudy days. Sunlight intensity is called irradiance, which is measured in watts per square meter (W/m^2). In summer, when the sun is nearly directly over head, solar irradiance at the Earth's surface is approximately 1,000 W/m^2. This irradiance is defined as "full" or "peak" sun, and it is the standard irradiance for testing and rating PV modules. At peak sun conditions, roughly 70% of the sun that enters at the top of the atmosphere penetrates to the surface of the Earth.

Over a one year period, PV modules in Boston will receive the most direct sunlight when the PV array is facing due south and is tilted at an angle that is approximately the latitude of the region (for Boston a 42 degree tilt provides the highest yearly energy production). However, tilting the PV array at the angle of latitude is not always the best solution for a project.

- Some rooftops may not be able to structurally withstand the additional forces imposed (wind, snow, etc.) as the tilt angle of a PV array increases.
- PV arrays tilted at lower angles will not need to be spaced as far apart to avoid shading from adjacent rows, therefore a greater quantity of modules can be installed. This may be desirable if a property has limited space.

While these considerations may require a PV system to be installed at a non-optimal tilt, systems with less-than-ideal tilt angles can still produce significant, economical electricity. Typical residential solar PV systems are flush mounted to south-facing roof areas. These systems are pitched at the same slope as the building's roof. This type of installation frequently provides adequate production to make the systems economically viable while also improving the aesthetics of the installation.

Shading

Shading portions of a PV array will have adverse effect on the system's performance. It is important to determine during a site assessment if a potential location for the PV array will be shaded, especially between the hours of 9 a.m. and 3 p.m. This is important, as the output of PV modules may be significantly impaired by even a small amount of array shading. A careful assessment using an hourly computer simulation program is necessary to determine the benefits of orientations. A minimum of six hours of unshaded operation is important for best system performance.

Fig. 3.1. Solmetric Sun Eye Device. Source: Solmetric

Shading calculations can be performed by hand by taking accurate measurements, noting surrounding objects and their position relative to a potential area, and using a sun path chart for the appropriate latitude. Several tools are also available to assist installers with easily identifying areas that will be shaded during crucial times of the day and throughout the year. The most commonly used tools include the Solmetric Sun Eye (Figure 3.1), the Solar Pathfinder (Figure 3.2) and the Acme Solar Site Evaluation Tool (Wiley Electronics).

Fig. 3.2 Solar Pathfinder On-Site Close-Up – objects shading the site are reflected in dome of device)
Source: Celentano Energy Services

Orientation

System orientation is another critical factor in PV system design and siting. Facing the PV array due south is ideal; however, slight deviations will not considerably reduce power production. For example, an unshaded PV array with a tilt of 35 degrees and facing +/- 45 degrees away from due south (SE or SW) will still receive 92% of the annual solar radiation in comparison to a PV array facing due south. Fully understanding what the orientation will be at construction must be understood very early in the project. Many roof orientations are not ideal for solar PV so the impact of less-than-optimal orientation must be understood prior to finalizing system design.

Capacity of Existing Electric Service

Photovoltaic systems deliver electricity to a building via a breaker in the existing electrical service panel. If the breaker size, as determined by the maximum current output from the PV inverter, is limited based on the rating of the panel, electrical system upgrades may be necessary to accommodate a new PV system. This potential added cost should be considered when evaluating price proposals from solar installers.

Roof Structure and Age

For rooftop applications, installers must determine if the roof is able to accommodate the additional weight of the PV array and how the system should be attached to the existing structure. Building permitting authorities and inspectors review codes and guidelines with installers to ensure that roofs can support the load of a PV system.

Because PV systems are designed to last more than twenty years, it is recommended that buildings with older roofs have their roofs replaced before installing solar. Roof membrane failures that occur after a PV system is installed may require building owners to remove and then reinstall the PV system in order to fix the leaking roof. Most PV installers will work with professional roofers to ensure that systems are installed in a way that does not void existing roof warranties and modern PV racking system have an excellent track record of maintaining roof membrane integrity.

3.4 Additional Reading Material and Resources

A Consumer's Guide Get Your Power from the Sun , U.S. Department of Energy, December 2003 DOE/GO-102003-1844

City of Boston (2010) Renew Boston website. Last accessed: www.RenewBoston.org

MassSAVE (2010) MassSAVE website. Last accessed: www.MassSAVE.org

Solar Site Evaluation Tools & Techniques to Quantify & Optimize Production, M. Galli, P. Hoberg, SOLARPRO Optimal Design, Installation & Performance, December/January 2009

Chapter 4. The Solar Boston Map

The Solar Boston map is an online tool that both tracks the city's progress towards the Mayor's 25 MW goal and allows city property owners to do a high-level feasibility analysis of their buildings. Developed through a collaboration between the Mayor's Office of Environmental and Energy Services, the Boston Department of Innovation & Technology (DoIT) and the Boston Redevelopment Authority, the Solar Boston map has helped city residents and business owners explore their buildings' solar potential. The map also features key information about areas of the city where solar PV systems may require special design and installation considerations. The map depicts the **Area Network**, a portion of the NSTAR distribution grid where interconnection of distributed PV systems can be challenging. The map also delineates areas of the city overseen by the Historic District Commissions or the Landmarks Commission. Solar systems installed in these Boston neighborhoods require special design considerations so as to not alter the historic character of city's building stock.

The Solar Boston map is a GIS-based platform that includes a number of critical information layers that allow users to develop a high-level shading analysis of their roofs. This feature allows building owners to determine if their roof is well suited for solar PV system. The Solar Boston map shading data layer was generated using a high-resolution scan of the city. This shading data is used in the Solar Boston map to predict building heights and to generate a shading analysis of each building in the city.

4.1 Using the Solar Boston Map to Understand a Building's Solar Potential

In order to examine a building's solar potential, log on to gis.cityofboston.gov/solarboston. To access the map, close the pop-up window describing the program. The map highlights solar installations across the city and also catalogs other renewable energy technologies installed in Boston. Users can hover over the solar, wind or hydro map icons to learn more about individual renewable energy systems in the city. The Solar Boston map also allows users to view the city map from one of three perspectives – street, terrain or aerial. These can be selected in the upper right hand corner of the map.

Analyzing a building's roof size and shading

To find a building using the Solar Boston map, click the Tools menu in the upper right hand corner of the site. A box will pop up on the screen that allows users to enter their street address and zip code. Because many street names in Boston can be found in multiple neighborhoods, it is necessary to include a ZIP code in the search function. After entering the address information and pressing enter, the map will zoom in and highlight the selected building.

The Solar Boston map gives users two ways to measure a building's roofline for solar analysis—either through a direct building selection function or by drawing a building's roof outline. The direct selection method may not be suitable for roofs with complex geometry such as gabled roofs or roofs with large mechanical equipment systems. If a building has a flat, relatively unobstructed roof, a user can click the **Select Building** feature in the Tools pop-up box. After clicking this button, a crosshair cursor will appear as the mouse pointer. Move the crosshair over the target building and click in the center of the roof. The mapping program will calculate the roof's size and analyze any shadows the may fall on the roof from surrounding buildings. A **Solar Potential** box will open over the selected roof. The first tab in this box will detail the estimated solar radiation that would fall on a square meter of the building's roof space in an average year (Figure 4.1). The **Calculations** tab (Figure 4.2) of the **Solar Potential** box allows users to estimate the potential size and energy output of a solar PV system on the selected building. Users can move the **Useable Roof Percentage** slider to estimate the amount of roof space that will be available for a solar system. A typical solar installation will take up between thirty and fifty percent of a roof's total area. Once the percentage of useable roof space is selected, the **Solar Potential** box will calculate an estimated system size (in kilowatts), the potential yearly system energy output, potential electricity bill savings and the potential annual avoided CO_2 emissions.

Analyzing the solar potential of complex roofs can be done using the **Draw Area** function in the **Tools** pop-up. Instead of selecting the **Select Building** function, click on the **Draw Area** icon. Use the crosshairs to outline the edge of the target building's roof. Once the roofline is outlined, double-click the last selected roof corner to begin the roof size calculation program. Calculating the roof size from a roof drawing may take several minutes. Once the program has analyzed the roof space, the same **Solar Potential** box described above will appear on the map screen.

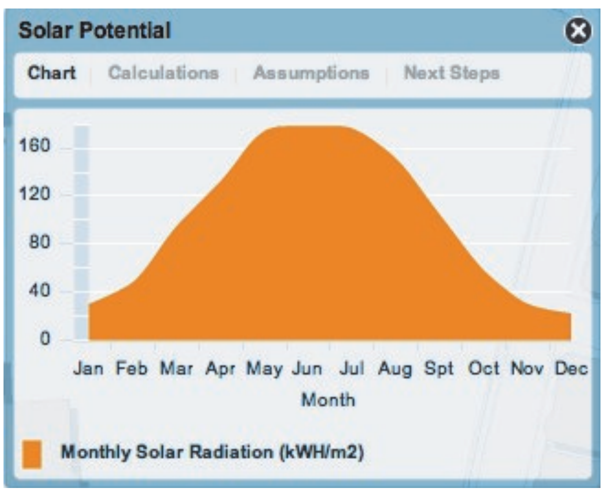

Fig 4.1 Solar Potential box showing the monthly average solar radiation falling on a square meter of roof space.

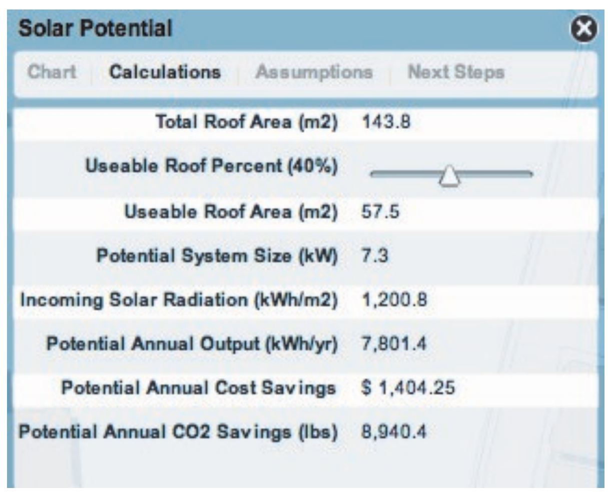

Fig. 4.2 Solar Potential Box showing Useable Roof slider, system size and system outputs.

Determining whether a building is in the NSTAR Area Network

Certain areas of the electricity distribution grid in the City of Boston present special challenges for interconnecting PV solar systems. These regions, known as **Area Networks**, are found in high-density areas of the city including Back Bay, Beacon Hill, the Financial District and the North End. Figure 4.3 outlines the major regions of Boston that have area network grid infrastructure. Some building within the area network will be able to accommodate solar PV systems; however, building owners should understand that area network interconnection may not be feasible in some locations.

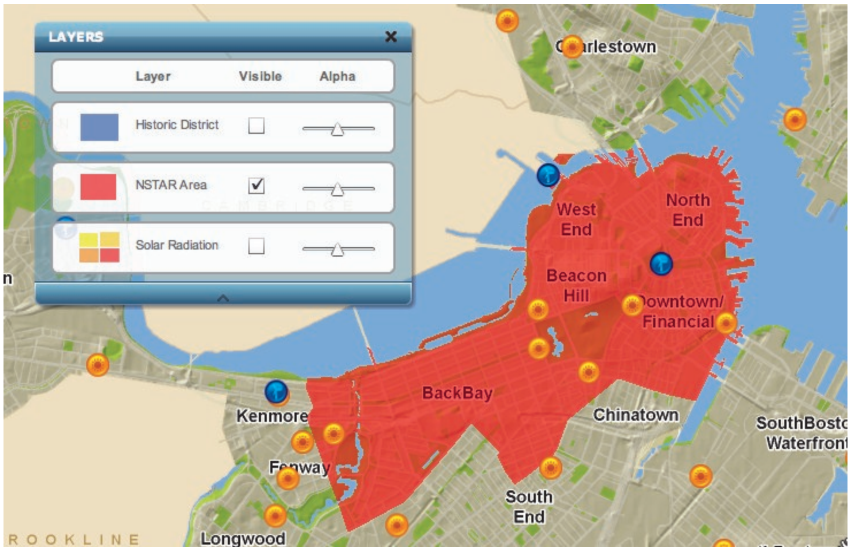

Fig. 4.3 The NSTAR area network as depicted on the Solar Boston map.

Users can map their building's on the Solar Boston map to determine whether they are in NSTAR's area network grid. This information is critical when discussing a potential PV system with a prospective installer. In order to access the Solar Boston map **area network** overlay click the **Layers** tab in the upper right hand corner. Select **NSTAR Area** in the **Layers** box and click **Acknowledge** to dismiss the pop-up. The area network will be highlighted in red on the map. Building owners in the **Area Network** should contact NSTAR early in the project feasibility study process to determine if PV is right for their property.

Determining if a building is in a Historic Districts

Boston's Historic District Commissions protect and preserve the architectural character of many of the city's historic neighborhoods. The nine Historic District Commissions review proposed exterior building alterations within their designated district. Similarly, the city Landmarks Commission has jurisdiction over exterior alterations on designated Boston landmarks. Solar PV systems installed in a historic district or on a landmark must receive a review and approval from either the local Historic District Commission or the Landmarks Commission to receive a building permit. Figure 4.4 details the city's nine historic districts.

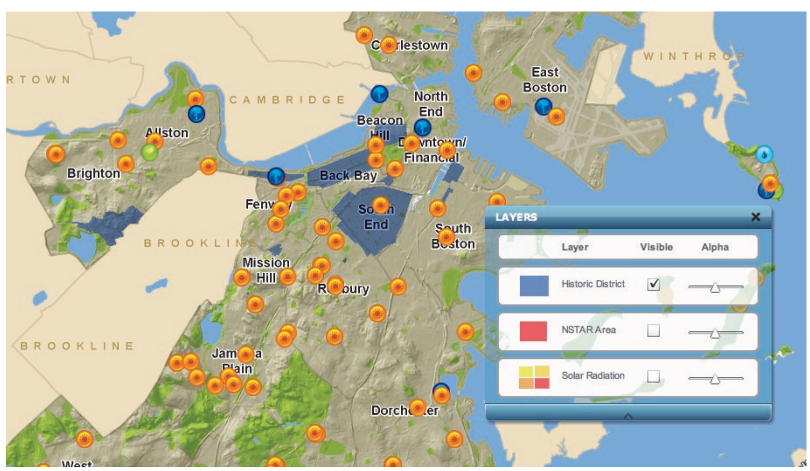

Fig. 4.4 The City of Boston's nine historic districts as depicted on the Solar Boston Map.

Boston property owners can determine if their buildings are within a historic district by selecting the **Historic District** box in the **Layers** pop-up box. The highlighted blue map regions outline the city's nine historic districts. A list of designated Boston Landmarks can be found on the Landmarks Commissions website at: www.cityofboston.gov/landmarks. If property owner are interested in building a PV system in a historic district or on a designated landmark building they should contact the Boston Landmarks Commission at 617-635-3850 with the address of the property and, if applicable, the name of the district to determine whether review by the Historic District Commission or Landmarks Commission will be required.

4.2 Additional Reading Material and Resources

City of Boston Landmarks Commission (2010) City of Boston Landmarks Commission Website. Last accessed: www.cityofboston.gov/landmarks

City of Boston (2010) Solar Boston Map. Last Accessed: gis.cityofboston.gov/solarboston.

Chapter 5. Incentives

A number of federal and state incentives exist to encourage development and installation of solar PV systems. The following section discusses key incentives that are driving solar PV investment in Massachusetts. Since many solar incentives are tax-related, system owners should consult a tax professional before claiming any solar-related credits or deductions on their tax returns.

5.1 Federal Incentives

Federal Investment Tax Credit (ITC)

To encourage consumers to invest in renewable energy or reduce their energy consumption, the US Congress created a Federal Investment Tax Credit (ITC). This program grants PV system owners a federal tax credit worth 30% of a PV system's installed costs. The ITC rules differ for residential and commercial systems.

Commercial and Industrial Federal Tax Credit and Grant

Systems placed in service before December 31, 2016 are eligible for the federal business investment tax credit equal to 30% of the installed cost of the solar PV system. The tax credit can be carried forward for 20 years if the value of the credit exceeds a business's tax liability. After 2016, the credit for solar energy property reverts to 10%. There is no cap on the size of the tax credit that a for-profit entity can claim under the ITC.

Under the American Recovery and Reinvestment Act of 2009 (ARRA), facilities eligible for the ITC that begin construction before December 31, 2010 may claim a one-time upfront treasury grant (in place of the federal investment tax credit) equal to 30% of the installed cost of the solar PV system. The treasury grant program expires on December 31, 2010. Future legislation may extend this program.

Residential Federal Tax Credit

Residential solar energy systems placed in service before December 31, 2016 are eligible for a 30% investment tax credit. Previously, the residential investment tax credit was capped at $2,000 per homeowner; however, this cap was removed for systems built after 2008 by *The Energy Improvement and Extension Act of 2008*. The residential tax credit can be carried forward to the succeeding tax year. Residential properties are not eligible to claim the federal treasury grant.

Five-Year Modified Accelerated Cost-Recovery Depreciation (MACRS)

The typical useful life of a PV system is more than 20 years; however, the IRS allows business owners to depreciate most PV system components using the five-year Modified Accelerated Cost-Recovery System (MACRS). System owners can accrue significant tax benefits by depreciating PV installations on an accelerated five-year schedule. Under the five-year MACRS schedule, solar PV systems are eligible for the depreciation schedule shown in the table below.

Year	Depreciation Percentage
1	20.00%
2	32.00%
3	19.20%
4	11.52%
5	11.52%
6	5.76%

System owners taking the federal Investment Tax Credit (see above) must reduce the system's depreciable basis by 50% of the tax credit amount. In other words, if the 30% tax credit is claimed, then only 85% of the PV system cost can be depreciated using the five-year MACRS schedule. From time to time, the Congress, through the IRS, grants bonus first-year depreciation credits for renewable energy systems. System owners should consult their tax advisor to see if their installations qualify for other current tax benefits such as bonus depreciation.

5.2 State Incentives

The Massachusetts Solar Renewable Energy Certificate (SREC) Program

The state requires electric utilities to purchase a portion of their retail electricity sales from qualified in-state solar PV systems. This requirement was implemented to meet the Governor's goal of installing 250 MW of solar PV in Massachusetts by 2017. The amount of solar electricity each utility needs to meet its regulatory obligations increases each year over the next seven to ten years. In order to meet this requirement, utilities purchase Solar Renewable Energy Certificates (SRECs) that are generated by qualifying PV systems in the state. Each SREC represents the generation of one megawatt-hour of solar generated electricity. SRECs can be bought and sold in credit markets or can be sold to utilities through long-term contracts.

The Massachusetts SREC market is a new incentive program started in January 2010. The program is designed to ensure that SRECs are sold at a price between $285 and $600 per credit. Given this expected price range, SREC sales will represent a significant incentive for solar system owners over the next few years. Qualified solar installers can help system owners understand how best to take advantage of this new incentive program. The state also maintains a website describing the details of the SREC market regulations.

Commonwealth Solar II

The Massachusetts Clean Energy Center also provides rebates for installation of small-scale distributed PV systems. The Commonwealth Solar II program provides direct rebates for residential and small commercial PV systems up to 10kW. The program offers incentives on a first-come-first-served basis. The Clean Energy Center publishes open program solicitations on a quarterly basis. Recently, these quarterly solicitations have attracted significant interest, and have been quickly oversubscribed. System installers typically are responsible for applying for Commonwealth Solar rebates as part of their turnkey contracting services. More information about the Commonwealth Solar II rebate program can be found on the MassCEC website.

Net metering

NSTAR provides PV system owners with the ability to export excess electricity back into the electric distribution grid. This benefit, known as net-metering, allows system owners to spin their electricity meter backwards, effectively crediting their billing account for electricity produced but not consumed on site. The NSTAR net metering tariff allows system owners to carry forward their monthly excess generation to future months and to use those credits to offset future electricity consumption. Excess generation is credited at or near the building's retail electric rate. The state Department of Energy Resources maintains a website that includes up-to-date information on net-metering regulations and also details utility limits on aggregate net-metering capacity.

Property and Sales Tax Exemptions and Excise Tax Deductions

The Commonwealth of Massachusetts provides a sales and property tax exemption for solar PV systems on both residential and commercial properties. The state also offers commercial and industrial PV system owners an excise tax deduction for solar power installations. Additionally, residential system owners can claim a personal state income tax credit of up to $1,000 to offset PV installation cost. System owners should consult the Massachusetts Department of Revenue for more information about applicability of these state tax-related incentives.

5.3 Additional Reading Material and Resources

Database of State Incentives for Renewable Energy (2010) DSIRE website: Massachusetts. Last accessed:
http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=MA

Massachusetts Clean Energy Center (2010) Commonwealth Solar II Program. Last accessed:
http://masscec.com/index.cfm/page/Commonwealth-Solar-II/cdid/11241/pid/11159

Massachusetts Department of Energy Resources (2010) Mass DG Collaborative Website. Last accessed: http://sites.google.com/site/massdgic/

Massachusetts Department of Energy Resources (2010) RPS Solar Carve Out Website. Last accessed:
http://www.mass.gov/?pageID=eoeeasubtopic&L=5&L0=Home&L1=Energy%2c+Utilities+%26+Clean+Technologies&L2=Renewable+Energy&L3=Solar&L4=RPS+Solar+Carve-Out&sid=Eoeea

Massachussets Department of Revenue (2010) Massachusetts Department of Revenue Website. Last accessed: http://www.dor.state.ma.us/

Chapter 6. Finding a Solar Installer

6.1 Selecting a Contractor

As with any major renovation, selecting the right contractor is critical to the success of the project. A number of resources are available to Boston building owners looking to find a qualified solar installer. The Solar Energy Business Association of New England (SEBANE) maintains a database of solar installers on its website (sebane.org). The Massachusetts Clean Energy Center also compiles a list of all installers who have completed solar installations as part of their incentive programs. This list is a useful guide for residents and business as it catalogs the installed costs of many of the PV systems in the state. Building owners can use the information on this site to gauge whether price quotes from installers are reasonable given the current solar market.

What to look for in a Solar Installer

In order to install solar PV panels in Massachusetts, solar installers must be licensed electricians. Many solar installers have received solar specific training and have completed significant coursework in PV system installation. The National Association of Board Certified Energy Practitioners (NABCEP) is the leading solar installer credentialing organization in the country. NABCEP certified installers have had thorough training in solar system design, installation, and interconnection as well as project economic analysis. Many qualified and capable solar installers working in Massachusetts are not NABCEP certified; however NABCEP certification is considered the industry gold standard for solar certification.

It is recommended that prospective PV system owners receive estimates from multiple installation companies. Building owners should carefully research their solar contractor before signing a construction contract. Quality contractors will be eager to provide references for their previous solar work, and many solar system owners are happy to discuss their installation experience with other prospective PV system owners.

Most PV contractors provide turn-key services for their customers. A typical PV contract will include design services, system installation, permitting and interconnection, engineering certification and a long-term warranty. Photovoltaic installers will also work with property owners to obtain grants and rebates available from the state or federal government. Installers not offering turnkey services may leave homeowners with significant and time consuming paperwork.

What to look for in PV System Warranties

Solar PV systems are a significant investment and system owners should be sure to get industry standard warranties on all system components and workmanship. In order to qualify for the Massachusetts Commonwealth Solar Rebate Program, installers must provide a minimum five-year project warranty that includes both parts and labor. Additionally, the state program requires a minimum of a 10 year warranty for inverters, a 20 year production warranty for solar panels and a five year warranty or mounting hardware.

6.2 Information to Gather Before Contacting a Solar Installer

Before selecting a qualified contractor, there are several pieces of information building owners should assemble before reaching out to solar installers. Having this information available will help building owners and installer determine if a solar PV system is feasible for a building and will aid installers in quickly develop price proposals and system designs.

- Collect and organize the previous year's electricity bills. This information will be critical for determining the proper size of a PV system given a building's electricity load.

- Check the Solar Boston map layers to determine if the building is in either the NSTAR area network or a historical district. If in a historical district, check in with the Boston Landmarks Commission at 617-635-3850 to learn more about additional aesthetic guidelines for solar installations.

- If there is easy access to the roof, take a few notes on it. How big is it? What is it made of? When was the last time the roof was replaced or resurfaced? Is it flat or pitched? If it is pitched, in which direction does it face (e.g. due south, southwest, etc.)? Is there anything on the roof, or is the roof cluttered with mechanical equipment, chimneys, roof decks, etc. that could potentially shade solar systems?

- Check the building's southern exposure. Is there anything to the south of the building (e.g. trees or tall buildings) that would shade a system? Please note that the solar calculator provided as part of the Solar Boston map accounts for topography and the heights of nearby buildings, but it does not account for non-building shading, such as trees.

- Some rebate programs, like Commonwealth Solar, require homeowners to have had an energy audit conducted on their property within the past six years. If the building has had a recent energy audit, make sure that the appropriate paperwork is available in order to streamline the application process.

Site Assessment Overview

One of the first steps that must occur when considering a PV system for a property is a site assessment. Most qualified contractors will offer free site assessments as part of the business development services. A well-conducted site assessment will determine the viability of a solar PV installation for a particular property and can always be used to identify fatal flaws that may cause problems during project implementation. In addition to the steps listed below, a project developer should determine if there are any competing uses for the proposed or adjoining space that might hinder the implementation of the project. For example, it may be possible to determine if future nearby construction could shade the proposed site, or if a parcel might be better used for housing development, urban agriculture, or public open space. These issues should be explored as part of a site assessment.

The primary goals of a site assessment are to:

- Determine whether the array would be shaded during critical times of the day
- Determine the location of the array
- Determine the mounting method for the array
- Determine where the Balance-of-System (BOS) components will be located
- Determine how the PV system will interface with the existing electrical system
- Identify issues that could jeopardize the viability of a project or result in increased design and installation complexity and implementation cost such as insufficient electric service or insufficient structural support requiring costly upgrades
- Identify any concerns of the building owner that may impact the design such as aesthetic concerns or financing options

A thorough site assessment should be completed by each installer bidding on a project before they provide price proposals. This ensures that each installer fully understands all the conditions that may affect a building's solar potential and also helps installers to develop more accurate system price proposals.

6.3 Additional Reading Material and Resources

City of Boston (2010) Renew Boston website. Last accessed:
www.RenewBoston.org

MassSAVE (2010) MassSAVE program website: Last accessed:
www.masssave.org

Massachusetts Clean Energy Center (2010). List of Solar PV Projects in Massachusetts. Last accessed:
http://masscec.com/index.cfm?cdid=11379&pid=11163

Massachusetts Clean Energy Center (2010) System Requirements for Solar PV Systems. Last accessed:http://masscec.com/masscec/file/Attachment%20D_CSII%20Minimum%20Technical%20Requirements_V4_Final.pdf

National Association of Board Certified Energy Professionals (2010). NABCEP Website. Last accessed: http://www.nabcep.org

Solar Energy Business Association of New England (2010) SEBANE Yellow Pages. Last accessed:
www.SEBANE.org

Chapter 7. The Permitting and Interconnection Process

Solar projects require permits from two key organizations in Boston: the Boston Inspectional Services Department (ISD) and NSTAR, the local electric utility. ISD is responsible for issuing building and electric permits, while NSTAR oversees system grid interconnection. This section briefly describes the steps solar installers must follow in order to permit and interconnect solar PV projects in the City of Boston.

7.1: Utility Consultation and System Design

Before beginning any work on a solar system, installers and/or customers should consult the Solar Boston map to determine whether the proposed solar facility falls within a historic district or NSTAR's area network. Solar systems located within either one of these regions may be subject to additional permitting, zoning, or interconnection requirements. Installers and/or customer should contact ISD or NSTAR to ascertain any special requirements. Moreover, regardless of the location of the solar system, installers should always contact NSTAR early in the system design process to ensure that a PV system can be safely interconnected with the grid. Contact information for NSTAR interconnection staff can be found on the NSTAR interconnection website. Only after consulting with NSTAR, should one proceed with designing, purchasing and installing solar generating equipment.

7.2: Apply for the Building permit

To obtain a building permit in Boston, contractors must complete a building permit application. Depending on the characteristics of the proposed solar facility, homeowners or installers must complete either a short- or long-form building permit application:

1. *Short-form building permit applications* pertain to residential buildings with four units or fewer. Applicants eligible for the short-form building permit should see Step 2.1 of this guide.
2. *Long-form building permit applications* pertain to construction all other solar facilities. Applicants eligible for the long-form building permit should see Step 2.2 of this guide.

Building permit applications can be accessed online at:

onlinepermitsandlicenses.cityofboston.gov/isdpermits/

If using ISD's on-line system, installers must print a hardcopy of the application and submit it with appropriate drawings and documents in person at the ISD office. At time of submission, the applicant should be prepared to pay the $50 primary application fee. Once submitted, an ISD plan examiner is assigned to guide the building permit application through the permitting process. During this time, ISD engineers review plans to ensure compliance with the building, plumbing, electric, fire, zoning, or any other applicable codes. If the solar facility is located in a historic district or is a designated landmark, the local Historic District Commission or Landmarks Commission will also review the application for compliance with historical preservation rules.

After submitting the permit application, installers should be prepared to periodically follow up with ISD to determine the status of their application. ISD usually reviews permit applications within two to three weeks. Once approved, installers must pay final permit fees based on the total project cost, which are currently $10.00 for every $1,000 of stated project cost.

Step 2.1: Short-form building permit

On the short-form application, installers should note the occupancy type of the building, designate the work type as “other,” enter estimated project costs, and describe the size (in kW) and location of the solar system in the comments section. In addition to the application, the installer or homeowner should also include:

1. stamped layout drawings showing where the system is located on the roof along with roof structural drawings;
2. drawings of the mounting system, which are usually provided by the manufacturer;

Boston ISD additionally requires installers to provide proof of workman’s compensation insurance and a copy of the contract with the homeowner (or if the homeowner is the applicant, a homeowner waiver form is required).

Step 2.2: Long-form building permit

On the long-form application, installers should note the occupancy type of the building, designate the work type as “other,” enter estimated project costs, and describe the size (in kW) and location of the solar system in the comments section. Along with the application, installers should also include:

1. a letter from a professional engineer indicating that the roof is able to support the load of the system;
2. stamped layout drawings showing where the system is located on the roof;
3. a cost and control affidavit, which is generally completed by a licensed construction professional and attests that they will oversee and verify system construction in accordance with local engineering and code specifications;
4. and drawings of the mounting system, which are typically provided by the manufacturer.

Boston ISD additionally requires installers to provide proof of workman’s compensation insurance and a copy of the contract with the building owner.

7.3: Apply for an Electrical Permit

Solar installations also require an electrical permit from ISD. Only Massachusetts electricians with a valid electrician’s license and identification may apply for electrical permits in Boston. The electrical permit application can be accessed online, though it must be *submitted* either in person, through the mail, or via fax. In addition to a completed application, electricians must submit proof of workman’s compensation insurance and liability insurance. At time of submission, the electrician should also be prepared to pay a $20 primary application fee plus either:

1. $0.25 per amp up to 240 volts, or
2. $0.75 per amp over 240 volts.

Electrical permits are generally issued on the same day of application.

7.4: Apply for NSTAR Interconnection

The amount of time and information required for the utility interconnection application depends on the size and certification of the solar facility as well as the type of distribution power system to which it interconnects. There are three basic interconnection pathways, which are described below:

1. *Simplified interconnection*, the fastest route to interconnection, pertains to listed, inverter-based, single-phase systems less than 10 kW or three-phase systems less than 25 kW that are located on a radial power system. Additionally, a listed inverter-based, single-phase facility smaller than 15 kW located on a *spot* network power system is also eligible under certain conditions. For details on the simplified interconnection process, see Step 4.1 of this guide.
2. *Expedited interconnection* pertains to listed facilities on radial electric power systems that pass certain pre-specified screens. For details on the expedited interconnection process, see Step 4.2 of this guide.
3. *Standard interconnection* has the longest maximum time period and highest potential costs. It pertains to "all facilities not qualifying for either…simplified or expedited interconnection processes on radial and spot network [power systems], and for all facilities on area network [power systems]." For details on the standard interconnection process, see Step 4.3 of this guide.

NSTAR Interconnection applications can be accessed online at:

www.nstaronline.com/residential/rates_tariffs/interconnections/

Additionally, all customers should indicate on their interconnection application if they intend to net meter and fill out Schedule Z "Additional Information Required for net Metering" as appropriate. Interconnection fees vary by type and are detailed below.

Step 4.1: Simplified interconnection

For most simplified interconnections, there are no fees associated with the interconnection approval process. On receipt of a complete application, NSTAR verifies that the facility equipment passes three basic screens for interconnection on a radial distribution system. NSTAR is obliged to process the application within 15 business days. Customers should include inverter certification information, specifically the UL 1741 listing, in order to complete the simplified interconnection expeditiously. The Simplified application is filled out on-line and the electric account number must be known to fill out the on-line application. If this is a new meter or a standalone system the application cannot be filled out on-line and the application must be sent either by e-mail or regular mail to one of the listed contacts. Please note that facility upgrades may be required. A witness test is usually not required for the Simplified application.

Step 4.2: Expedited interconnection

For expedited interconnection, customers must pay interconnection fees of $3 per kW with a minimum of $300 and a maximum of $2,500. In addition, they may have to cover fees for engineering reviews, facility upgrades, O&M costs, and witness tests. Depending on the extent of the review process, application reviews can take up to 60 days. Once a completed application is received, NSTAR will apply a screening methodology and assess whether any distribution system modifications are required for interconnection. If one or more screens are not met, NSTAR may require additional modifications. A witness test and witness test fee are required for all Expedited Applications

Step 4.3: Standard interconnection

For standard interconnection, customers must pay interconnection application fees of $3 per kW with a minimum of $300 and a maximum of $2,500, as well as fees for impact and detailed study, facility upgrades, O&M fees, and witness test costs. The standard interconnection process can take up to 150 days to complete. A witness test and witness test fee are required for all Expedited Applications.

The standard interconnection process requires an initial scoping meeting between NSTAR and the interconnecting customer to discuss the proposed interconnection and any fatal flaws that are immediately obvious. Following the scoping meeting, NSTAR and the customer will enter into an impact study agreement. The impact study is funded by the customer and completed by NSTAR and assesses whether any reliability or infrastructure issues would be caused by this interconnection. Depending on the outcome, an additional "detailed study" may be required. Once all studies have been completed, NSTAR sends the Interconnecting Customer an executable Interconnection Service Agreement, which includes a quote for any required distribution system modifications and reasonable Witness Test costs.

Regardless of the pathway to interconnection (simplified, expedited, or standard), once NSTAR verifies that the solar facility can be interconnected safely and reliably, it will sign the interconnection application and send it back to the customer. At this point, the system may be installed. Only the simplified application is signed and sent to the customer.

7.5: System Installation and Inspections

Once the system is installed, it is the owner's responsibility to ensure that the contractor(s) call the building and electrical inspectors to arrange an inspection time. Depending on the size and nature of the installation, a building inspector may (or may not) review the installation. ISD electrical inspectors, on the other hand, generally always inspect the system and must sign the "Certificate of Completion" for NSTAR.

Once signed by the electrical inspector, the installer must then return the Certificate of Completion to NSTAR. Following receipt of the Certificate of Completion and when they have received all other required documents or agreements, NSTAR will inspect the facility to ensure network integrity by arranging a "Witness Test." NSTAR is obliged to perform the Witness Test within ten business days of receipt of the Certificate of Completion and other required documents and agreements. Additionally, NSTAR is also required to furnish and install a net-metering capable electricity meter for the solar installation. Assuming the Witness Test and inspection are satisfactory, NSTAR notifies the interconnecting customer in writing that interconnection is authorized. At this point, the system may be turned on.

7.6: Turn the System on

…and email the Solar Boston Coordinator in order to have the system featured on the Solar Boston map.

7.7 Additional Reading Material and Resources

City of Boston Inspectional Services Department (2009). From the Ground Up – A Contractor's Guide. Last accessed from:
http://www.cityofboston.gov/isd/building/boa/forward.asp

Massachusetts Clean Energy Center (2009) Interconnection Guide for Distributed Generation. Last accessed from:
http://masscec.com/masscec/file/InterconnectionGuidetoMA_Final(1).pdf

May, Thomas J. (October 1, 2009). Standards for Interconnection of Distributed Generation. NSTAR Electric Company. M.D.P.U. No. 162B Last accessed:
http://www.nstaronline.com/docs3/interconnections/tariff.pdf. p. 7

NSTAR Electric (2010). Interconnection website. Last accessed:
http://www.nstaronline.com/residential/rates_tariffs/interconnections/

Chapter 8. Glossary of Common Solar Terms

Alternating Current: Alternating current is an electric current with a cyclically reversing current direction. AC is the form of electricity that is delivered to a home or business through the electric grid. Solar photovoltaic (PV) systems produce DC power, which must be converted to AC by an inverter.

Alternating Current Module (AC Modules): A complete, environmentally protected unit consisting of solar cells, optics, inverter, and other components, exclusive of tracker, designed to generate AC power when exposed to sunlight

Amorphous Silicon: A very thin layer of silicon that is deposited on a substrate (glass, metal or plastic) in a manner to create a PV module. This is one of the technologies used in making thin-film PV modules.

Area Network: A region of the electricity grid with complex multi-directional power flows. Distributed generation systems like PV can be difficult to interconnect in these grid regions.

Array: An interconnected system of PV modules that function as a single electricity-producing unit. The modules are assembled as a discrete structure, with common support or mounting. In smaller systems, an array can consist of a single module.

Azimuth: Azimuth is the horizontal angular distance between the vertical plane containing a point in the sky and true south. The azimuth angle is the location of the sun in terms of north, east, west or south.

Balance of System: The components in a PV system (other than PV modules) that include source-circuit combiner boxes, inverters, disconnects, overcurrent devices, electrical wiring, junction boxes and support structures.

Ballasted Mounting: A type of PV mounting system that is held on the roof using weights and does not require roof penetrations.

Batteries: In the context of PV systems, batteries are used for storing excess electricity generated by a PV system when the building is using less electricity than the system generates; batteries can store electricity for use when utility power is unavailable such as during a grid outage or for off - grid systems.

Building-Integrated Photovoltaics)BIPV): A term for the design and integration of photovoltaic (PV) technology into the building envelope, typically replacing conventional building materials. This integration may be in vertical facades, replacing view glass, spandrel glass, or other facade material; into semitransparent skylight systems; into roofing systems, replacing traditional roofing materials; into shading "eyebrows" over windows; or other building envelope systems.

Capacity rating: The maximum expected energy production from a PV system.

Cell Matching Losses: The loss in potential production due to the gaps in discrete solar cells.

Centralized Generation: A method of producing electricity with large, remote power plants that require high-voltage transmission lines to deliver the power.

Conservation: In the context of energy, using energy resources in such a way as to minimize energy consumption in relation to benefits gained.

Derate Factor: The value that represents the losses from the DC nameplate power rating to determine the AC power rating; the system derate factor is the mathematical product of derate factors of individual components in a PV system.

Direct Current: Solar PV systems produce electricity in direct current (DC), which is defined as the continuous flow of electricity through a conductor. In DC, electricity always flows in the same direction.

Distributed Generation: A method of producing electricity with small, efficient power plants located near or at manufacturing facilities, universities, hospitals, and other large institutions.

Energy: Energy is the ability to do work or the amount of work actually performed. Energy is given in kilowatt-hours (kWh) of electricity produced by a PV system or consumed in a home or business.

Energy-efficiency: The use of a lower level of energy to accomplish the same task

Flat Plate Collectors: An arrangement of photovoltaic cells or material mounted on a rigid flat surface with the cells exposed freely to incoming sunlight.

Grid-connected/Grid-tied: A solar electric or photovoltaic system in which the PV array acts like a central generating plant, supplying power to the grid.

Ground Continuity: A test that is performed to verify that the safety ground is present in an electrical system.

Ground Cover Ratio: The ratio of the PV array area to the total ground area.

Insolation: The amount of energy that shines on a building or area, equivalent to energy an usually expressed in annual kilowatt-hours per square meter.

Insulation Test/Megger: A test to see is the insulation of a conductor has been damaged in any way to cause a short circuit when normal power is applied to it (performed by a megometer)

Integral Mounting: A method for mounting PV modules on a building where the modules are integrated into the roofing or exterior of the building itself.

Interconnection: The process of connecting an electricity-producing technology (like a PV system) to the electricity grid.

Inverter: Equipment that is used to change voltage level or waveform, or both, of electrical energy (such as converting direct current electricity produced by a solar system into the alternating current electricity that can be used in a home or building). Commonly, an inverter [also known as a power conditioning unit (PCU) or power conversion system (PCS)] is a device that changes DC input to an AC output. Inverters may also function as battery chargers that use alternating current from another source and convert it into direct current for charging Batteries.

Isolation Device: A disconnect switch that is used to cut off the PV system from the grid

Kilowatt (kW): A unit of electrical power equal to 1,000 Watts, which constitutes the basic unit of electrical demand. The Watt is a metric measurement of power (not energy) and is the rate (not the duration) at which electricity is used. 1,000 kW is equal to 1 megawatt (MW).

Kilowatt-hour (kWh): A unit of electrical energy, equivalent to the use of 1 kilowatt of electricity for one full hour. Utilities measure customers' electric energy usage on the basis of kilowatthours, and electricity rates are most commonly expressed in cents per kilowatt-hour.

Life-cycle cost: The estimated cost of owning and operating a photovoltaic system for the period of its useful life.

Loads: Describes the amount of power (amps) consumed by an electrical circuit or device. Loads are usually expressed in amps but sometimes in watts. Also describes the amount of power carried by a utility system or the amount of power consumed by an electric customer at a specific time.

Losses: The discrepancy between energy or power produced at a source and the energy or power delivered to an end point; in PV systems losses are caused by individual components in the system including wiring, inverter/transformer efficiency, diodes and connections, soiling, etc.

Mismatch: The loss is solar production caused by having solar cells of differing sensitivities in the same array.

Megawatt (MW): Unit of electric power equal to 1,000 kW, or 1 million Watts.

Meter: A device used to measure and record the amount of electricity used or generated by a consumer.

Module: A complete, environmentally protected unit consisting of solar cells, optics, and other components, exclusive of tracker, designed to generate dc power when exposed to sunlight. A module is the smallest protected assembly of interconnected PV cells.

Monocrystalline: A type of photovoltaic (PV) cell technology produced by melting highly refined silicon. For a Monocrystalline silicon cell, a "seed" is dipped into molten silicon and allowed to solidify into a silicon "ingot," which is then sliced into wafers. The wafers are laminated between sheets of glass to produce a monocrystalline silicon cell. Compare with polycrystalline silicon cells.

Multicrystalline: A semiconductor (photovoltaic) material composed of variously oriented, small, individual crystals. Sometimes referred to as polycrystalline.

MVA: Apparent power expressed in million volt-amps.

NABCEP: North American Board of Certified Energy Practitioners, the certifying body for solar photovoltaic and thermal installers.

Net Metering: Net metering is a billing mechanism that credits solar system owners for the electricity exported onto the electricity grid. Under the simplest implementation of net metering, a utility customer's billing meter runs backward as solar electricity is generated and exported to the electricity grid and forward as electricity is consumed from the grid.

Off Grid: A renewable energy system designed to meet the full electrical requirements of a site. Requires batteries to store energy for use at times of lower production (e.g., nighttime). May also be coupled with a generator to provide additional power supply. Often an economical alternative in locations without direct access to utility lines. Compare with grid-connected system.

Open Circuit Voltage: The voltage that occurs in a module when it is not supplying any current) i.e. when the module is disconnected from all loads). The open circuit voltage of a module can also be used to determine the open circuit voltage of a circuit/string or the entire PV array.

Orientation: A term used to describe the direction that the surface of a solar module faces. The two components of orientation are the tilt angle (the angle of inclination a module makes from the horizontal) and the azimuth (based on true South, not magnetic North/South).

Panel: A collection of modules mechanically fastened together, wired, and designed to provide a field-installable unit

Photovoltaic: The technology that uses a semiconductor to convert light directly into electricity.

Polycrystalline Photovoltaics: See **Multicrystalline**

Power: Power is the rate at which energy is generated or consumed, that is, kilowatt-hours per hour (kWh/h) or kilowatts (kW)

PV Cell (also called a solar cell): The basic photovoltaic device that generates electricity when exposed to light.

PV Laminates: Flexible and lightweight PV modules that typically use triple-junction

SREC: Solar Renewable Energy Credit: RECs generated from a solar energy system.

Radial Networks: Areas of the electricity distribution grid designed in a radial pattern. These grid regions are typically easier to interconnect PV systems into than Area Networks.

RPS (Renewable Portfolio Standard): A policy set by federal or state governments requiring that a certain percentage of the area's electricity come from renewable sources.

Short Circuit Current: The current of a module measured when it is disconnected from the rest of the system. Measuring the short circuit current of a module is one way to test for good or bad modules. The short circuit current of a module can also be used to determine the short circuit current of the string/circuit or entire array.

Single Crystalline Photovoltaics: See **Monocrystalline**

Soiling: The accumulation of dirt on solar panels

Standard Test Conditions (STC): A set of controlled conditions under which PV modules are tested in a laboratory. The output rating of modules is typically based on output measured when subjected to these conditions.

Standoff Mounting: A method of mounting PV modules on a building where modules are mounted above and parallel to the roof surface.

String Sizing: Designing the basic electrical circuit of a PV array typically includes PV modules electrically wired in series; relevant for PV system design because the string size determines the maximum DC system voltage that the PV system will generate (important for electric code compliance).

Sun Chart: A chart denoting the position of the sun in the sky for a particular area with the altitude on the y-axis (typically 0 to 90 degrees) and the azimuth on the x-axis (typically -120 to +120 degrees or East to West). Graphs of the sun’s position in the sky can be made at different days of the year and by time of day.

System Commissioning: A quality oriented process for achieving, verifying and documenting that the performance of a system and assemblies meets defined objectives and criteria.

Thin Film Photovoltaics: A layer of semiconductor material, such as copper indium diselenide or gallium arsenide, a few microns or less in thickness, used to make photovoltaic cells.

Uninterruptible Power Supply: (UPS) — The designation of a power supply providing continuous uninterruptible service. A UPS will contain batteries.

Utility Grid (Grid): An integrated system of electricity distribution, usually covering a large area.

Utility-Scale: Utility-scale solar energy facilities are facilities that can generate large amounts of electricity to be put directly into the electricity transmission grid.

Watts (W): a standard unit of electrical power, named after physicist James Watt.
Kilowatts (kW): a standard unit of electrical power equal to 1,000 watts
Megawatts (MW): a standard unit of electrical power equal to 1,000 kilowatts

Weatherization: Modifying a building envelope to reduce energy consumption for heating or cooling; involves adding insulation, installing storm windows and doors, caulking cracks and putting on weather-stripping.

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