NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Implementing Solar PV Projects on Historic Buildings and in Historic Districts

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-7A40-51297
September 2011

Contract No. DE-AC36-08GO28308

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Prepared under Task No. SM10.1710

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Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721

Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Sponsor

This report was made possible through funding from the U.S. Department of Energy (DOE) Solar America Communities program. The Solar America Communities program is designed to increase the use and integration of solar energy in communities across the United States. Through federal-local partnerships and nationwide outreach, DOE supports local governments' efforts to accelerate adoption of solar energy. To learn more, please visit www.solaramericacommunities.energy.gov.

Acknowledgment

The authors would like to acknowledge the National Trust for Historic Preservation, whose staff contributed to the development of this report by providing historic preservation expertise. The National Trust for Historic Preservation is a national nonprofit that provides leadership, education, advocacy, and resources to help people save the places that matter to them. For more information, visit www.PreservationNation.org.

Additional Resources

Detailed notes and minutes from the Implementing Solar Projects on Historic Buildings and Districts workshop outlined in this report may be obtained at http://solaramericacommunities.energy.gov/solarprojects.aspx.

List of Acronyms

ACHP	Advisory Council on Historic Preservation
AC	alternating current
BIPV	building-integrated PV
CLG	Certified Local Government
DC	direct current
DOE	U.S. Department of Energy
DSIRE	Database of State Incentives for Renewables and Efficiency
ECM	Energy conservation measures
ESPC	Energy Savings Performance Contract
FERC	Federal Energy Regulatory Commission
GHG	greenhouse gases
IMBY	In My Backyard tool
kWh	kilowatt hour
$kWh/m^2/day$	kilowatt hours per meter squared per day
LEED	Leadership in Energy and Environmental Design
m/s	meter per second
NAPC	National Alliance of Preservation Commissions
NATHPO	National Association of Tribal Historic Preservation Officers
NCD	Neighborhood Conservation District
NEPA	National Environmental Policy Act
NCPTT	National Center for Preservation Technology and Training
NHPA	National Historic Preservation Act of 1966
NPS	National Park Service
NREL	National Renewable Energy Laboratory
PACE	property assessed clean energy
PPA	Power Purchase Agreement
PV	photovoltaic
SAM	System Advisor Model
SHPO	State Historic Preservation Office
THPO	Tribal Historic Preservation Office
UESC	Utility Energy Services Contract
Wp	Watt-peak

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1 Introduction

Despite a global recession, the number of photovoltaic (PV) installations in the United States grew 30% from 2008 to 2009[1]. A number of trends point toward continued growth of new PV installations. The efficiency of solar panels is increasing, while installation costs are going down. At the same time, federal, state, and local regulations are requiring that greater amounts of energy must come from renewable sources. Incentives for solar power technology implementation are being created and regulatory barriers removed. Corporations and governments are focusing on solar power to demonstrate leadership in environmental sustainability and resource conservation. Architects and builders are including PV arrays as a way to meet green building standards and property owners are seeking PV as a way to reduce their utility bills, as well as their carbon footprints.

This publication focuses on the implementation of PV systems on historic properties. Many private property owners, as well as local, state, and national government entities, are seeking guidance on how best to integrate solar PV installations on historic buildings. Historic preservationists maintain that preserving, reusing, and maintaining historic structures is a key sustainable design strategy while also recognizing the importance of accommodating renewable energy technologies where they are appropriate. In some cases, however, conflicts have arisen over the installation of PV panels on historic properties.

Addressing these conflicts and providing guidance regarding solutions and best practices is an important step toward resolving or eliminating barriers. Historic properties and districts in the United States provide tangible connections to the nation's past. Thousands of buildings, sites, districts, structures, and objects have been recognized for their historic and architectural significance. Local, state, and national designations of historic properties provide recognition, protection, and incentives that help to preserve those properties for future generations. At the national level, the National Register of Historic Places includes more than 86,000 listings, which encompass a total of more than 1.6 million historic resources. State registers of historic places also provide recognition and protection for historic sites and districts. Locally, more than 2,400 communities have established historic preservation ordinances.[2] Typically implemented through zoning overlays, these local land use regulations manage changes to hundreds of thousands of historic properties.

Over a period of 2 years (2007 and 2008) the U.S. Department of Energy (DOE) designated 25 major U.S. cities as Solar America Cities. DOE provided financial and technical assistance to help the cities develop comprehensive approaches to accelerate the adoption of solar energy technologies. The Solar America Cities partnerships represent the foundation of DOE's larger Solar America Communities program. As a part of this program, DOE identified the implementation of solar projects on historic properties and in historic districts as one area to address. A workshop titled "Implementing Solar Projects on Historic Buildings and in Historic Districts" was held in Denver, Colorado, in June of 2010. Participants included representatives from the solar industry as well as historic preservationists from nonprofit organizations and government agencies at the local, state, and national levels. The workshop provided an

[1] www.eia.gov/cneaf/solar.renewables/page/solarphotv/solarpv.pdf. Accessed June 2011.
[2] www.nps.gov/nr/. Accessed June 2011.

opportunity to gain a common understanding of solar technologies and historic preservation procedures and priorities. The workshop participants also discussed some of the challenges involved in locating PV systems on historic properties and identified potential solutions. This publication is based on the discussions that occurred at this workshop and the recommendations that were developed by participants.

Ideas expressed by participants in the workshop, and included in this document, do not necessarily reflect the opinion of any government council, agency, or entity.

2 Historic Preservation[3]

Historic preservation in the United States takes place in both the public and private sectors and at local, state, and national levels. Preservation began as a grassroots effort in the mid-1800s to save buildings associated with the nation's founding fathers—such as George Washington's Mount Vernon residence—for future generations to enjoy. Today, historic preservation still remains a largely grassroots movement, but has evolved into a multifaceted field. It encompasses not only individual buildings, but also a broad array of historic places covering districts, cultural landscapes, and archeological sites that represent diverse cultures and socio-economic groups.

A key set of agencies and organizations administer and advocate for historic preservation within the public and private sectors. In the public sector, the National Park Service (NPS) is the principal federal agency responsible for preservation programs and activities. The NPS administers the National Register of Historic Places, grant programs, and the federal rehabilitation tax credit. The NPS has recently published a document titled *Illustrated Guidelines on Sustainability for Rehabilitating Historic Buildings*, which details guidelines for implementing a variety of sustainability measures on historic buildings, including solar PV.[4]

The Advisory Council on Historic Preservation (ACHP) is the other principal public preservation agency at the national level. The ACHP reviews and comments on federal and federally assisted and licensed projects that affect properties determined eligible for listing on the National Register of Historic Places.

State Historic Preservation Offices (SHPO) provide the resources and programs of the national historic preservation program to citizens, communities, and organizations in each of the 50 states and territories. Tribal Historic Preservation Offices (THPO) may assume any or all SHPO functions on tribal lands on behalf of a federally recognized tribal community. Local historic preservation commissions review projects under local preservation ordinances. Some of these local commissions are Certified Local Governments (CLG). CLGs receive support from the NPS in partnership with SHPOs.

In the private sector, the National Trust for Historic Preservation (National Trust) serves as the only national nonprofit dedicated to saving historic places. Statewide and local preservation nonprofit organizations provide advocacy, technical assistance, and education programs at the respective levels. The National Trust's Main Street programs are found in more than 1,200 communities nationwide. The programs combine historic preservation and economic development to promote downtown and neighborhood revitalization.

These players work with a defined set of guidelines for the preservation, rehabilitation, restoration, and reconstruction of historic properties known as the Secretary of the Interior's Standards for the Treatment of Historic Properties (Secretary's Standards), as well as with federal, state, and local preservation laws.[5]

[3] The content for this section was guided by the National Trust's *Basic Preservation* publication printed in 2006.
[4] www.nps.gov/history/hps/tps/download/guidelines-sustainability.pdf. Accessed June 2011.
[5] www.nps.gov/history/hps/tps/standards_guidelines.htm. Accessed June 2011.

2.1 Historic Preservation Designations and Regulations

Historic and cultural resources that meet a set of criteria for significance may be listed in any of three types of registers: the National Register of Historic Places (National Register), a state register of historic places, or local register of historic landmarks and districts. Not all significant historic places have been designated or registered; many properties are eligible for listing but have not gone through the designation process yet.

The National Historic Preservation Act of 1966 (NHPA) enabled the creation of the National Register that is administered by the NPS and implemented by the SHPOs in each state. It is the official list of the nation's historic places worthy of preservation.[6] The term "historic property" is defined in the NHPA as "any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion on the National Register." As such, historic properties may include "artifacts, records, and remains which are related to such districts, sites, buildings, structures, or objects."[7]

Listing in the National Register provides formal recognition of a property's historical, architectural, or archeological significance and provides opportunities for specific preservation incentives, which might include:

- Federal preservation grants for planning and rehabilitation
- Federal historic tax credits
- Preservation easements held by nonprofit organizations or government entities
- Building code fire and life safety code alternatives
- Possible state tax benefits and grant opportunities.[8]

Some states and municipalities have established separate state and local registers of historic places in addition to the National Register. State registers closely mirror the National Register in the scope of benefits that the listing provides, but from a state perspective. Local registers are often guided by local preservation ordinances designed for specific communities and based on locally developed criteria.

Historic properties can be listed in any or all of the aforementioned registers. The type of designation is central to the application of preservation guidelines and regulations. When undertaking a solar project, owners of designated properties may need to consult a local preservation review board or other administrative body, such as the SHPO or THPO, prior to installation.

The NHPA establishes a federal policy for the preservation of cultural and historic resources in the United States. In addition to creating the National Register, it created the ACHP, whose primary role is to comment on federal undertakings that affect historic properties, as required in

[6] www.nps.gov/nr/about.htm
[7] National Preservation Act of 1966. (16 U.S.C. Section 470(w)(5)). See www.nps.gov/history/local-law/nhpa1966.htm. Accessed June 2011.
[8] www.nps.gov/history/nr/national_register_fundamentals.htm. Accessed June 2011.

Section 106 of the NHPA. A private owner or a state or local government acting without federal involvement has no restrictions placed upon it by Section 106. The regulation only applies to federal undertakings involving a property or properties listed in or eligible for listing in the National Register.

SHPOs are key participants in Section 106 processes, as are THPOs, if a project is on tribal land. They work closely with the federal agency to identify significant resources, assess the effects of the proposed undertaking, and find ways to avoid, minimize, or mitigate any adverse affects. Many states also have their own state Section 106 equivalents in state statutes to provide a level of protection to designated historic places that may be adversely affected by projects undertaken by state agencies.

Perhaps most relevant to the implementation of solar PV on historic properties is preservation at the local level. Preservation ordinances establish historic preservation commissions that provide either an advisory or regulatory role. For instance, a preservation commission may survey and designate structures itself or it may only be empowered to recommend designations to the city council. Similarly, some commissions have adopted local design guidelines (and, now, sustainability guidelines[9]) for historic districts and neighborhoods. Design guidelines illustrate the elements that define historic character in order to preserve the historic integrity of a collective neighborhood or individual property. They may be merely recommendations or they may be enforced through design review boards that approve or deny proposed alterations to a designated property based on the design review guidelines. Local review processes vary, so it is advisable to check with local planning or historic preservation staff to learn more.[10]

Neighborhood Conservation Districts (NCD) are another local planning tool that may be used to conserve historic properties. The purpose of an NCD is to ensure the protection of the unique character of a neighborhood from threats that would adversely alter that character (such as teardowns and commercial encroachment). NCDs differ in methods used, kinds of protection available, and level of neighborhood involvement. NCDs may require review and approval for any physical changes to a property, such as new construction, building alteration, demolition, and set-back changes.[11]

Lastly, preservation easements can possibly intersect with the installation of solar panels on historic properties. Easements are a private property interest conveyed by a property owner to a preservation organization or a government entity and require current and future property owners to protect the historic character of the property subject to an easement. Preservation easements may also protect natural land values as part of a property's historic setting. Therefore, the impact of installing a solar PV array on a building or land covered through the terms of the conservation easement would be reviewed by the easement holder.

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[9] See Noré V. Winter's publication on "Developing Sustainability Guidelines for Historic Districts" published by the National Trust for Historic Preservation and available for purchase at www.PreservationBooks.org.

[10] Many historic preservation commissions participate in the CLG Program. Commissions must meet state and federal criteria that make them eligible for certain benefits like special grants, training and technical assistance from SHPOs and the NPS.

[11] Julia Miller, *Protecting Older Neighborhoods Through Conservation District Programs.* Washington, D.C.: National Trust for Historic Preservation, 2004. 1-16.

The Secretary of the Interior is responsible for establishing professional standards and providing advice on the preservation and protection of all cultural resources listed in, or eligible for listing in, the National Register. The Secretary's Standards for Rehabilitation may be used by anyone planning and undertaking work on historic properties and are used by a wide variety of federal, state, and local governments and agencies to guide projects involving historic properties. Only federal agencies or projects with federal involvement are *required* to use the Secretary's standards. Some state and local entities have their own guidelines, as mentioned previously, often similar to the Secretary's standards.

The Secretary's standards are neither technical nor prescriptive, but are intended to promote responsible preservation practices that help protect the nation's cultural resources. These standards outline four treatment approaches: Preservation, Rehabilitation, Restoration, and Reconstruction.[12] They also provide consistency to the preservation of historic materials and features of historic properties undergoing one of the treatment approaches.

Preservation focuses on the maintenance and repair (protection and stabilization) of existing historic materials. Rehabilitation is altering or adding to an historic property to meet continuing or changing uses, while retaining the property's historic character. Restoration is depicting a property at a particular period of time in its history, while removing evidence of other periods. Reconstruction re-creates vanished or non-surviving portions of a property for interpretive purposes.[13] The treatment most applicable to solar installations is rehabilitation. The Secretary's Standards for Rehabilitation are summarized in Figure 1.

[12] Visit the National Park Service website at www.nps.gov/history/hps/tps/standguide/ for guidelines on each of the four treatments. Accessed June 2011.
[13] www.nps.gov/history/hps/tps/standards_guidelines.htm. Accessed June 2011.

1. A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces, and spatial relationships.
2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.
3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.
4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.
5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.
6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.
7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.
8. Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.
9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.
10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

Figure 1. Secretary of the Interior's Standards for Rehabilitation

Of the ten Secretary's Standards for Rehabilitation, two are particularly relevant to solar PV projects:

> **Standard 2.** The historic character of a property will be retained and preserved.
>
> **Standard 9.** New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

2.2 Incentives for Preserving Historic Properties

Preservation is encouraged not only through regulations but also through incentives at the federal, state, and local levels. The Federal Rehabilitation Tax Credit, the most well-known preservation incentive, allows for income-producing properties (industrial, commercial, or residential rentals) to earn either a 10% or 20% tax credit on rehabilitation expenses. Certified historic structures[14] are eligible for a 20% credit while noncertified, nonresidential properties placed in service before 1936 are eligible for the 10% credit. The rehabilitation work on tax credit projects must meet the Secretary's standards and be approved by the National Park Service.

Owners of historic properties who donate preservation easements to qualified easement holding organizations may be eligible for a charitable deduction. The deduction is made to federal income taxes for the value of the historic preservation easement. The contribution must meet the requirements of the Internal Revenue Service.

State and local incentives often provide more flexible benefits. For instance, they may be available for both income and non-income producing properties and may include an income tax deduction, a credit or abatement for rehabilitation, a special assessment for property tax, sales tax relief, tax levies, or property tax exemption. SHPOs are able to provide a list of available incentives relevant to their respective state. State and local incentive programs generally require that a project follow accepted preservations guidelines such as the Secretary's standards.

2.3 Resources for Historic Preservation

Many resources exist for providing information about the historic preservation process.

- Advisory Council on Historic Preservation (ACHP): www.achp.gov
  The ACHP is a principal national partner in the public sector and serves as an independent federal agency. The main function of ACHP is to review and comment on federal undertakings that affect properties that are listed on or eligible for listing on the National Register of Historic Places.
  - Citizen's Guide to Section 106: www.achp.gov/citizensguide.html
  - Section 106 flowchart www.achp.gov/regsflow.html
- National Alliance of Preservation Commissions (NAPC): www.uga.edu/napc/
  The NAPC is devoted to representing the nation's preservation design review commissions. NAPC provides technical support and manages an information network to help local commissions accomplish their preservation objectives. The Alliance also serves as an advocate at federal, state, and local levels of government to promote policies and programs that support preservation commission efforts.[15]
  - "National Alliance of Preservation Commissions Sample Guidelines for Solar Panels in Historic Districts" and "Solar Panels in Historic Districts": www.uga.edu/napc/programs/napc/publications.htm.
- National Association of Tribal Historic Preservation Officers: www.nathpo.org/
  The National Association of Tribal Historic Preservation Officers is a national nonprofit organization of tribal government officials who implement federal and tribal preservation laws. NATHPO's overarching purpose is to support the preservation, maintenance, and revitalization of the culture and traditions of native

[14] A certified historic structure is one that is listed individually in the National Register or located in a registered historic district and certified by the Secretary of the Interior as being of historical significance to the district.
[15] www.uga.edu/napc/. Accessed June 2011.

peoples of the United States.[16] Tribal Historic Preservation Offices (THPOs) may assume any or all SHPO functions on tribal lands on behalf of a federally recognized tribal community.

- National Center for Preservation Technology and Training: www.ncptt.nps.gov
  The National Center for Preservation Technology and Training (NCPTT) is a research division of the National Park Service. The NCPTT is using technology to serve the future of America's heritage through applied research and professional training. Working in the fields of archeology, architecture, landscape architecture, and materials conservation, the National Center accomplishes its mission through training, education, research, technology transfer, and partnerships.[17]

- National Register of Historic Places: www.nps.gov/nr
  Many SHPOs have digitized their files and put them online. The depth of information available varies from state to state, but ranges from basic location information to searchable databases with downloadable narrative descriptions and photos. The National Register provides links to these state sites at www.nps.gov/nr/shpoinventories.htm.

- National Trust for Historic Preservation: www.PreservationNation.org
  The National Trust for Historic Preservation serves as the only national nonprofit dedicated to saving historic places.
    - The National Trust's Position on Solar Panels can be found at http://www.preservationnation.org/issues/sustainability/solar-panels/.

- State Historic Preservation Offices (SHPOs): www.ncshpo.org
  SHPOs provide the resources and programs of the national historic preservation program to citizens, communities, and organizations in each of the 50 states and territories.

- Secretary of the Interior's Standards and Guidelines for the Treatment of Historic Properties: www.nps.gov/history/hps/tps/standguide/
  The Secretary of the Interior is responsible for establishing professional standards and providing advice on the preservation and protection of all cultural resources listed in or eligible for listing in the National Register. The Secretary's Standards for Rehabilitation may be used by anyone planning and undertaking work on historic properties and are used by a wide variety of federal, state, and local governments and agencies to guide projects involving historic properties. Only federal agencies or projects with federal involvement are required to use the Secretary's standards. Some state and local entities have their own set of guidelines, as mentioned previously, often mimicking the Secretary's standards.

[16] www.nathpo.org/. Accessed June 2011.
[17] www.ncptt.nps.gov. Accessed June 2011.

3 Solar Photovoltaics (PV)

Conservation efforts, environmental concerns, and mandates have prompted agencies, municipalities, and other entities to consider energy efficient and renewable energy technologies at facilities. Energy efficiency improvements, if not already undertaken, should be implemented prior to installing a PV system. Energy conservation measures, or ECMs, are the most cost-effective way to save energy and realize utility bill savings. The return on an investment in PV can often be enhanced when the building hosting the system is already energy efficient.

3.1 Solar PV Technology Overview

Solar energy technologies, such as solar PV, are mature, commercially available renewable energy technologies. PV arrays convert sunlight to electricity without moving parts and without producing air pollution or greenhouse gases (GHG). They require very little maintenance and make no noise. Arrays can be mounted on all types of buildings and structures. PV direct current (dc) output can be conditioned into grid-quality alternating current (ac) electricity or used to charge batteries.

Traditional “single crystal” solar cells are made from silicon, are usually flat-plate, and generally are the most efficient. “Multi-crystal” are a similar technology, but slightly less efficient. A third type of cell technology is called “thin film” because the solar cells are made from amorphous silicon or nonsilicon materials such as cadmium telluride. Thin-film solar cells use layers of semiconductor materials only a few micrometers thick. See Table 1 for an overview of module efficiencies for each type of module.

Table 1. Typical Efficiencies of Different Types of PV

Module Efficiencies	Single Crystal	14–19%
	Multi-crystal	13–17%
	Thin-film	6–11%

Building-integrated PV (BIPV) products may be appropriately suited for applications on historic buildings. These technologies can double as rooftop shingles and tiles, building facades, or the glazing for skylights.[18]

Figure 2 shows an example of this technology integrated into shingles. Examples of BIPV include shingles, single-ply membranes, and standing seam metal roofs. In some cases BIPV can add cost and complexity to a project and may not be universally available, but may help enhance acceptance of a project on a visible surface.

[18] www.nrel.gov/learning/re_photovoltaics.html. Accessed June 2011.

Figure 2. Thin-film solar PV shingles. *Photo from United Solar Ovonic, NREL/PIX 13572*

Most systems installed today are in flat-plate configurations that are typically made from solar cells combined into modules that hold about 40 cells. A typical home will use about 10 to 20 solar panels to power the home. Many solar panels combined together to create one system is called a solar array. For large electric utility or industrial applications, hundreds of solar arrays are interconnected to form a large utility-scale PV system.[19] These systems are generally fixed in a single position, but can be mounted on structures that tilt toward the sun on a seasonal basis or on structures that roll east to west over the course of a day.[20] Figure 3 shows the components of a typical PV system.

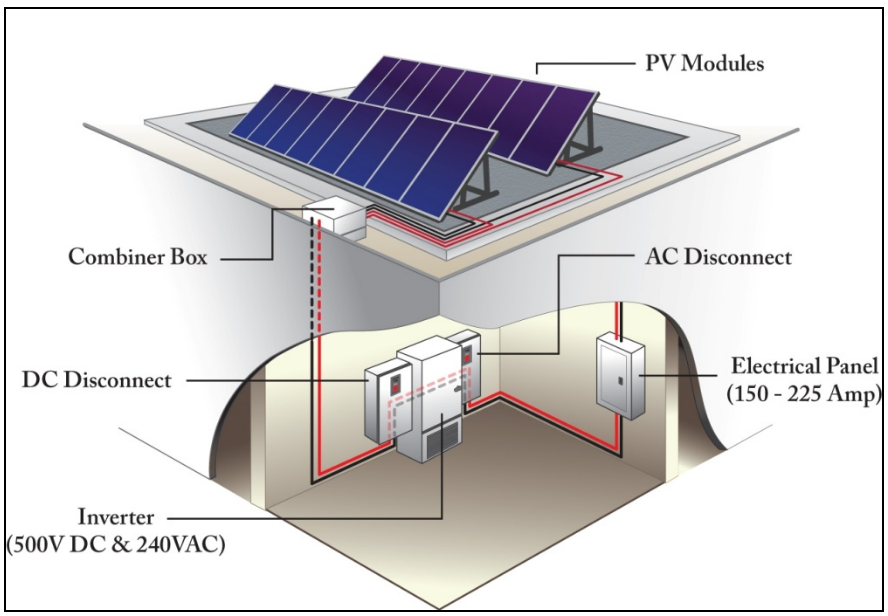

Figure 3. PV system schematic. *Illustration by Jim Leyshon, NREL*

The cost of PV-generated electricity has dropped 15- to 20-fold in the last 40 years. Grid-connected PV systems sell for between 20¢ per kilowatt hour (kWh) and 32¢/kWh in 2011, or about $5 per Watt-peak (Wp) to $8/Wp, including support structures and power conditioning equipment. Watt-peak is the power rating that a PV system measures under standard test conditions, and under which a panel could be expected to deliver its peak output. A National Renewable Energy Laboratory (NREL) study of 7,074 PV systems installed in 2007 reported a range of total capital costs averaging $8.32/Wp for small systems less than 10 kW and $6.87/Wp

[19] www.nrel.gov/learning/re_photovoltaics.html. Accessed June 2011.
[20] DOD RE Replication Pilot ESPC

for large systems greater than 100 kW. Costs reported for PV projects are decreasing rapidly, so a local solar installer may be the best source of current cost information. Operation and maintenance costs are reported at $0.008/kWh produced, or at 0.17% of capital cost without tracking and 0.35% with tracking.[21] They are very reliable and last 20 years or longer.[22]

A variety of financing mechanisms exist to help consumers overcome the significant upfront costs associated with the installation of PV systems. Third-party financing, in which an entity finances, owns, and operates the system, is a mechanism for installing a PV system for little or no capital and is most often utilized for commercial- or utility-scale systems. These mechanisms include: Power Purchase Agreements (PPAs), Energy Savings Performance Contracts (ESPCs), and Utility Energy Services Contracts (UESCs).[23] Mechanisms that can be used for residential-scale systems include home equity loans, solar leases, property assessed clean energy (PACE)[24] financing, or group purchases.[25]

The amount of electricity that a system produces depends on the system type, orientation, and the available solar resource. The solar resource is the amount of the sun's energy reaching the earth's surface, which varies across the United States. A higher solar resource means that more of the sun's energy is reaching the surface, which is optimal for PV system performance. The solar resource map in Figure 4 details the available solar resource throughout the country in kilowatt hours per meter squared per day (kWh/m^2/day). Resources are highest in the Southwest, and fairly high throughout the Western states, Texas, and Florida.

[21] Mortensen, J. *Factors Associated with Photovoltaic System Costs*. NREL/TP 620.29649. June 2001; p. 3.
[22] Guey-Lee, L. *Forces Behind Wind Powe*r. February 2001.
[23] www1.eere.energy.gov/femp/financing/mechanisms.html. Accessed June 2011
[24] As of September 2010, most residential PACE programs in the country were on hold given guidance from the Federal Housing Finance Agency (FHFA) related to the seniority of a PACE lien vis-à-vis existing mortgage loans. Refer to VoteSolar (www.votesolar.org) for periodic updates on PACE.
[25] www1.eere.energy.gov/solar/pdfs/48969.pdf. Accessed June 2011.

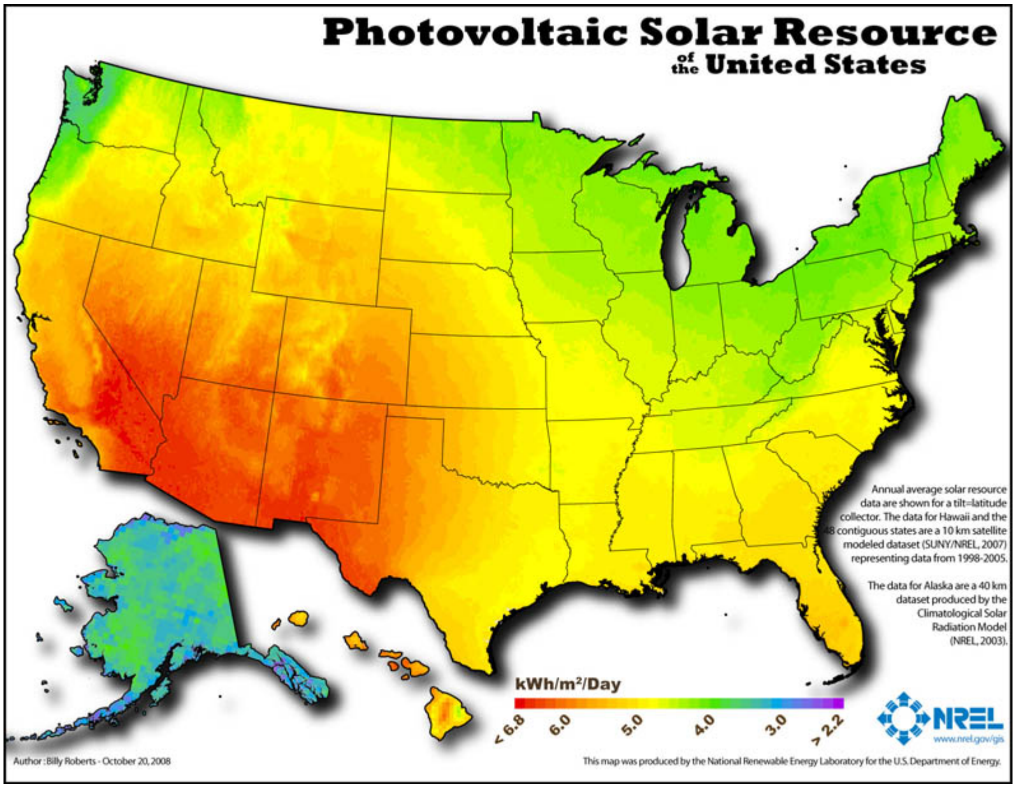

Figure 4. GIS map of U.S. solar resources

Referring to Figure 4, a properly oriented and unshaded PV panel in Washington state west of the Cascade Mountains may be expected to deliver its rated capacity for about 3.4 hours per day, while one in the desert in Daggett, California, may deliver its capacity 6.6 hours per day. A typical house uses about 25 kWh/day. Considering losses in the PV system, this could be supplied by a system of about 6.5 kW which would occupy about 500 ft^2 of roof area.

3.2 Siting of Solar PV

There are typically three scales of solar installations: utility-scale, commercial, and residential. Although this publication focuses on residential-scale solar installations, it is useful to understand the other types of locations.

- Utility-scale installations are very large arrays located on open lands, providing power for hundreds or even thousands of homes and businesses.
- Commercial systems are smaller and may provide power for multiple or single commercial or municipal buildings on campuses, in complexes, neighborhoods, or other special districts.
    - A subset of commercial systems is “solar gardens.” These systems are still relatively rare and may be limited in scope (or even prohibited) by state regulations. However, some states have recently passed legislation to facilitate the use of commercial-scale solar arrays or solar gardens. Commercial-scale systems offer potential advantages for locating solar PV in historic districts and campuses. Rather than attempting to find appropriate locations for solar panels on individual historic structures, a commercial-scale system might be located in a less visible or

impactful location, such as above a parking structure or on an open lot. Power can be lost in transmission from these arrays to the end use location, however, so distances need to be minimized.

- Residential-scale photovoltaic systems produce power for use on a single property. This type of installation is the focus of this publication.

The major challenge for siting solar PV technologies on historic buildings is appropriate siting for maximum electricity production. An ideal solar installation would be situated in an unshaded, south-facing location with an optimum tilt angle, and would supply electricity to a site where there is a demand for the electricity being produced. Not all sites are suitable for solar technologies. There are a few rules of thumb that are helpful in determining when solar technologies are appropriate for a site.

- It is important to identify an unshaded area for solar PV installation, particularly between the peak sun hours of 9 a.m.–3 p.m. Shade will reduce the output of a solar panel. Shade can be caused by trees, nearby buildings, and roof equipment or features (such as chimneys).

- It is best to orient fixed-mount panels due south in the northern hemisphere. Siting panels so that they face east or west of due south will decrease efficiency. However, that effect varies by location, and could be minimal.

  In the area of Boulder, Colorado, for example, the losses due to orientation are about 4% for a panel facing 45 degrees east of south and about 10% for one facing 45 degrees west of south (due to the mountains to the west). There is no loss of efficiency for a system facing due south.[26] While an orientation east or west of south is not ideal because of the resulting reduction in efficiency, it may be necessary due to the roof or building configuration.

- The optimal tilt angle for achieving the highest performance from a fixed-mount PV panel is equal to the latitude of a location, for locations in latitudes less than 20º. At higher latitudes, the correlation is not valid. Christensen and Barker (2001) analyzed the annual solar resource data for different latitudes.[27] At a location of 40° north latitude, an optimal tilt varies from 30° to 35° to maximize the annual energy production.

  Fixed-mount solar panels can be flush- or tilt-mounted on roofs, pole-mounted on the ground, or can be integrated into building materials, such as into roofs, windows, and awnings. However, a tilt angle equal to latitude is not always feasible because of factors such as roof pitch, wind, or snow loading considerations. It is possible to install panels at a different angle. The impact of a non-ideal tilt angle varies by location, and could be minimal.

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[26] Analysis in PVWATTS. Assuming: location = Boulder, CO; tilt=latitude (40 deg); DC to AC derate factor =0.77.
[27] Christensen, C.; Barker, G. (2001). "Effects of Tilt and Azimuth on Annual Incident Solar Radiation for United States Locations." Presented at 2001 Solar Energy Forum, Washington, D.C.

In Colorado, for example, the losses due to tilting a panel 10º greater than latitude are 2%, and tilting 10º less than latitude are 1%. There is no loss of efficiency for a system oriented at latitude.[28]

- The size and nature of an electric load must be well understood to properly select and size a PV system. PV systems can be designed to provide power simultaneously with the utility (grid-connected); independent of the utility (stand-alone, with batteries); or do either (dual mode). The systems can be designed to power any percentage of an electric load, from a very small percentage to more than 100% of the load depending on available area for the panels, availability of the sun, and what is allowed by utility policy. When considering a system that will be tied to the utility grid (grid-connected), it is essential to understand the applicable net metering rules and interconnection standards for the serving electric utility company.

  For electric customers who generate their own electricity, net metering allows for the flow of electricity both to and from the customer, typically through a single, bi-directional meter. When a customer's generation exceeds the customer's usage, electricity flows back onto the grid. This effectively offsets electricity consumed by the customer at a different time during the same billing cycle or is carried over as a credit on future billing cycles. Many state rules allow a credit to be carried for 12 months, with a resulting electricity credit resulting in either a check to the customer or a forfeiture of the value of the excess electricity produced at the end of the 12-month period. Net metering is required by law in most U.S. states, but these policies vary widely.[29] Some net metering programs reimburse customers for excess generation at the wholesale rate, while others reimburse at the retail value. Some policies specify a limit on the capacity of PV systems that can participate in the net metering program.

  Interconnection standards specify the technical and procedural process by which a customer connects a PV system to the grid. Such standards include the technical and contractual arrangements by which system owners and utilities must abide. State public utilities' commissions typically establish standards for interconnection to the distribution grid. However, the Federal Energy Regulatory Commission (FERC) has adopted interconnection standards for small generators interconnected to the distribution system that sell power to the wholesale market. Additionally, FERC has adopted standards for interconnection to the transmission level. Many states have adopted interconnection standards, but some states' standards apply only to investor-owned utilities—not to municipal utilities or electric cooperatives. Several states have adopted interconnection guidelines, which are not mandatory and generally apply only to net-metered systems.[30]

- Because PV modules have different efficiencies, it is important to consider the efficiency versus the available or required area of the PV system. Fewer modules

[28] Analysis in PVWATTS. Assuming: location = Boulder, CO; orientation = 180 deg (south); DC to AC derate factor =0.77.
[29] www.dsireusa.org/glossary/. Accessed June 2011.
[30] www.dsireusa.org/glossary/. Accessed June 2011.

made of a higher efficiency cell (such as single crystalline) would be needed for approximately the same power output as more modules made of a lower efficiency cell (such as thin film). Therefore, if a project location is space-constrained, then a higher efficiency, and potentially higher cost, module may make the most sense. However, if a project has an abundance of space, then a lower efficiency, less costly module may be most practical.

Table 2. Area and Efficiencies Associated with 1 kW of PV of Various PV Module Types

Type of Module	Efficiency of Module	Area of System
Single Crystal	19.3%	55 ft^2
Multi-crystalline	15%	71 ft^2
Thin-film	9.5%	99 ft^2

The efficiencies listed in Table 2 represent the fraction of incident solar radiation converted to electricity. These values are established by testing under standard rating conditions of 1000 W/m^2 sun, 25°C temperature, and 1 meter per second (m/s) wind speed.

3.3 Incentives for Solar PV

Financial incentives offered by the federal government and state governments, local utilities and municipalities, and private organizations have a great effect on renewable energy project economics, including solar PV. These incentives should be taken into account at all of the planning and feasibility stages. Potential incentives could include rebates, loans, tax incentives, grants, industry recruitment/support, bond programs, green building incentives, leasing/lease purchase programs, and performance-based incentives. The Database of State Incentives for Renewables and Efficiency (DSIRE) website provides a listing of all applicable incentives for each potential project location.[31]

3.4 Resources for Assessing Solar PV Potential

Many tools exist to help assess the technical and economic potential for solar PV at a specific location. These free tools can be used as a preliminary estimate of project potential by a property owner or project developer. However, a detailed feasibility study should be performed prior to ruling out or committing to a project.

- PVWatts™: rredc.nrel.gov/solar/calculators/PVWATTS/version1/
  The PVWatts™ calculator determines the energy production and cost savings of grid-connected PV energy systems throughout the world. It allows homeowners, installers, manufacturers, and researchers to easily develop estimates of the performance of hypothetical PV installations.

  The PVWatts calculator works by creating hour-by-hour performance simulations that provide estimated monthly and annual energy production in kilowatts and energy value. Users can select a location and choose to use default values or their own system parameters for size, electric cost, array type, tilt angle, and azimuth angle. In

[31] www.dsireusa.org. Accessed June 2011.

addition, the PVWatts calculator can provide hourly performance data for the selected location.[32]

- IMBY: www.nrel.gov/eis/imby/
  In My Backyard (IMBY) estimates the amount of electricity that can be produced with a solar photovoltaic (PV) array or wind turbine at a home or business. Homeowners, businesses, and researchers use IMBY to develop quick estimates of renewable energy production at locations throughout the continental United States, Hawaii, and northern Mexico.

  IMBY uses a map-based interface to allow users to choose the exact location of a PV array or wind turbine. Based on the location, system size, and other variables, IMBY estimates the electricity production one can expect from a system.[33]

- SAM: www.nrel.gov/analysis/sam/
  The System Advisor Model (SAM) is a performance and economic model designed to facilitate decision making for people involved in the renewable energy industry, ranging from project managers and engineers to incentive program designers, technology developers, and researchers.

  SAM makes performance predictions for grid-connected solar, small wind, and geothermal power systems and economic estimates for distributed energy and central generation projects. The model calculates the cost of generating electricity based on information provided about a project's location, installation and operating costs, type of financing, applicable tax credits and incentives, and system specifications. SAM also calculates the value of saved energy from a domestic solar water heating system.[34]

- DSIRE: www.dsireusa.org
  The Database of State Incentives for Renewables and Efficiency (DSIRE) is a comprehensive site for incentives and policies relating to energy efficiency and renewable energy. The information provided covers federal, state, local, and utility incentives. DSIRE is funded by the U.S. Department of Energy and is updated by the North Carolina Solar Center and the Interstate Renewable Energy Council on a quarterly basis. Solar project planners should refer to DSIRE to determine ways in which to improve the cost effectiveness of the project.

[32] rredc.nrel.gov/solar/calculators/PVWATTS/version1/. Accessed June 2011.
[33] www.nrel.gov/eis/imby/. Accessed June 2011.
[34] www.nrel.gov/analysis/sam/. Accessed June 2011.

4 Collaboration between Historic Preservation and Solar Disciplines

Collaboration between the historic preservation community and the solar discipline is imperative given the growing prominence of sustainable operations and the large number of buildings and districts designated, or that qualify to be designated, as historically significant. Criteria for successful identification and installation of solar PV are necessary, as is consideration of the technical, cultural, and institutional values that exist.

4.1 Criteria for Success

Each project and solar installation is unique. It is important to establish and understand the required levels of review and permitting at the very beginning of a project, as well as the expected savings and efficiencies of an installed system. There is no one single technical solution that will work in all applications. Therefore, defining an effective process for identification and installation is necessary. The criteria for successful projects can be broken into two different categories: a) solar and b) historic preservation. Successful solar projects establish criteria related to performance and economics. Historic preservation criteria are in the form of impacts to the character of an historic property.

4.1.1 Solar

Criteria for a successful solar project are predominantly driven by PV system performance and economics, both of which are largely dependent on project siting and location. A detailed overview of these considerations is provided in section 3.2.

- Performance
  The performance of a PV system is dependent on the type of technology selected as well as site characteristics, such as the available solar resource, impact of shade, and orientation and tilt angle. A detailed overview of these considerations is provided in section 3.2.
- Economics
  The economic feasibility of a project is dependent on the performance of the PV system; cost factors, such as the cost of avoided electricity, initial system cost, operating and maintenance (O&M) costs, availability of incentives; and other economic factors, such as discount rate and fuel escalation rate.

4.1.2 Historic Preservation

Criteria for a successful historic preservation project are largely driven by the impacts to the historic character of a historic property or district. There is the need to balance these impacts with the economics and energy savings of a given project.

- Impacts
  The various guidelines, such as the Secretary's Standards for Rehabilitation and local design guidelines, help define the appropriate treatments for historic preservation, rehabilitation, restoration, and reconstruction. Based on feedback and dialogue during the June 2010 workshop, and based on the definitions of the four treatments, rehabilitation is generally the most appropriate approach for integrating solar projects onto historic buildings or into historic districts. In general, this is the most widely

used preservation approach: "Of the four treatments, only rehabilitation includes an opportunity to make possible an efficient contemporary use through alterations and additions."[35] Rehabilitation is defined as, "altering or adding to a historic property to meet continuing or changing uses while retaining the property's historic character."[36]

Working with preservation professionals to identify the character-defining features and the potential location for a PV system is an important early step in the process to ensure that the system does not negatively impact these features.[37] Professional preservationists, preservation agencies, and preservation organizations are the best references in determining the character of a historic property. In some cases, local design guidelines will be in place to provide a set of guidelines for identifying character-defining features. The property owner would work with the local preservation commission to determine the effects of the PV system on the historic site.

It is helpful to reference NPS's guidance for "energy efficiency/accessibility considerations/health and safety code considerations."[38] This guidance provides information on retrofitting measures to improve energy efficiency. It states:

> Although this work is quite often an important aspect of rehabilitation projects, it is usually not a part of the overall process of protecting or repairing character-defining features; rather, such work is assessed for its potential negative impact on the building's historic character. For this reason, particular care must be taken not to radically change, obscure, damage, or destroy character-defining materials or features in the process of meeting code and energy requirements.[39]

It is also important to note that NPS's guidance recommends retaining plant materials, trees, and landscape features that perform passive solar energy functions such as sun shading and wind breaks. This is generally in line with common practice in the solar industry, which most often does not advocate removing these items in an effort to improve solar access.[40]

The project team should encourage outcomes that meet solar criteria while maintaining the integrity of historic resources. This involves minimizing the visual effects of solar panels and maximizing the preservation of historic features, materials, and spatial relationships. The National Trust provides the following guidance in the application of solar panels on historic properties.

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[35] www.nps.gov/history/hps/tps/standguide/rehab/rehab_approach.htm. Accessed June 2011.
[36] www.nps.gov/history/hps/tps/standards_guidelines.htm. Guidance on identifying, retaining, and preserving character-defining features can be found on the NPS's web feature called "Walk through Historic Buildings:" See www.cr.nps.gov/hps/tps/walkthrough/. Accessed June 2011.
[37] www.nps.gov/history/hps/tps/standguide/rehab/rehab_energyeff.htm. Accessed June 2011.
[38] www.nps.gov/history/hps/tps/standguide/rehab/rehab_approach.htm. Accessed June 2011.
[39] www.nps.gov/history/hps/tps/standguide/rehab/rehab_approach.htm. Accessed June 2011.
[40] www.nps.gov/history/hps/tps/standguide/rehab/rehab_energyeff.htm. Accessed June 2011.

1. **Locate solar panels on the site of a historic resource.** If possible, use a ground-mounted solar panel array. Consider solutions that respect the building's historic setting, locating the solar panel arrays in an inconspicuous location, such as a rear or side yard, low to the ground and sensitively screened to further limit visibility.
2. **Locate solar panels on new construction. In cases where** new buildings or new additions to historic buildings are proposed and approvable, encourage the placement of solar panels on the new construction. To achieve overall compatibility with the historic building and its setting, consider solutions that integrate the solar panel system in **less visible areas of the new design.**
3. **Locate solar panels on non-historic buildings and additions.** If the site cannot accommodate solar panels, and the project does not include new construction, consider placing solar panels on an existing, non-historic addition or accessory structure, thereby minimizing the impact of the solar installation on the significant features of the **historic resource as well as specifica**lly **protecting historic fabric against alteration.**
4. **Place solar panels in areas that minimize their visibility from a public thoroughfare.** The primary façade of a historic building is often the most architecturally distinctive and publicly-visible, and thus the most significant and character-defining. To the greatest extent possible, avoid placing solar panels on street-facing walls or ro**ofs, including those facing side street**s. **Installations below and behind parapet walls and dormers, or on rear-facing roofs, are often good choices.**
5. **Avoid installations that would result in the permanent loss of significant, character-defining features of historic resources.** Solar panels should not require alterations to significant or character-defining features of a historic resource, such as altering existing roof lines or dormers. Avoid installations that obstruct views of significant architectural features, such as overlaying windows or decorative detailing, or intruding on views of neighboring historic properties in an historic district.
6. **Avoid solutions that would require or result in the removal or permanent alteration of historic fabric.** Solar panel installations should be reversible. Use of solar roof tiles, laminates, glazing and other technologies that require the removal of historic fabric or would permanently damage such fabric must be avoided. Consider the type and condition of the material upon which installation is proposed as well as the method of installation and removal down the road. For example, metal and slate roofs may be able to accommodate solar panels better than other types of materials. It may also be possible, through the use of brackets, to minimize the points of attachment to a structure.
7. **Require low profiles.** Solar panels should be flush or mounted no higher than a few inches above the roofing surface and should not be visible above the roofline of a primary façade.
8. **On flat roofs, set solar panels back from the edge.** Flat roofs often provide an ideal surface for solar arrays. To minimize visibility, ensure that the panels are set back from the edge and adjust the angle and height of the panels as necessary.

9. **Avoid disjointed and multi-roof solutions.** Panels should be set at angles consistent with the slope of the supporting roof. For example, avoid solutions that would set panels at 70 degree angles when the roof slopes at a 45 degree angle. In addition, panels should be located on a single roof and arranged in a pattern that matches the configuration of the roof upon which they are mounted.
10. **Ensure that solar panels, support structures and conduits blend into the resource.** The visibility of solar panels and support structures can be substantially reduced if the color matches the historic resource and reflectivity is minimized.

Figure 5. National Trust for Historic Preservation guidance in the application of solar panels on historic properties[41]

According to the National Alliance of Preservation Commissions (NAPC), there are a handful of local jurisdictions that have adopted detailed application review guidelines for the installation of solar panels in historic districts.[42] The National Trust for Historic Preservation collected examples of municipalities and their solar guidelines relating to historic properties as a component to a policy guide: *Practical Approaches to Installing Solar Technology on Historic Properties*. See Table 3 for a summary of guidelines used across the United States.[43]

Table 3. Local Solar Panel Guidelines in Use across the United States[44]

Jurisdiction	Description	Contact Information
Alexandria, Virginia	Alexandria provides guidance on the use of solar collectors as part of its Design Guidelines for the Old and Historic Alexandria District and the Parker Gray District, adopted in 1993.	Planning and Zoning Department City of Alexandria 301 King Street, Rm. 2100 Alexandria, VA 22314 Tel: 703-746-3833 Website: www.alexandriava.gov
Boulder, Colorado	Along with developing a “Green Points System” for new development projects, Boulder has adopted guidelines on using solar collectors and improving overall energy efficiency as part of its Design Guidelines for Historic Districts and Landmarks. See § 3.1 and 8.3.4. It has also prepared a “Historic Building Energy Efficiency Guide.”	Planning & Development Services/ Long Range Planning City of Boulder 1739 Broadway Boulder, CO 80302 Tel: 706-542-4731 Website: www.bouldercolorado.gov

[41] National Trust for Historic Preservation. “Practical Approaches to Installing Solar Technology on Historic Properties.” 2011.
[42] The Alliance Review, National Alliance of Preservation Commissions. Athens, GA. “Going Green: Solar Panels in Historic Districts.” March/April 2008.
[43] National Trust for Historic Preservation. “Practical Approaches to Installing Solar Technology on Historic Properties.” 2011.
[44] Ibid.

Breckenridge, Colorado	The town has developed a “Solar Panel Policy” for projects on structures located in its conservation district (which includes the historic district). As of January 1, 2009, all development projects in Breckenridge must comply with its sustainable building code.	Community Development Department Town of Breckenridge 150 Ski Hill Road Breckenridge, CO 80424 Tel: 970-453-3160 Website: www.townofbreckenridge.com
Eureka Springs, Arkansas	Eureka Springs proactively developed guidelines to achieve both the goal of historic preservation and energy conservation. These guidelines are meant to ensure that one goal is not achieved at the expense of the other.	City of Eureka Springs Eureka Springs City Hall 44 S. Main Eureka Springs, AR 72632 Tel: 479-253-9703 Website: www.cityofeurekasprings.org
Grand Rapids, Michigan	The city’s preservation commission takes into consideration five factors in evaluating solar panel installation, including the structure’s historic character and architectural importance, the purpose of the installation, alternative means to conserve energy, visibility from adjacent public streets and adjoining properties, and the project’s design and compatibility with the structure.	Grand Rapids Historic Preservation Commission City of Grand Rapids 1120 Monroe Ave., N.W. 2nd Floor Grand Rapids, MI 49503 Tel: 616-456-3451 Website: www.grand-rapids.mi.us
Howard County, Maryland	Howard County has developed guidelines on the use of solar panels in historic districts in an effort to achieve balance between historic preservation and energy conservation measures. Titled “Use of Solar Panels and Other Solar Devices in Historic Districts,” the guidelines identify both recommended and discouraged actions.	Howard County Department of Planning and Zoning 3430 Court House Drive Ellicott City, MD 21043 Tel: 410-313-4428 Website: www.howardcountymd.gov
Montgomery County, Maryland	The county’s preservation commission includes design guidelines for the installation of solar panels in its design guidelines. While solar panels are permissible, they must be located “in unobtrusive places,” with preference given to locations away from the public view and on the grounds of the resource, new construction, and secondary resources.	Montgomery County Historic Preservation Office Montgomery County Planning Department 8787 Georgia Ave. Silver Spring, MD 20910 Tel: 301-563-3400 Website: www.montgomeryplanning.org

Ypsilanti, Michigan	The Ypsilanti Historic Preservation Commission has developed a number of fact sheets, including one on alternative energy systems. This fact sheet provides guidance on the installation of solar power systems based on the Secretary of the Interior's Standards for Rehabilitation.	Planning and Development Department City of Ypsilanti City Hall, 4th Floor One South Huron Ypsilanti, MI 48197 Tel: 734-483-9646 Website: www.cityofypsilanti.com

5 Process for Implementation

The steps, challenges, and solutions associated with the process for implementing solar PV projects on historic buildings and in historic districts were identified during the aforementioned workshop held in June 2010. Through large and small group discussions at the workshop, a process was devised for the successful implementation of solar PV projects.

The steps identified in this process are:

- Identify potential projects and stakeholders
- Engage stakeholders
- Follow appropriate review requirements
- Implement projects
- Evaluate impact of completed project.

Each step in the process is outlined below in the following steps.

5.1 Step 1: Identify Potential Projects and Stakeholders

When considering PV on a historic building or in a historic district, it is essential to identify relevant stakeholders and potential project locations.

Identifying Stakeholders

An initial step is to determine whether the property has been designated as historic at the local, state, or national level. The designation of a property will determine which set of stakeholders to engage. Projects will have a greater chance of success with abundant stakeholder contributions and advance logistical and technical considerations.

Early identification and engagement of all relevant stakeholders are large determinants of project success. Stakeholders may include facilities engineers and solar installation companies that can assist with the implementation of the project. Easement holders and private and commercial property owners are also important due to their control over the property or land where installations might be possible. Others include federal, state, and local governments that may have funding and renewable energy targets that need to be met, as well as financiers with knowledge of rebates, grants, third-party financing, and tax credits. For projects that receive federal funding, Section 106 review of that project is required. Programs may currently exist for funding opportunities that will dictate specific criteria of projects. For example, a federally funded grant project may require that a certain percentage of the funding be contributed by the state in which the installation is occurring. Therefore, reviewing the criteria related to these programs and engaging the relevant stakeholders is important. With all historic projects, it is important to engage the relevant governmental agencies, such as SHPOs, THPOs, and local preservation commissions, at an early stage to ensure that requirements for historic preservation are being met. Table 4 provides an overview of the leading public agencies responsible for implementing the historic preservation regulations, designations, and incentives relevant to solar PV applications on historic buildings and in historic districts.

Table 4. Public Agencies Responsible for Administering Historic Preservation Regulations, Designations, and Incentives Pertinent to Solar PV Installations on Historic Properties and in Historic Districts

		National Park Service	Advisory Council on Historic Preservation	Tribal Historic Preservation Office	State Historic Preservation Office	Certified Local Government/ Historic Preservation Commission
Regulations	Section 106 of the NHPA		X	X	X	
	State Preservation Law				X	X
	Local Preservation Ordinance					X
Designations	National Register of Historic Places	X		X	X	
	State Register of Historic Places				X	
	Local Landmark					X

Incentives	Federal Rehabilitation Tax Credit	X		X	X	X*
	State Rehabilitation Incentives				X	X*
	Local Rehabilitation Incentives					X

* Some responsibilities may be delegated to the local commission or planning office.

Identifying Projects

The identification of potential projects ideally begins with an initial goal-setting exercise. Determining, with appropriate stakeholders, what the motivations for and goals of the project are will help define and drive the project development throughout the entire implementation process. For example, goals could be related to municipality energy reduction or renewable energy use goals, building or neighborhood LEED certification requirements, or building owner and tenant motivations. Project identification may include an analysis of building stock to determine which buildings have the most feasibility for PV, an assessment of the potential impact to the character-defining features, consideration of electricity costs or good PV incentives, and an understanding of to-date energy efficiency measure implementation.

A detailed overview of PV siting considerations is provided in section 3.2. High costs of energy combined with the incentives and rebates for solar installations and historic building rehabilitations, along with legislation and the need for energy security, are all drivers for considering installation of solar projects on historic properties. Solutions other than the roof of a historic structure should also be considered, such as a carport over a parking area or a ground mounted array elsewhere on the property. There will be times when it is not possible to roof-mount a PV system on a historic building without negatively impacting its character-defining features, so one of these out-lying locations may be a viable alternative.

Siting PV may not be limited to locating solar on a single site or structure. There is potential for "district solar" and/or more distant solar locations than the site allows. District solar could make sense in some historic district situations, where grouping panels on a large institutional rooftop, open field or over a parking lot might be preferred; or a historic campus where locating PV in a hidden area could be a better solution than placing all the systems on visible rooftops. Lamar Buffalo Ranch in Yellowstone National Park is an example where the PV was placed away from the cluster of historic cabins. It should be noted that there are technical issues related to distance, as well as legal and regulatory issues when more than one property is involved.

5.2 Step 2: Engage Stakeholders

Stakeholders are those with a compelling or regulatory stake in the completed project. After project stakeholders have been identified, it is important to engage them to ensure requirements of historic preservation are met, resources are fully utilized, and more informed decisions are made. This will ultimately increase the likelihood of project success. The process for engaging stakeholders depends on the location and scale of the project. Different stakeholders will be involved in different phases of the process.

The project goals, type, and financing mechanism dictate the type of people who should be involved as stakeholders. For example, Section 106 of the NHPA will define the level of federal involvement on a project; however, state and local governments may have separate processes. Although not an exhaustive list, stakeholders may include the following:

- Adjacent property owners
- Technical assistance providers such as National Trust for Historic Preservation
- Local preservation commissions

- U.S. Green Building Council
- State historic preservation officers (SHPOs)
- Tribal historic preservation officers (THPOs)
- Tribal government and stakeholders
- Public recipients of grants or funding
- Planners
- Contractors
- Engineers
- Property owners
- Federal agencies
- Non-profit preservation and environmental groups
- Local government.

Entities in the construction process prior to completion, such as the manufacturers, contractors, and others with a vested interest in the promotion of or the sale and installation of the solar PV products, may be consulted for technical information relevant to the discussion, but not labeled as stakeholders. Members of the Association for Preservation Technology, for example, may consult and be paid for their professional involvement and review, but would be acting as individuals, not the association, and would be considered consultants rather than stakeholders.

The process of engaging various entities could be partially stipulated by legal requirements or local code. The process of engagement could be done through third-party advocates, public notices, statutes and mandates, internet announcements, conferences, workshops, awards, newsletters, solar advertisements, funding announcements, or public hearings.

By exploring all avenues available and considering various entities, a project will most likely be more successful as it will have the contributions of a number of stakeholders.

5.3 Step 3: Follow Appropriate Review Requirements

Introduced in section 2.1, the historic preservation review process for solar installations varies according to the type of designation for the property and whether the installation involves a government agency or government property.

- **Locally designated properties.** Historic properties may be identified and protected through a local historic preservation or landmark preservation ordinance. Most ordinances provide for the designation of both individual properties and historic districts. Historic districts generally include both "contributing" and "non-contributing" properties. Contributing properties are those that retain their historic integrity and contribute to the overall significance of the district. Design standards or guidelines may be in place for both contributing and non-contributing properties in local historic districts.

- **State register listed properties.** State registers include both individual properties and historic districts. State review processes vary greatly, so it is important to contact the SHPO for guidance regarding the review process in each state.
- **National register listed properties.** The National Register of Historic Places includes both individually listed properties and historic districts. As noted above, properties that are determined eligible for listing receive the same federal review as those that are listed. Contact the SHPO for information regarding National Register listed properties or determinations of eligibility. If a federal agency is involved in a project affecting a national register listed or eligible property, it must go through Section 106 review.

Other review processes may also be required. State and federal environmental protection processes should be examined. Some historic properties are protected by preservation or conservation easements. The easement holding entity should be involved in the solar installation from the earliest phase.

Requirements may be relevant to Section 106 (federal and state equivalent), National Environmental Policy Act (NEPA), local zoning and ordinances, local and national code requirements, electrical codes, structural integrity of properties, federal, state and local environmental goals, Secretary's Standards, setback codes, or Leadership in Energy and Environmental Design (LEED) requirements in certain cities (such as Boston). There may also be requirements to meet for funding mechanisms such as grants or incentives or third-party financing agreements (such as an Energy Savings Performance Contract [ESPC], Utility Energy Services Contract [UESC], or Power Purchase Agreement [PPA]).

If requirements are not observed, lawsuits may be actioned and responsible parties may be fined or issued stop work orders or citations. All of these consequences are costly, both in terms of money and time. It is essential to research requirements of all mandates, statutes, codes, and funding options before beginning work on a solar project on historic properties or in historic districts.

5.4 Step 4: Implement Project

The project is ready to be implemented once the project location, PV technology, and size have been identified, stakeholders have been engaged, and all requirements have been considered and met. Implementation may involve a number of stakeholders previously mentioned and requires open communication between the solar installation industry and the historic preservation community. Consideration should be given to the impact of project implementation and construction on the function of the building or district and its occupants. Also, projects must be implemented to maintain structural and historical integrity while ensuring solar projects are installed to maximize generation of energy.

5.5 Step 5: Evaluate Effects of Project

Evaluating a project after installation is a beneficial approach to take when installing solar projects on historic properties. By reviewing what was successful in the project implementation process, as well as what could be improved upon, the overall process can be improved to increase the rate of success of such projects in the future. Case studies or best practices can be created in order to share the experiences with other entities trying to replicate similar projects as well as with the public. Evaluations may be required through Section 106 during consultation, funding mechanisms (e.g., often grants will not be awarded in full without a post-installation evaluation), or for tax purposes. Evaluations are not typically done by historic preservation officers, but this may represent an area for improvement.

The project should be reviewed both during the process and after installation to analyze the coordination of preservation planners, installers, property owners, utilities, and bill payees. The review should also consider impacts on historic integrity, policies, neighbors, appeal boards, SHPOs, and the like.

Review criteria to consider include three key measures:

1. Energy savings and system performance. Did the installation produce the energy savings expected?
2. Impact on historic integrity. Did the installation affect the historic integrity of the property? Impacts may include physical impacts on historic fabric as well as visual impacts.
3. Financial impact. Was the installation cost effective? Over what period?

In all instances, whether beneficial or negative, there is much to be learned from evaluating the process after the installation has been completed. The results of the evaluation should be shared with all stakeholders in order to inform future projects. The installed project can also be used for outreach and education to the historic and solar communities and the general public. Educational opportunities include print and online outreach documents, in-building real-time displays of PV electricity produced and greenhouse gas (GHG) emissions avoided, Web-based PV system performance tracking, and interpretive displays or verbal tours. An example of a Web-based PV tracking system is provided in Figure below.

Figure 6. Web-based PV performance display. ***Graphic by Lucid Design Group***

5.6 Barriers

Multiple barriers often challenge the implementation of solar projects on historic buildings or in historic districts. Potential barriers were highlighted at the June 2010 workshop. While not an exhaustive list, these examples are presented to illustrate the potential challenges facing solar projects on historic properties.

- If building owners do not encourage or understand the energy efficiency measures that should be implemented prior to renewable energy installation for reduced energy requirements and lower energy costs overall, the renewable energy is less cost-effective.
- The cumulative effect of multiple installations on one historic property may exceed what each project displays individually.
- A lack of involvement by local government and industry professionals early in the planning and identification process may lead to additional challenges or prolong the project implementation process.
- Time constraints associated with funding may prove challenging to project managers in the planning and implementation phases.
- Review processes may be time consuming (e.g., applications for Certificates of Appropriateness) and may increase overall delivery time on the project and disengage stakeholders.
- Stakeholder time and resources may be limited, which makes it difficult to allocate staff and staff time to complete paperwork and reviews.
- Stakeholders may not be familiar with specific guidelines, which may increase the time and effort required for project implementation.
- Stakeholders may perceive that PV technology is rapidly advancing, which may discourage investment now due to the view that more aesthetic, smaller, more efficient, and potentially more cost-effective panels may be about to enter the market.
- The capital costs of PV projects can be inhibitive.
- Engaging stakeholders may be difficult in a variety of ways, including identifying the right person to take action, keeping the project team focused, and understanding the PV project implementation process.
- Requirements and enforcing agreements may be challenged by the lack of knowledge of the value of historic preservation or the details of the implementation process as a whole.
- Technical setbacks, like an existing historic electrical infrastructure that may not be capable of supporting a grid-connected PV installation, could present increased costs and project delays.

While the challenges facing every project are unique, this document intends to identify best practices that increase the likelihood of successful implementation of solar PV projects on historic properties. This information is intended to inform decision-makers and provide a starting point for the implementation process.

6 Case Study

The Colorado Capitol Complex comprises 18 buildings in downtown Denver, Colo., including the Colorado State Capitol, which was built between 1895 and 1903. Maintenance staff faced a limited budget for controlled maintenance, causing them to look for innovative ways to take care of the buildings. Over a period of four years, energy efficiency upgrades were made to the Capitol while protecting its historic integrity. In October 2008, Governor Bill Ritter announced that the Capitol was to become the first in the nation to obtain the U.S. Green Building Council's new Leadership in Energy and Environmental Design (LEED) certification for Existing Buildings (LEED-EB): Operations & Maintenance.

The LEED certification system provides an outline for buildings to use less energy, water, and natural resources, and improve the indoor environment. The LEED-EB certification is awarded to those who can certify that an existing building has been retrofitted in a manner that demonstrates certain efficiency standards for its ongoing operations and maintenance. The Colorado State Capitol received 41 out of 44 points submitted to attain certification. Other buildings within the Capitol Complex have received LEED certification as well.

Figure 7. PV Panels on Denver Capitol ***Photo by Eliza Hotchkiss, NREL/PIX 18594***

The annual budget for energy within the Capitol Complex is approximately \$3 million. Approximately \$1 million is being saved annually because of the energy-saving retrofits, specifically lighting upgrades; the improvements to windows, boilers, and chillers; and the electricity offset by the PV panels.

Building-specific improvements that have been made to the Capitol in order to obtain LEED-EB certification include:

- Water conservation efforts such as low-flow toilets
- Use of low-energy light bulbs and T-8 light fixtures
- Improved energy controls
- Use of green cleaning products

- Initiation and maintenance of a recycling program
- Purchase of Energy Star® electronics and equipment
- Use of environmentally friendly landscaping products and plans
- Installation of 10-kW PV system.

The 10-kW PV system (approximately 40 panels) on the roof of the Capitol was intended as a demonstration project with educational benefits. The attic was converted into an educational area, called Mr. Brown's Attic, where visitors can learn about Colorado's early history, construction of the Capitol, and the legislative process. From Mr. Brown's Attic, visitors can ascend 99 steps to an interior observation area that provides a panoramic 360-degree view of downtown Denver as well as a view of the PV system.[45]

With special access, visitors can also view the two inverters that convert the energy being produced by the solar panels from direct current (DC) into alternating current (AC) electricity so it can be used within the building's electrical systems. The panels are situated on the roof, just below the Capitol dome, so that they are not visible from street level. They face due south and due west to determine the decrease in efficiency between south-facing (optimal placement) and west-facing (less efficient) panels.

This project was funded through an Energy Savings Performance Contract (ESPC) with Chevron Energy Solutions. An additional project has been funded by a grant of $4.7 million from DOE for a ground-source, heat pump heat/cool project in the Capitol as part of the Chevron Energy Savings Performance Contract, which is estimated to cut utility bills by 30%. The savings associated with this additional work is $100,000 per year.

From the early stages of project identification to the installation and analysis of the PV system's effects, this case study can serve as a valuable example of the importance of each step in the implementation process.

- Identify potential projects and stakeholders

The Capitol was selected as a demonstration project due to a number of considerations, including funding mechanisms and project timing. It is involved in a performance contract that allows the excess savings from the utility budget to be used to fund energy-related projects. The Governor's Energy Office suggested a PV installation on the governor's residence, which is a historic property. However, this was not a viable option due to structural integrity. A PV system was installed on the carriage house roof instead. The Capitol was chosen because of an existing attic educational area renovation, the available funding from the performance contract and tax credits, as well as approval from both the SHPO and Capitol Building Advisory Committee for the installation with the agreement that the PV panels not be visible from the grounds of the capitol. The stakeholders involved were the Governor's Energy Office, the SHPO, the Capitol Building

[45] www.colorado.gov/cs/Satellite/CGA-LegislativeCouncil/CLC/1200536135302. Accessed June 2011.

Advisory Committee, the Department of Personnel and Administration, energy savings performance contractors, and the PV installers.

- Engage stakeholders

Stakeholders were engaged throughout the project. The engagement process was driven by the funding options available and the knowledge of potentially interested parties. Engagement occurred primarily through conversations and meetings relating to various requirements. For example, solar installers were engaged through the ESPC in relation to the funding and contract mechanism, whereas the historic preservation community was engaged during impact reviews by the State Office of Archeology, which represents the State Historic Preservation Officer. As part of the ESPC, the LEED-EB certification process was used to provide a third-party review of the energy conservation work performed. The LEED process and recertification process are part of ongoing maintenance and accountability to maintain energy performance.

Key to teamwork among stakeholders is mutual empathy for those involved. There may be a sense of doubt that the solar industry could or would be sensitive to historic considerations. Solar companies certainly can work with the historic building community, but it would help to have each party approach the project without a preconceived idea that the other is trying to be difficult. Both renewable energy and historic preservation are important objectives. The language of historic preservation speaks in terms of impact on a resource; solar projects seek renewable energy yield. Conflict may arise when there is an impact and a redesign would lower yield. Both points of view benefit from a clean energy source and lower operating cost while successfully protecting an historic resource.

- Follow appropriate review requirement

Requirements for historic preservation were met by ensuring the PV panels were not visible from the Capitol grounds, thus preserving the character and integrity of the historic features of the Capitol. The PV system was installed as an educational feature as part of the Capitol's attic museum. The PV system is tied into the presentation on the history of energy usage in the Capitol. The system was also installed as a demonstration project with half of the PV panels facing south and the other half facing west to compare the impacts on panel orientation. It is important that the installation can be easily removed or reversed without impacting the property.

During construction, weekly meetings were held to discuss progress and the observation of all project requirements. The PV installation required a state electrical permit, was validated by Xcel Energy for compliance with their rebate program, and was reviewed by a LEED consultant as part of the certification process.

- Implement Projects

The PV system was funded through tax credits and performance contracting. The length of the project was dictated by contractual challenges and stakeholder concerns relating to insurance and liability. The community was informed of the project through the approval processes associated with the Capitol Building Advisory Committee and the Colorado Historical Society.

- Evaluate impact of completed project

The response to the PV project by the public, historic community, solar installer, and the Governor's Energy Office has been positive. Power generation is monitored through a motion-sensing display in the attic, as well as an online PV monitoring system with secure log-in[46]. The geothermal heat pump project will connect to the same online monitoring system to export information relating to production. The project monitoring system has proven that the south-facing PV panels are producing energy within the PV installers' estimated range and shown that the west-facing panels are below the estimated production. The only drawback of the Capitol PV system is that not all tax benefits were captured to offset the initial costs of the project.

[46] www.fatspaniel.com/. Accessed June 2011.

7 Summary

Addressing the barriers associated with siting PV installations on historic properties can help expand the nation's potential solar resources while also preserving its heritage. In this way, the solar and preservation communities can work together to meet growing renewable energy needs.

The first step to overcoming barriers successfully is to better understand the processes for both historic preservation and solar PV project implementation and to work with professionals in each sector to receive appropriate buy-in and guidance. Establishing criteria for each sector assists in achieving a successful project. Solar PV projects can be assessed based on performance, cost, and economic payback of the system. Historic preservation can be assessed based on impacts to the historic character of the site, economics, and energy savings.

Ultimately, historic preservation and solar PV work toward achieving a shared objective: resource conservation. Educating key stakeholders and tracking project implementation is imperative to achieving success. This publication and the June 2010 workshop represent the benefits of partnership between the two fields to facilitate shared discussions and education.