Solar Mapping

Planners and the communities they serve are increasingly recognizing the importance of sustainable places. A critical aspect of helping cities improve their environmental and economic performances over the long term is supporting their transitions to cleaner fuel sources to reduce greenhouse gas emissions and improve energy security. A growing number of communities are discovering that the use and integration of solar energy can play an important role in helping them reach their sustainability goals.

Most people support renewable energy efforts in theory, but they may fail to act individually because of the uncertainties associated with installing solar energy systems. Most property owners are unaware of how much solar power potential exists on their building rooftops, where other systems have been installed in the area (and by whom), how much an installation will cost, and how cost-effective it can be in relation to their energy bills. Solar maps are innovative tools that can provide easy answers to these questions. They can help inform policy decisions, educate consumers, drive technological development, increase manufacturing capacity, and improve marketing methods. This briefing paper explains what solar maps are, how they work, and how communities can benefit from their use.

What Is a Solar Map?

A solar map is an internet-based tool that helps educate and inform users about solar technology by estimating the solar energy potential of building sites or open land and providing information about associated benefits. The purpose of a solar map is to promote greater public awareness about solar energy, enable consumers to discover the solar potential of their own properties, and facilitate increased solar usage among property owners.

Benefits of Using Solar Maps

A solar map can serve as a single place to store complete information on solar resources. Like the concept of a "one-stop shop" for permitting, solar map portals can store all federal, state, and local information regarding available solar incentives and programs. Solar maps are user-friendly, allowing users to make quick and easy assessments of the solar potential of their properties. When given minimal information such as a street address, the map can instantaneously generate data about potential costs, potential cost savings through incentives and rebates, and energy usage for that property. Additionally, solar maps are interactive. They can include tools to draw potential PV-system layouts or estimate shading from nearby structures or vegetation, providing a level of detail that allows users to assess an open space on a specific property or rooftop and take into account any obstructions that reduce usable area for panel placement. Finally, solar maps generate quantifiable

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outputs that can inform decisions made by government officials and the general public.

Users and Types of Solar Maps

Solar maps can be used by a variety of audiences. Local government officials (such as mayors, economic development directors, and planners) can use solar maps to track progress toward achieving sustainability goals stated in comprehensive plans, sustainability plans, or renewable energy plans. Solar maps can help communities run scenarios to determine anticipated outcomes and track completed installations to measure success in real time. In Santa Clara County, California, for example, solar mapping allowed government officials to estimate the effect that 10 potential solar-installation target areas would have on the county's CO_2 emissions. San Francisco's solar map displays citywide solar statistics including the amount of solar energy produced, annual cost savings, and reductions in CO_2. These figures help hold the city accountable to its residents and are used to gauge progress toward meeting established city goals. Planners can use solar maps to identify high-installation areas in the city and use those numbers to inform economic development or green job training efforts.

Installers may use solar maps to understand how use of solar technology has grown over time and determine where they should focus their business efforts. They can advertise their services or showcase their installations on solar maps. Additionally, they can extract data to use in strategic marketing and outreach efforts. Los Angeles County's solar map provides a list of tips for installers on how to make the most of the information solar maps can provide, including suggestions that installers use map data to develop targeted mailing lists for properties with high solar potential, target high-value properties, or develop return on investment (ROI) models for potential customers.

Utility providers can use solar maps to visualize the distribution of projects within their territory, gauge future distribution congestion issues, determine particular neighborhoods or regions with customer interest in solar, determine the rates at which local markets are developing, and estimate the anticipated reduction in customer demand for more traditional sources of energy in their service territories.

Homeowners and business owners can use solar maps to research the solar power potential of their homes or businesses. They can educate themselves on the costs of installation, financing options, potential energy savings, payback times, main-tenance requirements, life expectancies, and other factors. They can discover which neighbors have installed PV panels on their property, the sizes of the systems installed, and the amount of energy the panels are producing. This is powerful information in terms of behavior change and competition, which drives the market for renewables in the residential arena. Property owners can also use solar maps to research local installers or arrange for estimates. Solar maps enable property owners to do start-to-finish assessments of the solar potential of their properties—from investigation to education to action.

Solar maps can be used for projects of all sizes and can be customized to produce outputs that meet the needs of their users. If a city wants to measure its progress toward achieving sustainability goals, then its solar map needs to provide data at a city-wide level. In other instances, municipalities may want to determine the solar potential of more narrowly defined areas of the city, such as commercial and industrial buildings over 50,000 square feet, designated residential "solar neighborhoods," or specific economic corridors. Alternatively, the city might identify what it believes to be ideal locations for solar (such as highway interchanges, municipal buildings, or large industrial buildings) and want to see what effects installing solar in these locations would have on reducing energy costs and emissions. Further still, cities might use solar maps to determine the best locations for solar installations in the city.

Components of a Solar Map

A community can choose to incorporate a wide range of information into its solar map, but three levels of basic input data are needed to begin: topographic data, meteorological data, and financial data (Dean et al. 2009).

The most accurate form of topographical data is Light Detection and Ranging data (LiDAR). LiDAR data can be used to create three-dimensional digital elevation models (DEMs) that analyze the impacts of shading obstructions, identify roof tilt, and estimate the amount of roof area that can used for a particular installation (Dean et al. 2009). Although LiDAR provides the greatest degree of accuracy, it is also a significant expense for communities. Where LiDAR data are not available, a community can use high-resolution orthophotography along with building footprint and parcel data for feature and building identification. Many of these datasets are already available within city governments.
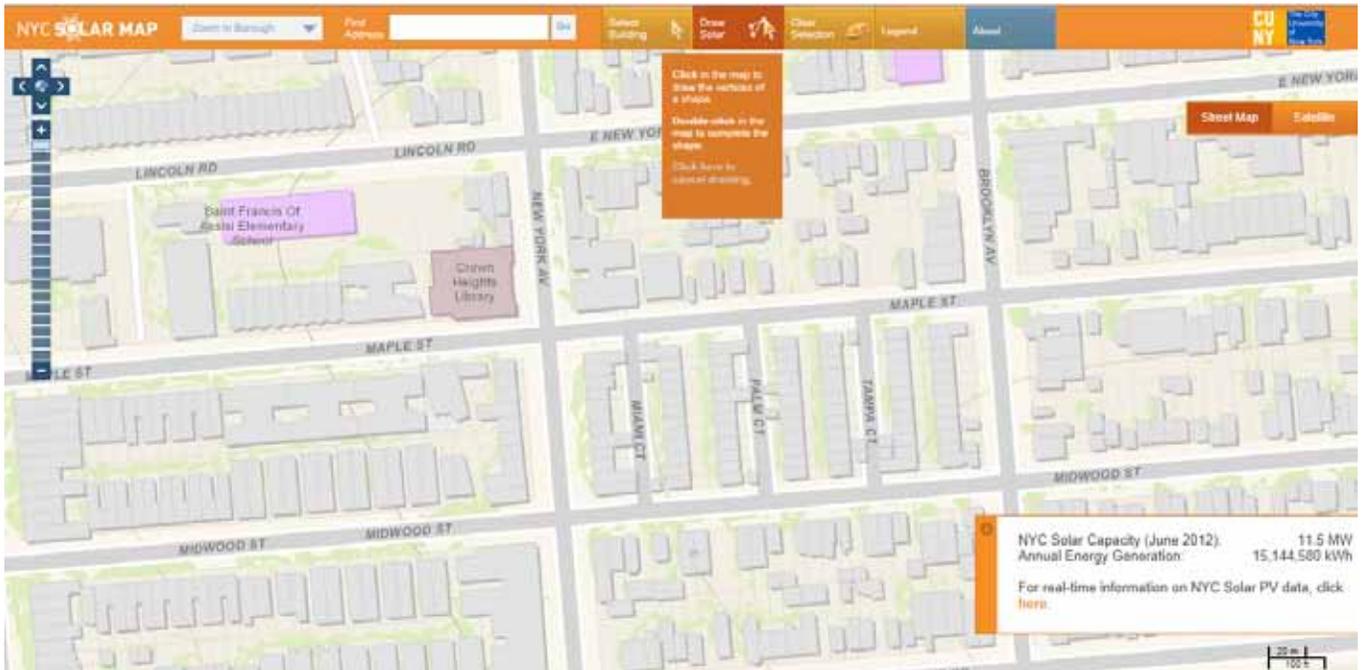
The Draw Solar tool in New York City's solar map allows users to draw a solar installation and immediately generate information on the installation including cost, financial metrics, electricity bill savings, environmental impacts, and available incentives. (Image courtesy of http://nycsolarmap.org/)

The second layer, meteorological data, is used to estimate the solar resource at a given site. This accounts for spatial and temporal variations in solar radiation and ultimately identifies how much solar resource is available for solar PV systems. Some maps make simplifying assumptions to calculate an annual solar resource estimate; for example, the City of San Francisco's solar map model uses an average of four hours of sunlight per day, while San Jose's assumes six hours. Other maps use hourly meteorological data that are derived from ground-based meteorological stations or satellite-derived meteorological data (Dean et al. 2009).

The third layer, financial and incentive data, is used to calculate the economics associated with a given installation. Typical data incorporated into map models include electricity rates, electricity escalation rates, and installed costs. Communities may also provide information on federal tax credits as well as state, local, or utility incentives (Dean et al. 2009).

Communities may choose to go beyond these three levels to include additional features that allow the map to serve as an all-encompassing source of clean energy information in their city. Additional features may include records on existing systems, links to local installers, photo galleries, news stories, case studies, information on permitting processes and capturing lo-cal incentives, schedules of local solar educational offerings, and general information about clean energy technologies.

Solar maps can provide answers to many questions property owners have about the solar potential of their properties. By typing in an address, a resident or business owner can estimate the amount of total roof area suitable for solar, potential system size, potential annual energy output, potential cost savings, and potential annual emissions reductions. Factors such as system type, energy costs, system payback, available incentives and rebates, and installation costs can be incorporated into the model as assumptions. Useful resources include the Database of State Incentives for Renewables and Efficiency (DSIRE; www.dsireusa.org), a clearinghouse for information on federal, state, and local solar incentives, and tools such as the Clean Power Estimator (www.gosolarcalifornia.org/tools/clean_power_estimator.php), which calculates the potential costs and benefits of installing a PV system at a residence or business. Cities can also customize their maps by providing links to local resources or using data obtained from local sources, such as energy costs from local utility providers and system types and installation costs from local installers. But creators and users of maps should note that the information obtained from a solar map is only as good as its data; if

the data are not accurate, neither is the information being fed through the solar map.

Some of the more advanced maps, like those of Salt Lake City or New York, offer interactive drawing tools that allow users to manually draw in an installation wherever they choose. This increases accuracy because the user can depict a more exact size of the potential installation and account for objects on the roof, such as HVAC systems or skylights, that might prohibit the placement of an installation. Additionally, users can consider multiple scenarios, such as comparing savings of an installation placed on a garage to one on a roof. Another city with an interactive solar map is Portland, Oregon. Its solar map has a shading slide tool that enables users to estimate the percentage of shade cast on their properties from trees and vegetation.

Finally, in most cities, when a property owner fills out a form to obtain solar incentives, the property is automatically registered and displayed on the solar map along with information such as system size, installation company, and energy output. The owner may choose to provide extra information like a quote about solar or a photo of their installation. Residents can use this information to determine which installers have experience in the local area. Government officials use this information to provide details on their solar programs, including the total number of solar systems currently installed, how much energy these systems are producing, how much money property owners are saving on their utility bills, and how much CO_2 is being offset by these installations. The information can also be used to track progress toward meeting solar installation goals. For example, the City of San Francisco is using its solar map to gauge progress toward reaching the former mayor's goal of having solar PV or solar thermal installed on 10,000 roofs by the end of 2012.

Developing and Maintaining a Solar Map

Solar maps can be created either by city staff or by consultants. A municipality considering developing a solar map in house should evaluate the qualifications of the staff on hand.

A handful of different technologies and methodologies are currently being used to create solar maps. Some cities have used ESRI's ArcGIS Server as their base system and supplemented it with applications such as ESRI's solar analyst extension or with 3D-modeling software to create more detailed analyses. Another technology commonly used in the western U.S. is the Solar Automated Feature Extraction (SAFE™) methodology,

currently under patent by CH2M HILL/Critigen. SAFE™ assesses the solar potential of buildings through a combination of aerial imagery and advanced 3D modeling. The method takes into account factors such as roof obstructions (air conditioning units, chimneys, vents), azimuth (the direction of the sun), shadowing from other buildings, and roof slants. This methodology also calculates total roof area, usable roof area for solar panels, the amount of electricity the panels can produce, the electricity cost reduction, and resulting CO_2 reduction. Other companies are beginning to develop solar maps through the use of open-source software programming.

Regardless of who is making the map and what technology is being utilized, many stakeholders should be at the table when the map is being developed. Utility providers can provide information on utility rates and who is currently utilizing solar energy. Solar installers can provide information on installation costs and available resource guides. Local government officials can offer information on permitting processes and community goals. Other solar advocates in the community can provide information on local resources, including available solar educational offerings and meetings.

The amount of time needed to create a solar map will vary based on geography and staff qualifications. If developing a map in house, communities should consider whether staff can make a full-time commitment to development of the solar map. Communities should factor in at least three months for stakeholder coordination and an additional three to six months to develop the map once all of the input data has been collected. The cost to produce a map varies, depending on data quality and availability, area size, and desired level of map detail, and can range from $20,000 to $200,000 (McDermott 2008).

Once a city has created a map, it must maintain the map to ensure accuracy. If a city develops its solar map in house, city staff will likely be responsible for map maintenance. Communities who hire consultants to create their maps can be trained to undertake updates or can continue to contract with those companies to maintain the maps. Most communities update their maps on a quarterly basis, but updates can take place as frequently as monthly or as infrequently as annually. Communities that do not undertake regular updates to their solar maps run the risk of providing outdated data, broken links, and inaccurate depictions of the prevalence of solar in their communities.

Communities with Solar Mapping Tools

Anaheim, California: *Anaheim Solar Map*
http://anaheim.solarmap.org/

Berkeley, California: *Berkeley SolarMap*
http://berkeley.solarmap.org/solarmap_v4.html

Boston, Massachusetts: *Solar Boston*
http://gis.cityofboston.gov/solarboston/

Cambridge, Massachusetts: *Solar Tool v.2.*
http://cambridgema.gov/solar/

Denver, Colorado: *Denver Regional Solar Map*
http://solarmap.drcog.org/

Los Angeles County, California: *Los Angeles County Solar Map*
http://solarmap.lacounty.gov/

Madison, Wisconsin: *Solar Energy Project (MadiSUN)*
http://solarmap.cityofmadison.com/madisun/

Milwaukee, Wisconsin: *Milwaukee Solar Map*
http://city.milwaukee.gov/milwaukeeshines/Map.htm

New Orleans, Louisiana: *New Orleans Solar Calculator*
http://neworleanssolarmap.org/

New York, New York: *New York City Solar Map*
http://nycsolarmap.com/

Orlando, Florida: *Metro Orlando Solar Map*
http://gis.ouc.com/solarmap/index.html

Portland, Oregon: *Oregon Clean Energy Map* (forthcoming)
http://oregon.cleanenergymap.com/

Riverside, California: *Green Riverside Green Map*
www.greenriverside.com/Green-Map-9

Sacramento, California: *Solar Sacramento*
http://smud.solarmap.org/

Salt Lake City, Utah: *Salt Lake City Solar Map*
www.slcgovsolar.com/

Santa Clara County, California: *Silicon Valley Energy Map*
www.svenergymap.org/

San Diego, California: *San Diego Solar Map*
http://sd.solarmap.org/

San Francisco, California: *San Francisco Solar Map*
http://sfenergymap.org/

Tallahassee, Florida: *Solar Interactive Map*
www.talgov.com/you/you-learn-utilities-electric-solar-map.aspx

Users should be aware of the assumptions that go into making a solar map. Although maps may be highly accurate, 100 percent accuracy cannot be guaranteed. All information generated by a solar map should be considered an initial assessment that helps the user decide whether to proceed with a solar installation or not. All information and values obtained from a solar map should be verified before moving forward with an installation. Communities should make sure to include disclaimers to this effect on their solar maps.

Solar Map Successes

San Francisco created the first municipal solar map in 2008.

Since then, at least 18 additional U.S. cities have created online solar maps to share local solar information with their constituents; see sidebar on p. 5 for more information on these maps.

In the two years after San Francisco's map came online, the city saw PV installations grow by 60 percent and the amount of solar electricity generated in the city doubled. The city has even used its own solar-mapping platform to help install municipal solar systems, including California's largest PV system with 25,000 panels generating about 5 MW (Leitelt 2010).

The City of San Diego is using its solar map to gauge progress toward its goal of having 5 MW of solar power installed on city buildings by 2013 and is tracking the energy production of

Case Study: New York City's Solar Map

Sustainable CUNY of the City University of New York heads the NYC Solar America City Partnership comprising CUNY, the Mayor's Office of Long Term Planning and Sustainability, and the New York City Economic Development Corporation, with the support of multiple other stakeholders through the NYC Solar America City Advisory Board.

Sustainable CUNY, on behalf of the city, has won three consecutive Department of Energy (DOE) grants (2007, 2009, 2012). A portion of the second grant was used to design and build the NYC Solar Map, the largest LiDAR-based solar map in the world. The NYC Solar Map supports PlaNYC goals to foster the market for renewable energy, which is part of the overarching mission to achieve a 30 percent reduction in greenhouse gas (GHG) emissions from 2005 levels by 2030. Additional funding to develop the solar map was provided by the City of New York and the New York State Energy Research and Development Authority (NYSERDA), with technical support provided by Con-Edison. The map was built in the Center for Advanced Research of Spatial Information (CARSI) at CUNY's Hunter College, with computational assistance by the High Performance Computing Center at CUNY's College of Staten Island.

Work on the solar map began in April 2010 when the City provided funds for the collection of LiDAR data by the Sanborn Map Company. Fifteen billion points of data were collected via nine post-midnight airplane flights across the city. The NYC Solar Map, which took about fourteen months to develop, was unveiled by the NYC Solar America City Partnership during the 5th annual NYC Solar Summit on June 16, 2011. The map cost

$210,000 to produce, with an additional $450,000 to collect the LiDAR data.

The solar map was completely custom built by hand—no templates were used in its development. It was designed to automatically add additional systems once they are uploaded and approved. Periodic updates, including text changes to the map or changes in assumptions, are handled by CARSI and Sustainable CUNY.

The solar map offers an exceptional amount of detail, providing building-specific information for over one million structures, and was designed to be as interactive and user-friendly as possible. It includes a drawing tool that allows the user to pencil in proposed installations on his or her property and compare differences in costs and energy savings of different location options. The map also incorporates a shading algorithm that considers both vegetation and buildings as well as city regulations including zoning and fire department codes. Additionally, the solar map contains an incentive calculator that allows users to estimate the environmental and financial benefits of a solar energy system based upon assumptions related to usable roof area, incentives, and system costs that are clearly detailed on the map as well as user inputs that help produce customized results. The solar map also produces additional data not visible to the public for use and consideration by city staff and elected officials, including the number of visits to the solar map each day and which locations generate those visits, and it charts the number of solar installations installed in the city.

The solar map also allows users to determine if their property

PV systems installed on 15 municipal buildings. As of August 2012, these facilities were producing 2.3 MW of electricity annually, halfway to the city's goal.

The City of Boston is using its solar map to assist in tracking the city's progress toward meeting its clean-energy goal of reducing greenhouse gas emissions by 25 percent by 2020. The progress tool indicates that the city is currently producing 7.8 MW of solar power compared to its goal of 25 MW by 2015.

The City of Denver is using its solar map to monitor success in educating the public about solar information. In the map's first month of activity it saw nearly 8,000 unique visitors, and within the first two months of the map's release, 14 leads had

been generated for solar installers from an online form (NARC 2012). Staff also plan to use the data for additional measurement purposes, including the number of jobs created.

Opportunities for Improvement

Solar maps serve as valuable tools to a variety of users. They provide quick and easy initial assessments of a property's solar potential and serve as excellent educational resources for the community. There are some variables not commonly incorporated into solar maps, however, about which users should be aware. The first is shading from trees and vegetation. Unless the map offers a shading slide tool (as in Portland's case), most solar

is in one of five Solar Empowerment Zones identified by the NYC Solar America City Partnership, areas in which solar energy installations will provide the greatest benefits to New Yorkers and the electric distribution system. Property owners in these zones may be entitled to benefits such as free data acquisition systems, technical assistance, and additional incentives. The Solar Empowerment Zones and the NYC Solar Map also assist ConEdison in determining where solar can best contribute to energy production, which could potentially defer or eliminate the need for costly upgrades to the electrical system that would increase electricity rates. ConEdison uses the solar map to evaluate the impact of solar production on network reliability, integrate solar into smart grid efforts, and improve demand-side management applications.

Sustainable CUNY's current DOE grant is helping to fund additional solar initiatives which will enhance the solar map's capabilities. Currently the solar map tracks solar capacity, but limited ability exists to track real-time solar energy generation of each installation. CUNY Ventures, a CUNY Economic Development Corporation entity, has partnered with IBM to create an Intelligent Operations Center (IOC) for solar that can link to the map. Once completed, the IOC will be able to display real-time energy generation outputs as well as other analytics. The Mayor's office will be able to use this data to measure progress against established energy goals. City and state energy policy holders will be able to analyze the actual value of PV generation to grid-constrained areas, which is a crucial tool for designing solar policies and programs that can help the city meet requirements to

generate 80 percent of its peak electrical load within city limits.

Other planned map enhancements include adding solar thermal components, strengthening the functionality of the map and improving its interactive nature, increasing the level of detail available with the drawing tool, and adding additional override flexibility so that a user can insert property-specific details when available into the map instead of relying on pre-populated inputs. Discussions are also underway to expand the map across the state of New York, though this requires obtaining LiDAR data for remaining communities which is critical to ensuring the same map precision afforded in New York City. Finally, Sustainable CUNY believes that the NYC Solar Map may be expanded to include other renewable energy sources, transforming the NYC Solar Map to the NYC Energy Map.

Since 2006 New York City has experienced a 1000 percent increase of solar energy capacity. Earlier this year, the city surpassed its 2015 solar energy target of 8.1 MW—three years early. As of June 2012, the city's solar capacity is 11.5 MW. The number of solar installations in the city exceeds 560 and the number of NYC solar installation companies has quadrupled.

The NYC Solar Map has played an integral role in advancing solar initiatives in NYC. The information generated by the map has helped a variety of stakeholders including the general public, utilities, planners, and elected officials understand the benefits of solar energy, and the planned map enhancements will only further increase the use of solar energy in the city.

The Solar Map is available on the Sustainable CUNY web site at http://nycsolarmap.com/.

maps consider shade from neighboring buildings but not from trees and vegetation. See the fifth briefing paper in this series, "Balancing Solar Energy Use with Potential Competing Interests," to understand why this could lead to potential future conflicts.

Second, most solar maps do not take into account existing regulations such as dimensional or development standards like height or placement requirements outlined in the zoning ordinance. Additionally, the maps do not factor in redevelopment potential in built-out areas. For example, surrounding buildings may be built to heights lower than the maximum height allowed. Redeveloping buildings to maximum height could impact a system's effectiveness.

Additionally, few smaller communities have taken an interest in solar mapping. This could be due to a variety of factors including lack of interest or knowledge, lack of adequate data, concerns over privacy, development costs, or staff qualifications. Although urban centers have a high number of rooftops, these spaces commonly house a variety of other objects including HVAC systems, skylights, greenroofs, or outdoor spaces which can reduce their solar energy potential. Although smaller communities may have less rooftop square footage, this square footage may be better suited for solar installations. This solar potential has not been adequately explored (Leitelt 2010).

Conclusion

Solar maps are innovative tools communities can use to promote greater public awareness about solar potential and to facilitate greater solar usage among property owners. They are user-friendly and interactive, generate immediate results, and can provide a complete resource for information on solar. Although solar maps are a relatively new tool, communities are beginning to realize the important roles they can play in achieving sustainability goals. Solar maps can be used to consider potential outcomes of various future solar scenarios as well as measure successes against established solar goals. They can help diminish individual uncertainty surrounding solar power by providing quantifiable data on installation costs, cost savings, energy savings, and local, state, and federal resources. In the future, solar maps will play pivotal roles in helping individuals and communities recognize their solar potential and the financial and environmental benefits associated with capturing that potential.

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Cover: San Francisco's solar map provides solar facts about the city including the number of PV systems installed, total CEC-AC capacity, estimated energy produced, estimated annual savings, and annual CO_2 reduction. *(Image courtesy: http:// sfenergymap.org/)*

Planning for Solar Energy Briefing Papers

This is one in a series of briefing papers providing planners with guidance on promoting solar energy use in their communities to help meet local energy and sustainability goals. APA produced this paper through its participation in the SunShot Solar Outreach Partnership (SolarOPs), a U.S. Department of Energy-funded initiative designed to help accelerate solar energy adoption on the local level by providing timely and actionable information to local governments.

Please visit our website at www.planning.org/research/solar/ to learn more about this series and APA's participation in SolarOps.