



Solar For Schools: A Case Study in Identifying and Implementing Solar Photovoltaic (PV) Projects in Three California School Districts

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SOLAR FOR SCHOOLS: A CASE STUDY IN IDENTIFYING AND IMPLEMENTING SOLAR PHOTOVOLTAIC (PV) PROJECTS IN THREE CALIFORNIA SCHOOL DISTRICTS

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ABSTRACT

The Department of Energy’s (DOE) Solar America Showcase program seeks to accelerate demand for solar technologies among key end use market sectors. As part of this activity, DOE provides technical assistance through its national laboratories to large-scale, high-visibility solar installation projects.

The Solar Schools Assessment and Implementation Project (SSAIP) in the San Francisco Bay Area was selected for a 2009 DOE Solar America Showcase award. SSAIP was formed through the efforts of the nonprofit Sequoia Foundation and includes three school districts: Berkeley, West Contra Costa, and Oakland Unified School Districts.

This paper summarizes the technical assistance efforts that resulted from this technical assistance support. It serves as a case study and reference document detailing the steps and processes that could be used to successfully identify, fund, and implement solar photovoltaics (PV) projects in school districts across the country.

Keywords: schools; solar photovoltaics

1. INTRODUCTION

School districts across the United States face trying times due to decreasing budgets and rising energy costs. Districts are required to do more with less. At the same time, schools provide a unique opportunity for energy efficiency and renewable energy application and education, not only through curriculum but also through technology deployment. California is an example of a state with significant budget deficits and a high potential for solar electricity, or photovoltaic (PV), technology deployment.

The Sequoia Foundation is supporting three California school districts—Oakland, Berkeley, and West Contra Costa

Unified School Districts—in the development of Solar Master Plans (SMP), documents that are intended to be incorporated in the districts’ Facilities Master Plans. The National Renewable Energy Laboratory (NREL) is providing technical assistance to these school districts and the Sequoia Foundation as part of the DOE’S Solar America Showcase program.ⁱ

The Solar America Showcase program seeks to accelerate demand for solar technologies among key end use market sectors. As part of this activity, DOE provides technical assistance through its national laboratories to large-scale, high-visibility solar installation projects that have the ability to impact the market for solar technologies through large project size, use of a novel solar technology, and/or use of a novel application of a solar technology. Selected showcase projects are replicable or have replicable components.

This paper will summarize the technical assistance efforts that have resulted from this technical assistance support. It will serve as a case study and reference document detailing the steps and processes that could be used to successfully identify, fund, and implement solar PV projects in school districts across the country. The goal of the technical assistance support was to enable and empower district representatives to understand PV technologies and opportunities, identify potential financing mechanisms, and institutionalize the inclusion of PV in the district master planning process.

Technical support included education of district stakeholders in the areas of PV technologies and financing options, electricity rate analysis to identify the most PV-friendly rates for the districts, building structural assessments, and an analysis of technical potential for solar PV. The support will culminate in the development of comprehensive, district-wide Solar Master Plans.

2. DISTRICTS OVERVIEW

The three school districts participating in the SSAIP (BUSD, WCCUSD, and OUSD) represent a total enrollment of nearly 78,000 pre-K-12 students and an annual budget of over \$835 million, and occupy nearly 200 school buildings, administrative offices, and adult education sites—many of which are candidate sites for future solar installations. Each of the three districts offers significant opportunities for PV installations:

- WCCUSD has a current total enrollment of 30,832 pre-K-12 students who attend its 53 schools. The district maintains over 70 separate facilities. Its current annual General Fund budget is approximately \$285M.ⁱⁱ
- BUSD has nearly 9,300 students who attend its 20 schools. It also maintains a number of administrative and support facilities, adding to a total of over 100 buildings in the district.ⁱⁱⁱ
- OUSD has an enrollment of almost 37,000 students in 91 K-12 schools spread over 5.8 million square footage of facilities.^{iv}

All three school districts are members of the Collaborative for High Performance Schools (CHPS) and have passed Board Resolutions supporting adherence to the CHPS Best Practices and CHPS-Rated Schools requirements in their design and construction programs.^v The mission of the Collaborative for High Performance Schools is to facilitate the design, construction, and operation of high performance schools. CHPS helps facilitate and inspire change in our educational system. The goals of CHPS are to:

- Increase student performance with better-designed and healthier facilities;
- Raise awareness of the impact and advantages of high performance schools;
- Provide professionals with better tools to facilitate effective design, construction and maintenance of high performance schools;
- Increase school energy and resource efficiency; and
- Reduce peak electric loads.^{vi}

Public school districts have shown an interest in installing PV systems. In 2004, the California Energy Commission (CEC) and the California Power Authority created the Solar Schools Program. This program was jointly funded by the CEC's Emerging Renewables Program and the Attorney General's Alternative Energy Retrofit Account and provided school districts with rebates that were twice the amount offered to residential customers.^{vii} The program attracted applications from over 60 school districts, but due to limitations in funding, only 28 schools received the

incentives. A total of \$4.5 million was awarded, which enabled the 28 CA schools to purchase and install solar PV systems with an expected generating capacity of 642 kilowatts (kW).^{viii}

BUSD and WCCUSD have shown their commitment to solar PV by installing a total of 237 kW on an elementary school and a high school. BUSD and WCCUSD plan to install four more systems in the summer of 2011. OUSD has small demonstration solar projects on four sites and ongoing energy efficiency projects on many of its older facilities, identified through energy audits coordinated by Pacific Gas and Electric Corporation (PG&E).^{ix} OUSD is considering the installation of PV at 17 sites over the next 18 months.

3. ENERGY EDUCATION

Not every school is an appropriate location for siting PV. This technology relies on good access to the sun and locations with large amounts of shading, or north-facing orientations are not practical. Other school-specific considerations include the age of the roof, a school's designation as historic or emergency shelter, the size of the roof, and the electrical load and associated electric costs of the school. School district staff can begin to assess the potential for PV at their schools with a basic understanding of the technology and these siting considerations.

This component of the technical support was education for school district staff. It included training in Energy Star's Portfolio Manager program and in solar mapping software. NREL also provided district staff with an overview of PV technology options and potential solutions to two common issues associated with PV installations at schools—thief and vandalism of panels.

3.1 Energy Star's Portfolio Manager Program

Cost-effective energy efficiency measures should always be considered as the first step in an energy program, and energy efficiency should be implemented prior to or at the same time as renewable energy technologies. Behavior change is also an important component towards achieving energy efficient school operations. The least efficient schools in our country use three times more energy than the best energy performs, and the top-performing Energy Star labeled schools cost forty cents per square foot less to operate than the average performers.^x

All three districts recognize the importance of implementing energy efficiency measures and have initiated a benchmarking process for their facilities through Energy Star's K-12 Portfolio Manager Program. Portfolio Manager is an interactive energy management tool that allows users

to track and assess energy and water consumption across an entire portfolio of buildings. Portfolio Manager can be used to set investment priorities, identify under-performing buildings, verify efficiency improvements, and receive EPA recognition for superior energy performance.^{xi}

NREL staff provided initial support to the districts as they began using Portfolio Manager, including setting up a Portfolio Manager training and providing guidance as the districts began to use this software tool.

3.2 Solar Technology Overview

3.2.1 Training

District representatives requested training in identifying opportunities for PV technologies on their facilities. NREL staff compiled and presented an overview of PV technologies, siting considerations, and web-based solar mapping tools, including NREL's In My Backyard (IMBY).^{xii} A solar PV mapping tool visually represents a specific site and calculates PV system size and projected electricity production.^{xiii}

IMBY:

- Estimates the electricity that can be produced with a PV array or wind turbine at a home, business, or school.
- Uses a map-based interface to allow the user to choose the exact location of to place the PV array or wind turbine.

This training was an effort to inform district representatives about the considerations for siting PV and to enable them to begin to identify appropriate locations on their own.

3.2.2 Technology Overview

NREL developed a brief report for district representatives that details the commercially available and emerging PV technologies; associated efficiencies, costs, and benefits; maintenance requirements; and other siting considerations. It includes single and multi-crystalline and thin-film technologies, as well as more recent applications such as building-integrated PV (BIPV), solar inks, and concentrated PV (CPV).

PV arrays convert sunlight to electricity without moving parts and without producing fuel wastes, air pollution, or greenhouse gases (GHG) during operation. 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 “mono-crystalline” solar cells are made from silicon, are usually flat-plate, and are generally the most efficient. “Multi-crystalline” are a similar technology but are slightly less efficient. Efficiencies for crystalline panels range from 13 to 19 percent.^{xiv} A third type called “thin-film” 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. Efficiencies for thin-film panels range from four to 12 percent.^{xv} Because of their flexibility, thin-film solar cells can be integrated into building materials (called Building Integrated PV or BIPV) such as rooftop shingles and tiles, standing seam metal roofs, or building facades.

Third-generation solar cells are being made from variety of new materials besides silicon, including solar inks using conventional printing press technologies, solar dyes, and conductive plastics. They are technically attractive because they are made of low-cost materials. Manufacturing these cells could be significantly less expensive than older solid-state cell designs. However, the efficiency expects to be a lot lower than the typical thin-film. A very promising new technology option is concentrating PV, or CPV. This tubular technology uses concentrators to focus direct solar radiation onto PV cells. Some of these currently available technologies reach efficiencies up to 29%.^{xvi}

Most PV systems currently being installed are in flat-plate configurations, which are typically made from modules that hold about 40 cells. 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.^{xvii} These systems are generally ‘fixed’ in a single position, but can be mounted on structures that ‘track’ or tilt toward the sun on a seasonal basis or on structures that roll east to west over the course of a day.^{xviii}

The cost of PV-generated electricity has dropped 15- to 20-fold in the last 40 years, and panels typically last 20 years or longer.^{xix} Grid-connected PV systems currently sell for about \$5/Wp to \$8/Wp (20¢/kWh to 32¢/kWh), including support structures and power conditioning equipment. Costs reported for PV projects are changing (decreasing) rapidly, so a local solar installer may be the best source of 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.^{xx}

The amount of electricity that a system produces depends on the system type and 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. Resources are highest in the Southwest, and fairly high throughout the western states, Texas, and Florida.

The document also includes an overview of PV monitoring equipment. Monitoring of PV systems can be essential for reliable functioning and maximum yield of a system. It can also be a valuable tool for community outreach and education. Especially in a school, displays of PV output and performance can be highly educational.

Monitoring can be as simple as reading values locally on an LCD display on the inverter such as produced AC power, daily kWh and cumulative kWh. For sophisticated monitoring and control purposes, environmental data—such as module temperature, ambient temperature, solar radiation, and wind speed—can be monitored. Remote control and monitoring can be performed by various remote connections, which can also send alerts and system messages. Data can be stored in inverters memory or in external data loggers for further system analysis.

The report also details possible solutions to potential barriers that districts sometimes face when PV systems are installed on schools—vandalism and theft. Some solutions are technical:

- Installing keyed fasteners at intermodule and end clamps. These fasteners use a unique pattern, which regular wrenches and screwdrivers are useless against. It's the same concept used for expensive automobile wheel fasteners. The installer or owner keeps the key needed to unfasten the hardware. A fastener costs about \$2–\$5.
- Install a reliable security camera system. Post signage around the perimeter of the system alerting of the security systems in place.
- Engrave each system component with school name to make it harder for vandals to resell them.

Some solutions are process- or maintenance-based:

- Check fences and gates for damage. Make repairs and keep gates locked.
- Cut back weeds and other vegetation around the campus to reduce fire risk and hiding places.
- Keep surrounded areas clean. Loose rocks that can be used by vandals should be removed.
- Check all lighting on campus. Replace all burned-out bulbs. Install lighting in currently dark areas. Consider installing motion sensor lights.
- Add or increase nightly patrols of campus, especially during the summer months when the weather is warmer and the days are longer.

Some solutions are education-focused:

- Get the community involved. Encourage the community to be concerned and watch for vandalism and theft.
- Add warnings about potential hazard and electric shocks from the system.
- Educate the staff and students on the consequences of vandalism and create a sense of ownership of the solar photovoltaic system.

4. SOLAR MAPPING

Solar mapping analyses can be used to inform decision makers about the availability of promising land or roof areas for PV, quantify that available space, and calculate potential PV capacity and electrical production. PV costs and electricity cost savings are also sometimes calculated.

4.1 SunPower Corporation's Analysis

SunPower Corporation provided aerial mapping estimates of solar potential for two districts and is currently completing the mapping assessment for the third district.^{xxi} This mapping estimate used an aerial snapshot of each school and employed a calculation methodology to determine the potential for PV installations at each location. Ideal locations for PV were manually selected such to avoid areas that appeared to be shaded based on the aerial imagery. The analysis did not take into account roof age or structural integrity.

These results are a high-level, first-cut attempt to quantify the potential for PV installations on these schools. It is a good way to identify potential sites and to begin to prioritize those for which a more detailed, on-site analysis of feasibility should be conducted.

The analyses for BUSD and WCCUSD have been completed; the analysis for OUSD is currently underway. SunPower is also currently updating the analyses for BUSD and WCCUSD.

The SunPower analysis for BUSD was completed in December 2009 and assumed:

- PG&E Electric Rate A6 yielding year 1 solar savings = \$0.223/kWh;
- Incentives at California Solar Initiative (CSI) Tier 6 = \$0.26/kWh;^{xxii}
- A total cost per Wp installed = \$5.75;
- Year one electric yield = 1,350 kWh per kWp; and
- Size and location of systems will vary significantly after design completion.

The SunPower analysis found a total potential PV capacity of 1,880 kWp at 11 schools in the BUSD. It estimated that on an annual basis these systems would produce approximately 2,500,000 kWh and save \$565,000 in avoided electricity costs.

The SunPower analysis for WCCUSD was completed in May of 2010, and it assumed:

- PG&E Electric Rate A6 yielding year 1 solar savings = \$0.19/kWh;
- Incentive at CSI Tier 7 = \$.19/kWh;^{xxiii}
- A total cost per Wp installed = \$5.75;
- Year one electric yield = 1,350 kWh per kWp; and
- Size and location of systems will vary significantly after design completion.

This analysis found a total potential PV capacity of 7,251 kWp at 42 schools in the WCCUSD. It estimated that on an annual basis these systems would produce approximately 9,700,000 kWh and save \$1.8 million in avoided electricity costs.

4.2 NREL's Analysis

NREL, expanding on SunPower's initial assessment, is working to take into account additional factors for identifying promising sites for PV feasibility. Considerations of roof age, structural integrity, electricity use, and costs, combined with the district's input, will result in a listing of schools from most promising to least for PV installation.

4.2.1 Structural Assessments

Based on findings from the SunPower and NREL analyses and district preferences, each district selected five of the most promising locations to receive structural assessments. The purpose of the structural evaluations was to rapidly assess if the existing framing can support a PV array and determine if there are potential structural deficiencies that may preclude the addition of a PV array. The evaluations were based on an in-house review of the available "as-built" drawings furnished by school districts; no site visit has been performed as part of this phase of the work.

4.2.2 Solar Master Plans

Based on findings from SunPower's solar mapping analyses, NREL's solar mapping analyses, and the structural assessments, and taking into account other considerations such as roof age, electricity use and costs, and the district's input, NREL will generate a listing of schools, from the most promising to least, for PV installation for each district. This listing, which will form the foundation of a Solar

Master Plan for each district, will serve as either a stand-alone document or be integrated with five- or ten-year Facilities Master Plans. By institutionalizing planning for PV installations into traditionally accepted and commonly used construction planning mechanisms, such as Facilities Master Plans, districts will likely have greater success in planning for and implementing PV.

5. FINANCING OPTIONS

It can be difficult, especially in today's budget climate, for districts to procure funding for energy efficiency and renewable energy (EERE) projects. There are a variety of financing mechanisms for EERE technologies that can be employed by districts. As part of this project, a financing guide was developed; this guide provides an overview of financial options, a variety of templates, signed project documents, and other reference materials that school districts can review as they pursue their own respective solar electricity generation projects.

The document is divided into three sections:

- Section I: Provides an introduction to financing PV on schools, including consideration of energy efficiency, roof viability and classroom impact.
- Section II: Discusses a direct ownership option, where the solar project is procured through a design-build contract. Here the school finances the project's purchase price with 100% debt financing which may include either traditional tax-exempt municipal bonds or taxable bonds that provide a form of federal subsidy; namely, Build America Bonds, Clean Renewable Energy Bonds, Qualified Energy Conservation Bonds, Qualified School Conservation Bonds, and Qualified Zone Academy Bonds.
- Section III: Focuses on the third party finance model, including Power Purchase Agreements and Energy Services Performance Contracts, with a brief description of New Markets Tax Credits and examples.

Case studies are incorporated into the document when relevant and available. The reference section of this report includes a number of pertinent documents related to financing solar installations on public schools and other public facilities. This document will serve as a resource for district representatives, and it is specifically crafted for schools.

6. RATE ANALYSIS

Compensation for commercial net-metered PV systems is dictated primarily by the utility rate structure under which the PV system and building operates. Electric utility tariffs across the United States consist of many different rate components, all of which have an impact on PV system economics. Identifying the effects of rate structures on system economics can help individuals and entities make informed choices on available rate structures in order to maximize their investment returns.^{xxiv}

An abundance of utility rate structures exist for school districts and these options can be confusing to understand. Advantages, disadvantages and other implications of each rate structure are sometimes hard to identify. As school districts implement energy efficiency measures and renewable energy technologies, the school’s electric load will be reduced (assuming no changes in operations such as additional students or operating hours). It is important, and complex, to consider the interactions on rate structure and total electricity costs of a reduced load, and school districts should be examining which rate structure each school is on and working to identify which structure is most beneficial (i.e., most cost-effective) to the school. This is especially important to consider when installing PV systems, as some rate structures are more economically favorable than others.

As part of this project, NREL conducted a utility rate analysis comparing the value of PV electric generation for different rate structures.

6.1. Berkeley High School Case Study

The Berkeley High School case study explores the impacts of various applicable retail rate structures on the value of electricity generated from a potential rooftop PV system. The analysis uses NREL’s System Advisor Model (SAM) and the OpenEI Online Utility Rate Database.^{xxv,xxvi} Inputs included measured building electrical load data, simulated solar data (using measured meteorological data from the same time period and location as the building load data), retail rate structures, and any applicable incentives. SAM used these inputs and other user specified parameters to evaluate system economics under each utility rate and PV penetration scenario. PV penetration is the percent of the building’s annual electric load that is met by the PV system. The results allow us to understand under which scenarios a PV system becomes economical.

First, the economic value of PV was examined under six applicable PG&E electric rate structures. The rates are: A-6, A-1 TOU, A-1, A-10, A-10 TOU, and E-19. The PV values, expressed in \$/kWh, under each of the six applicable rates are shown below in Fig. 1. Certain rates (E-19, A-10, A-10

TOU) yield values that vary with PV penetration. This is because these rates have demand charges, while the others do not.

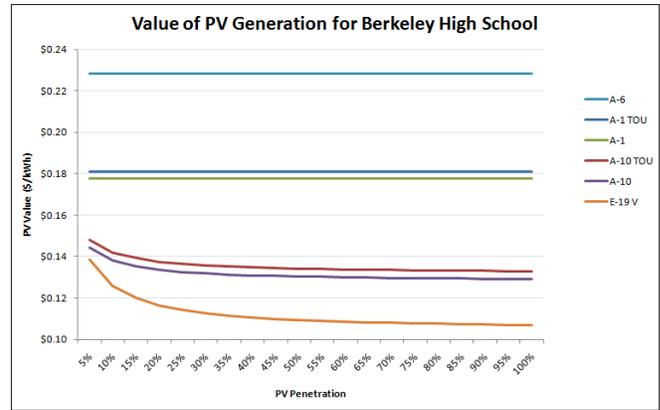


Fig. 1: Value of PV generation for Berkeley High School.

Next, the value of PV generation was calculated by comparing the building’s electricity cost with and without the PV system. The difference yields the PV value, which can be divided by total PV kWh generation to get a \$/kWh number. This method of calculating PV value is very useful when evaluating each rate independently. However, when comparing multiple rates, it is more useful to evaluate the *net* PV value. This compares the building’s electricity cost without the PV system *always using the least expensive rate(s)* and the building’s electricity cost with PV under the rate in question. The difference yields the *net* PV value. The data in Fig. 2 shows that rate E-19 is the most economical rate until a 35% PV penetration, after which rate A-6 becomes the most economical.

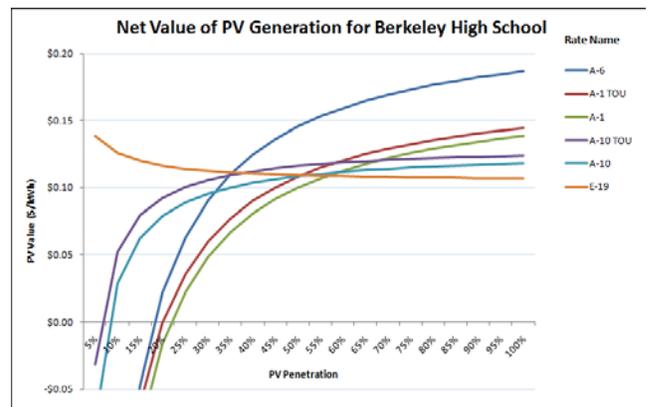


Fig. 2: Net value of PV generation for Berkeley High School.

PV value alone may not provide enough information for decision makers to understand what impacts they can expect on their electricity bill. To understand bill impacts, the cost of the PV system must be subtracted from the value it provides. If the PV value is greater than the cost, then the system yields a net electricity bill savings. The data below illustrates how Berkeley High School's bill savings varies with PV penetration and cost, based on *using the most economic rate(s)*. In this situation, the least expensive rates are E-19, up to 35% penetration, and A-6 for 35% penetration and beyond.

PV systems that are \$3/Watt (W) or below will always result in a positive bill savings, while systems \$5/W and above results in a net loss. These values can vary depending on how the system is financed and the availability of incentives. This is graphically represented in Fig. 3.

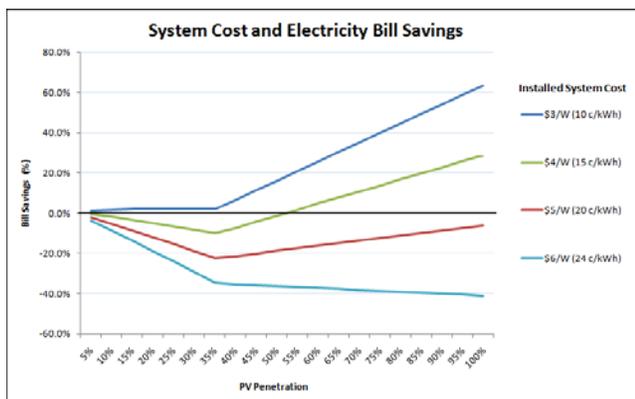


Fig. 3: System cost and electricity bill savings.

7. CONCLUSION

Schools present a unique opportunity for energy efficiency implementation as well as renewable energy deployment. They tend to have high and very consistent electricity loads with corresponding high utility bills. They also often have large land or roof areas for which to site PV technologies. Installing energy efficient or PV technologies on a school and incorporating these systems into curriculum is an effective, hands-on way to educate students about these important technologies.

This paper summarized the technical assistance efforts that were a result of the Solar America Showcase award. Information contained in this report can serve as a case study and reference document detailing the steps and processes that could be used to successfully identify, fund, and implement solar PV projects in school districts across the country. The goal of the technical assistance support was to enable and empower district representatives to understand

PV technologies and opportunities, identify potential financing mechanisms, and institutionalize the inclusion of PV in the district master planning process.

Technical support included education of district stakeholders in the areas of PV technologies and financing options, electricity rate analysis to identify the most PV-friendly rates for the districts, building structural assessments, and an analysis of technical potential for solar PV. The support will culminate in the development of comprehensive, district-wide Solar Master Plans.

As school districts are currently faced with budget uncertainties in parallel with energy reduction and renewable energy use goals, districts can integrate PV installations into the planning process through education, planning, and preparation for PV implementation.

One method for institutionalizing this process is to develop Solar Master Plans. These enable school districts to phase in solar projects over time, either by using voter-approved construction bonds or by taking advantage of financing (either low-cost or third-party). In some instances the PV system can even be used to generate revenue.

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14. ABSTRACT (Maximum 200 Words) The Department of Energy's (DOE) Solar America Showcase program seeks to accelerate demand for solar technologies among key end use market sectors. As part of this activity the DOE provides Technical Assistance through its national laboratories to large-scale, high-visibility solar installation projects. The Solar Schools Assessment and Implementation Project (SSAIP) in the San Francisco Bay area was selected for a 2009 DOE Solar American Showcase award. SSAIP was formed through the efforts of the nonprofit Sequoia Foundation and includes three school districts: Berkeley, West Contra Costa, and Oakland Unified School Districts. This paper summarizes the technical assistance efforts that resulted from this technical assistance support. It serves as a case study and reference document detailing the steps and processes that could be used to successfully identify, fund, and implement solar PV projects in school districts across the country.								
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