



Solar Energy in Schools

Webinar – June 11, 2025

nbi new buildings
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Agenda

- Welcome and Introductions
- Setting the stage and experience of the audience
- Planning for 50-year solar operations
- Power Purchase Agreement Best Practices
- Q&A and Closing

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Solar Energy in Schools - Overview

Onsite solar and PPA management for school facilities present unique challenges for building owners. Today we'll cover best practices related to:

- Design guidelines to facilitate ownership
- Post-construction commissioning and hand-off
- Data management and system monitoring
- PPA structure and management
- O&M best practices
- Energy and economic data management and use for demonstrating impact

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Today's Panelists



Desmond Ho
Santa Barbara Unified
School District



Gerald Robinson
Lawrence Berkeley National
Labs

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New Buildings Institute (NBI)

Mission: We push for **better buildings** that achieve **zero energy, zero carbon, and beyond**—through research, policy, guidance, and market transformation—to protect people and the planet.



St James Intermediate School | Myrtle Beach, SC
Credit: sL+a Architects

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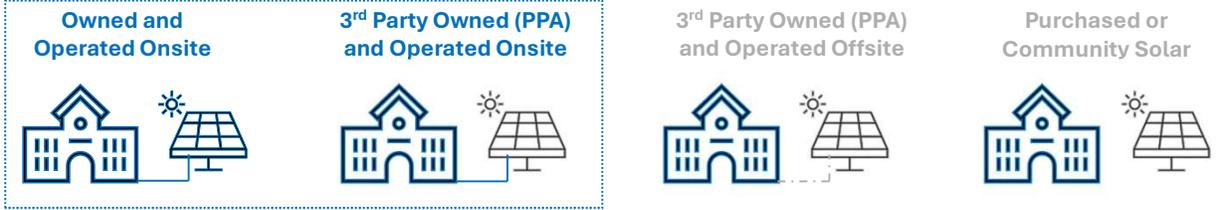
Polling Possum

- Join at menti.com
- Use code **4512 4930**
- Scan:



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Potential Solar Ownership and PPA Models



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Considerations for solar projects

- Technical specifications
- Structural considerations
- Ownership model
- Array siting
- Utility rates and tariffs
- Design standards
- **But...what about after construction??**

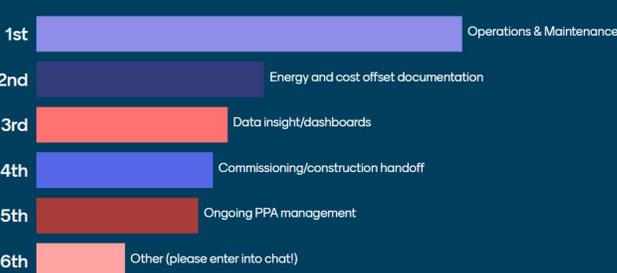


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Join at menti.com | use code **4512 4930**

Mentimeter

What has been the steepest learning curve as a solar owner? (what do you wish you knew more about for ownership or PPA)



Rank	Category
1st	Operations & Maintenance
2nd	Energy and cost offset documentation
3rd	Data insight/dashboards
4th	Commissioning/construction handoff
5th	Ongoing PPA management
6th	Other (please enter into chat)

Menti

Solar Energy in Schools

Choose a slide to present

Participant's experience with solar ownership, select the status for your organization

Based on today's session, what is one thing you hope to do next for your current or upcoming solar asset?

17:22

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50 Year Solar

Storm robust, safe, high performing & maintainable



Energy Technologies Area
BERKELEY LAB

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Agenda

1. The Fundamental of quality, safety & reliability
2. Success with elevated PV structures
3. Success with low sloped roofs
4. Criticality of O&M with Solar PV
5. Elements of an O&M Plan
6. Budgeting and Contracting O&M Plan

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Solar PV Systems Are Highly Reliable

- In a 2020 paper from NREL and LBNL, performance data from 100,000 PV systems was analyzed (totaling more than 7 GW) - <https://onlinelibrary.wiley.com/doi/abs/10.1002/pip.3262>
- Key Conclusions:
 - Majority of systems (80-90%) performed within 10% of predicted performance.
 - Considerable hardware issues arose within the first few years that could have been prevented with better training, certificates, and standards

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Tools: Code, Standards, Guidance, Best Practices

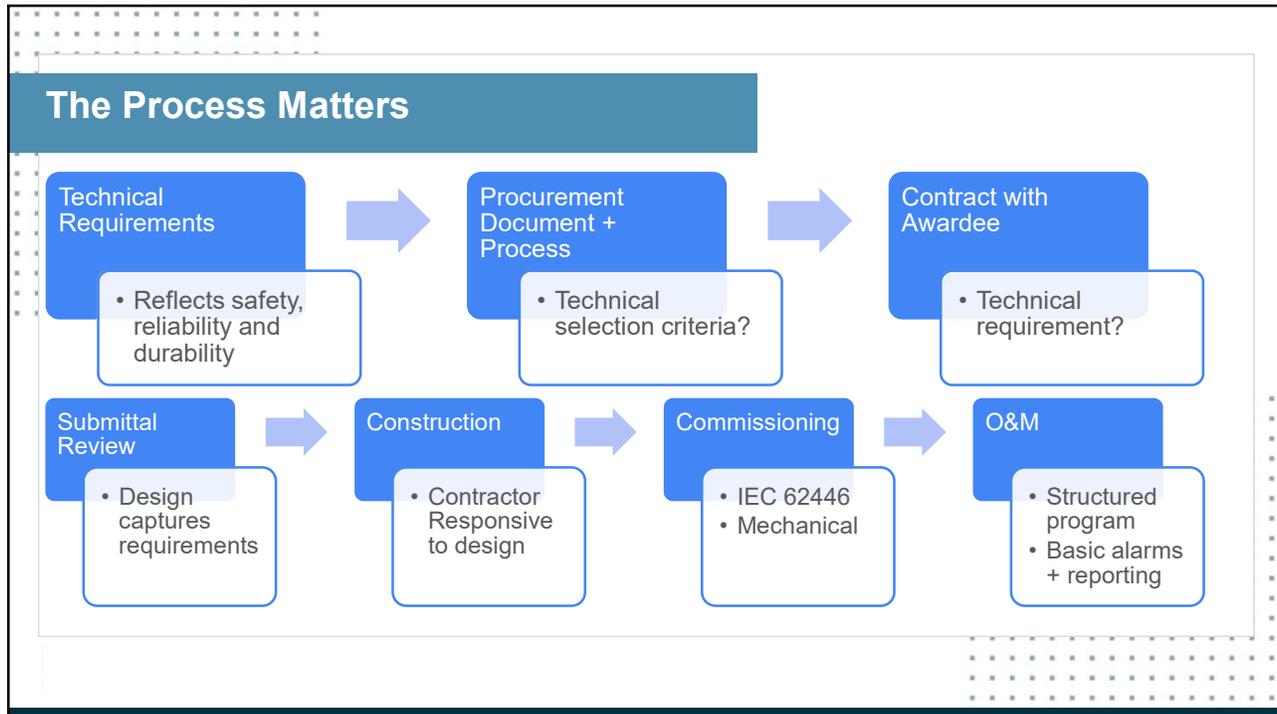
Codes: Requirements adopted by law in each state, legally enforceable and embody "Standard of Care" Codes dictate engineering, material and installation practices.

Standards: Specification developed by a standards development organization (SDO) that often recommend engineering, material and installation practices. Codes often draw from standards.

Guidance: Used to address codes and standards gaps. Language will often be used by code committees and might eventually become part of a code or standard.

Best Practices: Valuable knowledge gained from experience and often not well disseminated but highly valuable in addressing gaps in codes and standards.

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The Fundamentals: Accelerated Testing – Predictive of Quality & Safety

- Science-based series of accelerated tests have developed that are statistically predictive of quality and safety.
- The NREL “Qualification Plus” is foundational to accelerated testing is done at a nationally recognized test labs (NRTL); PV Evolutionary Labs (PVEL) and Renewable Energy Test Center (RETC)
 - [PV Evolution Labs \(PVEL\)](#)
 - [RETC, LLC PV Module Index \(PVMI\)](#)
- Tests in IEC standards are not considered rigorous enough yet – near all modules pass these tests

Photovoltaic Module Qualification Plus Testing

Sarah Kurtz, John Wohlgemuth, Michael Kempe, Nick Biscoe, Peter Haskie, Dirk Jordan, David C. Miller, and Timothy J. Silverman
National Renewable Energy Laboratory

Nancy Phillips
3M

Thomas Earnest
DuPont

Ralph Romero
Black & Veatch

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.
This report is available at no cost from the National Renewable Energy
Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-550-69000
December 2013
Contract No. DE-AC35-05OR21400

Photos Courtesy – PV Evolutionary Labs (PVEL)

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The Fundamentals: Critical Structural Connections

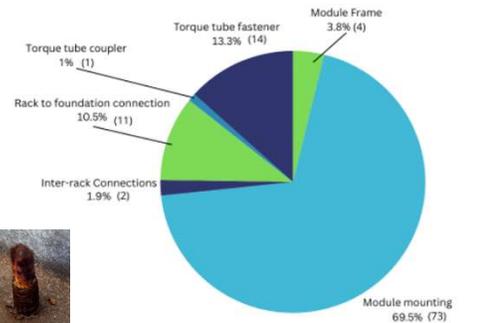
The Challenge

1. Preventing liberated modules and disassembly of racking is paramount.
2. Commonly used fasteners and fastening systems not covered in code yet.
3. These fasteners are loaded in complex ways not yet contemplated by rack designers.
4. Module frames are smaller and thinner.

Best Practices (soon to be code and guidance)

1. Module frame through bolted to frame.
2. Fastener system can resist "self-loosening"
3. For threaded fasteners – DIN 65151 rated.
 1. Compensate for short fasteners – sensitivity to loosening.
4. Topdown clamps capture front and back of frame and have large contact surface area.
5. Increased surface area on module lip – prevent tear out.

Results of 2023 Industry Survey



Photos by Gerald Robinson

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The Fundamentals: Wire Management

- NEC 690.31 does not cover some critical wire management topics:
 - Use of cable ties made of nylon polymers not able to last beyond a few months or years.
 - FEMP Resource: <https://www.energy.gov/femp/solar-photovoltaic-cable-management-best-practices-dc-string-cables>
 - Quick connects need to be from the same manufacture and catalog number.
 - Installation of quick connects is critical.



Photo by Gerald Robinson



Photo by Alt-e Store



Photo by Gerald Robinson



Photo by Cadmus Group

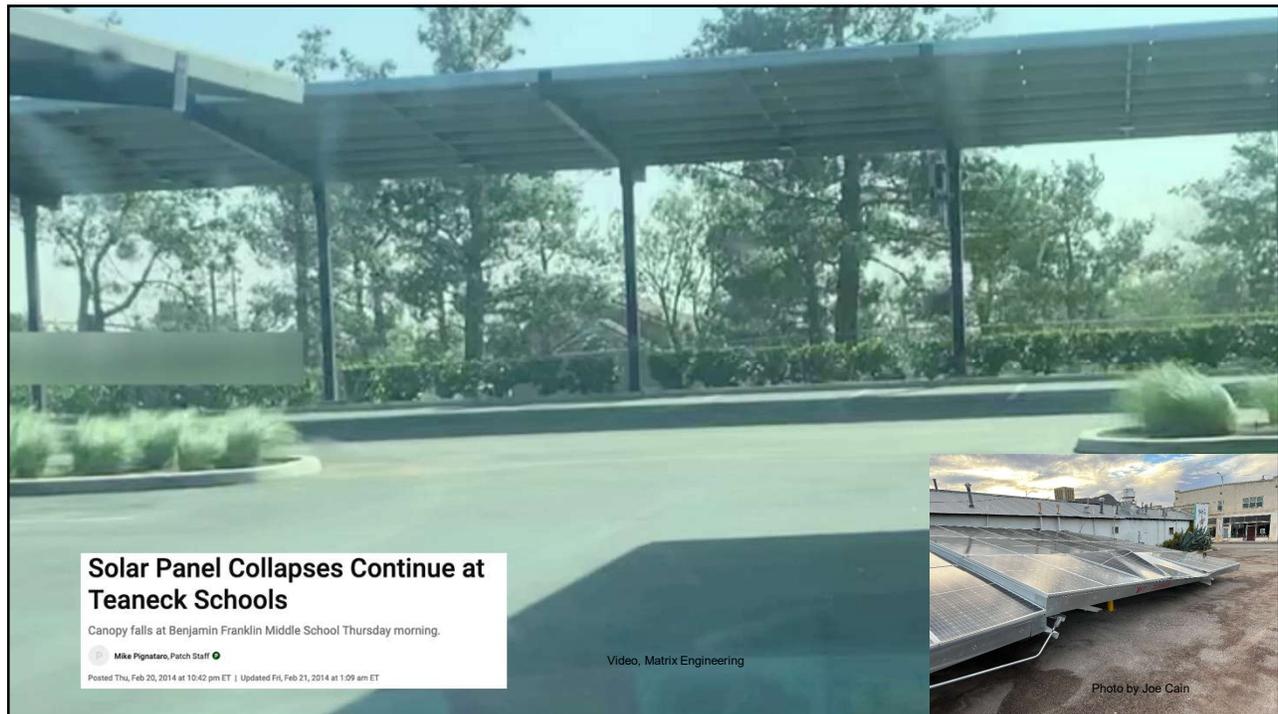
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Power Purchase Agreement (PPA) Verus Owned

- Safety
 - Roof
 - Structural integrity and material liberated from roof
 - Electrica shorting – life safety issues
 - Carport
 - Structural integrity and especially so under high wind in snow loading

- Resilience
 - System will be relied upon during outage
 - Part of an emergency response asset for the site

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Solar Parking Canopies – Fundamentally Enabling – EV Adaption

- Solar parking canopies are fundamentally enabling of EV fleet mandates:
 - E.O. 14057: Catalyzing Clean Energy Industries and Job Through Federal Sustainability: *Goal, 100 percent zero-emission vehicle acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027*
 - CEQ Quarterly Reporting requiring status on E.O. 14057
- Most parking canopies require connection to the building main electrical service which is the same pathway for EV chargers.



Photos by Gerald Robinson



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Solar PV Elevated Structures – Resilience

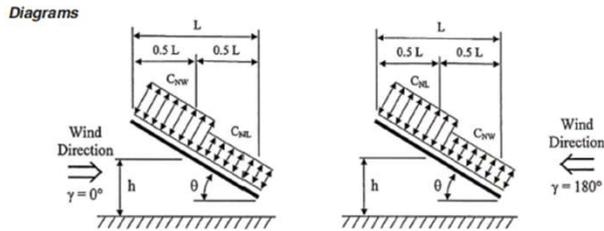
- Elevated structures often provide room to stage storage and electrical gear to create microgrids.
- If planned with the installation of a structure, some infrastructure can be integrated into solar portion; e.g. switchgear, conduit.
- Areas under elevated structures offer staging areas for any number of use cases for emergency response activities.



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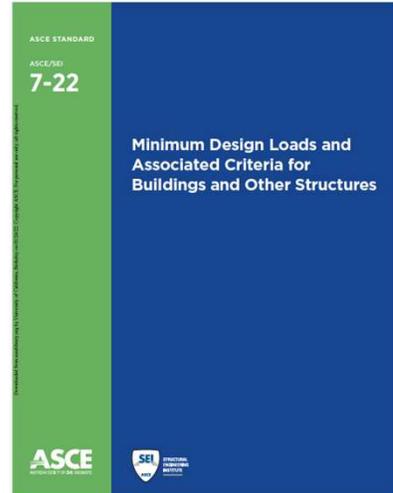
ASCE 7-22 Guidance from Solar Structures Committee Members

Key Challenge: Systems engineered using Monoslope (Section 27.3.2) roof methods with uncertain results.



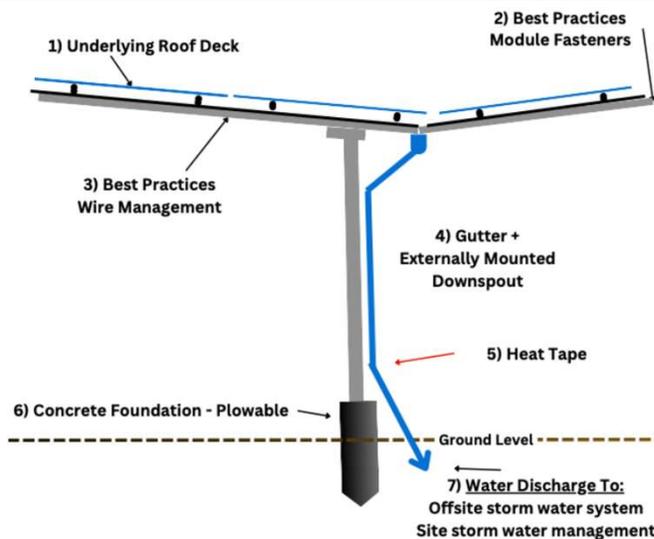
Recommendation: Use ASCE 7-22 (or current version) Section 29.4.5 “Ground-Mounted Fixed-Tilt Solar Panel Systems”.

- Adjusted for height
- Adding dynamic and static pressure coefficients



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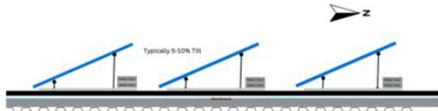
Storm – Winter Weather – “Y Design”



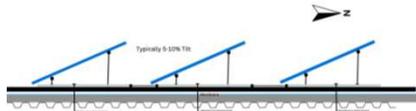
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Types of solar systems common to low pitch roofs

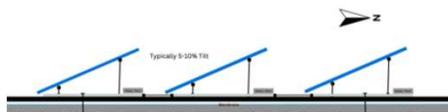
Low Tilt - Ballasted



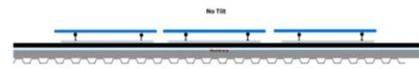
Low Tilt - Fully Anchored



Low Tilt - Hybrid Anchored + Ballasted

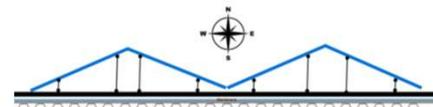


Flush Mounted



Solar Builder Magazine

East-West Systems



Solar Builder Magazine

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Roof Friendly Solar Installation?

- 1) How is the underlying roof maintained?
- 2) Can a roofer find a roof leak and then repair it?
- 3) How can a O&M personnel fix or replace a broken panel or bad string connector?
- 4) Moisture and algae growth degrading membrane – especially the seams.
- 5) How can maintenance personnel remove plant material?
- 6) Electrical faults go unnoticed and in the presence of dried plant material.



While costly, the greatest risk is not in the loss of the solar panels themselves, but in how that solar installation may impact the building upon which it is installed, and the contents below it. If a rooftop PV system contributes to a roof failure that leads to business interruption, the need for roof replacement or reroofing, or contents damage, the costs will surely be greater than the loss of the PV system. (FM Global)

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Elements of a Roof Friendly Solar PV Array

Roof maintenance

- Can the roof be maintained unimpeded after the solar is installed?
- Roof visual inspections by sight and with infrared imaging tools.
- The roof can be repaired without removal of solar array (or substantially so).
- Leafy debris can be easily removed.
 - Organic material, moisture and algae growth prevented.
- Negative interactions with birds and rodents; nesting and excess soiling.

Array spacing

- Push for high % of coverage as the only goal should be avoided.
- The amount of solar that can practically be placed on a roof and allow for maintenance.

Between row spacing	Roof coverage ratio Sqft Array/Sqft Roof
11" gap	80%
14" gap	75%
17" gap	70%



Photo Courtesy – Panelclaw

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Roof Friendly Solar PV Array – Elements – Best Practices

Maintenance of solar array

- No part of the array is entrapped, not accessible to repair and replacement.

Interactions between building HVAC, communications, window washing and solar array

- Walkways to and from these systems are designated and using foot bridges to traverse over pipes and conduit.
- Increased foot traffic to solar equipment planned for.
- Transecting pipes and conduit.



Life-safety risks

- Risks from liberated modules and building fires are greatly reduced.

Roof maintenance

- Snow removal without harming the solar array.



Photo by
Blackburn
Flag

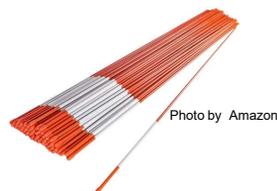


Photo by Amazon



Photos by Roofers Coffee Shop

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Roof Friendly Common solar PV Maintenance Activities

- Electrical test and inspection
- Replacement of micro-inverter or DC power optimizer – Module Level Power Electronics (MLPEs) now required by code – “Rapid Shutdown Requirements”
- Replacement of faulted or damaged modules (e.g. damaged from hail).
- Retightening loose fasteners.



Photo by Solar Builder Magazine



Photo by Affinity Energy



Photo by Gerald Robinson, LBNL



Photo by Solar Power World

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Roof Friendly – Negative interactions with wildlife

- Many negative interactions can be prevented
 - Good wire management can prevent electrical shorts from animal interactions.
 - Bird nesting + fire hazards and damage to underlying roof.
 - Simple techniques have proven effective.
 - Use of monofilament line can work well hung above array

Photo by Bird B Gone



Photo by Bird B Gone



Photo by Gerald Robinson



Photo by Andy Water, NREL



Photo by Solar Builder Magazine



Photo by SEI

Photo by Solar Builder Magazine



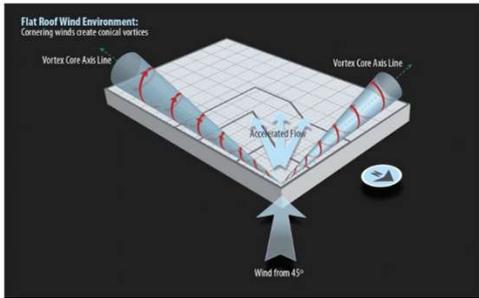
Photo by Bird B Gone

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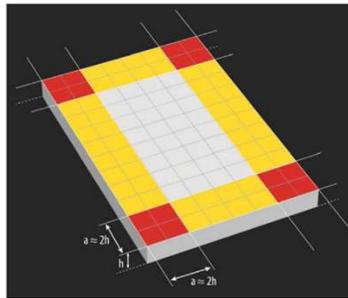
Structural Topic #1 – Vortex Shedding

Critical Role for Design Guidance - Bridging Code Revision Cycles

[SEAOC – Wind Design for Low Profile Solar Photovoltaic Arrays on Flat Roofs PV2-2012](#)



SEAOC PV2-12



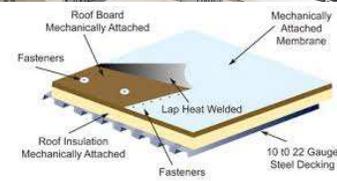
SEAOC PV2-12



Photos - Solar ABCs

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Structural Topic #2 - Billowing of Mechanically Attached Roofs



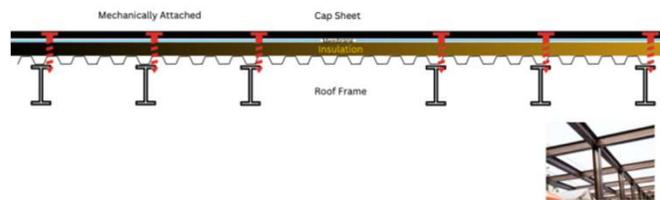
Courtesy NRCA

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Ballasted Versus Mechanically Attached

Summary Conclusions from SEAOC, ASCE-MOP, FM Recommendations + Direct Experience

Condition	100% Ballast Approach	Hybrid	Mechanically Attached
Dead and live loads	Maybe	Maybe	Maybe
High wind location	No Go	Likely	Likely
Moderate winds	No Go	Likely	Likely
Seismic loads	No Go	Likely	Likely



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Electrical/Fire – Prevalence

- Data on the prevalence of fires related to rooftop arrays are hard to obtain, however this is a major subject for insurers.
 - FM (formerly FM Global) has an extended test and certification program beyond UL 1703 codes requirements.
- Likely implications of NEC/NFPA 2023 Section 690.12 Rapid Shutdown
 - Module level rapid shutdown provides fire fighter safety but also arch and ground fault protection that is reliable.
 - As more states use more current versions of the NEC, there should be reduced roof fires from string wiring.

Bakersfield, CA Fire - 2009



Source – Exponent Inc

IKEA, Israel Fire - 2011



Source – Solar Power World

LaForge WI Fire - 2013



Source – Exponent Inc

Florence, NJ Fire - 2013



Source – Philly News

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Critical Importance of O&M

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Why is O&M Important?

Effective O&M Will:

- **Increase effectiveness of the impact of funds**
 - O&M is money well spent
- **Increase overall performance and reduce downtime**
 - Proper maintenance will keep systems operating at peak efficiency
- **Increase the lifespan of the system**
 - Components and Systems will fail
 - Does your mission allow you to live with that risk?
- **Keep equipment within warranty compliance**
 - Minimize having to start brand new procurements
- **Reduce safety risks**
- **Present a maintained appearance**



Source: Gerald Robinson, LBNL



Image source: [Solar Builder Magazine](#)

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What Happens If We Don't Care About PV O&M?



Source: Gerald Robinson, LBNL



Source: Gerald Robinson, LBNL



Source: Affinity Energy



Source: Gerald Robinson, LBNL

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Decision Making

- High Level Questions to Ask Yourself

Discover Steps to Optimize Your Photovoltaic System

❌ Do you have a formal O&M program at your facility?

🔧 Implement O&M program

👤 Will you be self-performing or hiring an O&M provider?

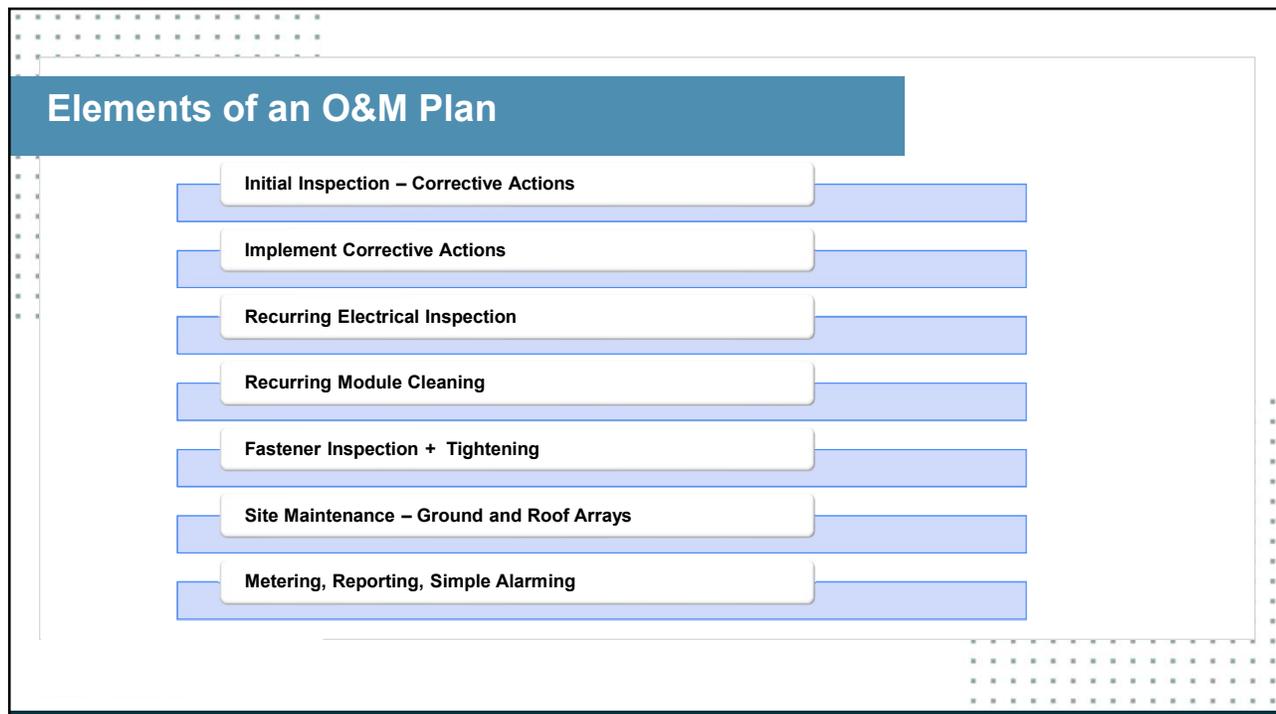
SELF-PERFORM O&M SERVICES

HIRE AN O&M PROVIDER

ADD TO EXISTING SITE OPERATIONS CONTRACT

⬅️ GO BACK ↺️ START OVER

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Solar PV O&M – Contract Language Template

- Accessing the template in the on GSA Acquisition Gateway
 - Step 1: URL link <https://acquisitiongateway.gov/category-management/resources/28> (Facilities & Construction URL in the Acquisition Gateway)
 - Step 2: Under Hot Topics to the left click “+” sign
 - Step 3: Click on “Photovoltaic (PV) PWS
 - Alternative Step: <https://acquisitiongateway.gov/documents/resources/22757> (URL link directly to the PWS template)

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Key Budgeting Topics

- Color of money challenge in budgeting: Draw from maintenance dollars but benefit utility budgets.
 - Funds should be moved from utility account to maintenance budgets
- Solar PV O&M is Cost Effective:
 - Performance gained or maintained greater than cost to perform maintenance
- How much will it cost:
 - Corrective actions + routine + unforeseen
 - Cost Calculator Tool – Email me and will send
- How to pay for O&M:
 - Performance based O&M: Pay \$/kWh basis

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Existing Systems with Recurring Problems

PV System Owner's Guide to Identifying, Assessing, and Addressing Weather Vulnerabilities, Risks, and Impacts

Guide helps agencies identify and correct existing solar PV vulnerabilities in order to avoid or minimize damage from severe weather.

[Federal Energy Management Program](#)

September 16, 2021

🕒 5 min

<https://www.energy.gov/femp/articles/pv-system-owners-guide-identifying-assessing-and-addressing-weather-vulnerabilities>

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Resources: On-Demand FEMP Trainings

- **O&M Best Practices for Small-Scale PV Systems**
 - <https://www.wbdg.org/continuing-education/femp-courses/fempfts27>
- **O&M for Optimal Photovoltaic System Performance**
 - <https://www.wbdg.org/continuing-education/femp-courses/femp56>
- **Planning, Procuring, and Managing Solar PV Systems for Long-term Performance (four-part series)**
 - Acquisition: <https://www.wbdg.org/continuing-education/femp-courses/fempodw076>
 - O&M: <https://www.wbdg.org/continuing-education/femp-courses/fempodw077>
 - Preventing & Recovering from Damage: <https://www.wbdg.org/continuing-education/femp-courses/fempodw078>
 - End of Performance Period: <https://www.wbdg.org/continuing-education/femp-courses/fempodw079>

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Severe Weather and Environmental Events - Resources

Severe Element	Resource
Hail	Addressed in slide deck and in FEMP resource
Wind	Utilize materials on the Structural section and FEMP resource: 1) Guide https://www.energy.gov/femp/severe-weather-resilience-solar-photovoltaic-system-design . 2) Case Study https://www.energy.gov/femp/articles/toward-solar-photovoltaic-storm-resilience-learning-hurricane-loss-and-rebuilding
Corrosion	Utilize FEMP resources: Coming
Forest Fires	Utilize FEMP resource: https://www.energy.gov/femp/solar-photovoltaic-hardening-resilience-wildfire
High snow loads	Utilize FEMP resource: https://www.energy.gov/femp/solar-photovoltaic-hardening-resilience-winter-weather
Earthquakes	Utilize latest version of ASCE 7 (7-22). Will result in some mechanical attachments to building structure.

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Thank You



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 LBNL, Energy Technology Researcher III
gtrobinson@lbl.gov

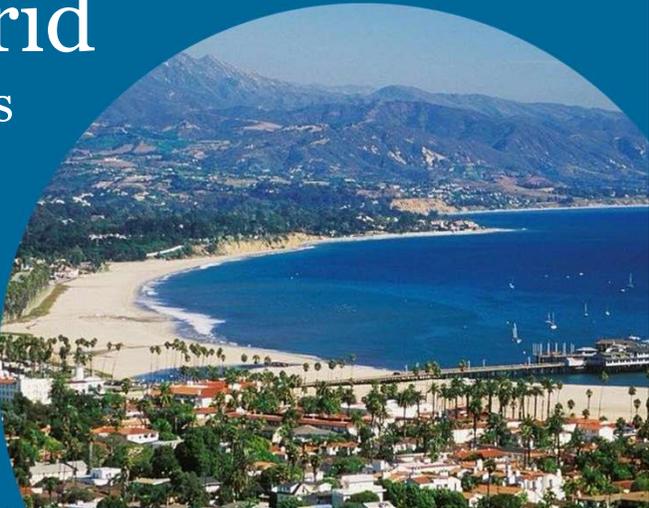
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SANTA BARBARA UNIFIED SCHOOL DISTRICT

Solar & Microgrid

Solar Energy in Schools

June 11, 2025




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Overview



- Project inspiration
- Project design
- Power purchase agreement
- Operations and maintenance
- Data and wish list

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School District



Santa Barbara Unified School District

- 12 Elementary
- 4 Junior High
- 5 High Schools
- Services 13,000 students
- 57.7% of students on free or reduced price meals
- 1600 staff

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Grid Vulnerability

- Location and nature of Santa Barbara County
- No power generation within County
- County split - mountain range splits power service

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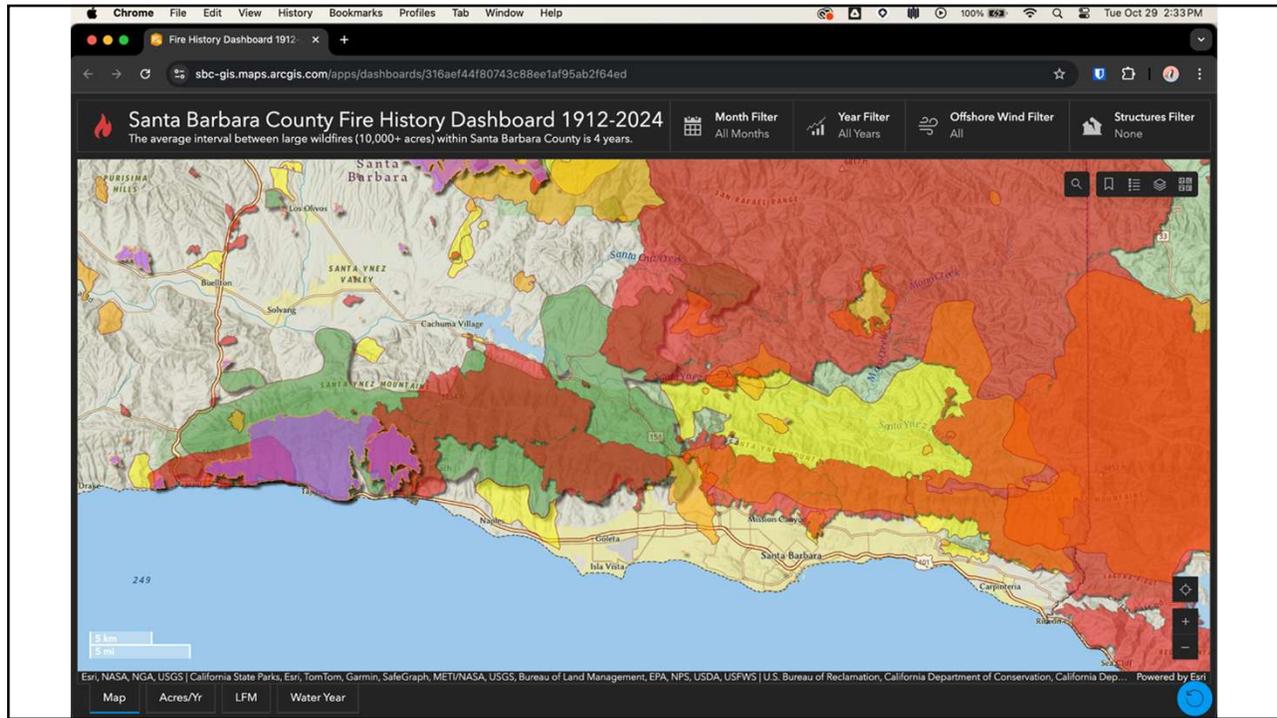
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Grid Vulnerability



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Community

- SBUnified school sites serve as emergency shelters during natural disasters
 - Microgrids power largest kitchens
 - Gyms/MPRs shelter
- Thomas Fire 2017, mudslides 2018, flooding 2023, etc. initiated the project

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Solar

- 14 solar arrays & 6 microgrids
 - Parking lots where feasible
 - Play fields for shading
- Provides 70% of SBUnified's overall electricity use
- Offsets 93% of GHG emissions from utility electricity use
- Microgrids for the largest facilities



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Microgrid

Tier 1 loads:

- Freezers, refrigerators, emergency shelter facilities, comms equipment (internet, radio etc)
- 100% resilience expected

Tier 2 loads:

- Multi-purpose rooms/gyms, site comms equipment
- 80% resilience expected

Tier 3 loads:

- Remainder of the school < 25% resilience expected

Normal usage to Emergency use continuum

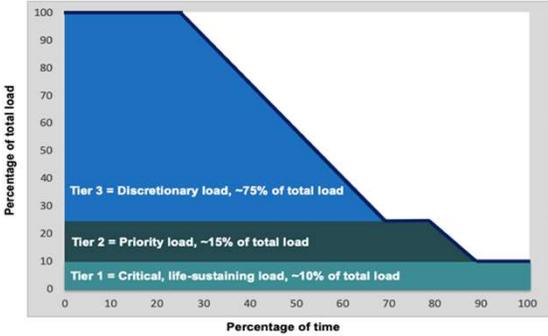


Illustration of resilience levels and loads for Tiers 1-2-3 load where (a) solar is sufficient to attain zero net energy (ZNE) and (b) storage capacity equals 2 hours of solar.
Source: Clean Coalition, analysis completed for UCSB

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PPA

Category	Value (Nominal \$)
Expected Financial Savings	\$7.78 million
Added Value of Resiliency	\$6.47 million
Future Value Streams	?

Power Purchase Agreement (PPA)

- 28-year non-escalating flat rate
- Traded slightly higher rates for \$1.2 million contingency fund
- Performance guarantee
- Original savings: \$7.7M
- Updated savings: \$14.0M

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Verify Savings

One junior high school example - \$0.187/kW transmission cost + \$0.085/kW generation grid vs \$0.1687/kW total cost solar. Bill for solar is higher because we pay for every extra kW generated - those will be credited.

For: Contact:

E-mail to:

Order Date	Reference	Payment Terms	Due Date
Mar 7, 2025	Santa Barbara - La Colina JHS	Net 30 Days	Apr 6, 2025

Item Description	Meter Reading	Quantity/UOM	Unit Price	Sub Total	Tax	Total
Solar Energy - February Generation	0	21,905.00 KWH	168.70/1000	3,695.37	-	3,695.37
				Subtotal		3,695.37
				Taxes		0.00
				Total Billed Amount		USD 3,695.37

Feb 03, 2023 - Mar 05, 2023

Total Usage	Avg Daily Usage	Total Cost
14,536 kWh	468.90 kWh	\$2,731.15

Usage Details

Charge Description	Quantity	Unit	Charge Factor	Amount
Customer charge	0.00	\$	\$0	\$156.12
Customer charge	0.00	\$	\$0	\$29.69
Facilities rel demand	135.00	KW	\$12.38	\$1,401.74
Facilities rel demand	135.00	KW	\$12.3	\$267.82

Solar billing

Utility billing

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O&M Best Practices



- Bake in operations and maintenance into PPA
- Value of performance guarantee - this will ensure consistent O&M
- Panels require cleaning every 6 months and annual inspections
- Runoff of panels - impacting parking lots and fields

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Lots to Learn!

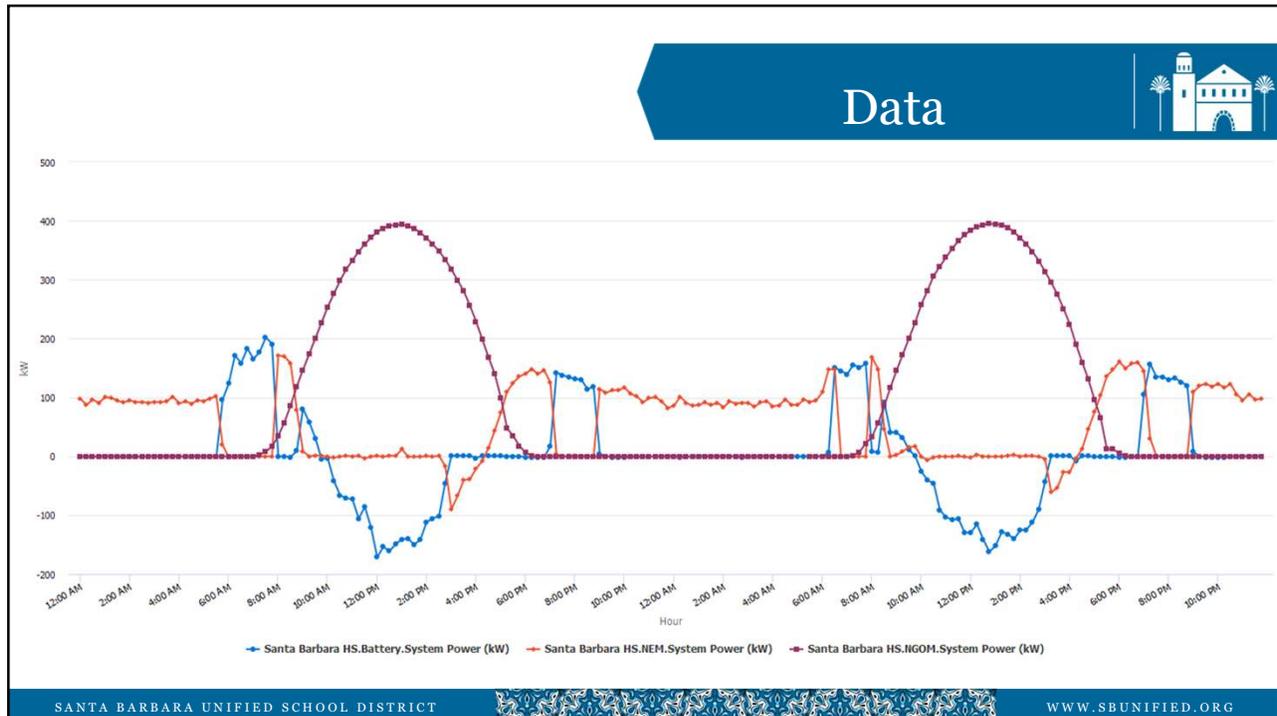


- 3x power outages in the last two months that tested our system
- Failure 1: loss of one phase of power
- Failure 2: voltage fluctuation - blew fuse for battery
- There will be teething pains!

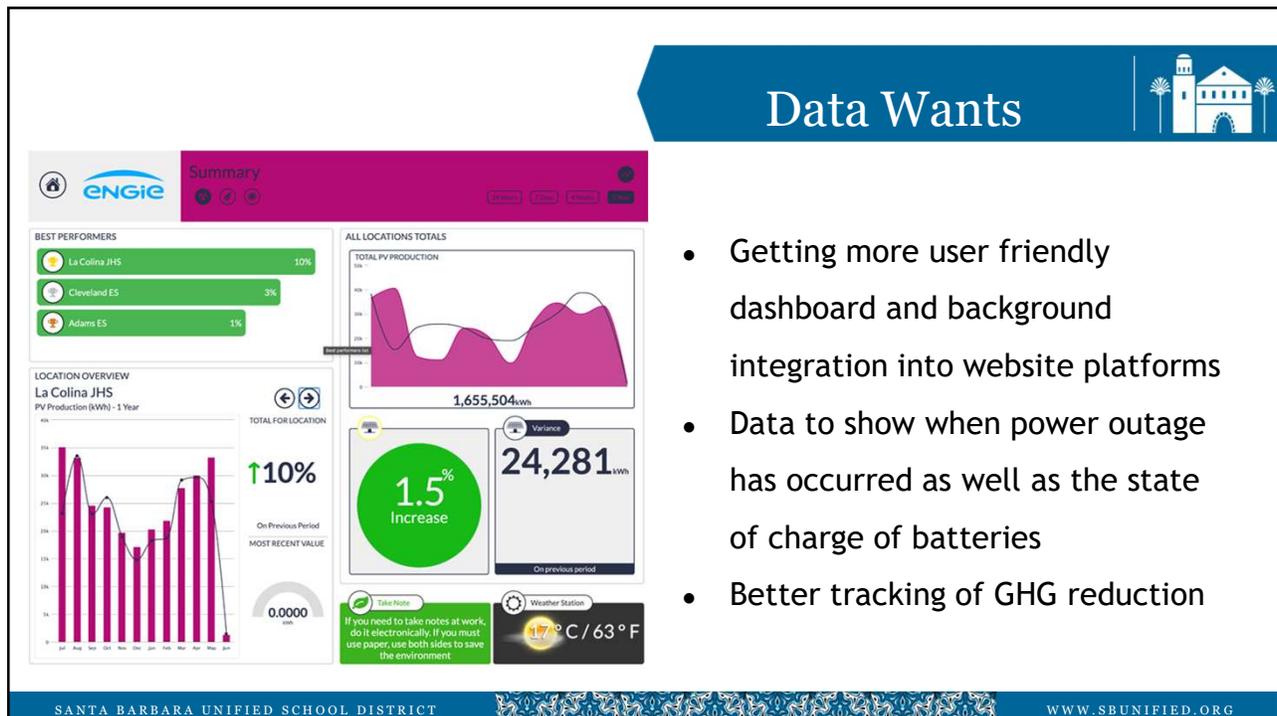
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- Getting more user friendly dashboard and background integration into website platforms
- Data to show when power outage has occurred as well as the state of charge of batteries
- Better tracking of GHG reduction

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Thank You



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Closing Thoughts



- Do your homework in design and contracting phase
- Consider how you will access and visualize your data – can you combine into an existing system or process?
- Ensure O&M Plan is considered prior to construction hand-off

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Mentimeter

Based on today's webinar, what is one thing you hope to do next for your owned or contracted onsite solar?

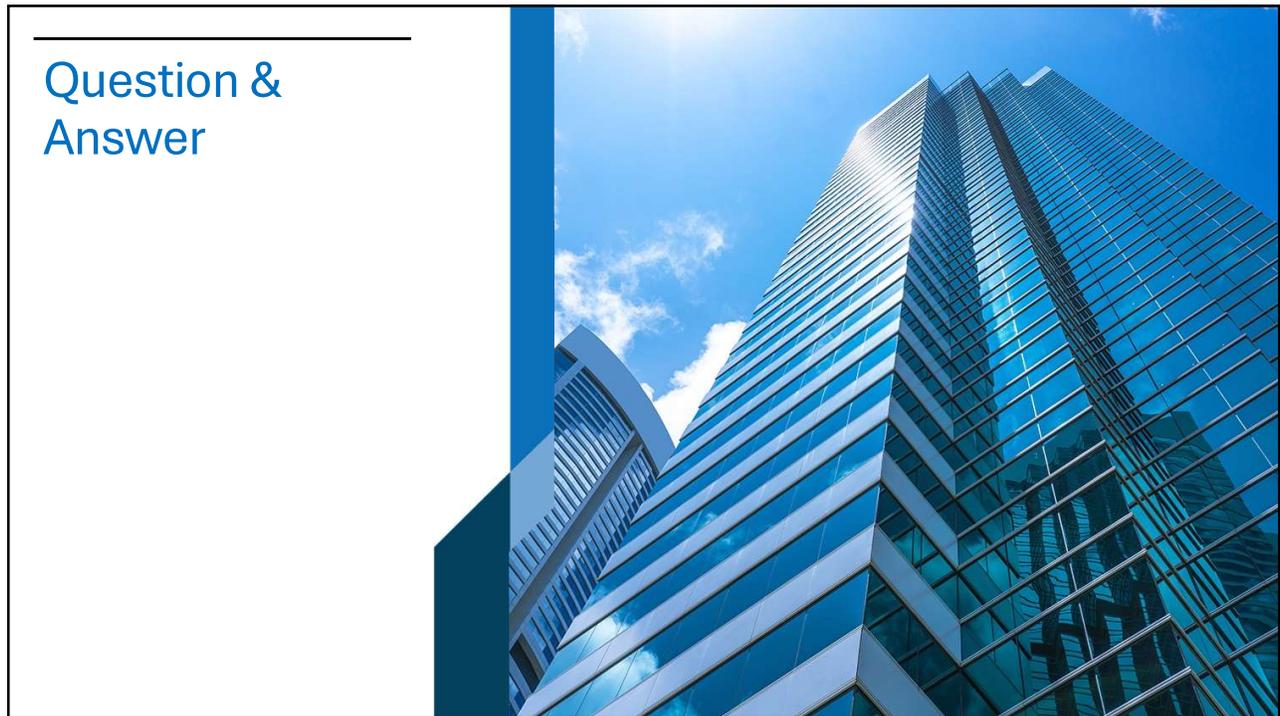
The word cloud contains the following terms: om planning, own, dashboard, celectrate, maintenance, training, collaborate, plan, report, maintenance plan, rfp, data, equipment communication, performance guarantee, management, research, ppa, and communicate.

Menti
Solar Energy in Schools

Choose a slide to present:

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Thanks for joining today!

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