California Solar Initiative

RD&D: Research, Development, Demonstration and Deployment Program

GO solar CALIFORNIA

Final Project Report:

Reducing California PV Balance of System Costs by Automating Array Design, Engineering, and Component Delivery

Grantee:

SunLink Corporation

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http://www.calsolarresearch.ca.gov/Funded-Projects/

Preface

The goal of the California Solar Initiative (CSI) Research, Development, Demonstration, and Deployment (RD&D) Program is to foster a sustainable and self-supporting customer-sited solar market. To achieve this, the California Legislature authorized the California Public Utilities Commission (CPUC) to allocate **$50 million** of the CSI budget to an RD&D program. Strategically, the RD&D program seeks to leverage cost-sharing funds from other state, federal and private research entities, and targets activities across these four stages:

- Grid integration, storage, and metering: 50-65%
- Production technologies: 10-25%
- Business development and deployment: 10-20%
- Integration of energy efficiency, demand response, and storage with photovoltaics (PV)

There are seven key principles that guide the CSI RD&D Program:

1. **Improve the economics of solar technologies** by reducing technology costs and increasing system performance;
2. **Focus on issues that directly benefit California**, and that may not be funded by others;
3. **Fill knowledge gaps** to enable successful, wide-scale deployment of solar distributed generation technologies;
4. **Overcome significant barriers** to technology adoption;
5. **Take advantage of California's wealth of data** from past, current, and future installations to fulfill the above;
6. **Provide bridge funding** to help promising solar technologies transition from a pre-commercial state to full commercial viability; and
7. **Support efforts to address the integration of distributed solar power into the grid** in order to maximize its value to California ratepayers.

For more information about the CSI RD&D Program, please visit the program web site at www.calsolarresearch.ca.gov.

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Abstract

SunLink, a California based company, is a leading provider of PV (photovoltaic) mounting solutions and other Balance of System (BOS) components to the California and U.S. markets. SunLink performed research, demonstration and deployment activities under a CSI (California Solar Initiative) grant entitled "Reducing California PV Balance of Systems Costs by Automating Array Design, Engineering, and Component Delivery."

These activities included research and further development of software design tools that enable automation of system layout and structural design as well as automated preparation of documentation needed for project approval and installation. Automating these tasks saves engineering and installation time, improves quality, and broadens the available market for rooftop solar installations.

Because of the unique aspects of PV arrays, the California Building Code does not contain specific provisions that allow for optimized structural design of PV arrays. Under the grant, SunLink extended its existing research to improve its knowledge of seismic effects on arrays, including verifying analytical models through extensive shake table testing of full size arrays.

Since SunLink projects occur throughout California, a database of local permitting requirements was developed under this project, and the database can be expanded as projects arise in new localities. SunLink and other solar stakeholders can use this information to facilitate the delivery of documentation that best illustrates to building officials the code compliance of optimized design, and better meets the requirements of local permitting agencies in California.

The combination of automated project design and reporting systems based on demonstrated engineering research, improved access to permitting agencies and officials, and broad dissemination of the lessons learned during the project, all contribute to creating additional opportunities for solar array installation in California.

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SunLink thanks the technology partners who supported the project — AutoDesk, Computers and Structures, Inc., the Pacific Earthquake Engineering Research Center (PEER). In particular, Wes Neighbour, PEER Senior Development Engineer, was instrumental to the success of the shake table tests.

SunLink also greatly appreciates the contribution of Melissa Reading for her organized and professional management of the many reports and deliverables generated during the project.

Glossary

AHJ	Authority Having Jurisdiction
API	Application programming interface
ASCE	American Society of Civil Engineers
AWS	Amazon Web Services
BOM	Bill of Materials
BOS	Balance of Systems
BPM	Business Process Management
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
CPUC	California Public Utilities Commission
CRM	Customer Relationship Management
CSI	California Solar Initiative
DSA	Division of the State Architect
DMS	Document Management System
EDM	Engineering Data Mart
ERP	Enterprise Resource Planning
LAN	Local Area Network
MATLAB	Matrix Laboratory - a numerical computing environment
MCS	Mineral Cap Sheet (roofing membrane)
OCR	Optical Character Recognition
ODBC	Open Database Connectivity
PEER	Pacific Earthquake Engineering Research center
PLM	Product Lifecycle Management
PV	Photovoltaic
PVC	Polyvinyl Chloride (roofing membrane)
PV-SAP	Photovoltaic Structural Analysis Program
R+C	Rutherford and Chekene
RD&D	Research, Development, Demonstration and Deployment Program
RMS	Roof Mount System
SAP2000	A structural analysis software package
SDS	Design spectral response acceleration factor
SEAOC	Structural Engineers Association of California
SELA	Structural Engineering Load Advisory
SLDS	SunLink Design Studio
SugarCRM	Customer relationship management product from vendor SugarCRM

Executive Summary

The California Solar Initiative seeks to establish 3000 megawatt (MW) of distributed generation in California by 2017. In support of this goal, CSI funded SunLink research to decrease the engineering costs associated with fully optimized PV systems. This project included automation of structural engineering, full-scale seismic testing of PV array behavior, analysis of wind tunnel testing for dynamic modeling of wind loads, development of a publicly accessible database of permitting agency requirements in jurisdictions across the State of California, creation of an automated document management system, and work that will facilitate code updates to overcome barriers to non-attached (non-roof-penetrating) designs that are necessary for broad building-owner acceptance of rooftop solar. Each of these separate tasks demonstrates opportunities for Balance of System cost reduction.

California-based SunLink Corporation is a leading provider of PV mounting solutions and other balance of system (BOS) components to the California and international markets. SunLink mounting systems are compatible with a wide range of solar modules. They are ballasted, flexible, interconnected systems that can be positively attached to the roof structure when necessary. SunLink projects are thoroughly analyzed to minimize array weight and cost while ensuring structural adequacy and safety. Using the software tools developed under this program, SunLink has been able to significantly reduce the time required for structural and project engineering of a typical roof-mounted commercial installation. The tools SunLink has created enable accurate and consistent documentation as well as rapid iteration of the custom designs required to maximize solar power output in rooftop installations. They facilitate communication with permit-granting agencies and retrieval of location-specific building code requirements, and rely on models which have been validated and calibrated through seismic and wind-tunnel testing.

This work serves the five CSI Research, Development, Demonstration and Deployment Program (RD&D) Principles of: 1) improving the economics of solar technologies by reducing costs and increasing system performance; 2) focusing on issues directly beneficial to California; 3) filling knowledge gaps to enable successful, wide-scale deployment of solar-distributed generation technologies; 4) overcoming barriers to technology adoption; and 5) using available data.

Engineering and Design Automation

SunLink has created a suite of integrated design tools for layout and model generation, now known as SunLink Design Studio (SLDS). Use of SLDS provides:

- Reduction of the time required to produce an accurate, original array layout and revise layouts when design changes occur.
- Reduction in the number of errors in component part numbers and quantities.
- Reduction in the opportunity for errors when defining the project design parameters and implementing the engineered design.

- Improved accuracy and efficient distribution of layout drawing information to all company departments requiring it: Sales, Project Engineering, Project Management, and Operations.
- Identification of rooftop shade-affected zones.

Recommendations

Firms should take full advantage of both automating their engineering processes and integrating their engineering systems. The development of standards of practice for solar PV will help PV system suppliers, engineering firms, building owners and permitting agencies work more effectively together to develop and share information.

Many smaller PV firms have neither the technical resources nor the capital to support a large scale development effort. SunLink-CSI work in these areas illustrates opportunities for the development of commercial software packages to support solar PV systems, either in the form of add-ons to existing engineering platforms, or new software tools for layout, design, and analysis.

Testing and Analysis

SunLink conducted seismic testing of full-scale production systems at the Pacific Earthquake Engineering Research (PEER) center. As the first solar manufacturer to conduct such tests, SunLink was most interested in validating and calibrating non-linear seismic analysis models that predict total horizontal displacements for unattached PV arrays. Further, SunLink has shared the results with building code officials to help inform new structural permitting standards that support the use of unattached PV mounting installations in areas of high seismicity. Because ballasted systems are less expensive to install and maintain than connected systems, these test results will ultimately help to lower costs for rooftop solar.

Two SunLink roof mount systems were tested on the shake table at PEER: Core RMS and Precision RMS. Each system successfully withstood the complete matrix of test loads, which included approximately 100 earthquakes. The testing validated the analytical models developed by SunLink and demonstrated that the analysis can accurately and consistently predict array response to a wide range of seismic events. These validated models support the position that unattached PV arrays can be safely and predictably utilized in seismic regions.

Analysis of the PEER testing was performed in collaboration with Rutherford & Chekene (R+C), a leading California structural engineering firm based in San Francisco.
For unattached solar arrays, the mass of the system and friction between the PV system and the roof surface govern the behavior of the array during an earthquake. In order to adequately design this type of system for the life-safety intent of the building code, the maximum sliding displacement of the array in each plan direction (upslope, down-slope, and cross-slope) must be determined. The array is then situated on the roof to allow for this displacement, both between the array and roof edge or other fixed rooftop objects and the other, independent PV arrays. The maximum displacement values also inform the design of the electrical wiring so as to ensure sufficient flexibility and slack.

SunLink had developed design tables based on analysis of computer models so that, with a given a set of roof conditions and a site-specific seismic intensity level for a project, engineers could determine the predicted maximum displacement of the unattached solar array. By performing full-scale shake table tests and analyzing the data gathered during those tests, SunLink and R+C were able to calibrate and validate these computer models, confirming that the design tables were conservative, and capable of providing sufficient sliding displacement capacity for any specific project.

Another aspect of SunLink's testing was the development of dynamic wind modeling methods for analysis of roof-bearing PV arrays. Application of these models helped SunLink identify cost-effective design and risk strategies. A central aspect of the SunLink dynamic analysis approach is the ability to economically and efficiently scale the analysis to include thousands of runs across a range of load and structural parameters. Wind loading is stochastic and the peak wind loads that govern design occur very rarely. A statistical picture of array response is needed to provide insight into design issues that affect cost and performance. The speed and rapid convergence of these models allow them to generate meaningful statistics for specific cases in a reasonable amount of time running on a small cluster of PCs.

Recommendations

Research testing and analysis of full-scale, ballast-only PV systems in seismic regions confirms that displacements due to system sliding during an earthquake are predictable. With the continued dissemination of test results and the evolution of standards permitting, we expect that an increasing number of unattached rooftop PV systems will be permitted, thereby reducing the cost of rooftop solar arrays and increasing market penetration.

Building codes do not yet specifically address the challenges of designing solar PV arrays. Additional testing can help demonstrate the limits of safe and efficient PV systems operation. This can help support additional penetration of solar in California by increasing the inventory of available roof sites.

The research and analysis performed by SunLink and R+C into the performance of unattached PV systems on roofs in seismic areas was utilized by the Structural Engineers Association of California Solar Photovoltaic Systems Committee to produce a report entitled "Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays."

The results of testing can be disseminated and implemented much more quickly than the traditional code revision cycle. The SEAOC Reports that this research helped support are already being cited by code officials and used as guidelines for permitting solar PV systems in California.

Agency Database and Document Management

Under CSI funding, SunLink created a web-accessible database application that includes contact information for the engineering and permitting of solar projects within building departments across all 58 California counties. The underlying MySQL database is able to accommodate frequent changes and additions through a user-friendly administrator interface. This interface is currently accessed through a password-protected website, but can also be transitioned into a publicly managed platform should there be interest in moving the database application to a wiki-format. The database is available to the public and management will be transitioned over the next year.

SunLink has selected and piloted a Document Management System that integrates and maintains consistency across all documents relating to a project: the layout, bill of materials, structural analysis, agency requirements, and sales documents.

Recommendations

California-based solar PV companies can achieve efficiencies and qualitative benefits through the use of Document Management Systems. Solar PV companies interested in implementing Document Management Systems should strongly consider performing a pilot. In our pilot, we determined that workflow capabilities, metadata functionalities, and document management features are three key factors in successful DMS implementation. A cloud-based installation provides an efficient way to support a pilot and provide a gradual and cost effective entry to DMS deployment.

Developing replicable processes to create and manage engineering deliverables helps reduce the cycle time and number of cycles required to support permitting activities. Reducing plan check cycles makes both solar firms and the solar industry more productive.

The California Agency Permit Document Requirements Database created under this grant is an important first step in creating a single point of access for information to support the entire California solar industry. However, any such database must be managed and continually updated to provide any value to its user community. SunLink recommends that the initial site be accessed via the Go Solar/CSI site. One feasible update method is a Wiki approach whereby members of the California solar community take responsibility for insuring that the information contained is accurate and up-to-date. Even so, the site will always require some minimal amount of oversight to be successful.

This approach could become a model for organizing and sharing other types of solar information. In particular, there would be clear value in the development of a standard module database with up-to-date module information supplied and certified by the module manufacturers and available to all California solar industry participants.

Summary

Taken together, this work has created a set of calibrated and validated software tools that ensure design consistency, decrease engineering time, enable cost-effective design iterations, extend full-optimization capability to a wider market of potential customers, help guide code refinements, and provide tools to the broader PV Solar community to enhance the penetration of solar photovoltaic systems in the State of California.

1 Introduction

1.1 SunLink

SunLink Corporation manufactures integrated PV balance of system solutions that reduce the cost of installation, ease permitting, and enhance system design flexibility. SunLink's industry-leading solar roof and ground mount racking systems, HomeRun™ combiner boxes, and wire management tools have been proven on more than 250 MW of commercial and utility-scale PV projects at 1,200+ sites across North America. SunLink RMS, Core RMS and Precision RMS offer customers roof-friendly PV racking options suitable for a wide-range of roof environments.

1.2 SunLink Products

The highly engineered, interconnected systems that SunLink provides differ significantly from solar racking systems manufactured by other suppliers. By designing structural members to link PV modules in both the north-south and east-west direction, SunLink systems provide the ability for sharing of wind loads across the array, and thus lower overall ballast weights. This makes SunLink systems viable for a wider range of commercial roofs.

Core RMS, SunLink's galvanized steel system, features a sturdy grid assembly that provides superior strength and load distribution for framed or laminate installations of 10° tilt or less. The system is very simple to install while at the same time durable through extreme environmental conditions.

Precision RMS, SunLink's most flexible rooftop mounting solution, makes solar a viable option across a wide range of rooftops. With feet that can be adjusted on-site to align loads with structural elements of the roof, Precision RMS is ideal for roofs with limited deck capacity and can accommodate uneven roof surfaces. The system's stiffness and linked rail design can withstand conditions in the highest wind and seismic zones and its aluminum frame can endure corrosive environments.

Core RMS Precision RMS, and the legacy SunLink RMS, are all included in the software suites developed under this project.

1.3 SEAOC Code Committee

Recently, a SEAOC (Structural Engineers Association of California) committee has addressed the "lack of clarity and specific requirements in applying structural building code provisions to solar photovoltaic systems." The members of this committee include SunLink and Rutherford & Chekene structural engineers. Two reports have been issued – *Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays* and *Wind Design for Low-Profile Solar Photovoltaic Arrays on Flat Roofs*. The reports propose changes to the current California Building Code to provide prescriptive methods for PV systems similar to those provided for other structural systems. This is an important step for the industry, one that is essential for consistent, safe design and permitting of rooftop solar systems. SunLink's CSI-funded research informed the work of this committee and is credited in the seismic report.

1.4 Meeting CSI Principles

The five CSI RD&D Principles have guided SunLink's CSI work from its inception. They have been met in the following ways:

Principle 1, to improve the economics of solar technologies by reducing costs and increasing system performance, was met by automating the design and structural engineering of rooftop solar arrays, creating and analyzing dynamic wind analysis models, and performing seismic tests and analysis of full-scale PV systems. These tasks have all contributed to the ability to produce fully optimized systems that are engineered for both system performance and lower cost, a goal shared by SunLink and CSI.

Principle 2, to fund work focused on issues directly of benefit to California, was met by the creation of the California database of permitting requirements, which will be of direct benefit to the development of rooftop solar in the state. The work on the seismic response of solar systems is also particularly pertinent to California as one of the most seismically active areas in the country.

Principle 3 prescribes filling knowledge gaps to enable successful, wide-scale deployment of solar distributed generation technologies. The most important task from this viewpoint is the shake table testing at PEER to establish the validity of models that predict the behavior of non-attached rooftop PV systems during seismic events.

Principle 4, overcoming barriers to technology adoption, was met by the seismic and wind testing and analysis, which will inform the development of code compliant design methods for unattached solar systems. This has the potential to bypass the resistance of building owners to allowing roof penetrations, and further opens the commercial rooftop market.

Principle 5, which emphasizes using available data, is met by the use of the large body of previously obtained boundary layer wind tunnel testing data from the University of Western Ontario as input to the dynamic wind analysis performed in this project.

1.5 Summary

The major activities of the SunLink grant support the five principles of the CSI program and are described in the next sections.

2 Automation -- Structural analysis and design automation

SunLink provides customized module mounting systems and other balance of system (BOS) components for photovoltaic (PV) arrays. Its customized systems mount the vast majority of the PV modules on the market, and offer customers options for panel tilt angle and row spacing, so that systems can be optimized, both on low-slope building roofs and on the ground. SunLink has identified automated array design and engineering as critical to its goal of reducing the engineering time and cost needed to produce its highly optimized photovoltaic array support structures.

2.1 Overview of SunLink's Array Design Process

SunLink's PV array mounting products provide mounting solutions that are customized and optimized to best meet the constraints and environmental conditions of each project. Every project is designed by selecting and configuring standard product components, and then verifying that the system can safely withstand code-level wind, snow, and earthquake loads. For roof-mount systems, this verification checks the Wind Uplift Resisting System (WURS) which involves ballasts, roof connectors, and interconnection between panels, to insure that the system can safely resist wind loads. (The design and verification of a SunLink product for a particular project is called Project Engineering, or more broadly, Systems Engineering, for the purpose of CSI reporting.) Once the project is designed, an accurate Bill of Materials (BOM) and set of layout drawings are essential for the successful delivery and installation of the PV mounting system.

In many ways, SunLink's design process for the application of its products mimics that of other structurally customized building component products, such as trusses, glazing, cladding, and curtain walls. Some of the automation steps developed at SunLink and described in this report are relevant to these industries as well. However, SunLink's design automation tools are focused on the design challenges unique to PV arrays, particularly low-slope rooftop arrays.

2.2 Advantages of Automation

Automation improves the efficiency of the SunLink systems engineering process, reduces the potential for errors, and allows for the development of more optimized designs. The benefits of design automation include the following:

1. Through its customized drawing commands shortcuts, and built-in layout rules, SunLink's automation software (called SunLink Design Studio, or SLDS) reduces the time required to produce an accurate array layout drawing. This allows alternative designs to be more quickly evaluated and optimized, and it reduces the time required to revise layouts if changes occur during the course of a project. The design rules

built into SLDS prevent certain types of layout errors, saving the time and costs correcting such errors would cause.

2. The SLDS Configurator together with the Engineering Data Mart, greatly reduce the engineering time required to adapt mounting systems to new modules, or to new array geometry, such as row spacing or tilt. This allows array layouts to be quickly created for any module or geometry within the design limits of SunLink's mounting systems.

3. The automated daily synchronization of the Engineering Data Mart with SunLink's product life cycle (PLM) parts database and enterprise resource planning (ERP) software allows SLDS to ensure that an accurate bill of materials (BOM) is created for every array layout; i.e. that all parts are the current production parts, and that they are correctly used and counted in the array assembly. This eliminates many opportunities for error, and reduces the need for time-consuming and tedious manual quality assurance procedures.

4. SLDS provides a tool that can quickly identify rooftop shade-affected zones, a key part of roof-top array design.

5. SLDS captures all project engineering parameters, displays them in a consistent manner on the layout drawings, and passes them to the photovoltaic structural analysis program PV-SAP. This reduces opportunities for errors in the project design parameters, and again the need for time-consuming and tedious manual quality assurance procedures.

6. SLDS automatically builds SAP2000 analysis models for each sub-array, for use by PV-SAP. Without this functionality, design optimization of the WURS for each sub-array at the project level would not be practical.

7. PV-SAP together with the PV-SAP dashboard in the SELA, the MATLAB analysis data file, and PV-Array Viewer automates and organizes wind and seismic analysis of each sub-array on each project. The project engineer can quickly set up and run the analyses and see key results, leading to significant reductions in project engineering time. Also, project engineers can look at "what if" scenarios much more easily, allowing for increased design optimization.

8. Automation allows for trained technicians to design arrays, allowing the design process to be easily and economically scaled, and to be practical for projects of any size. Additionally, SLDS can be used by SunLink's customers with minimal training, reducing the time and documentation needed to arrive at an approved array layout.

2.3 Automation Challenges and Best Practice Recommendations

The development of in-house software tools presents many challenges that must be met through planning, management, and business processes. As they are brought online, the software tools must mesh with ongoing engineering, sales, and production operations, with minimal interruption. SunLink has faced and found solutions for the issues identified in this section as part of its in-house software automation tool development.

2.3.1 Development path and prioritization

Because of the need for new software to mesh with and support on-going systems engineering, SunLink uses a scrum-based agile software development approach for the development of SunLink Design Studio (SLDS.) Scrums average 2 to 4 weeks in length. Rally software is used to collect all user stories, and organize and manage the scrums. A software advisory committee, consisting of management and SLDS users throughout the company, meets periodically to provide additional feedback and long-range software development planning.

PV-SAP/PV-ArrayViewer, developed by R+C, has a smaller user base of Project Engineers. The software development process is handled using ProjectLocker, which offers Apache Subversion (SVN) for version control and archiving, and Python-based Trac for logging of user stories, bug reports, and development requests.

2.3.2 Testing, bug fixes, and quality assurance

New versions of SLDS are first tested by an automated script that creates sample designs and checks for any “breaks” in basic functionality. Next, new features are tested by one layout designer and one project engineer. Once fully tested, new versions are announced to the SunLink user base via an email enumerating and explaining new functionality. Bugs are posted back to Rally, with critical bugs getting immediate attention until a patch version is issued. A similar process is used for PV-SAP/PV-Array Viewer updates.

2.3.3 Backward compatibility

As new product components or design functionalities are introduced, and AutoCAD layout templates are updated, backward compatibility must be managed in order to allow automation software to work with older projects that may need to be revisited. SLDS checks the layout drawing template version and Engineering Data Mart (EDM) information whenever an existing project is opened. SLDS disables functionality if it is incompatible with the template version that was used for the layout drawing, and offers the user the option to update the assembly if it is out of date with the EDM. If the user chooses to not do so, SLDS functionality is further disabled in order to avoid the possibility of creating an inaccurate BOM.

PV-SAP maintains a version library, and incorporates a utility to change the version that the project engineer is currently using. The version used for each sub-array analysis is stored in the SELA dashboard for that analysis, so that the project engineer can set MATLAB to use the correct version if a prior project needs to be revisited.

2.3.4 Integration and compatibility with commercial software

Installing new versions of commercial (or open source) software into the automation stack must be carefully coordinated to avoid downtime due to incompatibility. New external software upgrades must be tested to make sure they function with the rest of the software, following the same procedures used for in-house software, prior to production use. Because outside users of the software (customers and consultants) may time commercial software upgrades differently, decisions must be made about the viability of maintaining multiple versions of the stack, and timing software upgrades to mesh with other product enhancements and upgrades.

2.3.5 Training and documentation

Successful use of design automation requires that users are properly trained, and that software functionality, limitations, and design rules are properly documented using manuals (written with Microsoft Word), browser-based documentation (http files), Wikis, mouseover pop-ups, or other means. Source code must also follow good formatting and commenting practices.

In order to extend the software tools to customers and consultants, SunLink offers call-in and email based installation and user support as well as Web-based training sessions for new users.

2.4 Software Choices

2.4.1 Computer-aided design (CAD) software

SunLink chose Autodesk's AutoCAD software prior to the grant project and Autodesk is one of SunLink's project partners. SunLink chose AutoCAD as its drafting solution for layout drawings for several reasons:

1. AutoCAD is ubiquitous in the architecture, engineering, and construction industries, and its native file format (.dwg) is the preferred format for sharing CAD data with customers. SunLink array layout CAD data is provided to customers for use in stringing, electrical, and other drawings that are part a project's construction documentation set. Without exception, these data are always requested in AutoCAD.dwg format.

2. AutoCAD has an extensive command set, and is very extensible, with a robust and well developed application programming interface (API). This is important for the support of add-on automation software such as SLDS.

3. Autodesk is based in San Rafael, as is SunLink. SunLink employees are closely familiar with the ObjectARX API and with AutoCAD.

2.4.2 Structural Analysis Software

SunLink considered two commercial options for structural analysis software in its design automation stack; SAP2000 by Computer and Structures and Autodesk's Robot Structural Analysis Professional. SunLink selected SAP2000 because it is widely used and well-vetted, it has extensive modeling options (including non-linear analysis), it has an open application programming interface, and it can accept different input formats and write output to several formats. SunLink has also made use of the open-source structural analysis package OpenSees. OpenSees is a valuable research tool, but is not deemed sufficiently vetted for use on commercial projects.

2.4.3 SunLink Design Studio

SunLink Design Studio is an AutoCAD add-on currently written for 64 bit AutoCAD 2013. It uses AutoCAD's ObjectARX API and is written in C++ employing the.NET framework, using the Microsoft Visual Studio integrated development environment.

2.4.4 Engineering Data Mart

The Engineering Data Mart (EDM) is a data store hosted on a MySQL database containing engineering-oriented data. Some of the data contained in the EDM include SunLink component and assembly numbers, component weights, and module information. SLDS accesses EDM data for generating layout blocks, records EDM information in the proper locations on the layout drawing, and then exports this information to the SELA and the SAP models.

The Engineering Data Mart is populated with ERP data through the use of an Extract, Transform, and Load (ETL) application. ETL tools and applications are commonly used for data warehousing and data integration.

The ETL jobs that export data from the Epicor ERP system to the EDM run daily. The EDM exposes engineering data in Epicor in order to simplify automated access, reduce demands on the ERP system during business hours, and improve SLDS response times.

2.4.5 Summary

At SunLink, carefully conceived and implemented software design automation tools play a key role in reducing project engineering time and the design costs associated with customizing and optimizing SunLink's PV array mounting products for specific projects. Similar tools are needed throughout the industry to bring to market products that are well-designed and meet code safety requirements, but are optimized for site conditions in order to reduce costs. The overview presented here of SunLink's software development choices and processes will be useful to other companies in the development of similar tools.

3 Document Management System

SunLink evaluated, selected and implemented a Document Management System (DMS) during a three-month pilot. The pilot provided SunLink with insights into the benefits and efficiencies that might be gained by solar PV companies by implementing a DMS.

3.1 Scope

SunLink formed a pilot team that consisted of 15 SunLink personnel representing various departments including Sales, Project Management, Engineering, Layout, and Information Technology.

A portion of the SunLink project workflow was rigorously documented beginning with the creation of a project based on a customer quote request and continuing through the submittal of a contract for final customer approval. This workflow included SunLink process steps for Layout, Budgetary Estimate, Project Management, and Project Engineering. Finally, test projects were limited to SunLink's roof mount systems. Only Document Management Systems under $100,000 were evaluated.

3.2 Requirements & Evaluation Criteria

As part of the DMS evaluation process, two types of requirements were used to identify candidates: 1) A standard list of functionalities typically found in document management systems and thought to be applicable to solar PV businesses was identified. 2)A second set of requirements based on internal needs and reflecting additional functionalities critical to solar PV businesses was also established. The combination of the two sets of requirements guided the software selection process.

3.2.1 Document Management Functionality Criteria

The list below contains the typical DMS functionalities that vendors' products were evaluated against.

1. Functionality
2. Legacy Document Migration
3. Storage / Archiving
4. Document Types
5. Document Viewers & Editors
6. Document Versioning
7. Document Workflow
8. Document Audit Trail
9. Document Scanning / OCR
10. Integration With Microsoft Office
11. Integration With External Applications

12. Metadata / Reporting
13. Form Based Document Creation
14. Folder Templates / Document Templates
15. Document Input Methods
16. Document Merging
17. Document Conversion
18. Security & Users
19. Document Search Capabilities
20. User Interface / Interaction
21. Technology - Architecture
22. Technology - Web Based

3.2.2 SunLink / Solar Industry Specific Functionality Criteria

There are some criteria that apply to solar PV projects that also were used to evaluate vendor products.

Functionality	**Description**
Project Management Workflow	Support for PV solar project based workflows
Project Management Status Notifications	E-Mail and / or other notifications to alert project managers and other department team members of status changes during the course of a project workflow
Project Management Status Dashboard	A visual report or dashboard which can be used to determine the current status of a project workflow
Support for Solar PV Metadata Elements	Support for industry Metadata elements such as solar PV modules, project size in KW, racking system type, number of modules, project location, latitude, longitude, tilt angle, customer, etc.
AutoCAD Support	Features related to solar PV layout drawings including viewers and integration capabilities if available

3.3 Software Evaluation

In order to conduct a Document Management System pilot, SunLink had to first identify a vendor and product to use. Potential candidates were identified primarily through the use of web searches and web sites that focused on the DMS and BPM space.

Products were evaluated based on the functionality criteria established in the previous section of this document. As can be imagined, different products were reviewed to different degrees depending on what the initial product reviews revealed. In some cases, products were ruled out based on initial reviews of the websites. On the other hand, multiple conversations and multiple demos were provided to the pilot team for products that seemed to meet the majority of the criteria. Finally, in some cases such as for OpenText and Pervasive, the sheer cost of the products eliminated them from contention.

3.4 Software Selection

After an extensive review of several DMS vendors, SunLink determined the M-Files product was best suited for our business model, business size, and industry segment.

3.4.1 M-Files DMS Overview

M-Files Corporation is a Microsoft Gold Independent Software Vendor (ISV) Partner and an Autodesk Authorized Developer. The latter is a big plus for solar PV companies like SunLink which rely on AutoCAD for layouts and drawings.

The M-Files DMS also includes a .NET API which can be used to integrate with external systems such as a CRM. Alternatively, ODBC can also be used as an integration method for data lookups. SunLink used ODBC integrations to look up metadata values from its ERP. It is worth noting the M-Files architecture can be deployed as a cloud, enterprise, or hybrid solution.

For additional information, please refer to the M-Files website: http://www.m-files.com

3.5 SunLink Pilot

In order to determine the benefits and/or drawbacks to the use of a DMS for a solar PV BOS provider such as SunLink, a pilot of the selected DMS was performed. The pilot consisted of processing a number of projects through the DMS workflow and using the features of the DMS to simulate a real life production environment.

3.5.1 Detail Pilot Scope

To keep the scope of the project manageable from a resource and time perspective, the following boundaries were established:

1. Roof mount systems only
2. Starting point is creation of new project based on customer quote request
3. End point is the customer acceptance or rejection of a contract (should a project reach this point in the process)
4. Integrations in scope include CRM integration and ERP ODBC lookups. All other potential integrations were out of scope for the pilot and were performed manually
5. Customer interactions with the workflow were simulated by Sales personnel
6. A small team was assembled to carry out the pilot.

3.5.2 Pilot Team & Departments

Based on the established scope, the pilot participants included the following departments: Sales, Layout, Project Management, Engineering, IT, Operations, and Management. The Pilot team was responsible for establishing the pilot requirements, DMS configuration requirements, processing projects and documents in the DMS, and providing feedback for the DMS activities.

3.5.3 Pilot Workshops

In order to establish the detailed process requirements and configuration needs for the pilot, two separate workshop sessions were held with the Pilot Team. The majority of work revolved around the design of the project based workflow. The workflow consisted of a typical solar industry BOS provider process of creating a project for a particular solar installation through having a customer approve the business contract for the solar racking.

3.5.4 Pilot Workshop Deliverables

Pilot Workshops yielded two documents. The first document was a detailed flow chart showing the process steps and logic for the new project through customer contract approval. The second document was a detailed matrix identifying each process step in the workflow document and specifying its requirements in terms of metadata to be gathered, possible next steps, required documents, and other specifics about the process step. These two documents were used as the primary references for configuring the DMS environment.

3.5.5 Pilot DMS Environment Configuration

Before a DMS can be used to process projects and documents, it must be configured. For the purposes of the pilot, the M-Files document vault, (DMS repository), was hosted on the cloud. This eliminated IT administration and infrastructure concerns associated with an enterprise deployment. The following sections detail aspects of the DMS that required configuration in preparation for the pilot. As the pilot progressed, the configuration and setup of the DMS was fine-tuned based on user feedback. The Information Technology Department pilot participants were granted administrator privileges to access and configure the DMS environment. Once the M-Files Client and Vault connection were established, a user could access the M-Files application and begin using the DMS.

3.5.6 User Configuration

M-Files, like the majority of its peers, requires named user accounts in order to track activity in the system and assign permissions for the various features available in the software. As part of the configuration setup, users, user groups, and permissions on the objects in the system were established.

Each pilot participant was provided with a user account to use the DMS. Permissions were configured for users based on User Group (Sales, Layout, Structural Engineering, etc.) or individual user based on the business requirements.

3.5.7 Workflow Configuration

For Solar PV BOS providers and other project-based companies, workflow definition is one of the most time consuming and important configuration items in the DMS. Based on the findings of the pilot workshops, a workflow for roof mount systems was created.

The workflow definition includes specifying the order in which process steps occur, determining branches and paths between steps, configuring assignments and notifications for process participants, and establishing permissions for each step. Essentially, the configuration of the Project Workflow determines how project process steps will be executed and how well the model mimics the real life business process flow.

3.5.8 Document Configuration

As part of the DMS configuration, Document Types need to be established. This is true both so that that different types of documents can be associated with different metadata elements and to improve efficiency of searches by searching for a particular document type. Finally, documents exist in a variety of formats and some are created using templates.

For the purposes of the pilot, a number of documents typically found as part of solar PV sector business processes were defined.

Some of the document types established for the pilot include:
1. AutoCAD Layout
2. Sales Contract
3. Customer Module Spec Sheet
4. Building Drawings
5. Customer Contributions
6. Engineering SAP & MATLAB Files
7. Budgetary Estimate
8. Email
9. Final Wind Load Report

3.5.9 Metadata Configuration

Metadata are data elements that can be associated with different objects in the system. They represent a powerful concept in DMS systems as these data elements can be used for a number of purposes including reporting, automatically taking action on objects based on metadata values (such as workflow steps), and searches. For the pilot, metadata elements were defined for projects and for documents. The defined metadata elements, not surprisingly, reflect data elements required in Solar PV projects.

3.5.10 Views

Views are flexible tables within the M-Files system for viewing data. While different from reports, these grids allow users to display data pertinent to their needs through the use of data filters and selected data columns.

3.5.11 Reports

One of the powerful features of the M-Files DMS is reporting on metadata values. As part of the pilot, SunLink had M-Files create a few reports based on Pilot Team recommendations as made during the Pilot Workshops. In addition to tabular reports, M-Files also supports charts and other graphical report types.

3.5.12 Pilot Execution

After the configuration of the DMS vault, M-Files conducted a two hour training class on the use of the DMS. The training covered the standard system feature set and provided a general overview on working with project workflows.

After the M-Files training, several mock solar PV projects were created to test the workflow configuration and train the Pilot Team users on the solar PV specific workflow created in M-Files based on the Pilot Workshop. This internal training familiarized each of the Pilot Team's members with each of their responsibilities during the project workflow.

Once the Pilot Team had processed the mock projects and felt comfortable working in the system, real solar PV projects were selected for the team to process in M-Files while in parallel performing the standard process (without the DMS). In order to mitigate risk of impacting live projects, a test environment of the SugarCRM was used. This completely isolated the existing live process from the DMS pilot environment.

During the course of the pilot, the Pilot Team provided feedback to IT personnel. As the Pilot Team familiarized itself with the DMS and the project workflow, changes were requested to improve functionality, improve efficiency, and provide more capabilities for the users that yielded additional benefits of the system. For example, standard naming conventions established at the beginning of the project were modified to provide additional flexibility, and new views were created for users to more efficiently view the information required by their departments.

3.6 Pilot Outcome / Results

The following sections summarize the findings of the Pilot Team.

3.6.1 Pilot Team Feedback

At the conclusion of the pilot, team members were surveyed to evaluate the impact of the DMS. Of the team members polled, all were found to be in favor of deploying a DMS permanently. More than 80 percent of respondents were strongly in favor of this position. This is a strong indicator that the benefits of the DMS were significant to their work.

Regarding efficiency, all respondents to the survey indicated they had seen an improvement in productivity. Half the respondents indicated the use of a DMS was somewhat more efficient than the existing process. The other half found the DMS to provide significant gains in productivity.

Based on the survey results, we conclude the DMS provides work efficiencies and sufficient benefits that users would be in favor of using one permanently in the organization.

3.6.2 Benefits of a Structured DMS

The following benefits identified during the DMS pilot program are extensible to other firms in the solar industry if they follow similar DMS implementation programs:

1. Standardization of processes through the workflow functionality.
2. Enforcement of process rules and metadata entry through workflow constraints.
3. Improved ease of use and administration through the cloud.
4. Standardization of file naming conventions and file versioning, and elimination of duplicate documents.
5. Organizational improvement through archive functionality.
6. Provision through Data and Views of better ways to manage information and tailor data to users' needs.
7. Improvement of resource and deadline management through workflow and metadata functionality.
8. Ability to roll back to a previous version of a document.
9. Provision through Metadata reporting of process insights previously unavailable.
10. Creation and tracking within the system of task assignments.
11. Ease searching and locating documents and objects.
12. Ability to control access permissions down to the document level.
13. Ability to share documents with external parties using web portal.

3.6.3 Lessons Learned

Piloting the DMS on the cloud was definitely the right approach. While not all vendors offer this option, this proved a very efficient way to conduct the pilot. Using a cloud instance eliminated the need for IT administration and setup of DMS-related hardware and software. In addition, there were no significant up-front costs as would have been the case with an enterprise deployment. Finally, a cloud approach made accessing the DMS simple, requiring only a connection to the internet. Firewall and networking challenges were avoided. However, the cloud does potentially pose problems related to integration with systems within the company's enterprise. This needs to be evaluated on a case by case basis.

While gathering requirements and details up front for the configuration of a DMS is valuable, expect changes once a pilot is underway. A pilot team should allot plenty of time for making changes to the model and testing the changes during the course of the pilot.

3.7 Conclusions regarding DMS in Solar Industry

The pilot demonstrated that the use of a DMS can benefit solar PV companies by enabling better efficiencies, improved quality, and process standardization.

Of the features provided by the DMS, the project workflow and management functions (such as views, notifications, and task assignments) proved extremely valuable. The traditional document management functions such as document version control and document searching also provided significant improvements over the current practice of employing a traditional file server without document management capabilities.

Based on the findings, SunLink plans to pursue a complete deployment of a DMS and would suggest other solar PV companies to consider investing in one as well.

In summary, the results of the pilot indicate that a DMS can provide quantitative improvements in solar company worker productivity and work quality, as well as qualitative improvements. The standard DMS features related to documents provide advancements over standard file server practices. These include efficient search, associated metadata, version control, revision history, and security. In addition, workflow capabilities and reporting, especially related to projects and project management, provide significant advantages over typical manual processes.

4 Seismic Testing and Analysis

The solar photovoltaic industry is growing, and a significant portion of new projects consist of large arrays installed on top of existing buildings with flat or low-slope roofs such as warehouses, big-box stores, and schools. To minimize cost and maintenance requirements in these types of installations, building owners and solar installers typically prefer to use solar panel support systems that do not require penetrating the roof membrane. However, without specific guidelines in US building codes for solar, design engineers, plan check engineers and building officials typically refer to requirements for nonstructural components, which prescribe systems that are positively attached to the roof structure.

SunLink, through this CSI-funded research that included non-linear computer analysis and shake table testing, has shown that ballasted, unconnected systems satisfy the life safety-based intent of the structural code. By demonstrating acceptable performance, SunLink conforms to the requirements of both the 2009 International Building Code (ICC 2009) and ASCE 7-05 (ASCE 2006) for permitting alternative design methods. This supports SunLink's and CSI's goal of increasing solar penetration in markets previously deemed unsuitable for roof mounted PV systems.

4.1 Project Approach

SunLink's objectives in executing full-scale shake table tests of unconnected roof mount PV systems were as follows:

1. To develop a set of roof motions that covered a range of seismic intensities
2. To develop a matrix of tests that investigated the behavior of two of SunLink's rooftop solar systems and key variables such as roof surfaces, ballast arrangements, and roof slopes
3. To run a suite of seven earthquake roof motions for the range of test setups, using the Pacific Earthquake Engineering Research (PEER) shake-table facility
4. To determine seismic displacement demands, array component forces and deformations, and their relationship to ground motions
5. To validate computer models and show that ballasted, unconnected systems satisfy all code-based life safety criteria, thereby facilitating acceptance of a simpler, less expensive design

4.1.1 Experimental Roof Motions

In order to accommodate the limited displacement capacity of the PEER table, the SunLink research team, including partner Rutherford & Chekene, filtered and spectral-matched earthquake motions recorded at two California locations during two different earthquakes. The resulting experimental roof motions are conservative in terms of determining seismic design displacement designs, sliding amplitudes, and orbits of the unattached solar arrays, such that the nonlinear computer analysis models can be validated and calibrated.

4.1.2 Matrix of Tests

Unattached rooftop solar arrays are typically installed in a broad range of conditions related to the type and condition of the roof. To investigate the range of parameters deemed likely to affect the response and the sliding behavior of the unattached solar arrays, the SunLink research team conducted earthquake tests on combinations of the following key parameters:

1. Array system (Core RMS and Precision RMS)
2. Roof surface (PVC and mineral cap sheet)
3. Heavy and light ballast
4. Wet and dry surface
5. Flat and slightly inclined roofs

4.1.3 Execution of Tests

SunLink's Precision RMS and Core RMS roof mounted PV systems were analyzed in full-scale tests at the PEER shake table. Because roof mount systems are typically installed on a variety of roofing materials, each with a different coefficient of friction, the SunLink team constructed two unique roof structures. One 18x25 foot timber-framed roof was surfaced with a mineral cap sheet (MCS) membrane and the other with a polyvinyl chloride (PVC) membrane to represent the range of possible coefficients of friction. Each roof was installed on a subassembly steel frame and tilted to the appropriate angle when it came time for testing. While presenting the research team with some logistical challenges, this method allowed for the greatest diversity in the test regimen while maintaining efficiency in the allotted time at the PEER shake table.

Each test setup was subjected to three different three-component roof displacement input-histories, two of which were high-pass filtered, spectral-matched motions and one of which was unmodified. For the two filtered roof motions, seismic intensities of SDS = 0.5g, SDS = 1.0G and SDS = 1.5g were tested.

4.1.4 Gathering of Test Data

To record the behavior of the solar array test specimens during the shake table tests, the research team created instrumentation layouts using ten accelerometers, twelve wire potentiometers measuring displacement, and two linear variable Novotechnik transducers measuring displacement across the system diagonals. This instrumentation setup was able to accommodate both flat and sloped roof condition for both the Precision RMS and Core RMS models.

4.1.5 Computer Model Validation

From a qualitative perspective, the seismic testing of unattached solar arrays confirmed our prediction that sliding displacements are negligible in small earthquakes (the ten-year event) and manageable in large earthquakes (the thousand-year event). The displacement values we recorded were within the ranges put forward by the previously-created computer analysis models, and by further calibrating those models, we anticipate being able to increase the accuracy of our seismic design of unconnected solar systems.

4.2 Project Outcomes

*The full-scale shake table tests of the SunLink roof mount PV systems provided the data necessary for validating and optimizing computer analysis models of friction-based unattached arr*ays. Once the computer models are confirmed as accurate, these models can then predict the displacement behavior of SunLink systems in any seismic environment.

4.3 Conclusion

The shake table tests clearly demonstrate that friction limits the sliding displacement that solar arrays experience when subjected to design-level and maximum-considered earthquakes. For systems on low-slope roofs (0 to 7 degree slopes), designers can accommodate these seismic displacement demands by providing adequate displacement capacity for electrical wiring and components. We found that design seismic displacements tend to increase with higher site seismicity, lower coefficients of friction, and steeper roof slopes. Therefore, it is important that designers accurately capture the anticipated seismicity of a project location and the maximum roof slope on which a PV system is installed. It is also essential to perform full-scale friction testing of the interface between the solar array and the roof membrane.

4.4 Recommendations

Moving forward, the solar industry in California will continue to benefit from additional seismic testing of unattached PV arrays. Additionally, continued dissemination of the research results obtained during the course of this grant will help move building officials and plan check engineers toward a better understanding of the behavior of solar arrays during earthquakes.

4.5 Public Benefits to California

Unattached PV systems allow for greater solar penetration due to decreased system and installation costs, as well as allowing PV to be installed on structures unsuitable for mechanical connections through the roof membrane. By confirming that solar arrays can and should be designed as friction elements interacting with the roof surface during seismic events, this research facilitates the conversation towards permitting unattached systems in regions of high seismicity.

5 Database – California Agency Permit Document Requirements Database

In addition to providing customized module mounting systems and other balance of system (BOS) components for photovoltaic (PV) arrays, SunLink also provides essential documents used for the permitting and constructing of these arrays. These documents must be accurate, integrated, and consistent for use by the customer, other consultants, and permitting agencies. Thus, access to the engineering parameters and permitting requirements to create these documents is necessary for SunLink's ability to deploy projects and achieve solar energy market penetration goals.

An impediment to creating and providing accurate engineering documentation for the engineering, permitting, and construction of SunLink projects is the fact that permitting agency requirements for projects vary so widely. Each may amend the building code to tailor it to specific geographical requirements. There is no central source of information that clearly defines these agency-specific requirements for PV arrays, nor does a set of solar project engineering guidelines exist for low slope rooftop projects. This lack of transparency and uniformity can make numerous engineering revisions necessary, creates delays, and adds cost to the permitting of solar projects in California.

Based upon SunLink experience in permitting projects in California, SunLink determined that a web-accessible database application incorporating specific data parameters necessary for the engineering of solar projects would improve the efficiency of the permitting process. In order to create such a database, the following tasks were performed:

1. A set of engineering, permitting, and contact information parameters commonly used through the life cycle of a solar design project was defined.
2. The parameters were organized into a user-friendly database architecture.
3. A number of software platforms were evaluated for their ability to store agency information, accommodate frequent additions and changes to the database, and allow for ease of data lookup functionality.
4. In order to allow for the greatest flexibility in user access and future deployment to the greater California solar community, Django, an open source web application framework which was originally created to manage database-driven websites, was selected. The MySQL database, an open source database on which Django can run, was chosen.
6. An HTML user interface that mirrors the design of the Go Solar California website was created.
7. Initial data, based on SunLink's experience in various geographical markets in California, was added to the database.
8. Testing was initiated within the SunLink engineering group.

5.1 California Agency Web Application Project Overview

5.1.1 Purpose and Goals

The intent of the California Agency Web Application is to reduce the time and cost of permitting a solar project by improving the access to necessary technical information. By developing a web portal for gathering permitting data, the solar industry in California will benefit in the following ways:

1. Reduce the time and effort required in gathering engineering requirements for solar in a particular geographical area.
2. Improve communication between building owners, solar installers, engineers, racking manufacturers, and permitting departments.
3. Encourage future universal code requirements for the installation of solar in California.

5.1.2 Challenges

Due to the myriad of California building departments, gathering technical information and ensuring it is current for every community in California poses a challenge. SunLink has developed an initial database of permitting requirements in California by starting with its history of California projects, and adding many more, but the success of a public web application will depend on the participation of the California solar community in expanding the database and maintaining its accuracy.

5.1.3 Platform

The Django framework allows for flexibility in the creation, maintenance, and future modifications of the California Agency Web Application. It was chosen to provide the greatest number of users the greatest ease in user experience while simultaneously allowing for maximum participation in data collection and maintenance by the solar community in California. In order to achieve this goal, each user type can access different levels of the web application. As a user navigates through the levels of the web application to which they have access, they will be presented with a new user interface design and variable levels of control over the web application database.

5.2 California Agency Web Application Functionality

Anyone with interest in California solar would have the ability to search for a California community, defined as any town, city, or census-designated place and view the governing agency's permitting requirements for that community. The information available depends on the data loaded into the database, which reinforces the necessity for the California solar community to expand and maintain the database.

5.2.1 Search

When the general user first accesses the web application they will be presented with a search page. The Go Solar California links are included on this search page in order to allow the solar community access to further solar information.

5.2.2 Community Information

After the user enters the California community for which they are researching California permitting requirements, a page displays the following information:

- The California community's governing building agency
- A web link to the community's webpage
- Whether the community is incorporated or not and the incorporation date (if relevant)
- The community's county and a hyperlink to the county's webpage
- The community's population

5.2.3 Agency Contact

The following tab provides additional agency information for the selected community. It displays:

- The building agency name
- The building agency address
- The building agency phone number
- The building agency website

5.2.4 Personnel Contact

The next tab for a community's data is Personnel Contact Information. This page contains the following information:

- Contact personnel name and title for building agency
- Contact personnel email
- Contact personnel phone number
- Notes regarding additional personnel contact information

5.2.5 Permit Data

The Permit Data Page shows possible information that could be displayed for a given building agency. This page contains the following:

- Building code website
- Link to specific permitting requirements for solar on roofs
- Link to specific permitting requirements for solar on ground
- Design wind speed
- Exposure category
- Minimum wind pressure
- Link to wind map

- Information about the agency’s compliance with California Fire Requirements
- Link to electrical permitting requirements
- Link to alternate means and methods permitting
- Information about the agency’s acceptance of ballast-only roof mounted systems
- The design ground snow load
- The design roof snow load
- Link to snow map
- Link to permit maps
- Link to Agency

5.2.6 Documentation and Links

The Documentation and Links Page of the California Agency Web Application, shows the webpage that will contain any additional documentation and links about solar permitting in the given community. This page completes the accessible information for the general public for a given community. From this page, any user could navigate back to the original search page for information on another community or navigate to the Go Solar California website.

5.3 Database Login with Administrator Privileges

If a user has login credentials to access the database front-end portion of the site, they will be able to add, delete, or edit information to which they have administrator privileges. In addition to the generally available web application pages, the following administration pages become accessible:

5.3.1 Search

While any general users can search for communities in California, a user with Database Login Credentials can also add a community to the database. In order to do so, the user would login to the administration page of the California Agency Web Application, navigate to the Community page, and click “Add Community Name.” Once a community name is added, the user must link to a relevant building agency. This parameter is required. This and any other required data parameters appear in bold print.

5.3.2 Community Information

In addition to linking to a relevant building agency, a user with Database Login Credentials can also add information to the community he or she creates. This information will appear on the Community Information Page of the California Agency Web Application. However, since these fields are not shown in bold print, they are not required. If these fields have not been completed, a general user will still be able to search for the new community name, but will see nothing on the corresponding Community Information Page.

5.3.3 Agency Contact

Once a community name is added to the database, a user with Database Login Credentials can log off the administration interface and the changes to the California community would be saved and stored in the database. However, if the user wishes to add, edit, or delete information for a California building agency, they must navigate to the Agency page of the administration interface. From this point, clicking on an agency name will bring the user to the data interface for that particular agency. There, the agency information can be edited. Any changes to the agency contact information will appear to general users who subsequently access the Agency Contact page.

5.3.4 Personnel Contact

If the user with Database Login Credentials continues to navigate down the Agency page, they will find further data fields to edit the personnel contact information, shown in the Personnel Contact Information on the Administration Interface.

5.3.5 Permit Data

Permit data can also be edited on the agency page of the administration interface. Changes to these data fields will be seen on the Permit Data Page of the California Web Application.

5.3.6 Documentation and Links

Edited documentation and links on the agency page of the administration interface are shown on the Documentation and Links Page of the California Agency Web Application.

As the California Agency Web Application is currently constructed, all users with administrative privileges may also add and delete California Agencies. It is recommended that this setting be reviewed before public launch of the Web Application, particularly if a large segment of the California solar industry is granted administrative privileges.

5.3.7 Web Application Manager

The manager of the Agency Database web application can add, delete, or edit information to any community or governing agency, as well as control the application backend, which includes the specific data set included for each community and agency in California (the structure of the MySQL database) and the look and feel of the website (HTML and CSS).

The Web Application Managing user group has the ability to code in the Python computing language in order to maintain and directly edit the Django web interface code. This includes any schema changes to the database, i.e. eliminating or adding data parameters.

The Managing user group would also benefit from an understanding of web design. If the look of the web application needed to be changed, it could be altered through the Django HTML scripts.

5.4 California Agency Web Application Development Completed Milestones

Since the initiation of the California Agency Web Application development, the following milestones have been achieved under the SunLink--CSI grant:

1. The web framework, Django, and the open source database management system, MySQL, were chosen to implement the California Agency Web Application.
2. Web design using HTML and CSS was completed for two versions of the California Agency Web Application – one version to match the SunLink web design template, another to match the Go Solar California web design template.
3. The home page search field of the California Agency Web Application was created and debugged. In order to find solar permitting information for a California community, a user must input a California community's name. However, the name may be incomplete and lack capitalization while still resulting in a successful search. In addition, if the string of characters used in the search tool match portions of multiple California communities, all relevant communities and their data will be retrieved and displayed on the web application pages.
4. The California Agency Web Application was ported from a development server to a beta version, deployable server. This transition included numerous code-level changes to the Django framework.
5. The California Agency Web Application database was filled with preliminary data from SunLink's historical California projects.
6. Testing of the web application on various browsers commenced. Small changes were made to the HTML web design in order to ensure design consistency through all major web browsers.
7. The California Agency Web Application was released to the engineering team at SunLink. Users have administrative privileges in order to encourage ongoing data collection and validation as well as error debugging.

In summary, the California Agency Permit Document Requirements Database provides a useful tool for California Solar PV Stakeholders to access important information about agency requirements, specifications, locations, and personnel.

6 Recommendations

During the course of this development project, SunLink performed tasks in several defined areas:

- Engineering Automation – SLDS Engineering Automation
- Process Definition and Automation - Document Management Systems
- Full Scale Laboratory Testing - Seismic testing
- Organization and Access to Fragmented Information - Permitting Database

There are a number of recommendations that flow from this work. These apply at several levels, including the firm, the industry and the regulatory environment.

6.1 Engineering Automation

Firms should take full advantage of both automating their engineering processes and integrating their engineering systems. The development of standards of practice for solar PV will help PV system suppliers, engineering firms, building owners and permitting agencies work more effectively together to develop and share information.

Many smaller PV firms have neither the technical resources nor the capital to support a large scale development effort. SunLink-CSI work in these areas illustrates opportunities for the development of commercial software packages to support solar PV systems, either in the form of add-ons to existing engineering platforms, or new software tools for layout, design, and analysis.

6.2 Process Definition and Automation

California solar PV companies can achieve efficiencies and qualitative benefits through the use of Document Management Systems (DMS). Solar PV companies interested in implementing a DMS should strongly consider performing a pilot. Workflow capabilities, metadata functionalities, and document management features are three areas that our pilot determined to be key factors of successful DMS implementation. A cloud-based installation provides an efficient way to support a pilot and provide a gradual and cost effective entry to DMS deployment.

Developing replicable processes to create and manage engineering deliverables helps reduce the cycle time and number of cycles required to support permitting activities. Reducing plan check cycles makes both solar firms and the solar industry more productive.

6.3 Full Scale Laboratory Testing

Research testing and analysis of full-scale, ballast-only PV systems in seismic regions confirms that displacements due to system sliding during an earthquake are predictable. With the continued dissemination of test results and the evolution of permitting standards, we expect that unattached PV systems will increasingly be permitted on roofs, thereby reducing the cost of rooftop solar arrays and increasing market penetration.

Building codes do not yet specifically address the challenges of designing solar PV arrays. Additional testing can help demonstrate the limits of safe and efficient PV systems operation. This can help support additional penetration of solar in California by increasing the inventory of available roof sites.

The research and analysis performed by SunLink and R+C into the performance of unattached PV systems on roofs in seismic areas was utilized by the Structural Engineers Association of California Solar Photovoltaic Systems Committee to produce a report entitled "Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays."

The results of testing can be disseminated and implemented much more quickly than the traditional code revision cycle. The SEAOC Reports that this research helped support are already being cited by code officials and used as guidelines for permitting solar PV systems in California.

6.4 Organization and Access to Fragmented Information

The California Agency Permit Document Requirements Database created under this grant is an important first step in creating a single point of access for information to support the entire California solar industry. However, any such database must be managed and continually updated to provide any value to its user community. SunLink recommends that the initial site be accessed via the Go Solar/CSI site. One feasible method of updating is to take a Wiki approach whereby members of the California solar community take responsibility for insuring that the information contained is accurate and up to date. Even so, the site will still require some minimal amount of oversight to be successful.

This approach could become a model for organizing and sharing other types of solar information. In particular, there would be clear value in the development of a standard module database with up-to-date module information supplied and certified by the module manufacturers and available to all California solar industry participants.

7 Public Benefits to California

When SunLink and CSI began this project, it was with the explicit goal of increasing solar penetration in California through improvements in several areas of rooftop system design, engineering, and implementation.

The two most immediate and broadly useful SunLink outputs from this effort are 1) the permitting official database, and 2) the near-term direct impact of the seismic testing on code setting for unattached arrays.

Additional public benefit will be garnered over time as the benefits of the engineering automation and document standardization work become widely known and implemented by other solar design firms and permitting agencies.

7.1 California Agency Permit Document Requirements Database

The permitting agency database was initially promised as an application with 10 entries. It was envisioned as a structure, but a nearly-empty one. As delivered, there are 1579 community entries covering all 58 California counties. This is a credible and useful start to what will become a central source of permitting and agency contact data for individuals and solar installation companies alike. When the database is integrated into the Go Solar website, with which its design is compatible, it will be easy to locate and a significant timesaver for those who wish to obtain permits for solar systems.

7.2 Building Code Development for Unattached Solar Arrays

Ballasted, unattached photovoltaic systems are less expensive to install and maintain than connected systems. They have not, however, had a clear path to acceptance in all permitting agencies, and were not addressed by standard building codes. The work performed under this grant has contributed importantly to efforts to incorporate into building codes sections specifically relevant to the wind and seismic characteristics of PV systems.

The seismic testing funded at PEER by this grant was essential to SEAOC in the design recommendations in their report “Structural Seismic Requirements and Commentary for Rooftop Solar Photovoltaic Arrays,” which can be conveyed to the ASCE 7 committee on seismic of building components for possible inclusion in building codes. This is significant because unattached systems enhance building owner acceptance of solar, as building owners are often reluctant to install penetrating attachments through their roof membranes.

In addition to seismic testing, the dynamic wind analysis work funded under this grant is referenced in the SEAOC report "Wind Design for Low-Profile Solar Photovoltaic Arrays on Flat Roofs." This report proposes changes to ASCE 7-10.

SunLink has contributed to the safety and efficiency of installation of commercial rooftop PV in California by providing basic data and analysis essential for improvements in building codes. Better treatment of PV in standard building codes will result in a simpler and more uniform permitting process for all rooftop solar. Unattached rooftop PV systems, with their lower cost and lower risk compared to attached systems, are explicitly treated in the proposed code modifications for the first time. Owing to the decreased cost and risk of unattached systems, the SunLink-CSI seismic test results will ultimately help to lower average costs for rooftop solar and facilitate meeting the solar penetration goals of the California Renewables Standard.

7.3 Standardization of Permitting Packages

The recent SunLink pilot of a DMS has shown the potential of standardization of documents to improve the design and delivery of rooftop PV systems. As standard building codes for PV mature and are widely adopted, it will be possible also to standardize submittals for building permits. This will have a cost benefit that will be another factor helping to lower the cost of solar photovoltaic power in California.

7.4 Benefits to the Solar Industry

Lowering the cost of rooftop solar installations enhances the marketability of solar, increases the number of building owners who may opt for installation, and thus helps toward achieving the Renewables Portfolio Standard of 33 percent of generation in the State of California by the year 2020. Cost savings will arise from both the automation of systems design following the SLDS model, and from the efficiencies and quality improvements available through the implementation of the DMS. The roadmaps provided in SunLink deliverables for these two broad areas will facilitate the process for other solar companies in the state.

8 Conclusions

SunLink appreciates the opportunity to have performed extensive RD&D work under the CSI program. This research project has demonstrated opportunities for numerous benefits to the California solar industry, and has created a roadmap that others can follow to realize similar benefits in their firms.

These benefits include:

- Demonstrated efficiencies of engineering automation
- Better work products due to improved process definition and systems integration
- Improved information sharing and a more efficient permitting process
- Efficient portal-based access to public information
- Opportunities for further work to improve PV solar implementation in California

Finally, this work has demonstrated the value of the public-private partnership approach that can help move the solar industry towards more automated and efficient delivery of roof mounted projects.

9 Technology Transfer – Research Project Knowledge Sharing

Trade Journals and Press

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Maffei, J., Fathali, S., Telleen, K., Ward, R., and Schellenberg, A. (2012). "Seismic Design of Ballasted Solar Arrays on Low-Slope Roofs." Submitted to J. Struct. Eng.

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CSI Final Webinar December 18, 2012 – Itron Oakland offices

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Structural Engineers Association of California Solar Photovoltaic Systems Committee, "Wind Design for Low-Profile Solar Photovoltaic Arrays on Flat Roofs" SEAOC PV2-2012 August 2012.

University Lectures

Mike Williams – Stanford University – Civil and Environmental Engineering – Spring 2011 and Spring 2012

Mike Williams – UC Berkeley – Civil Engineering – Fall 2011