Energy Research and Development Division
FINAL PROJECT REPORT

ENABLING PHOTOVOLTAIC MARKETS IN CALIFORNIA THROUGH BUILDING INTEGRATED, STANDARDIZATION AND METERING IN THE CARBON ECONOMY

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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Enabling Photovaltaic Markets in Calfornia through Building Integrated, Standardization and Metering in the Carbon Economy is the final report for the Enabling Photovaltaic Markets in Calfornia through Building Integrated, Standardization and Metering in the Carbon Economy project (contract number PIR-07-012) conducted by SolarTech. The information from this project contributes to Energy Research and Development Division's Renewable Energy Technologies Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

Best practices and financial models for commercial and residential solar photovoltaic markets were developed by SolarTech through an ongoing outreach effort. This project studied installation costs of single-axis tracked medium concentration photovoltaic systems manufactured by Skyline and factory built pre-assembled modular ground mount solar photovoltaic systems manufactured by SunPods. Data on installation costs of factory and traditional built medium concentration photovoltaic systems using Skyline technology were collected and compared with traditional built on-site medium concentration photovoltaic systems. The study compared assembly speeds for photovoltaic arrays at different facilities. Results showed that significant amounts of time were spent walking and standing. In a well-designed factory much of this time could be eliminated. A significant amount of time was spent in material handling and the authors concluded that industrial engineering was needed to improve material handling efficiency. Specifications for material handling were included in this report. The first two arrays were constructed at a rate of 1.9 kilowatts per worker per eight-hour shift. This rate had improved to 4.1 kilowatts per worker per shift by the final 100 kilowatts. Data on installation costs of three smaller solar arrays in the 14-25 kilowatt range using SunPods' factory built arrays were collected and compared with traditional built on-site ground mount systems. The results showed that SunPods' arrays reduced on-site labor costs by up to 90 percent and reduced overall labor by a minimum of 50 percent when compared to traditional ground mount systems built on site. SunPods' cost now averaged $2.90 to $3.25 a watt per kilowatt power block on large utility-scale projects, which was projected to drop further with larger installations and economies of scale. This was a lower cost compared to the approximate $4.50 per watt analyzed in the National Renewable Energy Laboratory SolarTech study of 2010 for commercial scale projects.

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EXECUTIVE SUMMARY

Introduction

The high cost of solar PV modules represented the majority of a solar array system's cost and installation costs were not a factor until recently. The solar industry put little effort into reducing the cost of installation. The cost of installation and balance of system costs have recently begun to exceed the cost of the solar modules and associated hardware costs and these costs now represent the next area of focus in cost reduction. Traditional ground mount systems require larger installation crews, more man-days to assemble and more building inspection steps by the local permitting jurisdiction for concrete footing frame assembly and electrical wiring. Construction can be easily delayed and affected by weather conditions.

Project Purpose

The goal of this project was to develop and promote best practices for commercial and residential PV markets, including lowering the balance of system costs as a percent of the current $9/watt (W) system costs to $5/W and reducing the end-to-end PV project time from the current 25-50 weeks to nine weeks by 2013. Another goal of the project was to develop innovative financial models and market mechanisms that could enable solar PV to find cost parity with utility grid power without government incentives.

Specific research objectives included:

- Contribute to lowering installation costs by 40-45 percent by developing Plug & Play technology for residential and commercial systems.
- Contribute to lowering installation costs by developing, documenting and disseminating installation best practices for residential and commercial systems.
- Improve and extend the system lifetime for financial compatibility with typical utility energy generation models through better performance monitoring, string-level microinverters and supermodule assemblies.
- Bundle building integrated PV systems with energy efficiency for residential markets. This would enable a carbon economy as per California Assembly Bill 32 through real-time monitoring with carbon credit meters and creating reports of individual sites that generate carbon offsets, including a complete financial model of key variables for evaluation and recommendations for policy changes.
- Identify projects for demonstration installations to illustrate the benefits in the first four objectives in "real-world" applications, including the Santa Clara University 2009 DOE Solar Decathlon Solar House.

Project Results

Installation costs of single-axis tracked medium concentration PV (MCPV) systems manufactured by Skyline and factory built pre-assembled modular ground mount solar PV systems manufactured by SunPods were studied. Data on installation costs of factory and traditional built MCPV systems using Skyline technology were collected and compared with traditional built on-site MCPV systems. The study compared assembly speeds for two arrays at Skyline Solar's headquarters in Mountain View, California; a two-array demonstration system in Durango, Mexico; and the final 100 kilowatt (kW) of a 500-kW installation in Durango. Detailed time studies were conducted of the Mountain View assembly tests and the results showed that significant amounts of time were spent walking and standing, both with and without parts in hand. Much of this non-productive or minimally productive time could be eliminated in a well-designed factory in the field. The Mountain View builds clearly showed that time spent in material handling (preceding actual assembly) was significant and that industrial engineering was needed to improve the efficiency of material handling. Specifications for material handling developed by Skyline were included in this report. The first two arrays in Mexico were constructed at a rate of 1.9 kW per worker per eight-hour shift. By the final 100 kW, this rate had improved to 4.1 kW per worker per shift.

Data on installation costs of three smaller solar arrays in the 14-25 kW range were collected and compared with traditional built on-site ground mount systems. These solar arrays used SunPods' factory built arrays and were shipped to the host site. The results showed that SunPods' arrays reduced on-site labor costs by up to 90 percent. SunPods' factory built solution reduced overall labor by 50 percent or more when compared to traditional built on site ground mount systems due to reductions in overall manpower time to build, fabricate and install the systems. SunPods' all in cost on large utility scale projects averaged $2.90 to $3.25 a watt per kilowatt power block and was projected to drop further with larger installations and economies of scale. This is a lower cost in comparison to the approximate $4.50 per watt analyzed in the National Renewable Energy Laboratory (NREL)-SolarTech study of 2010 for commercial scale projects.

Integrated photovoltaic (PV) systems with energy efficiency for residential markets and for enabling a carbon economy were studied by Santa Clara University (SCU). SCU developed an innovative carbon meter, conducted direct current to direct current (DC-DC) shade mitigation quantification research and monitored net energy savings in 2007 and 2009 United States Department of Energy (U.S. DOE) Solar Decathlon Solar Houses on the SCU campus.

This carbon meter study developed a methodology to measure the real-time energy footprint of a building structure including conventional and renewable energy sources and energy losses, taking into consideration daily and seasonal weather loads. The methodology could be initially applied to set a baseline for a candidate structure for upgrades then monitored in real-time after upgrades to quantify energy savings and/or convert to carbon credits. This would be ideal for a negawatt financing structure. A patent application was submitted for the methodology developed.

The DC-DC shade mitigation quantification research developed a methodology to measure and quantify the shade mitigation benefits of the various devices coming on the market, such as

microinverters, alternating current (AC) modules and DC to DC power management. The results of the study could be further developed into a standard.

The carbon meter and shade mitigation research were demonstrated on the 2007 and 2009 U.S. DOE Solar Decathlon Solar House at SCU. The 2009 Solar House was displayed on the Washington, D.C., Mall during the Solar Decathlon contest week in October 2009. Throughout the grant program the 2007 Solar House served as a living lab for these developments.

Project Benefits

This project demonstrated how installation costs for residential and commercial solar PV systems could be reduced. Reduced installation costs could make solar PV technologies more competitive with other forms of energy and could increase the market penetration of these technologies. Increased use of solar energy would reduce greenhouse gases that contribute to climate change as well as other air emissions that cause air pollution.

CHAPTER 1: Introduction

In 2008 SolarTech's evaluation determined that the State is not likely to meet its CSI goals of 3000MW by 2017 under the current system of delivering Solar PV systems to residential and commercial customers. The Recipient has identified six major market barriers of which four are addressed in this grant: Permitting, Performance, Installation and Financial. The purpose of this grant and related projects are to accelerate the growth of PV systems in the residential, commercial and industrial sectors by reducing installed system costs, removing barriers to market growth and maximizing the net value of solar systems and the renewable energy produced. The Value Delivery Chain for Solar PV is plagued with inefficiencies and unnecessary costs. The traditional construction trade mode of delivery, which treats every installation as a custom project, is inefficient. The Recipient believes removing inefficiencies and costs is both possible and necessary. In order to meet the CSI objectives, the end-to-end delivery process of Solar PV to the customer must improve by 15-18 percent annually through 2013. The Recipient plans to achieve this goal by developing and recommending best practices, providing industry standards for installation systems, integrating energy efficiency of buildings into the energy quantification, improving performance of PV systems through Supermodules, offering market and financial analysis and recommendations, and enabling a carbon credit market.

1.1 Research Goals, Objectives, and Approach

1.1.1 Research Goals

- Through the development and promotion of best practices for commercial and residential markets:
    - Contribute to lowering the balance of system costs, as a percent of the current $9/Watt (W) system costs to the projected $5/W system costs.
    - Reduce the end-to-end PV project time from the current 25-50 weeks to 9 weeks by 2013.
- Develop innovative financial models and market mechanisms that could enable Solar PV to find cost parity with Utility Grid power without government incentives.

1.1.2 Research Objectives

- Contribute to lowering installation costs by 40-45 percent with the development of Plug & Play technology for residential and commercial systems.
- Contribute to lowering installation costs with the development, documentation and dissemination of Installation Best Practices for residential and commercial systems.
- Improve and extend the system lifetime for financial compatibility with typical utility energy generation models through better performance monitoring, string-level microinverters and Supermodule assemblies.
- Bundle building integrated PV Systems with energy efficiency for residential markets, enabling a Carbon Economy as per AB 32 through real-time monitoring with Carbon Credit Meters, create reports of individual sites that generate Carbon-Offsets to include

a complete financial model of key variable for evaluation, and recommend policy changes.

- Identify projects for demonstration installations, including the Santa Clara University 2009 DOE Solar Decathlon Solar House, to illustrate the benefits in the first four objectives in "real-world" application.

1.1.3 Research Approach

Industry Best Practices, Management Strategies, Innovative Financial Models, and Market Mechanism

SolarTech was responsible for the Industry Best Practices and Management Strategies section and the Innovative Financial Models and Market Mechanisms.

SolarTech is an industry association working in the following six areas to lower the business process costs or otherwise hidden soft costs of growing the solar PV market:

- Performance metrics and reduction of ambiguity to the consumer
- Installation best practices
- Streamlining the Utility Interconnection process
- Streamlining the permitting process
- Streamlining Finance and/or driving new and innovative ways to finance solar
- Defining workforce development needs and guiding training institutions for training delivery

Each one of these initiatives is backed by an industry member led committee. The Committee performs three key functions:

- Define market need and amplify the call to action
- Identify existing solution and promote
- Identify solution gaps and propose new standards and best practices

All of the above is accomplished through a variety of methods from industry surveys, forums, symposiums, Summits, committee working groups to partnerships with other industry associations. Thus the most effective approach that garnered the most industry input was to leverage the SolarTech committee leadership process to identify and deliver to the grant objectives.

The SolarTech Installation committee can take responsibility for the Microinverter and AC Module Application Guide.

The SolarTech Performance committee can take responsibility for the SEE report and the performance work with Sandia Labs leading to the securitization efforts with the Finance Committee and CalCEF.

The SolarTech Permitting committee can take responsibility for the Online Permitting Interoperability standard, surveys and numerous studies.

The SolarTech Finance committee can take responsibility for the many legal templates developed to reduce transaction costs and the securitization efforts with the Performance Committee and CalCEF.

This allowed for an industry voice, vetting of ideas and subsequent adoption.

Carbon Meter, DC-DC Shade Mitigation Quantification, and Santa Clara University 2007 & 2009 DOE Solar Decathlon Solar Houses

Santa Clara University was responsible for three major items:

1. Carbon Meter Methodology for AB 32 and resulting patent application
2. DC-DC Shade Mitigation Quantification Methodology
3. Demonstration installations on the Santa Clara University 2007 & 2009 DOE Solar Decathlon Solar Houses

All three were university/student research projects through the Office of Sponsored Research, and proceeded in that fashion:

1. The carbon meter project developed a methodology to measure the real-time energy footprint of a building structure including conventional and renewable energy sources, and energy losses taking into consideration the daily and seasonal weather loads. The methodology can be initially applied to set a baseline for a structure candidate for upgrades, then monitored in real-time after upgrades to quantify energy savings and/or convert to carbon credits. Ideal for a mega-Watt financing structure. A patent application has been submitted for the methodology developed.
2. The shade mitigation study developed a methodology to measure and quantify the shade mitigation benefits of the various devices coming on the market, such as microinverters, AC Modules and DC to DC Power Management. The results of the study can be further developed by the Energy Commission into a standard.
3. Both of the above developments, and additional developments, are demonstrated on the 2007 & 2009 DOE Solar Decathlon Solar House on the campus of Santa Clara University. In addition the 2009 Solar House was displayed on the Washington DC Mall during the Solar Decathlon contest week in October 2009. Throughout the grant program the 2007 Solar House has served as a living lab for these developments.

These projects allowed a number of undergraduate and graduate engineering students at Santa Clara University to refine their engineering skills in the renewable energy sector and contribute to some very significant developments. Installation costs of single-axis tracked medium concentration PV (MCPV) systems manufactured by Skyline and factory built pre-assembled modular ground mount solar PV systems manufactured by Sunpods

Skyline Solar was responsible for proving the Supermodule concept based single-axis tracked medium concentration PV (MCPV) technology. The Skyline project and the SunPods project share key goals with one distinction. The difference is technology. Both projects aimed at proving that a more efficient approach to commercial and industry scale solar would reduce the installation costs and thus the overall cost per Watt installed. Skyline would demonstrate that the concept was applicable to concentrating solar technologies and SunPods would demonstrate that the concept would benefit flat-panel solar technologies. The basic concept is no different than that which was originally pioneered by Henry Ford in 1907 to lower automotive production costs, extended to hundreds of other industries in the last 100 years to streamline a factory approach, and remove the in-field custom component costs. The goal for solar is to demonstrate and publish that these same efficiency and cost reduction techniques apply to solar PV regardless of technology and project size. In fact the cost benefits should increase with size just as a larger automotive factory is more cost efficient as the variable costs begin to dominate over the fixed costs.

Installation Cost of Supermodule Concept Based Single-axis Tracked Medium Concentration PV (MCPV)

Skyline Solar is a solar PV system manufacturer focused on reducing system costs through innovative assemble methods. Skyline is focused on brown-field, and other open space applications. Skyline is a pioneer in medium concentration silicon-based technology, or as they refer to as High Gain. The product design already existed, but a redesign was initiated to make it easier to assemble in the field, and use a "kitted approach." The next phase of the research approach was to identify several projects that could be tested against standard installation techniques for cost benefit analysis. In order to comply with the grant contract deadline a project in Durango, Mexico was chosen when the first choice of Edwards AFB was delayed. The Durango project was divided into a 100kW and 400kW section to allow cross comparison of old versus new methods. After an initial 7.5kW pilot to refine the techniques, the 100kW section saw the application of the new method. The projects were constructed and then compared for installation costs improvements. Data was collected, analyzed and reported.

Installation Cost of Factory Built Pre-assembled Modular Ground Mount Solar PV

SunPods contrasted with the Skyline project by offering a different technology approach to proving a similar factory manufacturing approach to lowering costs.

SunPods is a solar PV system manufacturer focused on reducing system costs through innovative factory assemble methods. SunPods is focused on the agricultural, brown-field, landfill and other open space applications. SunPods is the first company to manufacturer a complete system in a factory and ship direct to the site. Minimum field installation required. Since the product design already existed the research approach was to identify several projects that could be tested against standard installation techniques for cost benefit analysis. Systems were built and shipped to three different size projects and then compared to installation costs of comparable sized traditional installations. Data was collected, analyzed and reported.

Chapter 2:
Research Results

2.1 Industry Best Practices, Management Strategies, Innovative Financial Models, and Market Mechanism

As described in section 5.3, SolarTech leveraged its committee structure and membership to explore two separate areas of research:

1. Best Practices and Management Strategies
2. Innovative Financial Models and Market Mechanisms

The first program activity resulted in the following key products:

1. 2010 SolarTech PV Adoption Consumer Study Summary
2. Solar Energy Estimate (SEE) Report implementation and launch
3. Online Solar Permit Application Inoperability Standard
4. Microinverter & AC Module Application Guide
5. Solar PV System Performance Assessment Guideline
6. 2011 Study of Solar Permitting & Inspection, and Adoption Dashboard proposal
7. Solar3.0 National Platform for Dissemination of Best Practices and management Strategies

The second program activity split into two areas:

1. Reducing Transaction Costs through standardized transaction documents
2. Increasing Credit and Liquidity through securitization establishing Solar as an Asset Class

The first program activity began in 2009 with SolarTech leading a team of industry leaders to develop a suite of documents to lower transaction costs. Since late 2010 transaction costs and credit liquidity have been major topic of discussion at all SolarTech finance events and forums. The industry leaders who significantly contributed to these works were law firms Milbank, K&L Gates, Paul Hastings, Stoel Rives, and Wilson Sonsini; the accounting firm of Davis Wright Tremaine, LLP; project developers Beyond Solar, Photon Energy Solutions and Tioga Energy; and the Grenich Capital renewable energy fund. Their significant contribution of pro bono time and talent (sometime exceeding $40,000) made this work possible.

Over the course of this research, SolarTech produced 13 products and influenced several major national initiatives. The products include and are further explained:

1. Purchase Power Agreement (PPA) and Site Lease Contract Templates

2. Engineering Procurement & Construction Agreement Template
3. SolarTech Operating Lease Agreement
4. Due Diligence Checklist
5. Finance Option Tutorial
6. Finance RFI and Companion Spreadsheet

The securitization effort didn't begin until late 2011. A team of highly influential individuals, led by SolarTech and CalCEF, has been assembled into a working group to explore the barriers to this topic and work towards a demonstration project by the end of 2012. However, outside of committee meeting reports, no physical work product was produced by the conclusion of the grant. The results and plans of this securitization working group are detailed in the separate report SolarTech published for the Finance phase of this program. However, it is important to note that the securitization discussion within the industry is long overdue, but now making considerable progress due to the leadership of SolarTech and CalCEF in part funded by this PIER grant.

Other Major Initiatives Influenced by this Grant Include:

Solar PV Permitting and Inspection guidelines and recommendations to jurisdictions forthcoming from the Governor's office in the next two months.

DOE SunShot RoofTop Challenge and the focus on Permitting and Inspection

DOE SunShot Solar3.0 and the focus on Permitting, Inspection and Inspector Training

Sandia National Labs Performance Research and Modeling

NREL Study of Balance of System Soft Costs

2.1.1 SolarTech PV Adoption Consumer Study Summary

The study examined the attitudes and concerns of consumers towards the purchase of a residential solar PV system. The study analyzed 224 respondents from Santa Clara County, a significant solar market, and targeted median income families. 11 percent of the respondents owned solar PV systems at the time of the study. The study highlighted several consumer confusions which imped the purchase decision:

- Level one – Price, reliability, warranty, and incentives
- Level two – Installation ease, return policy, aesthetic appeal, and modular design
- Level three – Financing Instruments, i.e. loans and leases

Most surveyed (97 percent) felt the price was too high even though their understanding of current prices was inaccurate (on the low side for 2010 prices), and reliability was the next major concern at 94 percent.

The most interesting result was the response to an unaided question to name a solar firm they can recall. Regardless that most survey respondents claim to be knowledgeable and have researched solar (42 percent via internet for solar specific, 91 percent via internet for general information, and 82 percent through friends and family for general information) 63 percent of the respondents could not accurately name any single company that provides solar residential services. This also included those who owned panels and those who didn't.

The release of this report was promoted with both a press release and webinar in early 2011.

The webinar was recorded and is available on SolarTech's web site.

This report was one of the elements that led to the next product for discussion, the Solar Energy Estimate (SEE) Report.

2.1.2 Solar Energy Estimate (SEE) Report Implementation and Launch

During the 2009 and 2010 Annual SolarTech Performance Symposium in partnership with InterSolar North America (typically July in San Francisco), an industry call to action by the participants was for a better performance prediction tool for residential consumers. This need and call to action was echoed at the annual SolarTech Leadership Summits for 2010 and 2011 during the performance breakout sessions. Thus began the definition and development of the Solar Energy Estimate Report.

The SEE Report concept is modeled on the well-known Federal EPA miles-per-gallon rating system for new cars. In the new car market (and by extension the used car market) consumers have become very familiar and confident in this rating system to assist in their purchasing decisions. Yes, the consumer knows that their individual mileage will vary, but as a neutral, reliable relative measurement it has become an important decision making tool. Surveys (other reports included in this grant) of existing tools indicated considerable difficulty for even sophisticated users, and thus beyond the realm of usefulness for unsophisticated consumers simply wanting some simple answers. Four requirements for the ideal consumer-facing tool were identified:

- Easy to use with minimum of input variable the consumer would have to track down.
- Standardized default parameters and calculation methods. The EPA MPG rating model differs from solar PV in one important respect. New cars are standard products that can be road tested as built. Solar PV proposals are un-built custom project with predicted not actual performance. However, the performance committee and industry participants eventually agreed on a standardized calculation process leading to the same end goal. This includes locating the service at a single internet portal in order to control the standardization, and disallow "gaming" the numbers.
- Standardized reporting format. A simple one-page PDF report was designed with the consumer in mind. All performance predictions and background information are plainly visible in the same format regardless of who generates the report.

- Easily linked to any solar PV quotation system and intended to complement existing quotation tools with an easily verifiable standard. The typical solar sales person should easily be able to offer their client the standard quotation tool output and the SEE Report. The SEE Report would set a reliable confidence building baseline for consumer purchasing decisions.

The industry participants felt that the ideal would be a tool that predicted $/kWhr and not just kW system output and annual kW production. However, $/kWhr predictions are highly dependent on rate schedules and financing structures creating a complex set of variables that need more industry discussion before agreement can be reached on standardization.

The SEE Report also aimed to be as consistent as possible with the CSI EPBB calculator under the same input conditions, and both use PV Watts as the main calculation engine. The SEE Report locks down more of the default variable, making it difficult for the sales person to increase production predictions by lowering degradation factors, which the consumer wouldn't understand. The values of the degradation factors are clearly displayed on the report. However, it does allow manufacturers to adjust how their name-plate STC ratings are used in the calculations. There is a trend in the industry to screen module products from centered at the STC rating to the STC rating representing the worst case minimum of the production population distribution. The SEE Report calculation tool is built on the existing SolarHub industry database tool containing a wide range of manufacturer product information under the control of the manufacturers. This allowed for a means to include a variable the manufacturers could control to tell the SEE report to either degrade the STC rating (or not) to be consistent with the manufacturers true understanding of their product's performance. SolarTech believes this is a valid approach and doesn't impact consumers in any negative way.

A webinar was conducted in March 2011 to secure final industry agreement to proceed; development began in June 2011, with introduction via a press release in October 2011. A webinar was held in December 2011 to build on the announcement.

Subsequent to the release SolarTech has need working with the various solar sales tool manufacturers to promote and build adoption for the SEE Report in the residential space. In February 2012 a team of marketing students from San Jose State University began development of a marketing plan to better drive adoption to both consumers and installers. This plan is due to be unveiled during another webinar planned for May 24th.

Visit www.solarhub.com.

2.1.3 Online Solar Permit Application Inoperability Standard

This document is written with several players (stakeholders) in mind who have roles and responsibilities that either directly or indirectly relate to the online permitting process. Some of these players require conceptual process information, while others, particularly software vendors, require enough technical information to understand the proposed interoperability standard. These stakeholders include:

- City building departments that must approve and inspect photovoltaic system installations
- Solar integrators (contractors) who install photovoltaic systems
- Software vendors who develop Web-based permit applications to expedite the manual building process for photovoltaic systems
- Utility companies that connect the photovoltaic installations to the power grid and provide rebate incentives to consumers

It is important to note that this document represents Phase I of the Online Permit Application process interoperability standard, and as such, it describes a general approach to automating the building permit process and its interfaces to the various stakeholders. This approach makes it easier to understand the proposed software standard as a means of communication between the stakeholders. Because this document describes a proposed online solution, it is also important to note that this solution has yet to be prototyped or tested.

Considerable industry input went into this deliverable to address the ongoing conversation on the impact of Permitting, Inspection and Interconnection. This remains a key area of industry concern, as illustrated by the most recent SolarTech survey in 2011. It is the number one issue in permitting sections of all four annual SolarTech Leadership Summits; and several Permitting and Interconnection Symposiums hosted by PG&E and Southern California Edison. Although SolarTech will not claim that this specific document has been adopted by any particular jurisdiction or software provider (although it was demonstrated at SolarTech's 2010 Summit), the constant drum beat of SolarTech sensitizing the industry to this issue through numerous seminars is making progress. In May 2012 the City and County of San Francisco (CCSF) will release the first truly online solar PV permit application, with several East Bay jurisdictions affiliated with the East Bay Green Corridor (EBGC) studying a new third-party solution for possible adoption. Several jurisdictions in Sonoma County are following the developments of EBGC and CCSF for possible follow-on adoption. Continued awareness building by SolarTech will lead to broader state-wide adoption and improvements.

2.1.4 Microinverter & AC Module Application Guide

With the variety of organizations involved in the installation side of solar PV creating standards and best practices, and the reluctance of solar project integrators to either share their internal process or adopt an externally developed process; it was difficult to determine the most valuable contribution SolarTech could make with the grant. For example the DOE Solar Instructor Training Network rolling out in 2011 would cover a wide range of current best practices; as well as training offered by Underwriters Laboratory University, International Association of Electrical Inspectors (IAEI), International Code Council (ICC) and Interstate Renewable Energy Council (IREC)'s certification of training institution for (North American Board of Certified Energy Practitioners**)** NABCEP certified installer and sales training programs. These programs were already rolling out at the time the grant was awarded to SolarTech in June 2008. Initial efforts by the SolarTech Installation Committee in an installation manual fell short of what was already available. In 2009 SolarTech's Installation Committee

began a series of conversations with industry stakeholders concerning the real "upcoming" needs. The real concern, that no one was addressing, was the microinverter and AC module products on the horizon. The leader Enphase had already suffered through numerous product installation delays caused by building inspectors unfamiliar with the new technology, and the potential for more delays due to new technology confusion was a growing concern. This led to the first Microinverter and AC Module Forum in March 2010 hosted at Intertek. Over 30 different companies attended including building inspectors and other code experts. The consensus was to focus on an application guide for code officials and integrators for microinverters and AC modules. A draft outline proposal was ready for review by the next Forum hosted by SolarTech in March 2011 at UL.

Following this forum a team was assembled and worked diligently for 7 months to pull the final document together in time for introduction during the Solar Power International time frame in Oct. 2011.

This is a significant product of importance to the industry. It clearly spells out existing and applicable National Electronical Code (NEC) 2008 and 2011 building codes (article 690), UL 1703 and 1741 standards and IEEE 1547 in how they are to be applied to the safe and effective installation of microinverters and AC modules. Written in plain English, this document provides a ready guide for installers and building inspectors to streamline any negotiations or confusions during the PV permit application process or final inspection process.

The document was introduced through a webinar in December 2011, and a third Microinverter forum was held in March 2012 to discuss improvements towards a second revision and other supporting tools. The consensus from the March 2012 forum was to condense the document to a single page laminated quick reference guide. Subsequent to that meeting SolarTech's Solar Sonoma County partner in the DOE RoofTop Challenge grant proposed a similar laminated quick reference guide for general installations issues. SolarTech will be working in 2012 to combine these two efforts into a single project and drive development as part of the 2012 Installation Committee plan.

This document is available as a download from www.solartech.org for $29.95. The 2012 goal is to develop a double-sided laminate version that installers can "toss" in their toolbox.

2.1.5 Solar PV System Performance Assessment Guideline

The purpose of this project has been to summarize existing performance metrics commonly used in the industry and to outline effective assessment metrics and associated calculation methods considering factors such as level-of-effort to perform the assessment (cost) and the value of the assessment (benefit). Consideration was given to the size of the system, availability of data, relative uncertainty inherent in the assessment, short-term or long-term assessment periods, known degradation mechanisms, and relevance to the industry need. The project included research, summarizing and comparing methods, evaluating effectiveness, and generally evaluating performance assessment methods currently used during and after commissioning. The objective of the project was to define methods which would enable quick identification of actual performance that deviates from expected performance.

Values for performance metrics, such as final yield, daily and monthly performance ratio, and AC DC yields, are often stated in reports, plots provided, and shown occasionally with uncertainty bars. The plots illustrate typical seasonal variation and the influence of weather and derating conditions, and are interesting but they are not useful to make near-term decisions. Relatively large uncertainty, which is inherent in metrics for short assessment periods, is not pointed out. Attempts have been made to reduce variation but work is still needed to make these metrics more useful.

The Performance Assessment guideline is applicable to and may be used on any size system, however is targeted for the PV market segment of 100kW and larger systems which use technologies where the module characteristics are provided by the manufacturer and for which performance models are available. The guideline focused on systems with fixed flat panel PV modules.

The purpose and need for performance assessment can best be summarized from an owner's perspective by the questions that are often asked:

1. How is my system, or portion of my system, performing currently in comparison to how I expect it to perform at this point in its life?
2. How is my system performing for both the short-term and long-term in comparison to how it is capable of performing with its given design and site location?
3. How is my system performing over an assessment period in comparison to other, similar systems in similar climates to help make operating and maintenance decisions?
4. Did I get what I paid for in terms of cost of energy?
5. How is my system performing compared to the last assessment period (trending)?
6. What is the annual kWh AC energy production per installed KW DC (Yield)
7. What is my cost of energy in terms of initial and maintenance costs relative to kWh energy production over the life of the system?
8. When do I need to do maintenance, such as cleaning, based on performance?
9. Aware that an individual module is damaged based on inspection, but the overall system performance is not noticeably affected, how do I do a more accurate performance assessment to determine if other modules are damaged?

The purpose of the assessment affects which metric is appropriate to use. For example, the commonly used metric of Performance Ratio (PR), as defined by IEC61724 and NREL, is appropriate to trend a specific system or compare systems in similar geographic locations. If PR is used to evaluate a system in San Francisco, CA, compared to a similar system in Daggett, CA, incorrect conclusions would be reached. Specifically, using PVWATTS Version 1, a 100kW system in San Francisco with latitude tilt has a calculated PR of 0.73 with an output of 145,000 kWh/year, while a 100kW system in Daggett with latitude tilt has a PR of 0.69 with an output of

171,000 kWh/year. Even with a lower PR, the Daggett system has higher output and therefore higher performance.

One purpose of the performance assessment is to detect changes in system performance; usually decreases in performance, to allow the system owner to investigate and potentially perform cost effective maintenance. This can be done best on a relative scale of trend where the specific performance of the system is compared to itself. If the design related derate factors or calculation methods are not exactly correct, this approach reduces sensitivity of the metric value to the assumptions used.

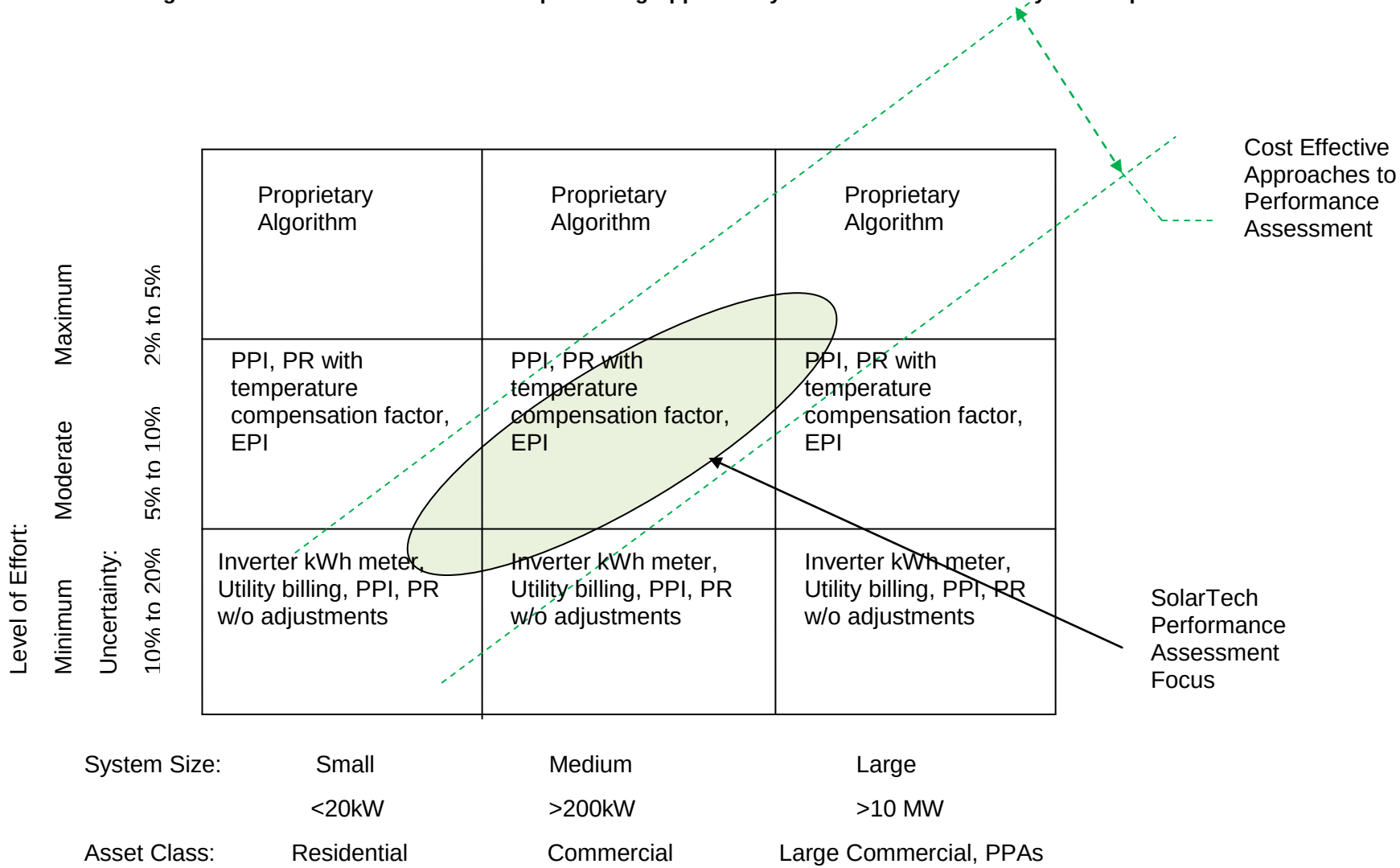
Another purpose is to provide a performance parameter to compare systems of potentially different designs and locations on an absolute scale. In this case it is necessary to use multiple derate factors or alternatively an accepted PV model to calculate expected performance with actual weather data over the assessment period. The actual performance divided by expected performance would then determine a Performance Index (PI), in this case an Energy Performance Index (EPI).

The performance assessment method and associated metrics used must also consider the cost and benefit of the assessment. Generally, the degree of accuracy and depth analysis correlates to the level-of-effort and cost. The level-of-effort related to the amount of data and analysis in the performance assessment should be comparable to the expected benefits gained. Small systems could use simplified methods, with correspondingly greater uncertainty (10 percent to 20 percent) but still having the capability of detecting equipment failures and degrading conditions. Larger systems typically have comprehensive monitoring systems and analysis algorithms with correspondingly lower uncertainty (2 percent to 5 percent) to detect subtle performance changes.

It should be emphasized that system performance is different than system value. The performance of a system is related to actual AC energy output relative to its capability as designed and operated; whereas, value of a system is the system cost relative to the annual AC energy output. Also, performance is different than reliability. Failures affect reliability which in turn affects performance.

Figure 1 shows the relative types of assessment and the applications.

Figure 1: Performance Assessment Map Showing Applicability of Guidelines Covered by This Report



The guideline was developed to be applicable to fixed flat panel PV module technology.

The final report has been drafted, but was still under review by Sandia Labs and the SolarTech Performance Committee at the time this report was drafted. Final publication is expected by summer 2012 and will be available on SolarTech's web site.

2.1.6 2011 Study of Solar Permitting & Inspection

Annually since 2009 SolarTech has conducted a study of permitting and inspection issues and gagging improvements. 2011 was the first year where we could get a very comprehensive result across a large region of the Bay Area[1]. This study was able to look at both integrator responses and authority having jurisdiction (AHJ) (building officials) responses in a significant way.

No surprise, neither side agrees on how long a permit application should take. However, the real surprise is the difference in responses relative to the antidotal claims. 50 percent of the responding Integrators claimed it takes less than a day. While only 29 percent of the responding AHJs claimed less than a day and more than 86 percent claiming less than a week. The Integrator distribution had a long tail meaning that over 45 percent of the respondents claimed a week to more than two weeks. This is probably the source of numerous industry complaints.

Often the AHJs will claim that the delay was caused by the integrator not submitting the right information (as requested in published city's guidelines); and the integrator will claim that the city's process is too burdensome. Often both are correct, and an industry-wide resolution will promote more solar PV growth.

In terms of issues most likely cited for inspection failures, Integrators responded that signage and grounding was the most common; and AHJ noted general electrical issues.

The small portion of non-solar inspection failures (<14 percent) were generally related to California Fire Code issues.

Also more than half of the AHJs responding indicated and strong willingness to work towards a common uniform code platform for solar PV across a wide region. This is great support for the initiatives that San Francisco, Solar Sonoma County and East Bay Green Corridor will undertake in 2012 for the DOE RoofTop Challenge.

However, just new permitting and inspection statistics was not the whole point of this project. Clearly differences in interpretation of reality between the Solar Integrators and AHJs will exist for some time to come in spite of improvements or absents thereof. How can we best capture those perceptions in the future for a realistic evaluation by city or state officials or industry trade groups?

[1] Subsequent to the release of this report, SolarTech partnered with NREL and Lawrence Berkeley National Labs to conduct a comprehensive national survey. These results are discussed in a separate report.

Thus the second half of this project was to explore and define an Adoption Dashboard to monitor the adoption status and progress of integrators and AHJs towards commonly accepted and efficient processes in the areas of permitting, inspection and interconnection.

Similar in concept to Yelp.com, it allows for a straight-forward ranking process where integrators can rank AHJ performance as well as the AHJ providing a self-ranking and supporting materials.

This is a proposal that could be deployed statewide, and then driven nationally as a California best practice leading the nation.

This is a very well thought out and fully illustrated proposal concept. Should funding become available to build a demonstration prototype, we believe this will improve the data gathering on the whole of topic of permitting, inspection and interconnection, and over time narrow the gap between integrators and AHJs in sorting out the difference between actual versus perception.

2.1.7 Solar 3.0 National Platform for Dissemination of Best Practices and Management Strategies

As discussed earlier, there are many governmental and non-governmental organizations in the solar PV space working to improve the solar industry and SolarTech's goal is to promote those efforts whenever appropriate instead of "reinventing the wheel" to use that cliché.

Thus a major contribution of this grant was the development of a dissemination platform, first begun in early 2011 as the California Solar Challenge. With the successful award of the Solar3.0 grant from the DOE as part of the SunShot Program, SolarTech now has a three-year funding stream to work with the major partners at a national level to build out the National Platform concept. Those partners include:

- International Association of Electrical Inspectors
- UL University
- Interstate Renewable Energy Council and the Solar Instructor Training Network
- ICLEI – Local Governments for Sustainability

Besides establishing the website as a one-stop for dissemination of ALL best practices, Solar3.0 will also actively push these tools and developments to interested communities and businesses starting with the top 100 based on market assessment; more than half are in California.

The first priority is training. Over the last couple of years a wealth of instructor training (train the trainer) targeting integrators and inspectors training has been developed. Now the task is to get it out there and get people better training, both inspectors and installers. This is the key goals of Solar3.0. The Solar3.0 team, in conjunction with IREC and DOE, will be launching a series of training leveraging the SITN (Solar Instructor Training Network). The RoofTop Challenge team (North SF Bay Area, led by SolarTech) will do likewise locally in conjunction with the City College of San Francisco, which is the local technical resource for Northern

California for the SITN. The SolarTech RoofTop team will be conducting a series of such trainings (both technical and process based) over the next year and collaborating with the four other California RoofTop teams to share best practices. All under the umbrella of the Solar3.0 Platform.

Germany is often cited as the model to emulate. One of the items SolarTech's research discovered in the depth of installer training in Germany resulting from its long history of trade unions and guilds. The singular benefit of this has been the acceptance of "self-inspection." The integrator doesn't have to wait for the local city AHJ inspector to sign-off on the project. His training and certifications allow him to sign-off on his own work, without wasting the time waiting for an inspector.

There are many cultural factors that may or may not allow US solar PV inspections to evolve in that direction (although it did with solar thermal), however, it is clear that the better both inspectors and integrators are trained the better off the overall industry will be and be able to grow and the most optimum rate.

This can be found at www.solartech.org and the official SunShot Solar3.0 website which is www.solar30.org.

2.1.8 Purchase Power Agreement (PPA) and Site Lease Contract Templates

This is a full featured contract template for Power Purchase Agreements, including the Site Lease agreement. It has been characterized as one of the most balanced agreements between the project developer, off-taker and funding entity. As a $395 download from the SolarTech website it represents just one hour of legal time for what could run as much as $100,000 for custom contract template from a mid-level law firm. Firms with more standing in the energy field charge considerably more.

The download consists of the fully editable WORD source that the client's legal counsel is at liberty to modify. All downloads are free to SolarTech members, and we have no means to track member downloads. However, for non-member downloads at $395, over $40,000 have been sold since the document was released in 2010, including some international customers. This speaks for itself as to the value of the document and potential savings.

2.1.9 Engineering Procurement & Construction Agreement Template

After the PPA contract is signed then the selected EPC firm will require a construction agreement in order to begin procurement and construction. This document provides another template for those interested in getting into this part of the business.

2.1.10 SolarTech Operating Lease Agreement

This is a standardized lease template offered by SolarTech for operating lease structures used to finance solar PV projects. This Form of Lease is designed for use with projects located in California, but can be adapted for projects located in other states. The following tutorial illustrates the complexity of these kinds of agreements and the need for standards: **Operating Leases versus Capital Leases**. An **operating lease** is a lease the term of which is relatively short compared to the economic useful life of the asset (such as a solar PV system) being leased. An

operating lease is commonly used to acquire equipment on a relatively short-term basis. Thus, for example, a solar PV system, which typically has an economic life of at least 30 years, may be leased to a customer for ten years under an operating lease. A **capital lease** (also called a **finance lease**) is akin to a debt-financed purchase of equipment by the lessee, with the lease payments to the lessor representing payments of principal and interest on the amount financed by the lessor.

In an operating lease, the lessor (or owner) transfers only the right to use the asset to the lessee. At the end of the lease period, the lessee must return the asset to the lessor. Because the lessee does not assume the risk of ownership of the asset, the lease expense is treated as an operating expense in the lessee's income statement and the lease obligations do not affect the lessee's balance sheet. In a capital lease, the lessee assumes some of the risks, and enjoys some of the benefits of ownership, of the asset.

Consequently, the lease, when signed, is recognized both as an asset and as a liability (for the lease payments) on the lessee's balance sheet. Each year, the lessee must take a depreciation charge on the asset and also a charge for the interest expense component of the lease payment. In general, capital leases require that expenses be recognized sooner than under equivalent operating leases.

Because companies frequently prefer to keep leases off their books to avoid the recognition of liabilities and defer the recognition of expenses, there is a strong incentive on the part of companies to report leases as operating leases. In the United States, the determination of whether a lease is an operating lease or a capital lease is made under Financial Accounting Standards Board ("FASB") Statement No. 13.

This is also a $395 download from the SolarTech website it represents just one hour of an accounting professionals time for what could run as much as $100,000 for custom contract template from a mid-level accounting firm. Firms with more standing in the energy field charge considerably more. The download consists of the fully editable WORD source that the client's legal counsel or financial advisor is at liberty to modify. All downloads are free to SolarTech members, and we have no means to track member downloads. However, for non-member downloads we have witnessed less traffic in this document template than the PPA. This may be due to SolarTech's own slowdown in marketing communications with the departure of our Marketing Director in 2011, or it may be a different beast not so easily converted to a standard template.

2.1.11 Due Diligence Checklist

Released in late 2011 this document is a checklist of the standard items a project developer should have ready answers to before seeking project financing. This document is available for free from www.solartech.org.

2.1.12 Finance Option Tutorial

For new entrants in the project sponsorship world, this document provides a brief overview of the possibilities and requirements of the various solar PV financing mechanisms. This document is available for free from www.solartech.org.

2.1.13 Finance RFI and Companion Spreadsheet

Similar to the Due Diligence Checklist (a brief outline), this document provides a "fill in the blank" template for all of the information a financer will request. It comes as an Excel Spreadsheet for easy modification. This document is available for free from www.solartech.org.

These last three documents were not released until late 2011, so an adoption progress report is too early to gage. However through Solar3.0, SolarTech will be enabled to promote their widespread usage.

2.2 Carbon Meter, DC-DC Shade Mitigation Quantification, and Santa Clara University 2007 & 2009 DOE Solar Decathlon Solar Houses

The four key products and results from the Santa Clara University segment of this project are:

- State of the Industry Study of BIPV and Power Management Technology for Solar PV
- Carbon Meter Methodology for AB 32 and resulting patent application
- DC-DC Shade Mitigation Quantification Methodology
- Demonstration installations on the Santa Clara University 2007 & 2009 DOE Solar Decathlon Solar Houses

2.2.1 State of the Industry Study of BIPV and Power Management Technology for Solar PV

The world of solar power is broad, and continuously expanding. Solar photovoltaic technology converts sunlight into electrical power, and the most common substrate for solar panels is silicon. Silicon is cheap and the manufacturing technology is well established. Multi-junction cells are one alternative for a silicon cell. A multi-junction cell has multiple layers of different substrates, each of which has a different band gap energy, and therefore can absorb a different wavelength of energy from the sun. Multi-junction cells are more complicated and costly to produce, but are also capable of achieving higher efficiencies than silicon cells. Multi-junction cells are used in concentrated solar power (CSP) technology, also called concentrated photovoltaic (CPV) technology. Mirrors and lenses can be used to focus sunlight onto a smaller area cell that is capable of absorbing a greater portion of the potential solar energy. The smaller area needed in a multi-junction cell offsets the additional costs of the technology. Also, different combinations of substrates are also being applied to very thin materials. This is known as thin-film solar technology. Thin-film can be flexible, lightweight, and often very easy to install, but typically has much lower efficiencies than standard silicon-based solar cells. Thin-film technology can be applied in many more types of installations due to its versatility, however, which helps overcome the barrier of lower efficiencies. Thin-film technology is also one of the least expensive photovoltaic technologies to manufacture and install.

In addition to these methods, there is another area of technology that focuses on integrating technology that converts sunlight to electrical energy into existing structures in unique ways that may not involve simple panels on rooftops. This is called BIPV. BIPV includes photovoltaic materials that can be used to replace materials in exterior portions of a home or building, such

as the facades, roofs, or skylights. Many BIPV compounds have the extra advantage in that they work well in low concentration indirect solar irradiation such as would originate from cloud cover. New buildings are increasingly incorporating BIPV into their construction as a key source of power. In addition to power generation, replacing exterior portions of the building with solar collectors reduces the costs for building materials and labor that would have covered those portions replaced by BIPV. However, the retrofit of existing buildings to produce power generally is a more complex and potentially more costly proposition; the installation of BIPV in existing buildings is often cost-prohibitive.

As an integral part of researching the BIPV market, it was essential to obtain some industry input to understand how current products are performing, and to identify trends and unmet needs in the market. To be thorough, industry members from all segments of the market were interviewed, including manufacturers, installers and roofers. Although opinions varied within each segment, all shared the same major sentiments on BIPV today:

Efficiency: The most common concern for the future of BIPV is the relatively low efficiencies of current BIPV technologies. If the efficiencies could be raised, it could greatly boost market popularity.

Cost of Installation: In general, current BIPV technologies involve greater installation costs than traditional PV panels. This is due to fitting technology into existing structures and wiring cohesively, as well as the often times greater cost per watt? of the products themselves.

Ease of Installation: Installers expressed that BIPV is usually more complicated to install than standard panels. Wiring systems can become much more complicated with BIPV. Existing structures often require additional work to be done relative to new construction, related to removal of materials (e.g. roofing) for module installation and running new wiring within the existing structure. The extra effort required for retrofit installations contributes to the higher cost of installation.

New vs. Retrofit: The general feeling of the industry is that, because of the issues stated above, BIPV is better suited for new housing, especially for larger housing developments, than for retrofitting existing houses.

Repairs: When a panel integrated into a flat roof or a facade begins to malfunction, the process of replacing it requires taking apart and reassembling the adjacent building envelope. This process requires much more manpower and time than the simple replacement of a mounted module on a roof.

This report looks at a number of different technologies and solutions currently in the market but most importantly this report studies the Return on Investment of these products. Ten different scenarios were studies including no PV, standard panel PV, Thin-Film, SolarMagic technology add-ons, and new products like SunSlates. The first scenario is the reference base line which is simply an average California home with no solar technology. The other nine scenarios then

perform a Net Present Value evaluation of the technology under study as compared to the baseline scenario 1. An example follows.

Table 1: Summary of Costs for Five Scenarios

Scenario	Total Cost	NPV	NPV Savings Relative to Scenario 1	NPV Savings/W Relative to Scenario 1
1. Standard Non-Solar	($26,264)	($15,363)	--	--
2. Basic PV Installation	($23,170)	($7,119)	$8244	$2.50
3. Thin-Film Installation	($23,866)	($7,173)	$8190	$2.48
4. SolarMagic	($22,416)	($6,365)	$8998	$2.73
5. SUNSLATES	($27,674)	($10,840)	$4523	$1.37

There are many factors to consider in the world of BIPV technology. Roof shape, shingle type, and additional roof features all play a part in determining which technologies and orientations will be the most beneficial to a given house. Often, BIPV products must be integrated delicately into existing housing elements so as to preserve the weatherproof capabilities of the roof. In order to prevent the need for major structural modification, BIPV installations can become more complicated than traditional PV installations, especially on a wiring integration level.

BIPV products vary greatly across the market. Some collectors replace windows or overhangs, while others replace all or part of an existing roof, as in the case of Atlantis' SUNSLATES. Other products are designed to be additions to additions to specific types of roofs, such as the Uni-Solar PV laminate for standing seam metal roofs. Other products focus on power management and optimization of traditional PV arrays in order to allow them to function at less optimal conditions, making the option of solar available to more homes.

A BIPV product should be selected based on the factors in play at each home. While each factor would have an impact on the cost of implementing each technology, the costs of a number of products were compared to one another based on the characteristics of a basic California home. Despite the wide variety of products, the given cost for any of them was within 20 percent of the others with the given set of assumed values. Any changes in those values could greatly affect those numbers. System size, cost of electricity, electrical consumption, operating efficiency of the system, dropping costs of collector technology, and available incentives could all have an impact on the cost of each product to implement. In this way, there is no one product that is far superior to the others – each product has a given set of circumstances in which it is the best product available for the target application.

The full report is available at www.solartech.org.

2.2.2 Carbon Meter Methodology for AB 32 and resulting patent application

The Santa Clara University team developed a method based on energy balance to determine the thermal performance of residential buildings, energy consumption and losses, calculate the overall net, and translate into a carbon savings and thus implement a real-time carbon meter.

Energy consumption in residential and commercial buildings represents a large component of the total energy consumed in most countries. In US, the building sector consumes approximately 30 percent of the total energy use, with the residential sector consuming close to 20 percent of the total. Furthermore, energy consumption is the largest operating cost in most homes. Thus, consumers should be motivated to implement cost-effective energy saving strategies in their homes. The energy profile for residences in the US suggests the potential for energy savings strategies with respect to heating, cooling, hot water, lighting, and appliances. The most popular areas for consumers to invest in energy efficiency include energy efficient appliances, better wall insulation, energy efficient lighting, and energy efficient heating and ventilation equipment (HVAC).

Characteristic building parameters such as the overall heat transfer coefficient, thermal inertia, and radiation factors are extracted by analysis of nighttime and daytime readings of indoor and outdoor temperatures, solar radiation, and total energy usage of the building. It is shown that the overall heat transfer coefficient (thermal response) *UA* of the building is linear with the difference in indoor and outdoor temperatures. Radiation factors for the building can be represented as nonlinear functions of time. Validation of the model is done using two different residential buildings located in different areas. Results indicate small differences between the predicted model energy performance and the actual measured energy performance. The model developed here may be implemented as a tool to monitor real-time energy performance of a building and can be useful for establishing a sustainability rating based on demonstrated performance rather than intended. Other proposed applications are evaluation of carbon emissions and offsets from residential buildings and sizing of HVAC systems.

This project resulted in several conference reports, the final project report with a complete description of the methodology, and a patent application. The patent application title and application number are, "Estimating energy savings and carbon offsets for buildings in real-time" #13/410805 filed March 2, 2012.

Following is a brief description of the methodology.

In general the carbon meter proposed here is composed of three main elements: the sensors, the model, and the display (Fig. 2). The required sensors to determine the load of the building envelope include thermocouples and a flow meter. Each appliance must include a sensor to determine its energy consumption. If the building has solar panels the amount of energy generated is determined from the inverter. The second component of the carbon meter is the model.

The model validation gives certainty on the results and predictions of the carbon meter. Such validation is performed only once. The last component is the display; the carbon meter algorithm can include the energy consumption by components or the total energy consumption.

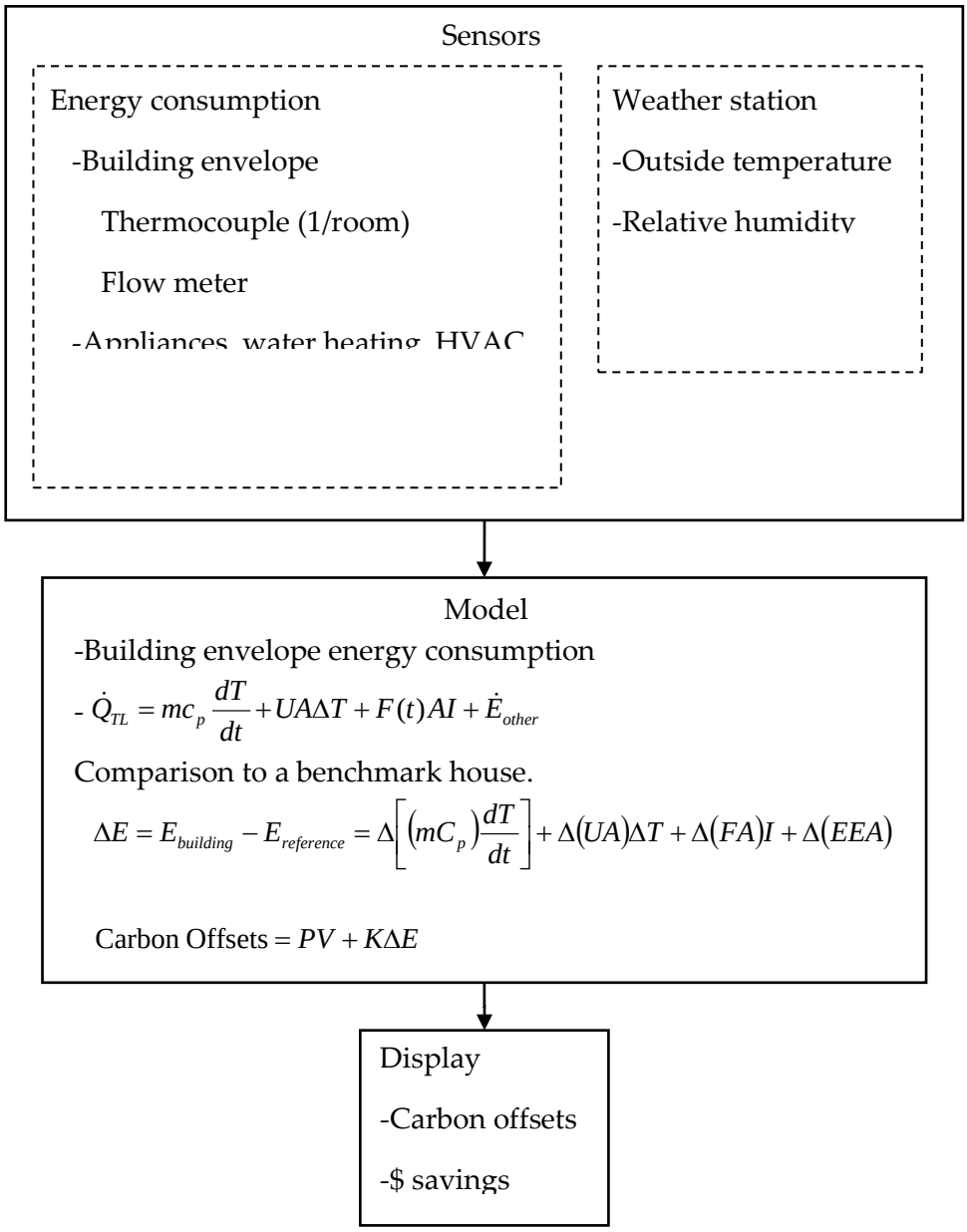
Using conversion factors for the cost of energy, the total savings (or additional incurred cost) can be estimated in terms of carbon offsets or money. The cost of the carbon meter hardware may be reduced by reducing the number of required sensors to a minimum and computing the savings using remote computers. Thus, a communications capability must be provided, but computing and significant storage may be done more efficiently in offsite locations, possibly making use of computing in "the cloud."

California Clean Energy Fund (CalCEF) is an independent nonprofit corporation working to advance clean energy using tools from finance, public policy and technological innovation. It was formed in 2004 from the PG&E bankruptcy settlement negotiated by the California Public Utilities Commission (CPUC). The fund will make equity investments totaling at least $30 million in emerging clean energy technology companies. CalCEF will invest in companies located in PG&E's service territory and elsewhere that are developing technology or products that could benefit the region. SolarTech is working with CalCEF on increasing the liquidity and lowering the cost of solar PV financing. CalCEF is already pioneering and piloting a "negawatt[2]" PPA model for energy efficiency upgrades and decommissioning. Thus the Carbon Meter Patent is a perfect opportunity for them to explore.

The full Carbon Meter report is available at www.solartech.org.

[2] An industry buzz word meaning savings or offset of megawatt levels of energy consumption.

Figure 2: CM Meter Components.



2.2.3 DC-DC Shade Mitigation Quantification Methodology

The electronic portion of the solar industry has seen great strides in the last five years. Advances in real-time data collection and communication protocols and power management electronics have outpaced solar cell advancements. The motivation in this phase of the project was to develop a way to quantify the energy savings claims of two new classes of devices: Microinverters and DC to DC Power Optimizers. The two technologies serve fundamentally different system needs, but do share one common goal: shade mitigation. Shade is a major

problem in many solar applications. In cases where the shade is almost constant the best solution is to avoid the area. However, there are many cases where the sharing effect is transitory. Structural elements such as a vent pipe, chimney or power pole sweep a transient shadow across the array every day (or seasonally) and the resulting transitory power loss can be significant. In such cases if the energy mitigation of an attached technology solutions can be quantified, then the designer can easily incorporate solar in those locations and easily predict the results. Thus, a "design-side" Plug-n-Play solution.

Santa Clara University undertook the challenge of designing and testing a methodology to accurately evaluate and quantify any shade mitigations claims.

This project leveraged the 2007 DOE Solar Decathlon House as a living test lab.

The result is several conference papers and a final report for this grant fully describing the methods developed. The report is highly insightful in several ways:

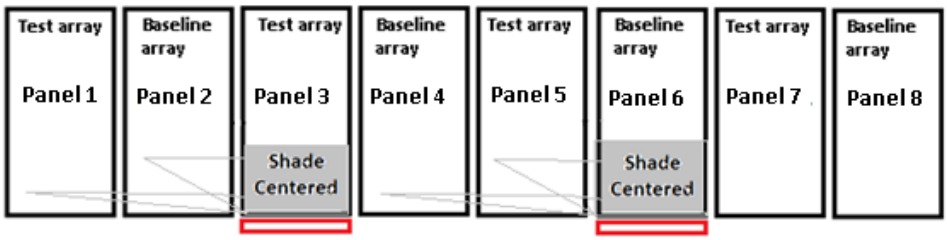
1. First is the methodology itself and the analysis
2. Next are the results which confirm some manufacturer claims and dispute others.
3. Last is the consumer protection implication. Yes, there is a certain amount of self-regulation within the industry. Bad products will eventually be weeded out. However, just as the Energy Commission saw the need to develop a CEC panel rating to curtail the exaggerated claims of some systems based on STC ratings without any derating; it is well to consider the implications of exaggerated shade mitigation claims on forecasted system performance. On the other hand these are important technologies; and should be recognized, encouraged and compensated when the claims are valid. The CEC currently does not recognize or offer any incentive reward for these technologies.

The following shows an illustration of the methodology and a snapshot of the results.

A sweeping shade test requires that the two arrays be equally shaded. The shading device has a wooden base and vertical PVC supports, reinforced with wooden doll rod centers to add rigidity. Two layers of colored opaque plastic sheeting were stretched over the PV frame. The shade was one panel wide and was made tall enough to cast a shadow on approximately 25 percent-30 percent of the total area of the panel when centered in front of the panel, at the time in the day that the shadow fell only onto the panel immediately in front of the shading device. The shading plane was 81 cm wide and was placed normal to the surface of the flat roof. The height of the shading plane varied with time of year. A setup of the shading devices used in the installation is shown in Figure 3.

Figure 3: Photograph Showing the Two Shading Devices: One Directly in Front of a Panel (This is Part of the Test Array) and the Other Directly in Front of the Panel that is Part of the Baseline Array.

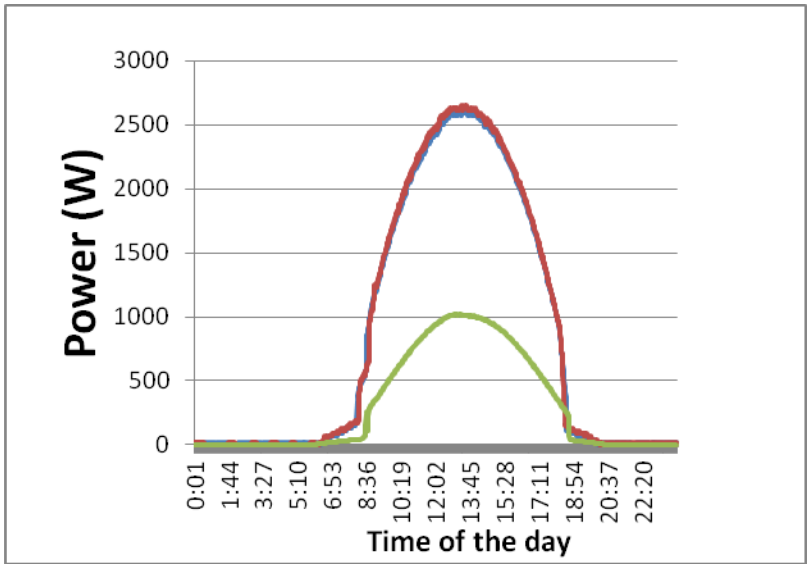
Figure 4: A Top View of the Test Configuration with Shading Devices and Shade Projections for Different Times of the Day



One shading device was centered in front of a panel of the baseline array and a second was centered in front of a panel of the test array. Figure 4 shows the location of the shading device in red and identifies the panels that would be affected by the shade caused by this device as the sun sweeps across the sky. The two panels left of the center panel and the center panel will experience shade in the morning and a set of two to the right of the centered panel and the center panel will experience shade during the evening. As the sun moves across the sky during the day, an equal amount of shade is cast over each of the arrays thus making the conditions as identical as possible for both test arrays.

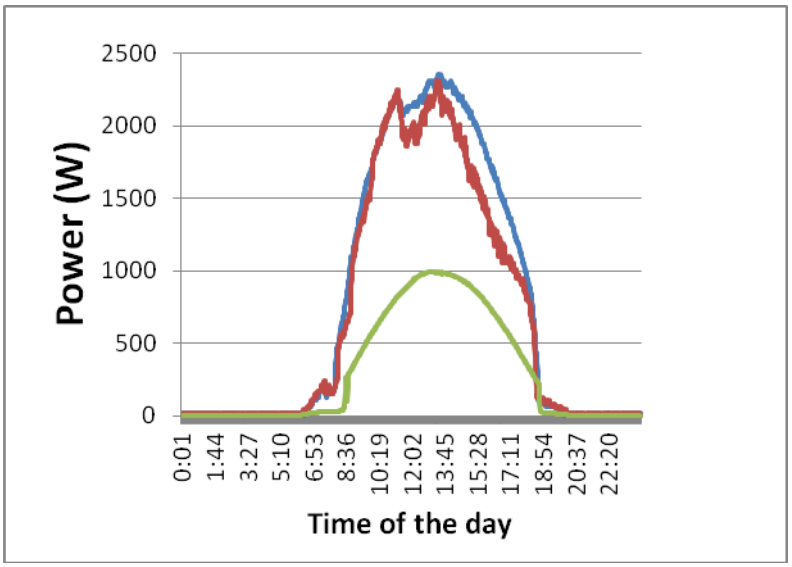
Power obtained over the course of a clear sunny day for the baseline and test array for the buck-boost optimizer in the absence of partial shading is plotted in Figure 5. Results for this and all such plots have been normalized by multiplying the baseline array power produced by 1.0134, as described earlier.

Figure 5: Power Produced by Baseline (Red) and the Buck-Boost Optimizer (Blue) Arrays over a Clear Sunny Day. Insolation (Green) on the Surface of the Panels is Also Plotted in Watts/m^2



Power obtained over the course of a clear sunny day for the two arrays with shading devices casting partial shade is shown in Figure 6.

Figure 6: Results for Partially Shaded Baseline Array (Red) and Buck-Boost Test Array (Blue) over the Course of a Sunny Day. Insolation (Green) on the Plane of the Collectors is Plotted in Watts/m^2

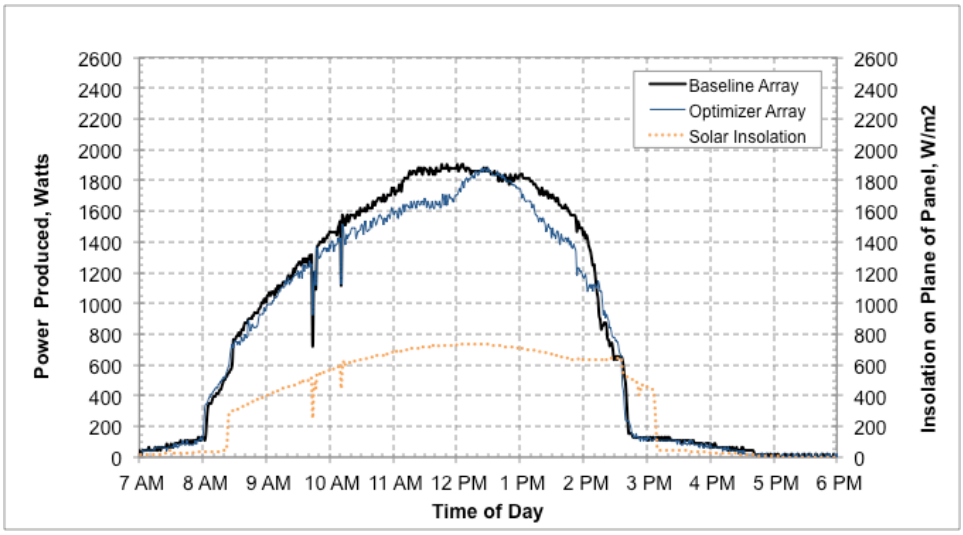


This device illustrates an overall energy recovery in the presents of a shading event. Integration of the area under the curve will yield the total energy loss mitigation.

The next plot shows a device not performing as claimed.

Power obtained over the course of a clear sunny day for the two arrays with shading devices casting partial shade are shown in Figure 7, for the impedance matching technology. The device never exceeds the baseline result under any condition.

Figure 7: Results for Partially Shaded Baseline Array and Impedance Matching Array over the Course of a Sunny day. Insolation on the Plane of the Collectors is Plotted in Watts/m^2.



Return On Investment (ROI)

The final task of the project was to study the ROI of these devices. It is one thing to recover potentially lost energy, but if the cost of the recovery technology exceeds the value of the energy recovered, then it is much better to simply avoid the shaded locations. Following are the analysis results of the three technologies tested.

Table 2: Energy Savings for the Buck-Boost Architecture over a Period of 25 Years and the Corresponding Cost Benefits

	Buck-Boost architecture				
Year of Sevice	Energy savings for Buck-Boost array production (Peak summer)	Energy savings for Buck-Boost array production (Partial Peak summer)	Energy savings for Buck-Boost array production (Off -Peak summer)	Energy savings for Buck-Boost array production (Parital Peak Winter)	Energy savings for Buck-Boost array production (Off Peak winter)
1	126.5333626	11.21362539	102.0915033	1.33641292	135.8172375
2	125.90	11.16	101.58	1.33	135.14
3	125.27	11.10	101.07	1.32	134.46
4	124.64	11.04	100.56	1.31	133.79
5	124.02	10.98	100.06	1.30	133.12
6	123.40	10.93	99.56	1.29	132.45
7	122.78	10.88	99.06	1.28	131.79
8	122.17	10.83	98.56	1.27	131.13
9	121.56	10.78	98.07	1.26	130.47
10	120.95	10.73	97.58	1.25	129.82
11	120.35	10.68	97.09	1.24	129.17
12	119.75	10.63	96.60	1.23	128.52
13	119.15	10.58	96.12	1.22	127.88
14	118.55	10.53	95.64	1.21	127.24
15	117.96	10.48	95.16	1.20	126.60
16	117.37	10.43	94.68	1.19	125.97
17	116.78	10.38	94.21	1.18	125.34
18	116.20	10.33	93.74	1.17	124.71
19	115.62	10.28	93.27	1.16	124.09
20	115.04	10.23	92.80	1.15	123.47
21	114.46	10.18	92.34	1.14	122.85
22	113.89	10.13	91.88	1.13	122.24
23	113.32	10.08	91.42	1.12	121.63
24	112.75	10.03	90.96	1.11	121.02
25	112.19	9.98	90.51	1.10	120.41
25 yr Total	2980.60	264.59	2404.61	30.50	3199.13
Total 25 year DC-DC Optimizer Gain (kWhr)		8879.43			
Value in constant dollars		$2,926.15			

Table 3: Energy Savings for the Parallel Voltage Boost Architecture over a Period of 25 Years and the Corresponding Cost Benefits

	Parallel Voltage boost technology				
Year of Sevice	Energy savings for Parallel Voltage Boost array production (Peak summer)	Energy savings for Parallel Voltage Boost array production (Partial Peak summer)	Energy savings for Parallel Voltage Boost array production (Off -Peak summer)	Energy savings for Parallel Voltage Boost array production (Parital Peak Winter)	Energy savings for Parallel Voltage Boost array production (Off Peak winter)
1	192.2111956	245.5117527	263.0347899	2.925794223	387.4933512
2	191.25	244.28	261.72	2.91	385.56
3	190.29	243.06	-114.17	2.90	383.63
4	189.34	241.84	-113.60	2.89	381.71
5	188.39	240.63	-113.04	2.88	379.80
6	187.45	239.43	-112.47	2.87	377.90
7	186.51	238.23	-111.90	2.86	376.01
8	185.58	237.04	-111.34	2.85	374.13
9	184.65	235.85	-110.78	2.84	372.26
10	183.73	234.67	-110.22	2.83	370.40
11	182.81	233.50	-109.67	2.82	368.55
12	181.90	232.33	-109.12	2.81	366.71
13	180.99	231.17	-108.57	2.80	364.88
14	180.09	230.01	-108.02	2.79	363.06
15	179.19	228.86	-107.48	2.78	361.24
16	178.29	227.72	-106.94	2.77	359.43
17	177.40	226.58	-106.40	2.76	357.63
18	176.51	225.45	-105.87	2.75	355.84
19	175.63	224.32	-105.34	2.74	354.06
20	174.75	223.20	-104.81	2.73	352.29
21	173.88	222.08	-104.28	2.72	350.53
22	173.01	220.97	-103.76	2.71	348.78
23	172.14	219.87	-103.24	2.70	347.04
24	171.28	218.77	-102.72	2.69	345.30
25	170.42	217.68	-102.21	2.68	343.57
25 yr Total	4527.69	5783.05	-1961.20	70.01	9127.80
Total 25 year DC-DC Optimizer Gain (kWhr)		17547.36			
Value in constant dollars		$5,928.30			

Table 4: Energy Savings for the Impedance Matching Architecture over a Period of 25 Years and the Corresponding Cost Benefit

	Impedance matching technology				
Year of Sevice	Energy savings for Impedance Matching technology array production (Peak summer)	Energy savings for Impedance Matching technology array production (Partial Peak summer)	Energy savings for Impedance Matching technology array production (Off -Peak summer)	Energy savings for Impedance Matching technology array production (Parital Peak Winter)	Energy savings for Impedance Matching technology array production (Off Peak winter)
1	-64.91449618	-92.12414309	-56.67815723	-18.21161737	-96.70463546
2	-64.59	-91.66	-56.39	-18.12	-96.22
3	133.14	-91.20	-114.17	-18.03	-95.74
4	132.48	-90.74	-113.60	-17.94	-95.26
5	131.82	-90.29	-113.04	-17.85	-94.78
6	131.16	-89.84	-112.47	-17.76	-94.31
7	130.51	-89.39	-111.90	-17.67	-93.84
8	129.86	-88.94	-111.34	-17.58	-93.37
9	129.21	-88.50	-110.78	-17.49	-92.90
10	128.57	-88.06	-110.22	-17.40	-92.44
11	127.93	-87.62	-109.67	-17.31	-91.98
12	127.29	-87.18	-109.12	-17.22	-91.52
13	126.66	-86.74	-108.57	-17.13	-91.06
14	126.03	-86.31	-108.02	-17.04	-90.60
15	125.40	-85.88	-107.48	-16.95	-90.15
16	124.78	-85.45	-106.94	-16.87	-89.70
17	124.16	-85.02	-106.40	-16.79	-89.25
18	123.54	-84.59	-105.87	-16.71	-88.80
19	122.93	-84.17	-105.34	-16.63	-88.36
20	122.32	-83.75	-104.81	-16.55	-87.92
21	121.71	-83.33	-104.28	-16.47	-87.48
22	121.11	-82.91	-103.76	-16.39	-87.04
23	120.51	-82.50	-103.24	-16.31	-86.60
24	119.91	-82.09	-102.72	-16.23	-86.17
25	119.31	-81.68	-102.21	-16.15	-85.74
25 yr Total	2770.84	-2169.96	-2599.02	-428.80	-2277.93
Total 25 year DC-DC Optimizer Gain (kWhr)		-4704.88			
Value in constant dollars		($920.51)			

Tables 1, 2 and 3 summarize the cost benefit of each device over a period of 25 years which could be the entire lifetime of the system. The total of each monthly energy output is the annual energy projection. Annual energy production is then degraded by the assumed silicon module degradation rate to get the energy of the next year, and so on. This simple analysis, which neglects potential differences in the energy rate inflation and the general inflation rate (or cost of borrowing funds), shows clearly the benefits of buck-boost technology. This ROI also neglects the impact of design time savings, due to the easy application of technology to solve a difficult system design problem. This technology, applied to the test array of the 2007 Solar Decathlon house, is projected to save $5928 over 25 years. At a nominal $200 per device, the cost for 16 devices would be $3200, showing a clear positive return on investment. Should electricity costs increase at a rate higher than inflation (or the interest rate used to borrow funds for the installation of the devices); the return on investment will be greater. With economies of scale

and the possibility of the devices being integrated with the panels during their manufacture, costs may be reduced significantly, leading to a substantially greater return on investment.

The full report is available at www.solartech.org.

Demonstration installations on the Santa Clara University 2007 & 2009 DOE Solar Decathlon Solar Houses

The 2007 and 2009 DOE Solar Decathlon houses were leveraged in the course of this project. The 2007 house served as the living lab while the 2009 house was under construction. The 2009 house then featured the carbon meter development and the BIPV central inverter electrical design during the Solar Decathlon Event Week on the Washington DC Mall in October 2009 (fig. 8).

The 2009 House (Refract House) allowed to demonstrate the process of integrating PV panels into the building's façade, a key element for BIPV, and to demonstrate the benefits of communicating the energy performance of the house and quantifying the associated benefits of the environment seamlessly.

Specifically, the 2009 SD House allowed demonstrating how PV systems can be integrated into contemporary building façades adding significant value to the structure as a whole unit and not as a separate unit. For this, it is essential that the solar technology is considered at very early design stages of the structure. The final design included 48 panels mounted on the roof with a custom system made from modular Unirac components. The racking system also allowed for back-clipping the panels and fitting flashing in array gaps, effectively achieving the desired appearance of a monolithic roof rather than a collection of panels. The design process and final product for this BIPV design are a pro-active legacy of further advancing BIPV in California markets.

The 2009 SD House also allowed for quantification of energy produced and consumed facilitating with it quantification of carbon offsets and associated financial incentives attributable to the combined energy production due to the solar technologies and improved energy performance of the 2009 Solar Decathlon house. This was possible by implementing the carbon metering strategy developed under PIER/SolarTech Grant and the high density instrumentation of the Refract House.

The 2007 Solar Decathlon house continued after 2009 as the living test bed for the DC to DC Shade Mitigation Studies and Carbon Meter methodology development. This allowed for an ongoing "living lab" in a number of ways that not only benefited the grant but created an ideal environment for the College of Engineering enabling engineering students to understand how these technologies work on real building systems, and engage manufactures of a wide variety of new building technologies from window coverings to thermal refrigeration and space heating.

Both the 2007 and 2009 houses are currently set up and open to the public on the Santa Clara University campus. Contact Dr. Mark Aschheim in the College of Engineering to arrange a tour:

mascheim@scu.edu

Figure 8: Refract House in Washington, D.C. Note the PV Panels in the Roof "Disappear" from View, Being Effectively Integrated into the Plane of the Roof (Unlike the Neighboring House to the Right).

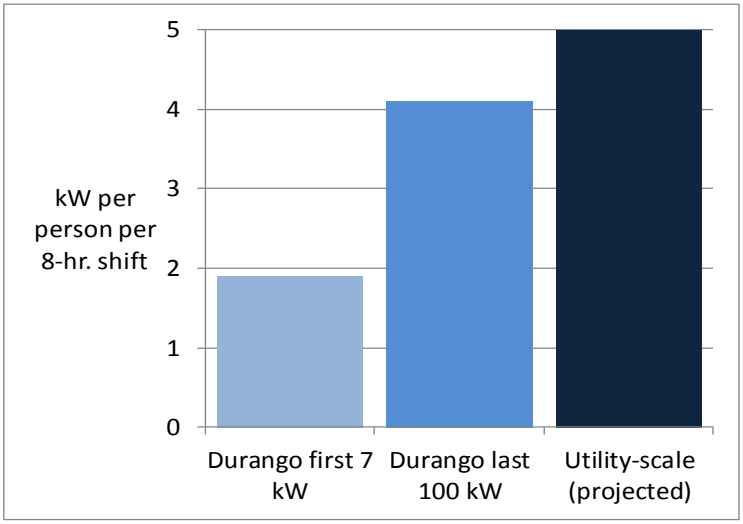
All Santa Clara Reports are available at www.solartech.org.

2.3 Installation Cost of Supermodule Concept Based Single-Axis Tracked Medium Concentration PV (MCPV)

Skyline Solar finished its portion of the project culminating in 100kW of a 500Wk installation in Durango, Mexico. Skyline characterized their approach as "Factory in the Field."

The following two illustrations highlight the advantages of the "Factory in the Field" approach to reducing install costs.

Figure 9: Productivity Comparison



A pace of 4.1 kW per person per shift was observed in Durango, and we believe a pace of 5 kW per person per shift is entirely achievable with full implementation of the Factory in the Field model.

The low cost of the X14 System is made possible by its low materials and installation costs. This, coupled with the fact that it tracks the sun over a 170 degree range of motion, results in very low LCOE and high IRR.

Figure 10: LCOE and IRR Vary with DNI

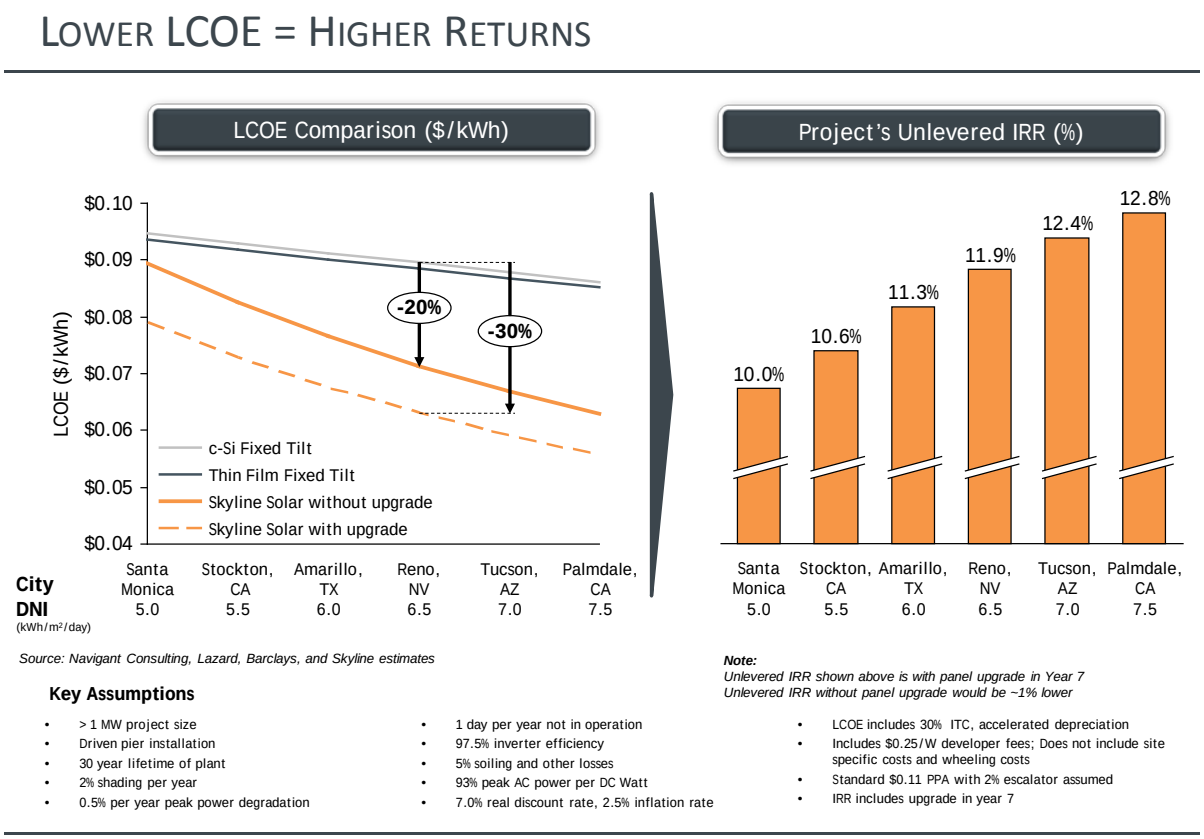


Illustration Credit: Skyline Solar

The resulting White Paper Report is available from both Skyline Solar and SolarTech websites.

2.4 Installation Cost of Factory Built Pre-Assembled Modular Ground Mount Solar PV

As compared with Skyline technology, the SunPods portion of the project is based on common flat-panel solar PV. The other distinction is a fully deployable ready to install system out the factory door. The system is easily shipped to any site within a 200 mile radius (an cost/benefit limit), quickly placed on most ground surfaces with minimum preparation, and requiring no more complicated electrical installation than standard EV charging equipment. In fact, that is one of the key applications, where the full system, with charger, can also originate from the factory.

In theory this appeared valid, but what are the real numbers in practice? SunPods' goal was to benchmark several installations side by side and gather the resulting installation numbers for both materials, site prep, and labor. Three smaller installations were selected in the Fresno,

California area as larger planned project sites ran into permitting delays. The numbers below speak for themselves.

- Project A: 25kW name-plate rating
- Project B: 16.8kW name-plate rating
- Project C: 14.4kW name-plate rating

Figure 11: Example Cost Analysis of SunPods Ground Mount and Traditional Ground Mount for a 25 kW Solar Powered Irrigation System in Fresno.

System Cost	Traditional Ground Mount	SunPods Ground Mount
Size in Watts (DC-STC)	25,000.00	25,000.00
Site preparation	$ 322.00	$ 125.00
Foundations - Holes - Rebar - Concrete	$ 6,320.00	$ -
Rack System Material Cost	$ 12,433.00	$ -
PV Modules	$ 28,267.00	$ -
BOS (inverters - disconnects - fuses)	$ 19,748.00	$ -
Total System Cost	**$ 67,090.00**	**$ 64,925.00**
Installation Cost		
Crew Size	3.00	3.00
Installation time (man days)	39.00	6.00
Installation Time Frame (days)	13.00	2.00
Installation labor Cost	$ 9,343.00	$ 994.00
Project Management Cost	$ 950.00	$ 1,200.00
Overhead Soft Cost (purchasing - warehouse)	$ 2,821.00	$ 1,600.00
Freight Cost	$ 1,727.00	$ 3,240.00
Total Installation Cost	**$ 14,841.00**	**$ 7,034.00**
Total Capital Cost	**$ 81,931.00**	**$ 71,959.00**
Cost Per Watt (DC-STC)	**$ 3.28**	**$ 2.88**

SunPods Factory Built Fabrication and Installation Time

Project A	Fabrication	Time	Project A	Fabrication Time	Time	Total	Time
Crew Size --Fabricate--->	2.00	Men	Crew Size	3.00	Men		Men
Man-days for Installation	18.00	Man-Days	Man-days for build/install	6.00	Man-Days	24.00	Man-Days
Install Time (Project Days)	6.00	Project Days	Installation Time Frame (days)	2.00	Project Days	8.00	Project Days
Project B	**Fabrication**	**Time**	**Project B**	**Fabrication Time**			
Crew Size --Fabricate--->	2.00	Men	Crew Size	2.00	Men		Men
Man-days for Installation	6.00	Man-Days	Man-days for build/install	2.00	Man-Days	8.00	Man-Days
Install Time (Project Days)	2.00	Project Days	Installation Time Frame (days)	1.50	Project Days	3.50	Project Days
Project C	**Fabrication**	**Time**	**Project C**	**Fabrication Time**			
Crew Size --Fabricate--->	2.00	Men	Crew Size	2.00	Men		Men
Man-days for Installation	11.25	Man-Days	Man-days for build/install	2.00	Man-Days	13.25	Man-Days
Install Time (Project Days)	2.00	Project Days	Installation Time Frame (days)	1.00	Project Days	3.00	Project Days

Traditional Ground Mount Site Build Time

Project A	Site Built	Project A
Crew Size	3.00	Crew Size
Man-days for build/install	39.00	Man-days for build/install
Installation Time Frame (days	13.00	Install Time (Project Days)
Project B	**Site Built**	**Project B**
Crew Size	4.00	Crew Size
Man-days for build/install	20.00	Man-days for build/install
Installation Time Frame (days	6.00	Install Time (Project Days)
Project C	**Site Built**	**Project C**
Crew Size	4.00	Crew Size
Man-days for build/install	25.00	Man-days for build/install
Installation Time Frame (days	6.00	Install Time (Project Days)

SunPods Time Advantage

Traditional Ground Mount Site Built			SunPods Factory Built			Difference Between Systems	
Project A	**Total**	**Time**	**Project A**	**Total**	**Time**	**Total**	**Time**
Man-days for Installation	39.00	Man-Days	Man-days for build/install	24.00	Man-Days	15.00	Man-Days
Install Time (Project Days)	13.00	Project Days	Installation Time Frame (days)	2.00	Project Days	11.00	Project Days
Project B	**Total**		**Project B**				
Man-days for Installation	20.00	Man-Days	Man-days for build/install	8.00	Man-Days	12.00	Man-Days
Install Time (Project Days)	6.00	Project Days	Installation Time Frame (days)	1.50	Project Days	4.50	Project Days
Project C	**Total**		**Project C**				
Man-days for Installation	25.00	Man-Days	Man-days for build/install	13.25	Man-Days	11.75	Man-Days
Install Time (Project Days)	6.00	Project Days	Installation Time Frame (days)	1.00	Project Days	5.00	Project Days

System Cost Difference

Project	Site Built System	Cost/Watt	SunPods	Cost/Watt	Cost Difference	Cost Difference Watt
Project A	$ 81,931.00	$ 3.28	$ 71,959.00	$ 2.88	$ 9,972.00	$ 0.40
Project	**Site Built System**	**Cost/Watt**	**SunPods**	**Cost/Watt**	**Cost Difference**	**Cost Difference Watt**
Project B	$ 49,726.00	$ 3.11	$ 45,520.00	$ 2.70	$ 4,206.00	$ 0.41
Project	**Site Built System**	**Cost/Watt**	**SunPods**	**Cost/Watt**	**Cost Difference**	**Cost Difference Watt**
Project C	$ 44,988.00	$ 3.21	$ 43,047.00	$ 2.99	$ 1,941.00	$ 0.22

**System material cost with traditional site built systems involves wide material cost, so it's hard to make an apple-to-apple comparison with system cost. The cost does not include overhead and mark up or permitting cost. However, we believe the results prove the concept and also demonstrate economies of scale for larger projects once fixed costs are satisfied.

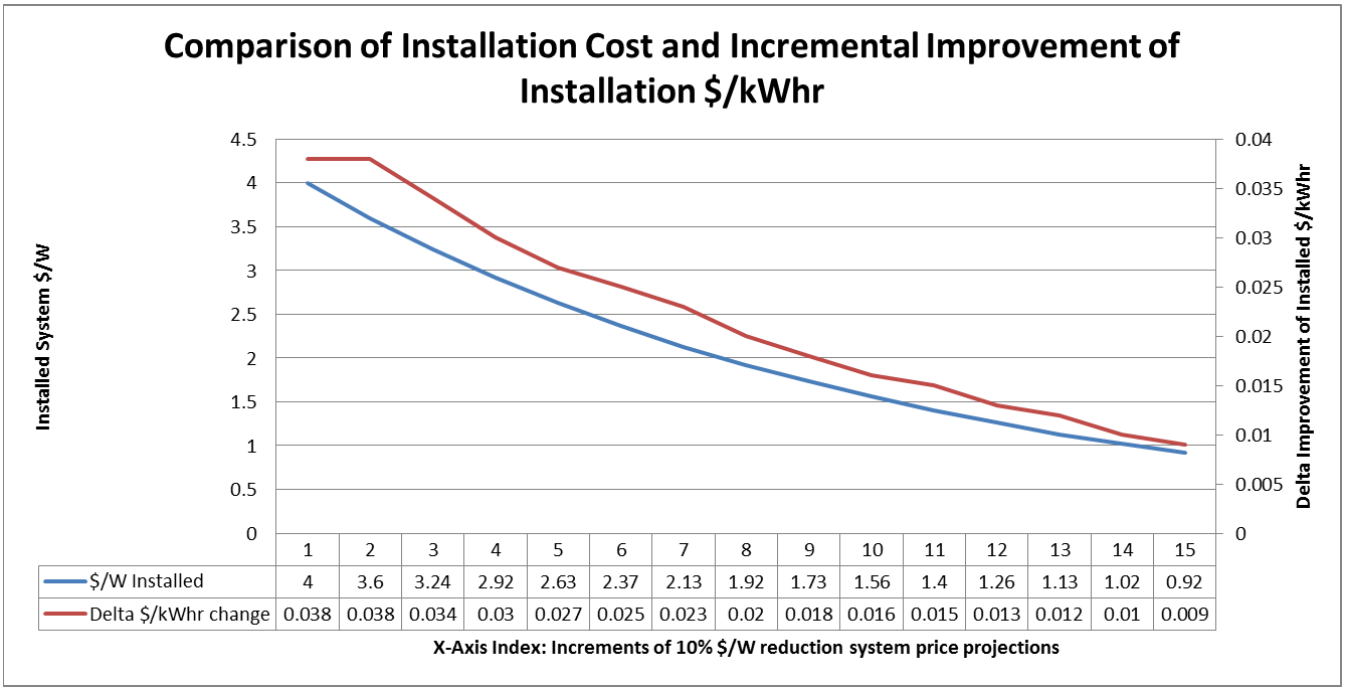
The resulting White Paper Report is available from both SunPods Energy and SolarTech websites.

Final Thoughts

The goal for both SunPods and Skyline was to demonstrate and publish results of benefit to the industry to replicate. The key goal was lowering installation costs, which in turn lowers the overall system purchase price. This is an especially important consideration for financing. The lower the overall "sticker" price the easier financing will be and resulting payback over the

system life. In evaluating system installation and overall purchase price for this study, one does not need to consider energy production, which is dominated by local insolation and microclimates among other factors. In the case of these projects it was impossible to gather any reliable production data due to the rush to finish installation before the grant contract deadline expired. However, if we normalize out the effects of insolation and microclimates, and complicated finance structures, thereby just focusing on the key variables of this study, we can simulate relative $/kWhr improvements as installation costs ($/W) decline. The following simulation used a tool developed by the firm Energy+Environment Economics under the sponsorship of the California Public Utilities Commission as part of the 2011 CSI Cost-Effectiveness study published April 2011. For the SunPods projects the traditional construction cost numbers average around $3.20/W and the SunPods costs come in at about $2.88/W. Thus the simulation begins at $4.00/W and drops by increments of 10 percent at 15 data points to under $1.00/W installed costs. The simulation assumes a "cash" purchase and zero CSI rebate to again remove unnecessary complications. However, Federal and State taxes along with ITC are included in the simulation. The resulting $/W and Δ $/kWhr are plotted. The Δ $/kWhr should not be interpreted as absolute savings projections, again this is impossible without knowing the exact annual energy production, utility tariff and finance program, and thus the red line in the following figure will shift up or down depending on the local project conditions. Instead what is illustrated is the relative first year $/kWhr savings indicating that $/kWhr savings do track installation $/W reductions.

Figure 12: Simulation of Δ $/kWhr Savings as $/W Installation Costs Decline. Since the Red Line is a Difference Curve the First Data Point is Mathematically Irreverent.



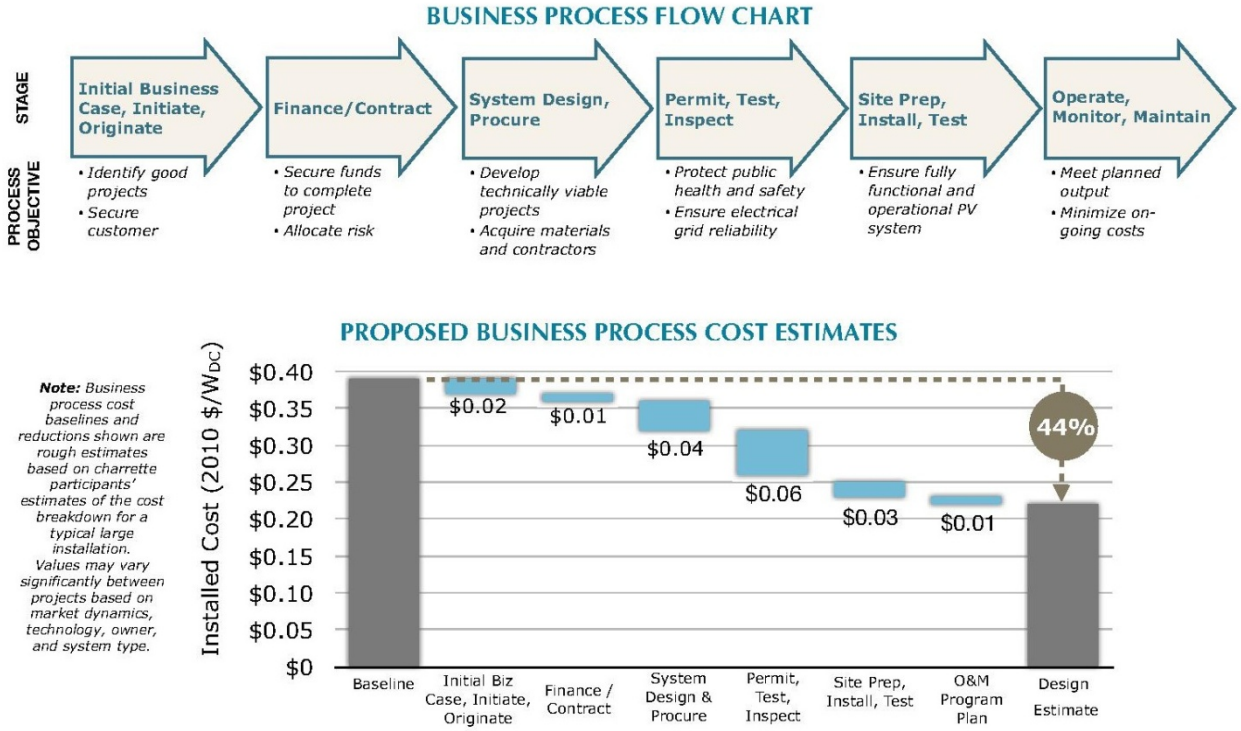
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$/W Installed	4	3.6	3.24	2.92	2.63	2.37	2.13	1.92	1.73	1.56	1.4	1.26	1.13	1.02	0.92
Delta $/kWhr change	0.038	0.038	0.034	0.03	0.027	0.025	0.023	0.02	0.018	0.016	0.015	0.013	0.012	0.01	0.009

This simulation exercise also illustrates that both curves may be approaching a diminishing return at about $0.50/W installed due to other fixed cost factors.

Chapter 3:
Market Impact

The soft cost issue was first reported in a 2007 White Paper by SolarTech[3]. It was further refined in a Charrette led by Rocky Mountain Institute in partnership with SolarTech in July 2010[4]. The justification for a focus on soft cost is that as module prices plummet, soft costs become the more dominate variable in the overall cost equation. Even at a module cost of $0.00/Watt, the overall installation costs would still exceed $2.00/Watt in comparison to DOE national targets of $1.00/Watt. The following figure (13) illustrates the estimates from the charrette team.

Figure 13: Proposed Process Cost Reductions, Source Rocky Mountain Institute. Total Baseline is Estimated to be $0.39/W. Possible Business Process Reductions are Estimated to be $0.17/W or 44% to $0.22/W.



This analysis identified $0.17/Wdc installed in soft cost reduction opportunities bringing the total to just over $0.22/Wdc. As the illustration demonstrates, these soft costs are comprised of customer acquisition and financing costs, permitting, inspection and interconnection costs and other unnecessary operation and maintenance costs.

[3] "SolarTech: Creating A Solar Center of Excellence," June 2007

[4] "Achieving Low-Cost Solar PV: Industry Workshop Recommendations for Near-Term Balance of System Cost Reductions," Sept. 2010, www.rmi.org.

It should be noted that the overall charrette also covered physical design and industry scale cost improvement opportunities. This immediate report is focused on business process improvement opportunities.

To further refine this portrait of hidden soft costs, SolarTech entered into collaboration with NREL and Lawrence Berkeley National Labs to conduct the first comprehensive industry survey of soft costs for calendar year 2010[5].

This survey looked at several categories of soft costs:

- Number of Installed Systems in 2010
- Number of MegaWatts installed in 2010
- The average installed costs to the integrator in 2010
- The average end customer price in 2010

Of the above costs what percentage is attributable to the following?

- Modules
- Inverters
- Other hardware (racking, wiring, etc.)
- Process Soft Costs (customer acquisition, permitting, inspection, interconnection, financing, contracting, installation and performance)
- Operating overhead, sales tax and margin

Additional labor hour breakdowns were requested of:

- Number of hours preparing permits
- Number of hours submitting permits
- Number of hours completing inspections
- Number of hours completing the interconnection process
- Number of permits completed and submitted through some form of online system

The commercial data response population was not as statistically complete as would be preferred for straight forward analysis, and will require under sampling techniques. However, the residential population response is significant.

Preliminary[6] analysis of overall process soft costs indicate the following findings:

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[5] The final report will not be released until May 2012. This is over 13 months from when the project was first envisioned and 17 months from the close of 2010. This time span is much too long to a rapid moving industry and indicates opportunity need for innovation.

Reported soft costs averaged 14 percent of total costs with 25 percent representing 95 percent of the respondent population of 60 data points.

Converting to $/W the numbers translate to a mean of $0.64/W, with $1.30/W representing 95 percent of the respondent population used in the calculation representing 60 data points.

This represents a 65 percent increase over the $0.40/W number arrived at in the RMI analysis.

The analysis based on reported labor hours indicates a slightly different result picture (n = 60), representing approximately 6897 installations or 15 percent of all US 2010 solar PV capacity added.

Table 5: Residential Segment NREL Survey Results

2010 5kW **Average BoS Non-Hardware Residential PV Benchmark*** Customer Acquisition Factored in		
NREL/Solar Tech Data	**$/ install**	**$/W**
Permit preparation	269	0.05
Submit permit package	78	0.03
Permitting inspection	148	0.03
Interconnection	71	0.01
Apply for & receive incentives	95	0.02
Sub-Total (excluding fees)	**661**	**0.15**
Permit fee	431	0.09
Customer Acquisition	**2801**	**0.56**
TOTAL	**$3893**	**$0.80**

*excludes interconnection fee (Nominalized to typical 5kW residential system)

Overall, including all soft costs, the results indicate that business process costs benchmarked in the SolarTech-NREL analysis (including assumed permitting fees) total $1.52/W for residential systems (ranging from $0.66/W to $1.66/W between the 20th and 80th percentiles).

[6] Final NREL-SolarTech report due April 2012.

Additionally 13 percent reported that they are able to submit applications online some percentage of the time. And, 39 percent reported that they do experience additional burdens and restrictions in the permitting process due to local requirement that are beyond state or national code requirements.

Regarding cycle time, it is important to note that in 2008 claims of as long as 12 weeks for a solar permit were common. By mid-2011 Integrators were reporting less than a day for a typical 5kW solar PV system and city and county building officials were reporting from one to three days to complete a permit application. How to interpret the survey data? The global average selling price for PV modules fell from $3.55 per watt ($/W) in 1998 to $1.25/W in 2011[7], while average installed costs declined from $11.00/W to $6.20/W over the same period. With reduction in module price accounting for 52 percent of the total decline in average installed system cost, non-module components represent a significant, and increasing, portion of PV system prices in the U.S. Thus, in order to track and analyze the rapidly evolving price structures of PV systems, a thorough understanding of non-module cost components is needed.

The $0.80/W of Table 4 represents the average total overall soft costs which includes other factors such as securing financing, repeated trips to the AHJ permitting office to correct application issues, similar delays on the interconnection side, and training. Although the final result in Table 4 might appear to be reasonable, a close examination of the average reported hours indicated opportunities for improvement. It also represents an assumed single successful pass at the permitting, inspection and interconnection process. The results are not granular enough to capture the costs of multiple cycles to correct issues, except as reflected in the overall total of $5.71/W[8]. The interpretation of the results is compounded by attempting to arrive at the same answer from a different analysis path. The respondents reported that on average 14 percent of their costs were Business Process Soft Costs. We can start with the overall reported finished system price of $5.71/W, remove the reported Customer Acquisition cost ($0.56/W), sales tax and profit ($0.59/W) and take 14 percent of the difference. This produces a soft cost expense of $0.64/Watt. This is comparable to the Table 4 result minus Customer Acquisition, which is $0.24/Watt. Thus we have an uncertainty spread from $0.24/W to $0.64/W for hidden business process soft costs. The SolarTech/NREL study arrived at a final BoS Non-Hardware Soft Costs of $1.50/W against a SunShot Goal of $0.65/W. This number includes the $0.24/W for Permitting and Inspection in addition to Customer Acquisition, Design, and labor. However, as we've just seen the real number could be as high as $1.90/W ($0.39/W higher by other analysis for soft costs), and most likely the case on the distribution tail if repeated visits to the building department could be considered. Thus we can draw five conclusions:

1. The DOE SunShot program plans to set a goal of $1.50/Watt for residential by 2020. Under current 2010 cost analysis, the module, inverter and other BoS hardware costs

[7] Module prices for large quantity buyers in unrestricted international commodity market; module size typically >150 watts sold in quantities of 500 -1,000 unit minimums.

[8] As derived in the SolarTech-NREL survey data.

could be FREE, with no profit, sales tax and supply chain costs and the resulting non-hardware business costs would still be $1.50/Watt.

2. Peeling the $1.50/W number apart and on close inspection of Permitting and Inspection, the $0.24/W is an opportunity for improvement. Inspection of the hourly numbers indicates opportunities to reduce this by half. After all we are referencing a typical 5kW residential installation; it shouldn't take 8 hours on average to prepare a permit package.
3. The real number, considering the multiple cycle issue is probably closer to RMI's $0.39/W, which is an easily justified conclusion based on the reported 14 percent hidden costs analysis in the above paragraph. A similar survey by SunRun and AECOM[9] reported $0.50/W.
4. Other opportunities exist to lower both Customer Acquisition and Installation labor costs.
5. Variability and confusion in the final results of all of these studied indicates another opportunity. A better data collection method across all phases of the system deployment process would produce better decision analytics to better guide Energy Commission and DOE program agendas to support the industry.

These five points are the driving motivation behind the many research elements of this grant.

[9] "Economic and Fiscal Impact Analysis of Residential Solar Permitting Reform," July 2011, http://www.sunrunhome.com/download_file/view/415/189/

Chapter 4:
Technology Transfer Plan and Activities

Pursuant to the goals of the PIER program the Energy Commission strives to ensure that developments under these kinds of grants reach the market for adoption and commercialization.

Throughout the course of this grant, SolarTech has pursued an ongoing outreach effort through its various Summits, Symposiums, Forums, Webinars, Press Releases, and Website. These past activities are well documented in other sources provided the Energy Commission. Thus instead of reviewing a list of past activities it will be more valuable to the reviewer to describe future outreach activities and the industry needs as defined in the last SolarTech Leadership (last relative to this grant) of March 7-8, 2012.

It has been mentioned several times that through the DOE SunShot program, SolarTech was awarded two grants related to business process soft costs:

- Solar3.0 National Platform
- RoofTop Solar Challenge

Taking the RoofTop Challenge first, SolarTech is leading one of four California teams out of 22 nationally that were similarly awarded. The SolarTech team is comprised of the City and County of San Francisco (CCSF), East Bay Green Corridor (EBGC), Solar Sonoma County (SSC) and Clean Coalition to drive development of the following (sample):

1. E-permitting deployment in CCSF, with commercial e-permitting SW investigations and recommendations for the 19 SSC and EBGC communities.
2. Virtual Net-metering Guide
3. Solar Access Options & Recommendations Guide
4. Standardized streamlined permitting across the 19 SSC and EBGC communities
5. Installer training for local AHJ practices
6. Solar financing options in the local area and guidelines
7. Interconnection business practices manual and recommendations for IOUs and MUNIs.
8. Webinar Series to promote all of the above.

The Solar3.0 team then takes these developments from the various RoofTop teams, plus similar types of developments from 100 identified leading communities nationally, to share, ratify and promote the "best of the best." A cross-pollination of sharing and review through webinars, websites, local symposiums and local community outreach events.

The following four pages are the results of two days of convening of over 200 industry participants (March 7 & 8, 2012) in identifying the industry successes and needs looking forward. This then becomes the 2012 call to action for the SolarTech Committees to build work plans to solve the business process hidden costs issues of the solar PV market.

Summit Installation Sessions Report/Recommendations

Solution Paths

- Working well – Just scale it
  - A NEC and I Codes
  - B Training
  - C German methods
- Market gaps
  - "Building code requirements" is known, must go faster
  - 'Lack of ASTM Standard' is known, little is being done
  - 'Systems Approach" is over the horizon
- Top priorities
  - A Education & public awareness
  - B Plug-n-Play systems
  - C Certification (components & installers)
- Impact on soft cost reduction
  - $0.50 / W, cost of capital (%)

Execution & Adoption

- Highest priority markets
  - Solar America cities
  - Common priority markets:
    - Residential
  - Unique priority markets: Commercial rooftop
- Keys to adoption
  - A Public awareness
  - B Use ASTM for systems standard
  - C Industry collaboration & leadership
- What are the risks?
  - A Roof failures
  - B Bad PR
  - C Bad/restricted policy

Summit Performance Sessions Report/Recommendations

Solution Paths

- Working well – Just scale it
  - O&M risk manageable, but overlooked
- Market gaps
  - ***Transparency:*** Lack of transparent data in market
  - ***Standardization:*** Need standardized methods for assessing data to reduce solar resource risk; Takes long time to develop standards
  - ***Bankability:*** High degree of subjectivity in defining "bankable" product
- Top priorities
  - Open access to performance data
  - Need to create "best practices" for assessing performance of plants
  - Involve Independent Engineers to help standardize definition on bankability
- Impact on soft cost reduction
  - ***$/W impact:*** Variation in energy yield leads to increase in system cost (10% over-prediction → 10% increase in cost)

Execution & Adoption

- Highest priority markets
  - C&I market
  - California, Texas and New Jersey
- Keys to adoption
  - ***Performance data:*** Trusted 3rd party needs to help create standards to build transparent performance data from power plants; Learn from other markets like Germany and/or require monitoring
  - ***Standardization:*** Standardization of Independent Engineer evaluations; Standardization of communication and monitoring methods
  - ***Securitization:*** Transparency needed to eliminate technology risk and enable securitization of the market
- What are the risks?
  - ***Policy risk:*** ITC uncertainty makes financing long term projects more difficult
  - ***Perceived risk:*** Perceived risk higher than the actual risk of projects. We may be leaving money on the table

<u>Summit Permitting Sessions Report/Recommendations</u>

Solution Paths

- Working well – Just scale it
  - Standardization in pockets
  - Certification—drive adoption
  - Streamlining, SolarABCs, etc.
- Market gaps
  - Known (See Solar3.0 / SunShot)
- Top priorities
  - Training for Permitting Officials
  - Permit Training for Installers
  - Development of a Toolbox
  - Third Party options as "battery backup"
- Impact on soft cost reduction
  - $.50 - $1.00 / W, cost of capital (10-25%)

Execution & Adoption

- Highest priority markets
  - West
  - CA, AZ, MA, NJ
  - Identify key cities across U.S.
- Keys to adoption
  - Survey AHJs to gauge training requirements
  - Survey Industry to identify key factors to expanding in AHJs
  - Utilize DOE leverage to demonstrate viability of options and drive adoption
  - Utilize technology to expedite and streamline permitting

- What are the risks?
    - Pushback from jurisdictions
    - Success

Summit Finance Sessions Report/Recommendations

Solution Paths

- Working well – Just scale it
    - Existing tax equity sources are trained
    - Debt financing on utility scale markets is fairly efficient
    - Lending in residential space doing well
- Market gaps
    - ***Participation gap:*** Less than 5% of banks lending to solar plants
    - ***Tax equity:*** Limited resource (2 own 80%) & lack of transparency
    - ***C&I market:*** In no-man's land and hence scalability an issue
- Top priorities
    - Close participation gap in banks; Create Green bank
    - Expand scope of tax equity participation
    - Policy to stimulate C&I market (Example: REIT, Commercial PACE)
- Impact on soft cost reduction
    - ***Cost of capital:*** 200-400 bps premium on solar assets (700 bps for tax equity)

Execution & Adoption

- Highest priority markets
    - C&I market
    - Residential market
- Keys to adoption
    - ***Standardize:*** Standardize criteria and rating methodology for assessing credit risk in Solar assets
    - ***Simplify & Amplify:*** Simplify message to educate all parties; Take time to become credible advocate with regulators and educate utility commissioners
    - ***Train:*** Train banks and rating agencies in the space and increase participation from broader market
- What are the risks?
    - ***Policy risk:*** ITC expiring in 2016;Low incentive for new banks to get into tax equity market;
    - ***Net-metering:*** 5% cap issue
    - ***Scalability risk:*** Volume needs to grow to attract more banks

Summit Interconnection Sessions Report/Recommendations

Solution Paths

- Working well – Just scale it
    - IREC Freeing the grid
    - IREC interconnection and net metering best practices guideline
    - Online application SDGE and FLP
- Market gaps
    - Tariff vs. Process

  - Utilities who have benefited using existing solutions vs. those who have not
- Top priorities
  - Online application with Software validation & transparency
  - Educating applicants, identify people who need help
  - Marketing campaign to PUCs and Munis demonstrating existing solutions via webinars
- Impact on soft cost reduction
  - Cycle time for on-line application submittals is <5 days, txn costs?

Execution & Adoption

- Highest priority markets
  - Solar 3.0 top 100 cities
  - Regional (SMUD, LADWP, PG&E, SCE)
- Keys to adoption
  - Communication - not just to utilities but to PUCs, munis' and elected officials and/or sustainability rep
  - Buy-In
  - Education - importance of doing it correctly, benefits of doing it correctly

Chapter 5:
Production Readiness Plan

The PIER program has a public interest responsibility to see that new technology developments resulting from grant funds are commercialized and become an economic benefit to California.

1. The Skyline Solar X-14 High Gain system is in production, just needs more demand, easier financing and easier regulatory hurdles.
2. The SunPods system is also in production, and has enjoyed a considerable volume of installations throughout 2011. It too would benefit from an easier regulatory environment. A 200kW demonstration site targeted for this grant demonstration never materialized due to conditions grandfathered into the property by the previous owner, and the length of time it takes to challenge these siting issues through the local planning department. As long as financing and site permitting are easily obtained, the demand exists and the factory is ready to ramp.
3. The Carbon Meter Methodology of Santa Clara University needs further vetting by interested investors. The goal would be for Santa Clara University to license the technology to interested investors. SolarTech is currently consulting with CalCEF to see what recommendations their background can provide and introductions to investors they can offer.
4. The Shade Mitigation Methodology is offered to the Energy Commission to pursue.
5. All of the other developments under this grant are business processes and best practices. It takes considerable amount of time to drive adoption, especially within city and county jurisdictions. For example, the DOE funded Solar ABCs Expedited Permitting recommendation is an ideal ready-to-adopt simply process for cities and county jurisdictions for under 15kW system sizes. Yet we have seen in other reports connected with this grant that the permitting process alone can account for from $0.15/W to $0.39/W. This is an area that will simply take a lot of evangelistic outreach activities through Solar3.0 by SolarTech and others.

Chapter 6:
Conclusions and Recommendations

This grant has benefitted the stakeholders of California in the following key ways:

1. Development of several key products and solutions that otherwise would not have happened, for example:
    a. Carbon Meter Methodology from Santa Clara University
    b. Shading Mitigation Methodology study from Santa Clara University
    c. Skyline & SunPods Supermodule study
    d. 2010 SolarTech PV Adoption Consumer Study Summary Solar Energy Estimate (SEE) Report implementation and launch
    e. Online Solar Permit Application Inoperability Standard Microinverter & AC Module Application Guide
    f. Solar PV System Performance Assessment Guideline
    g. 2011 Study of Solar Permitting & Inspection, and Adoption Dashboard proposal.
    h. Solar3.0 National Platform for Dissemination of Best Practices and management Strategies
    i. Purchase Power Agreement (PPA) and Site Lease Contract Templates
    j. Engineering Procurement & Construction Agreement Template
    k. SolarTech Operating Lease Agreement
    l. Due Diligence Checklist
    m. Finance Option Tutorial
    n. Finance RFI and Companion Spreadsheet
2. Helped launch SolarTech, the only solar PV trade association focused on lowering business process soft costs and streamlining the industry.
3. This led directly to becoming a national-level brand that could apply for and win two significant grants from the DOE. Grants that specifically take many of the initiatives undertaken with this PIER grant and extending these initiatives to a national stage. A national organization directly benefits California Stakeholders in two key ways:
    a. A national-scale organization is stronger and better able to serve the interests of California than a small regional organization.
    b. California is still a leader in renewable energy accounting for 30 to 40 percent of the national capacity deployed to date, but great ideas and important developments in solar PV are happening in numerous other renewable energy centers of progress across the national landscape. A national association like SolarTech is best positioned to share these developments with local California interests as well as share California-based developments with other regions. This cross "pollination" of ideas and best practices builds a healthier renewable energy economic base.

The adoption and progress metric side, SolarTech has an opportunity through the DOE grants for Solar3.0 and RoofTop Challenge to continue to drive adoption of best practices and drive down hidden costs.

However, progress measurement of the impact of a new business techniques development and new technology on the overall cost of solar PV in residential, commercial and distributed generation markets remains the single biggest hurdle. The SolarTech-NREL survey exercise demonstrated both the kinds of analytical decision making data that is possible, but also a host of problems affecting data collection integrity. The final report, scheduled to be published in June 2012, is based on 2010 data collected in 2011-2012 at an estimated overall cost of $200,000.00. This kind of research into various hidden costs is extremely valuable to government policy makers working on economic externalities, such as solar and renewables, but very slow and costly. NREL conducts a quarterly project financing survey to and struggles with adequate data collection. All mature industries have metrics that the individual private firms participate in through either volunteer action or government regulations. Example, the Semiconductor Book to Bill ratio. The renewable energy sector needs to find an economical method that generates useful data for analytical analysis of the industry's health. This poses an opportunity for the Energy Commission.

The CSI data base was an enlightened requirement connected to the rebate program that provided a significant source of valuable data. However, it didn't go far enough in several areas, some of which were identified in the 2010 CSI Cost-Effectiveness Evaluation. The soft cost data collection issue covered in this grant are not covered by any other report or process. If the industry leaders and policy makers are going to be able to make the right financial decisions in the right areas, they are going to need access to data that covers more than just the size of the system, utility territory, and selling price.

The final recommendation is for performance data. Just as with business process soft costs, it is impossible to get good historical data on the performance of these systems versus the design targets. This impacts progress in two areas:

1. No clear picture for Operations and Maintenance purposes to determine when a system is performing as expected or requires attention.
2. Impacts financial credit and the loanable funds market for solar. Without a reliable source of performance data the actuarial risk analysis function within banks, rating agencies and insurance institutions can't asses a fair rating for solar PV. This leads to a higher than reasonable interest rates by those few lending institutions that venture into the solar space.

SolarTech would encourage the Energy Commission to engage in the conversations currently in process with all of the institutions mentioned above in addition to Sandia National Labs and NREL to best evaluate how the Energy Commission can best engage and support these developments.