

**PIER RENEWABLE ENERGY  
TECHNOLOGIES PROGRAM**

**SOLAR PHOTOVOLTAIC  
RESEARCH PLAN**

**CALIFORNIA  
ENERGY  
COMMISSION**

**DRAFT STAFF REPORT**

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Arnold Schwarzenegger  
*Governor*

# CALIFORNIA ENERGY COMMISSION

Golam Kibrya  
Elaine Sison-Lebrilla  
***Principal Authors***

Elaine Sison-Lebrilla  
***Manager***  
**Energy Generation Research Office**

Martha Krebs  
***Deputy Director***  
**Energy Research and Development Division**

B.B. Blevins  
***Executive Director***

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# ABSTRACT

The Solar Photovoltaic Research Plan identifies the priority research, development, and demonstration investments to be made by the Public Interest Energy Research program at the California Energy Commission in the short term (2006-2010). These investments will help the state meet its aggressive renewable energy policy goals set through the California Solar Initiative, Senate Bill 1 (Murray), and the Renewable Portfolio Standard. The primary role of PIER Renewables solar PV program is to help the state meet its aggressive goals for solar by investing in high priority research projects. For example, the California Solar Initiative target of 3,000 MW solar generations by 2017. The research plan was developed with extensive inputs from external stakeholders representing the government, utilities, solar companies, advocacy groups, and research organizations under the oversight of a steering committee composed of key decision makers for the Energy Commission and California Public Utilities Commission.

The stakeholders identified the high priority milestones, which were from the end user, market support, and grid integration platforms. It was also revealed that production technology milestones, although very important, was of less priority for PIER as many of them were being pursued by the U.S. Department of Energy and the solar industry. PIER Renewables will focus on the high priority milestones with emphasis on later stage demonstration projects as opposed to early basic research. PIER Renewables will make use of the “natural laboratory” in California, especially with grid integration, end use, and market transformation.

**Key words:** Renewables, solar photovoltaic, PV, milestones, platforms, California Solar Initiative, CSI, RPS.

## Table of Contents

EXECUTIVE SUMMARY .....	1
CHAPTER 1: INTRODUCTION .....	2
Background.....	2
Solar PV Research Plan Rationale .....	2
Solar PV Research Plan Approach .....	4
Overview of Report .....	5
CHAPTER 2: CALIFORNIA ENERGY POLICIES RELATED TO SOLAR PV .....	7
Overview .....	7
Solar PV Policy .....	7
Other State Energy Policy Supported by Solar PV .....	7
CHAPTER 3: SOLAR PV RD&D ROADMAP .....	9
RD&D Roadmap Framework .....	9
Vision .....	9
Platforms.....	10
RD&D Milestones.....	10
CHAPTER 4: SOLAR PV RD&D PRIORITIES .....	17
Participating Stakeholders .....	17
Prioritization Criteria.....	18
General Prioritization Results.....	20
Tier 1 Priority RD&D Milestones .....	22
Tier 2 Priority RD&D Milestones .....	24
CHAPTER 5: IMPLEMENTATION OF SOLAR PV RESEARCH PLAN.....	26

## List of Figures

Figure 1:“RD&D Planning Effort Process”.....	4
Figure 2:“Steering Committee Members”.....	5
Figure 3:“Solar PV Research Plan Approach Process” .....	6
Figure 4:“Solar PV Energy Policy” .....	9
Figure 5:“Solar PV Roadmap Framework”.....	11
Figure 6: “Solar PV Roadmap Milestones – Production Technologies Platform”.....	15
Figure 7:”Solar PV Roadmap Milestones - Grid Integration Platform” .....	16
Figure 8:”Solar PV Roadmap Milestones- End Use Platform”.....	17
Figure 9:”Solar PV Roadmap Milestones- Market Support Platform”.....	18
Figure 10:”List of Stakeholders Interviewed”.....	19
Figure 11:”Prioritization Criteria for PIER Solar PV RD&D” .....	21
Figure 12:”Scoring Scale”.....	22
Figure 13: “Prioritization of Solar PV RD&D Milestones” .....	23



# EXECUTIVE SUMMARY

The Solar Photovoltaic Research Plan is the first of a series of research plans to be developed by the California Energy Commission Public Interest Energy Research (PIER) program for each renewable resource/technology area identified in the PIER Renewables Roadmap<sup>1</sup>. Each research plan will define priority research, development, and demonstration investments over the short term (2006-2010) that will help the state meet its aggressive renewable energy policy goals. The Solar Photovoltaic Research Plan will also serve as a model for PIER Renewables to prioritize research needs for the remaining resource/technology areas identified in the PIER Renewables Roadmap.

A Steering Committee, formed by key renewable energy decision makers within the Energy Commission, with input from California Public Utilities Commission staff, guided the development of the Solar Photovoltaic Research Plan. The plan relied on the input of key stakeholders representing the government, utilities, solar photovoltaic companies, advocacy groups, and research organizations to prioritize the research needs.

The primary role of PIER Renewables is to help the state meet its aggressive renewable energy policy goals by investing in high priority research projects. This year, California passed the California Solar Initiative<sup>2</sup> and Senate Bill 1, which call for 3,000 MW of new solar generation by 2017. These ambitious policies serve as the guiding principles for the Solar Photovoltaic Research Plan.

An analysis of the milestone scores provided by the stakeholders revealed a set of high priority milestones with both high relative impact and relative need. The highest ranking milestones are from end-use, market support, and grid integration platforms, indicating that PIER Renewables should focus solar photovoltaic efforts primarily on those platforms.

The milestones in the production technologies platform represent a relatively lower need, as stakeholders believe PIER should not play a significant role in production technologies given that the U.S. Department of Energy and the solar industry are focused on this area. Milestones in the grid integration platform tended to have a high need score, as stakeholders believe that PIER plays an important role in this area. However, these milestones also tended to receive lower impact scores. As for milestones in the end-use and market support platforms, they ranged widely in both importance and need.

PIER Renewables will concentrate on a number of key issues while implementing the Solar Photovoltaic Research Plan. It will focus on later stage demonstration projects instead of early research. PIER Renewables will also take advantage of the “natural laboratory” in California, especially with regard to grid integration. It will coordinate with other solar photovoltaic research programs in the state to leverage its efforts and maximize the benefits. PIER Renewables will also play a key role in supporting the solar industry.

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<sup>1</sup> *Public Interest Energy Research Renewable Energy Technologies Program Research, Development and Demonstration Roadmap*, June 2006

<sup>2</sup> CPUC Proceeding R.06-03-004

# CHAPTER 1: INTRODUCTION

## Background

The Public Interest Energy Research Program (PIER) at the California Energy Commission (Energy Commission) was established in 1996 by legislation that includes a requirement that at least \$62.5 million be collected annually from investor-owned utility ratepayers for public interest energy research and development efforts that are not adequately provided by competitive and regulated markets. PIER supports research, development, and demonstration (RD&D) projects that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

PIER funding focuses on seven programmatic areas including renewable energy technologies. PIER Renewable Energy Technologies Program (PIER Renewables) focuses on RD&D that:

- Advances market adoption of renewable energy resources and generating technologies through innovation, performance improvements and cost reduction, as well as advancing the production of transportation fuels with renewable resources.
- Enables effective interconnection of renewable generation to the electrical transmission and distribution system.
- Encourages end-user adoption of distributed renewables by addressing technology and market issues.
- Supports the development of appropriate market mechanisms and policies to enable sustainable renewable energy growth.

Between July 1, 2000 and June 30, 2005, PIER Renewables invested \$53.6 million in renewables RD&D activities, including but not limited to solar photovoltaic (PV), concentrating solar power (CSP), wind, geothermal, biomass, and waste-to-energy. The PIER 2005 annual report describes the RD&D projects funded by PIER Renewables and is available on the Energy Commission's website.<sup>3</sup>

## Solar PV Research Plan Rationale

The Solar PV Research Plan was preceded by a broader effort from PIER Renewables to develop an integrated renewable energy RD&D roadmap (Renewables Roadmap). Developed between December 2005 and June 2006, the Renewables Roadmap identified RD&D investments across multiple renewable energy resources/technologies (for example;

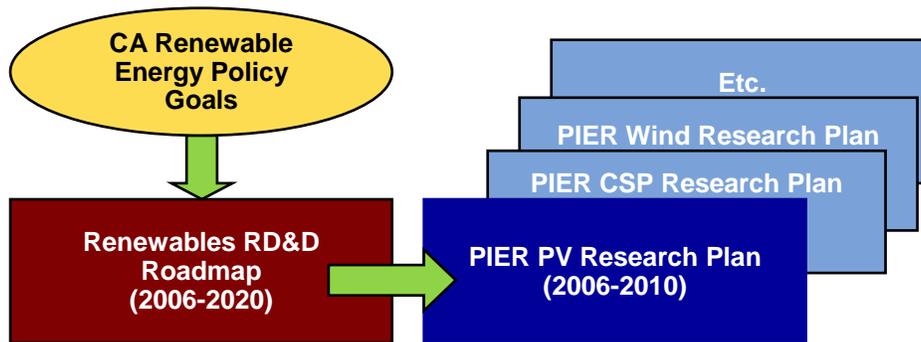
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<sup>3</sup> *2005 Annual Project Updates for the Public Interest Energy Research Program (PIER):*  
[<http://www.energy.ca.gov/2006publications/CEC-500-2006-037/CEC-500-2006-037-SF.PDF>]

solar PV, CSP, wind, biomass, geothermal) that will help the state meet its ambitious renewable energy policy goals by 2020. While the Renewables Roadmap provided a comprehensive view of RD&D needs, PIER Renewables has limited funds. As a result, PIER Renewables embarked on a process to develop research plans by technology/resource area to prioritize the RD&D needs identified in the Renewables Roadmap.

As illustrated in Figure 1, the Solar PV Research Plan is the first of a series of research plans to be developed for each renewable energy resource/technology area identified in the Renewables Roadmap. Each research plan will define priority RD&D investments over the short term (2006-2010) that will help California meet its aggressive renewable energy policy goals. The Solar PV Research Plan will also serve as a model for prioritizing research needs for the remaining resource/technology areas identified in the Renewables Roadmap.

**Figure 1: RD&D Planning Effort Process**



The Solar PV Research Plan was chosen as the first technology/resource area to pursue because solar PV is a key area of focus in California. The California Solar Initiative<sup>4</sup> (CSI) and Senate Bill 1 (Murray), Chapter 32, Statutes of 2006, call for 3,000 MW of the new solar generation capacity in California by 2017. Solar PV provides an opportunity for PIER Renewables to work with the Renewable Energy Program at the Energy Commission, the California Public Utilities Commission (CPUC), and other key stakeholders (for example: utilities), since all of these entities are engaged in and responsible for implementing CSI over the next 10 years.

The Research Plan will focus on the RD&D needs related to solar PV technologies, including residential, commercial, and government/non-profit applications. It will address RD&D issues common with other renewable energy resources/technologies only as they relate to meeting solar PV policy goals. It will not address CSP (for example: concentrating dish-sterling engine, parabolic trough, or power tower technologies). In addition, issues that pertain to large central, utility-scale PV facilities, such as siting, transmission, and environmental impacts, will be addressed in the CSP research plan since these issues are a major concern of many CSP installations and more relevant to the CSP Roadmap.

<sup>4</sup> CPUC Proceeding R.06-03-004

## Solar PV Research Plan Approach

A Steering Committee (Figure 2) was formed by key renewable energy decision makers at the Energy Commission, including leaders of the PIER program, the Renewable Energy Program, and advisors to the members of the Renewables Committee consisting of Chairman Jackalyn Pfannenstiel and Commissioner John Geesman. The Steering Committee also included a key member from the CPUC responsible for developing the CSI policies. The Steering Committee members played a key role throughout the process and guided the development of the Solar PV Research Plan.

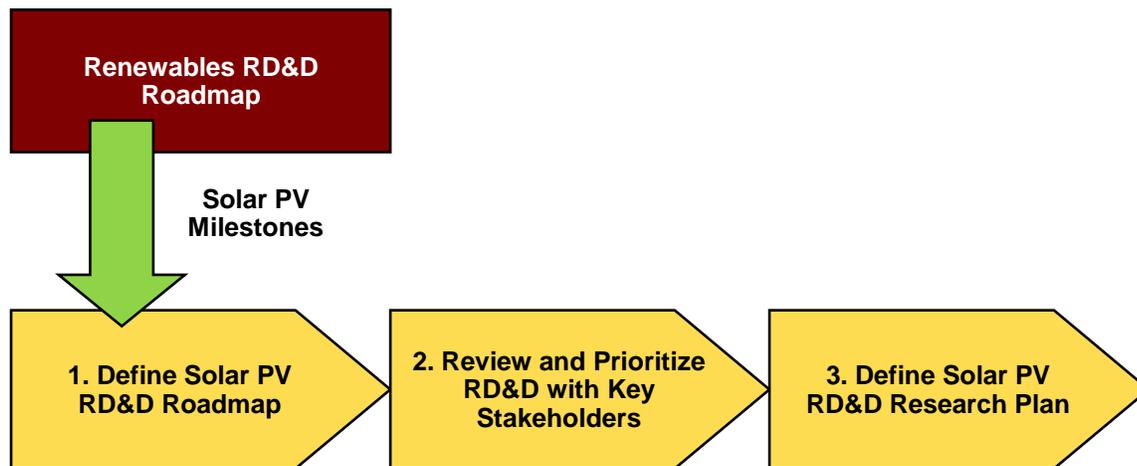
**Figure 2: Steering Committee Members**

Organization	Name	Reason for Inclusion in Steering Committee
PIER	Martha Krebs	Director of PIER; overall oversight of PIER research planning activities
PIER	Elaine Sison-Lebrilla	Interim lead for PIER Renewables program
PIER	Golam Kibrya	Lead for PIER Renewables solar projects
Energy Commission Renewable Energy Program	Bill Blackburn	Lead interface between Energy Commission Renewables Program and PIER on solar PV issues
Commissioner Geesman's Office	Suzanne Korosec	Adviser to Commissioner Geesman (member of Renewables and RD&D Committees)
Commissioner Pfannenstiel's Office	Tim Tutt	Adviser to Chairman Pfannenstiel and key liaison between Energy Commission and CPUC
California Public Utilities Commission (CPUC)	Jeanne Clinton	CPUC staff advisor responsible for developing CSI program framework

The Solar PV Research Plan was developed through a three-step process, as shown in Figure 3. During the first step, the Solar PV RD&D Roadmap was defined by the Steering Committee. This involved refining the Solar PV RD&D milestones identified in the Renewables Roadmap to ensure that they will help the state achieve its vision of 3,000 MW of new solar PV power by 2017.

During the second step, key stakeholders provided input to prioritize the RD&D milestones in the Solar PV Roadmap and determine which research initiatives were best suited for PIER funding. Approximately 20 stakeholders from state and federal government, municipal and investor-owned utilities, non-profits, universities, solar companies, and industry organizations were contacted.

**Figure 3: Solar PV Research Plan Approach Process**



The stakeholders were interviewed twice; first, to familiarize them with the Solar PV Research Plan objectives, second, to prioritize each milestone. Stakeholders scored each milestone based on its ability to meet the CSI and SB 1 goals and on its relative need for PIER funding. Stakeholders also provided general comments on each milestone and identified a number of additional milestones not included in the Solar PV Roadmap. Scores from the ranking process were analyzed to identify high priority milestones. These preliminary results were then shared at a workshop during the Solar Power 2006 conference for stakeholders to collectively discuss discrepancies in their rankings and provide additional comments on the analysis.

During the third and final step, the Steering Committee defined the Tier 1 (highest priority) and Tier 2 (high priority) milestones. The Steering Committee relied on stakeholder input to define these high priority milestones. The Steering Committee then held a public workshop to obtain additional comments on the Tier 1 and Tier 2 milestones. Comments were also gathered via e-mail. The Steering Committee incorporated input from the public workshop into the Solar PV Research Plan.

The exhaustive process to obtain internal and external input was followed to ensure the success of the Solar PV Research Plan. The plan reflects the input of key internal decision makers and has buy-in from key external stakeholders, including the CPUC, investor owned utilities (IOUs), and municipal utilities, and is consistent and complementary to the goals and programs of these organizations. The plan also reflects input from leading figures in the solar industry.

## **Overview of Report**

This report describes the Solar PV Research Plan, including the detailed Solar PV Roadmap developed initially as part of the Renewables Roadmap, in five chapters, including this introductory chapter.

- Chapter 2 contains California’s solar PV energy policy goals and the renewable energy policy directives relevant to solar PV.
- Chapter 3 provides an overview of the Solar PV Roadmap and includes a description of the research platforms and strategic objectives.
- Chapter 4 outlines the high priority milestones for Solar PV and the process used to develop them.
- Chapter 5 describes the next steps for implementation of the Solar PV Research Plan.

# CHAPTER 2: CALIFORNIA ENERGY POLICIES RELATED TO SOLAR PV

## Overview

The primary role of PIER Renewables is to help meet the state renewable energy policy goals by investing in high priority projects. The California Solar Initiative<sup>5</sup> (CSI) and Senate Bill 1, call for 3,000 MW of solar generation by 2017. These ambitious policies are the guiding principles for this Research Plan.

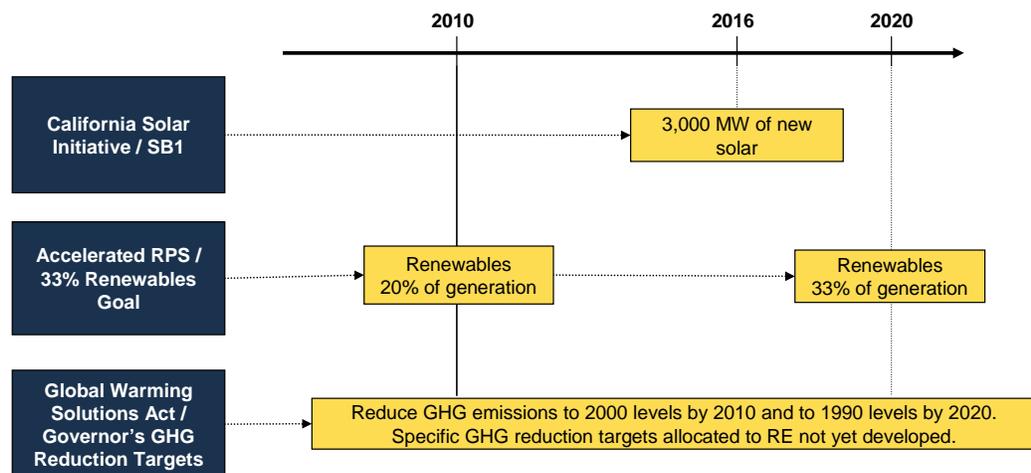
## Solar PV Policy

CSI establishes performance-based incentives that decline over time and are intended to help establish a self-sufficient solar industry within the next decade where solar energy systems are a viable mainstream option for homes and businesses. The solar market today is heavily subsidized, and tremendous efforts will be necessary to meet the state goal in 2017. As a reference, only 37 MW of grid-connected solar PV were installed in 2004, and the total amount of grid connected PV in California as of December 2006 is 198<sup>6</sup> MW. Ramping up solar installations to the level envisioned by the CSI will present a great challenge for the state.

## Other State Energy Policy Supported by Solar PV

While CSI and SB 1 represent the most aggressive solar PV goal, other state policies also support the growth of the solar PV market. Namely, California’s Renewables Portfolio Standard (RPS) and the Global Warming Solutions Act of 2006 (Assembly Bill 32 [Nunez], Chapter 488, Statutes of 2006), encourage the development of low-carbon forms of energy generation, including solar PV. Figure 4 illustrates the key policies supported by solar PV.

**Figure 4: Solar PV Energy Policy**



<sup>5</sup> CPUC Proceeding R.06-03-004

<sup>6</sup> [<http://www.energy.ca.gov/renewables/emerging-renewables/GRID-CONNECTED-PV.PDF>]

## ***Renewables Portfolio Standard***

California has established two goals that call for 20 percent of California's generation to be from renewable energy by 2010 and 33 percent by 2020. In 2004, renewables in California comprised approximately 11 percent of total generation<sup>7</sup>. Achieving the state's renewable goals will require a doubling of renewable generation by 2010 and a tripling by 2020. Currently, non-solar renewables such as geothermal, small hydroelectric, biomass, and wind contribute 97 percent of the state's renewable generation<sup>8</sup>, with solar providing only 3 percent. The growth in installed capacity through the CSI will not count toward RPS goals according to a proposed CPUC decision issued December 6, 2006.<sup>9</sup>

## ***The Global Warming Solutions Act and the Governor's Greenhouse Gas Emissions Targets***

In September 2006, the Governor signed the Global Warming Solutions Act (AB 32), which calls for a reduction in greenhouse gas (GHG) emissions to 1990 levels by 2020. Before this official legislation, the Governor also set the following GHG reduction goals: by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; by 2050, reduce GHG emissions to 80 percent below 1990 levels (Executive Order S-3-05). Although no direction has been given on exactly how these targets shall be achieved, renewable generation such as solar PV can play a critical role in reducing electricity use and therefore GHG emissions.

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<sup>7</sup> California Energy Commission Electricity Report

<sup>8</sup> California Energy Commission Website: [http://energy.ca.gov/electricity/gross\\_system\\_power.html](http://energy.ca.gov/electricity/gross_system_power.html)

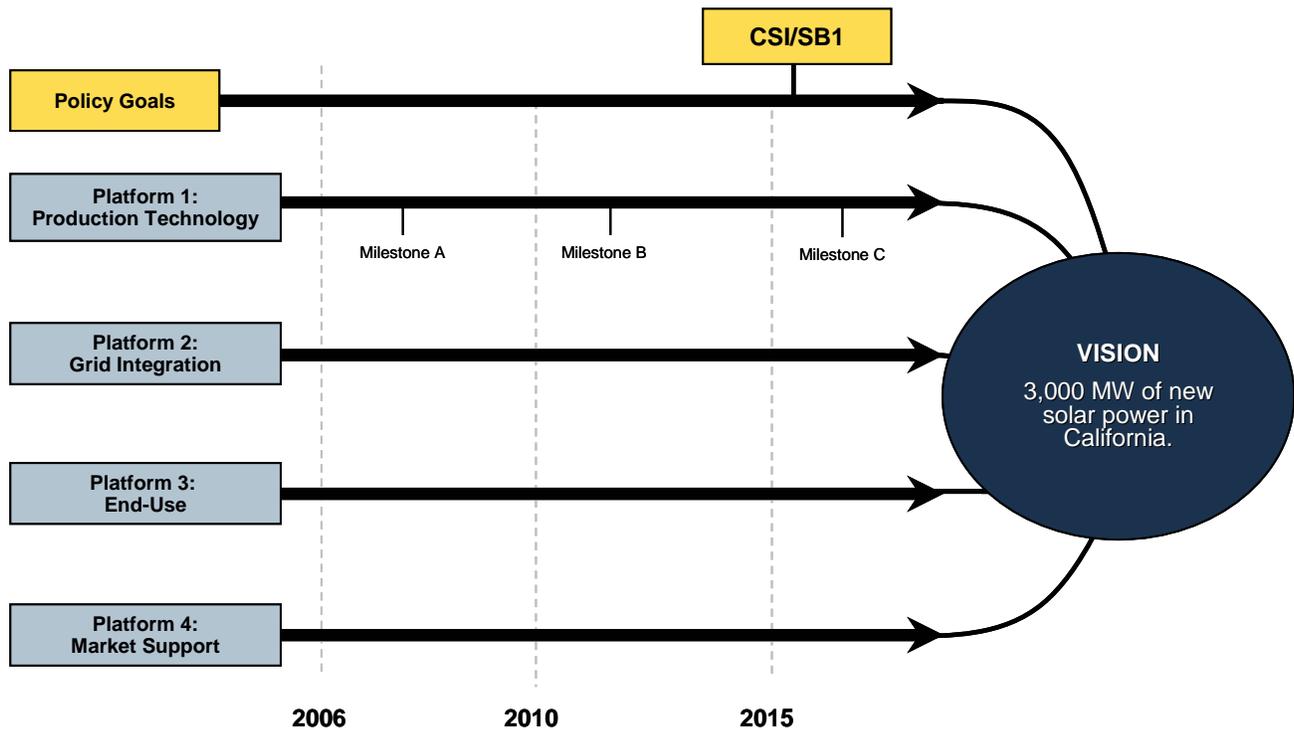
<sup>9</sup> CPUC, Proposed Decision of Commissioner Peevey, *Opinion Adopting Methods to Determine the Renewable Energy Credits from Renewable Distributed Generation*, December 6, 2006.

# CHAPTER 3: SOLAR PV RD&D ROADMAP

## RD&D Roadmap Framework

The Roadmap consists of four key elements: policy goals, vision, research platforms, and research milestones. The solar PV energy policies described in Chapter 2 form the foundation of the Solar PV RD&D Roadmap. The vision statement is crucial in helping to guide the RD&D activities of PIER Renewables. To achieve the vision, PIER Renewables has identified RD&D from four research platforms. Each platform contains RD&D milestones, which are a series of measurable goals. Together, these milestones and the platforms they represent support the state vision. Figure 5 illustrates the Solar PV Roadmap framework including the policy goals, vision, and research platforms.

Figure 5: Solar PV Roadmap Framework



## Vision

The policies and their goals have helped frame the program vision of achieving 3,000 new MW of solar by 2017. PIER Renewables intends to help California realize this vision through investment in solar PV RD&D.

## Platforms

The platforms establish strategic areas of focus for investment and management attention and indicate areas where PIER Renewables aims to make an impact. The strategic objectives that accompany each platform will help establish priorities for RD&D funding. PIER Renewables developed four platforms to help organize and structure research activities: production technologies, grid integration, end use, and market support.

**Platform 1: Production Technologies.** The strategic objective of the production technologies platform is to support the commercialization of PV technologies. RD&D activities in this platform have traditionally formed the majority of investments made by PIER Renewables and tend to concentrate on improving performance, reducing the cost of renewable energy generating technologies, and developing renewable energy resources.

**Platform 2: Grid Integration.** The strategic objective of the grid integration platform is to integrate PV into the distribution and transmission system. This platform includes RD&D activities to effectively connect renewable generation to the electrical transmission and distribution system, including the development of technologies for storage, shaping, and forecasting. Significant RD&D investments in grid integration will be required to accommodate the large amount of new solar PV generating capacity mandated by state policy.

**Platform 3: End Use.** The strategic objective of the end-use platform is to support end-user adoption of PV by addressing end-user specific technology and market issues. Like the grid integration platform, PIER Renewables has funded RD&D activities in this platform in the past, and it will continue to be important given current state policy goals. For example, meeting CSI goals will require improved performance, ease-of-use, and economics of distributed generation (DG) PV systems. RD&D activities that develop end-use technologies and interconnection, such as improved metering, monitoring, storage, and electricity conversion, are critical for the growing PV market in California. PIER Renewables will also target projects such as building integrated PV (BIPV) technologies that incorporate these technologies more seamlessly into buildings.

**Platform 4: Market Support.** The strategic objective of the market support platform is to support appropriate market mechanisms and policies that enable sustainable renewable energy growth. This platform contains RD&D activities that encourage renewable adoption by addressing issues that hinder market growth including inadequate policy, outdated regulation, and lack of an incentive structure as well as market acceptance of technology. Significant investment in market support for RD&D will be necessary to transform the heavily subsidized solar market into the self-sustaining market dictated by CSI and SB 1.

## RD&D Milestones

The RD&D milestones in the Solar PV Roadmap are a series of measurable goals, each with a defined target date that, collectively, will accomplish the strategic objectives and the vision. Figures 6-9 at the end of this chapter present the solar PV RD&D milestones developed for each research platform.

## ***Production Technologies RD&D Milestones***

The production technology RD&D milestones support the commercialization of PV technologies. The milestones call for improved design and installation procedures for optimized system performance by 2008, improved efficiencies (capacity factors of 18-20 percent by 2009 and 25.5 percent cell efficiency by 2015), and the development of competitive new solar products (distributed concentrating PV systems by 2009, cost-competitive building-integrated PV products by 2011, and alternatives to silicon-based PV such as nano technology and/or organic materials by 2015).

## ***Grid Integration RD&D Milestones***

The grid integration RD&D milestones support integrating into the distribution and transmission system. Significant RD&D investments in grid integration will be required to accommodate the large amount of new solar PV generating capacity mandated by state policy. The milestone target dates earlier than those for production technologies: five of the eight milestones will be completed by 2008, and the remainder by 2009 and 2010. The milestones aim to alleviate grid integration issues related to interconnection, net metering, storage, transmission and distribution, and coincidence with peak load. Because utilities are a key player in resolving grid-integration issues, one milestone aims to achieve utility acceptance of protocols to allow PV system operation during grid outages. Other milestones aim to identify synergies between PV systems and plug-in hybrids by 2008 and to demonstrate economic viability of new PV system storage technologies by 2010.

## ***End-Use Milestones***

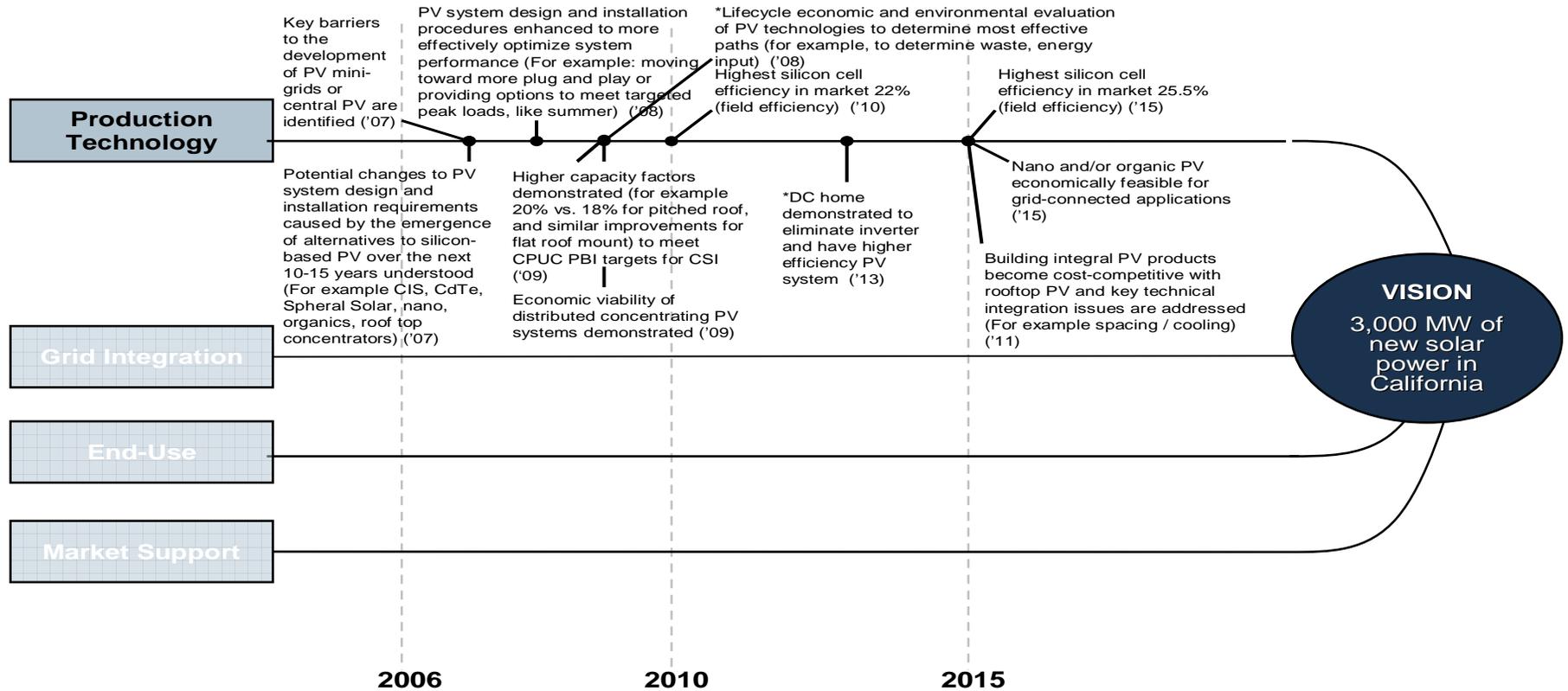
Milestones in the end-use platform are intended to support end-user adoption of PV by addressing end-user specific technology and market issues. The milestones call for a number of end-use improvements to improve PV economics, more efficiently integrate PV systems with buildings, and reduce operational and system risks. Milestones call for the development of new business models for utilities, homeowners and renters, a 30 percent decrease in PV inverter cost by 2012, and advanced metering and time-responsive tariffs to improve PV economics. Milestones also aim to identify synergies between PV and energy efficiency by 2008 and achieve widespread penetration of BIPV products by 2017. These milestones will provide improved performance, ease of use, and economics of PV systems, thereby supporting CSI and SB 1.

## ***Market Support Milestones***

Market support milestones support appropriate market mechanisms and policies that enable sustainable growth of solar PV. Significant investment in market support RD&D will be necessary to transform the heavily subsidized solar market into a self-sustaining market. Milestones call for improving PV education, including updating training for solar PV installers, building code officials, architects, and other building personnel. Milestones emphasize the creation and/or improvement of standards for buildings, energy efficiency, and module certification to ensure consistency and high performance. Milestones call for identifying barriers to PV adoption by public sector buildings and transforming California's capital rebates into performance-based incentives. The milestones also look outside

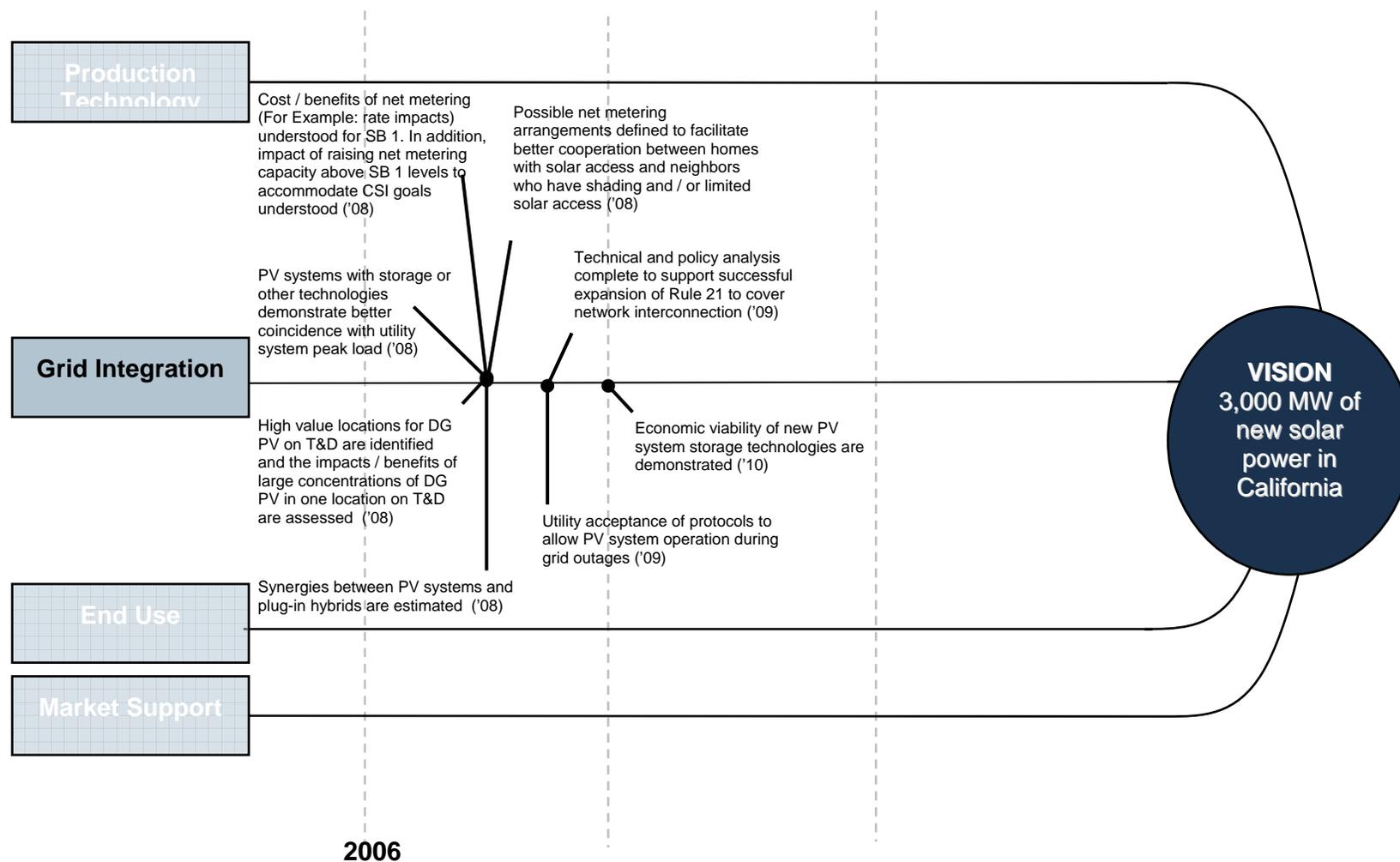
California to identify transferable RD&D strategies in strong international markets (for example; Japan and Germany), and policies/regulations in other states that may be hindering the California market.

**Figure 6: Solar PV Roadmap Milestones – Production Technologies Platform**



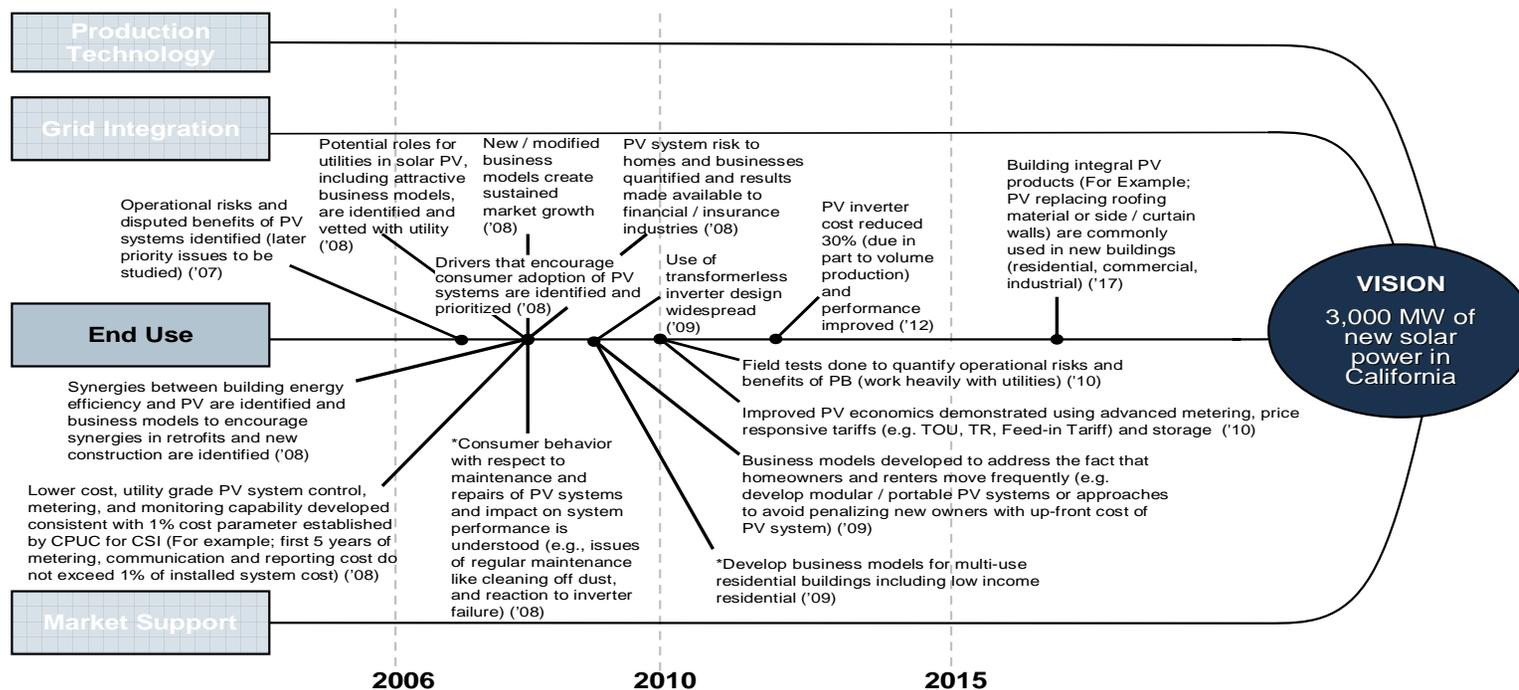
\* Milestone added by stakeholders during research plan prioritization process.

**Figure 7: Solar PV Roadmap Milestones – Grid Integration Platform**



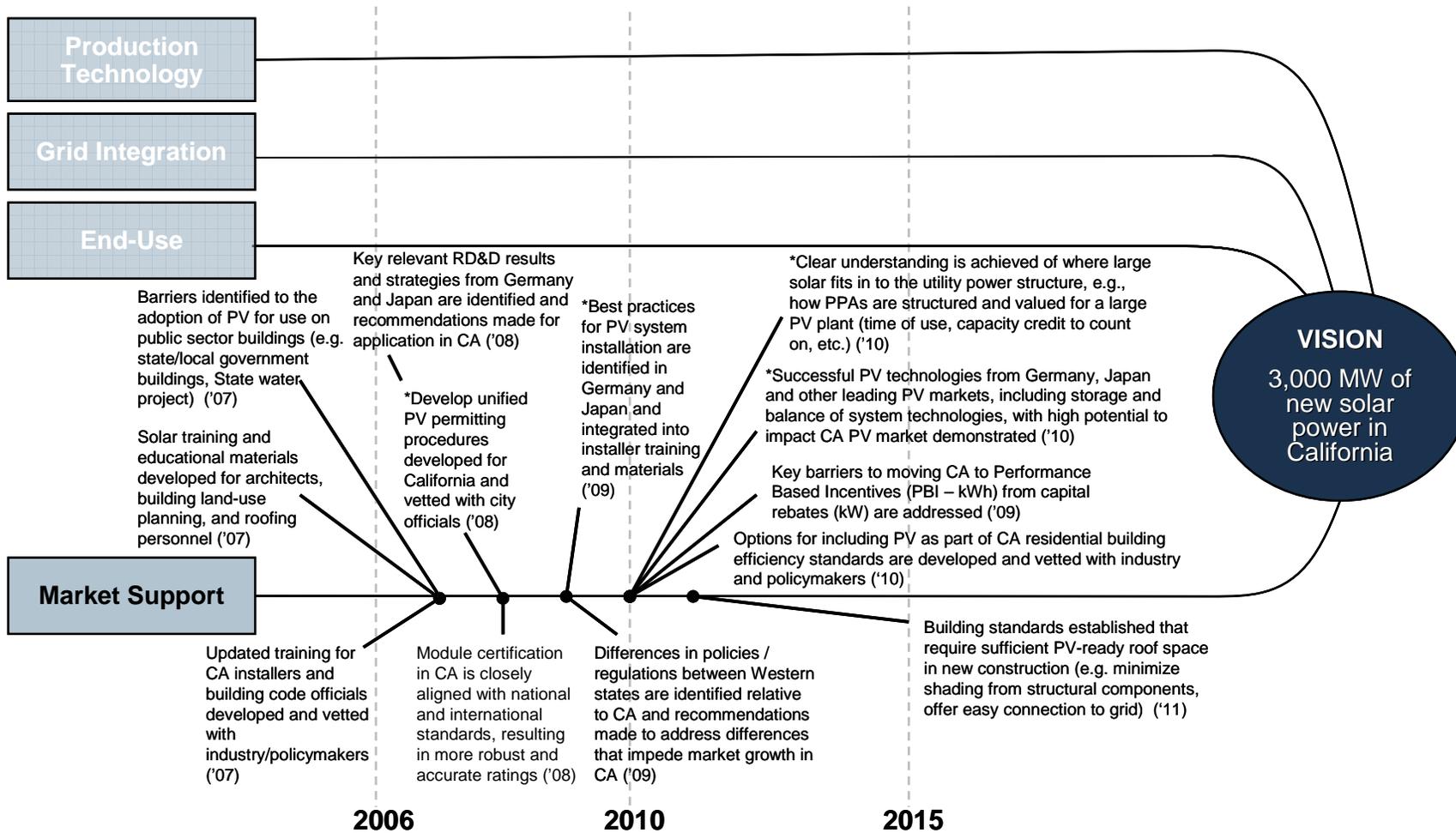
Note: PIER ESI performs research to address grid integration issues of DG, including PV

**Figure 8: Solar PV Roadmap Milestones – End-Use Platform**



\* Milestone added by stakeholders during research plan prioritization process.

**Figure 9: Solar PV Roadmap Milestones – Market Support Platform**



# CHAPTER 4: SOLAR PV RD&D PRIORITIES

The RD&D milestones developed in the Solar PV Roadmap reflect the RD&D needed to achieve California’s aggressive solar PV policy goals. To help prioritize the RD&D needs in solar PV, PIER Renewables obtained input from key stakeholders from government, utilities, solar PV companies, advocacy groups, and research organizations. This process helped identify a set of high priority research initiatives that will affect California’s solar market the most and are appropriate for PIER Renewables to focus on. This set of high priority milestones will guide PIER RD&D investment in solar PV.

## Participating Stakeholders

The first step in the process involved private interviews with a selection of targeted individuals. An effort was made to draw from a diverse pool of key organizations, including those with responsibility for implementing CSI and SB 1. In all, representatives from 17 organizations were interviewed, including state and federal government, municipal and investor owned utilities, non-profits, universities, solar companies, industry organizations, and the public at large. In many cases, multiple individuals from each organization were interviewed, and some of the stakeholders interviewed during the Renewables Roadmap process were solicited again for their input to the Solar PV Research Plan. Figure 10 presents a list of all the stakeholders interviewed for the Solar PV Research Plan.

**Figure 10: List of Stakeholders Interviewed**

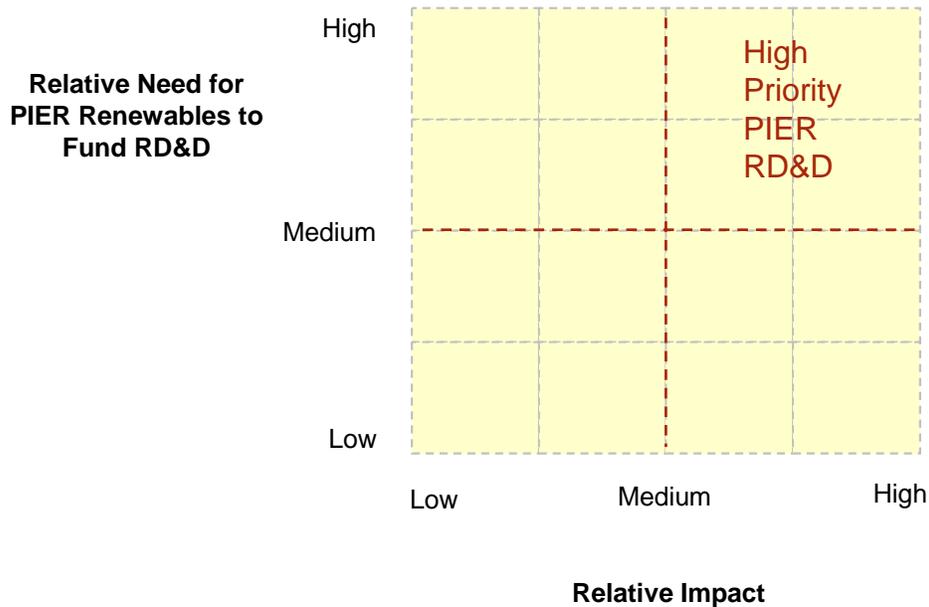
No.	Organization	Contacts
1	<b>Energy Commission Renewable Energy Program</b>	Bill Blackburn, Emerging Renewables Program Sandy Miller, Solar Program
2	<b>California Public Utilities Commission (CPUC)</b>	Jeanne Clinton, Clean Energy Advisor Jaclyn Marks, Regulatory Analyst
3	<b>CPUC Leadership</b>	Commissioner Michael Peevey
4	<b>Pacific Gas and Electric (PG&amp;E)</b>	Hal LaFlash, Director Renewable Energy Policy & Planning Bruce Bowen, Director of Regulatory Policy
5	<b>Southern California Edison (SCE)</b>	Stuart Hemphill, Director of Renewable and Alternative Power Wil Grady, Technical Advisor Renewable and Alternative Power
6	<b>San Diego Gas and Electric (SDG&amp;E)</b>	David Berokoff, Manager Technology Development James D. Corlett, Senior Technology Development Advisor
7	<b>Sacramento Municipal Utility District (SMUD)</b>	Jon Bertolino, Superintendent Renewable Generation Assets

8	<b>U.S. Department of Energy (DOE)</b>	Craig Cornelius, Technology Manager, Solar Energy Technologies Tom Kimbis, Technology Manager, Solar Technology Acceptance Steve Chalk, Acting Solar Program Manager
9	<b>National Renewable Energy Laboratory (NREL)</b>	Robert Margolis, Senior Energy Analyst
10	<b>Vote Solar</b>	J.P. Ross, Policy Director
11	<b>Clean Energy States Alliance (CESA)</b>	Mark Sinclair, Clean Energy Group Lew Milford, Executive Director
12	<b>Consol</b>	Rob Hammon, Principal
13	<b>California Solar Energy Industries Association (CALSEIA)</b>	Les Nelson, Executive Director Barry Cinnamon, President Gary Gerber, Chair of Policy Committee
14	<b>SunPower</b>	Dick Swanson, President and CTO
15	<b>PowerLight</b>	Brian Stone, VP Marketing Jack Peurach, VP Product Development Howard Wenger, Executive VP
16	<b>NanoSolar</b>	Brian Sager, VP Finance and Corporate Development
17	<b>University of California, Merced</b>	Roland Winston, Schools of Engineering and Natural Sciences

## Prioritization Criteria

Stakeholders prioritized each milestone in the Solar PV Roadmap based on two major criteria: the milestone's relative impact on meeting the program vision and the relative need for PIER Renewables to fund the milestone, as depicted in Figure 11. The milestones were scored and ranked according to the scale and criteria described in Figure 12. The milestones that achieved high scores for both potential impact and need for PIER funding were considered high priority areas for PIER RD&D efforts. The additional milestones added during the stakeholder interview process were not ranked.

**Figure 11: Prioritization Criteria for PIER Solar PV RD&D**



In scoring the potential impact of the milestone, stakeholders were asked to consider:

- How important is the RD&D to meet key state solar PV policy goals? (for example., CSI and SB 1)
- If this RD&D milestone is achieved, how transferable will the results be to industry?
- How likely is it that this RD&D milestone will be achieved?
- Is this RD&D milestone important or even critical in terms of other milestones that follow it?

In scoring the milestone’s need for funding, stakeholders were asked to consider:

- What is the relative size of the gap between the needed RD&D activity and the recent RD&D activities funded by other organizations (such as other groups within the Energy Commission, DOE and national laboratories, universities, private industry)? Will the milestone be met through those efforts?
- How likely is it that this RD&D milestone will be achieved?
- Is PIER the appropriate agency to fund this research?

**Figure 12: Scoring Scale**

Potential Impact				
1	2	3	4	5
Milestone will have no impact on helping CA meet CSI and SB 1.	Milestone will have small impact on helping CA meet CSI and SB 1.	Milestone will have medium impact on helping CA meet CSI and SB 1.	Milestone will have large impact on helping CA meet CSI and SB 1.	Milestone will be instrumental in helping CA meet CSI and SB 1.

Need for PIER Funding Score				
1	2	3	4	5
No need for PIER to fund; tremendous RD&D in this area already.	Small need for PIER to fund; there are substantial RD&D efforts in this area already.	Limited need for PIER to fund; some RD&D in this area with need for limited additional effort.	Large need for PIER to fund; only small RD&D efforts in this area thus far.	Tremendous need for PIER to fund; no RD&D in this area yet.

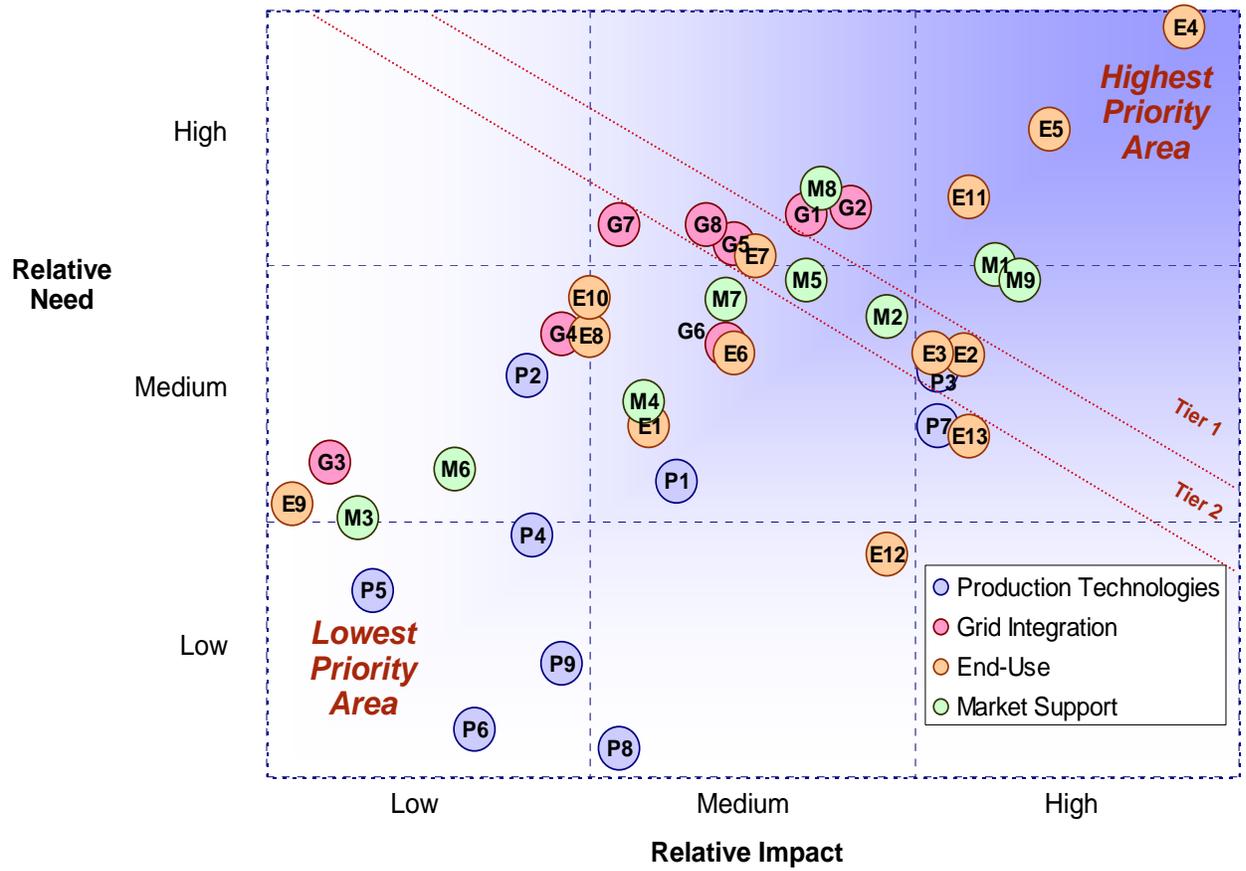
## General Prioritization Results

An analysis of the milestone scores provided by each stakeholder revealed a set of high priority milestones with both high relative impact and high relative need. The highest ranking milestones are from the end-use, market support, and grid integration platforms, which suggest that PIER Renewables should focus solar PV RD&D efforts primarily on those three platforms.

Overall, milestones in the production technologies platform received a low need score given that DOE and the solar industry are focused on this area. Milestones in the grid integration platform tended to have a high need score, but also tended to receive lower impact scores. Milestones in the end-use and market support platforms ranged widely in both importance and need. Figure 13 lists the milestones according to platform and shows the milestone ranking by the stakeholders.

**Figure 13: Prioritization of Solar PV RD&D Milestones**

(Milestones starting with P stands for production technology, G for grid integration, E for end use, and M for market support)



Platform	Number	Year	Milestone Description
Production Technology	P1	'07	Potential changes to PV system design and installation requirements caused by the emergence of alternatives to silicon-based PV over next 15 yrs understood
	P2	'07	Key barriers to the development of PV mini-grids or central PV are identified
	P3	'08	PV system design and installation procedures enhanced to more effectively optimize system performance
	P4	'09	Higher capacity factors demonstrated (e.g. 20% vs. 18% for pitched roof, and similar improvements for flat roof mount) to meet CPUC PBI targets for CSI
	P5	'09	Economic viability of distributed concentrating PV systems demonstrated
	P6	'10	Highest silicon cell efficiency in market 22% (field efficiency)
	P7	'11	Building integral PV products become cost competitive with rooftop PV and key technical integration issues are addressed (e.g. spacing/cooling)
	P8	'15	Highest silicon cell efficiency in market 25.5% (field efficiency)
	P9	'15	Nano and/or organic PV economically feasible for grid-connected applications
Grid Integration	G1	'08	Cost/benefits of net metering (e.g. rate impacts) understood for SB1, as well as impact of raising net metering capacity to accommodate CSI goals
	G2	'08	PV systems with storage or other technologies demonstrate better coincidence with utility system peak load
	G3	'08	Possible net metering arrangements defined to facilitate cooperation between homes with solar access and neighbors who have shading and/or limited access
	G4	'08	Synergies between PV systems and plug-in hybrids are estimated
	G5	'08	High value locations for DG PV on T&D are identified and the impacts/benefits of large concentrations of DG PV in one location on T&D are assessed
	G6	'09	Technical and policy analysis complete to support successful expansion of Rule 21 to cover network interconnection
	G7	'09	Utility acceptance of protocols to allow PV system operation during grid outages
	G8	'10	Economic viability of new PV system storage technologies are demonstrated
End-Use	E1	'07	Operational risks and disputed benefits of PV systems identified (later priority issues to be studied)
	E2	'08	Drivers that encourage consumer adoption of PV systems are identified and prioritized
	E3	'08	New/modified business models create sustained market growth
	E4	'08	Synergies between building energy efficiency and PV are identified and business models to encourage synergies in retrofits and new construction are identified
	E5	'08	Potential roles for utilities in solar PV, including attractive business models, are identified and vetted with utility companies.
	E6	'08	PV system risk to homes and businesses quantified and results made available to financial / insurance industries
	E7	'08	Lower cost, utility grade PV system control, metering, and monitoring capacity developed consistent with 1% cost parameter established by CPUC for CSI
	E8	'09	Use of transformerless inverter design is widespread
	E9	'09	Business models developed to address fact that homeowners and renters move frequently
	E10	'10	Field tests done to quantify operational risks and benefits of PV (work heavily with utilities)
	E11	'10	Improved PV economics demonstrated using advanced metering, price responsive tariffs (e.g. TOU, Feed-in Tariff) and storage
	E12	'12	PV inverter cost reduced 30% (due in part to volume production) and performance improved
	E13	'17	Building integral PV products (e.g. PV replacing roofing material or side/curtain walls) are commonly used in new buildings (residential, commercial, industrial)
Market Support	M1	'07	Updated training for CA installers and building code officials developed and vetted with industry/policy makers
	M2	'07	Solar training and educational materials developed for architects, building land-use planning, and roofing personnel
	M3	'07	Barriers identified to the adoption of PV for use on public sector buildings (e.g. state/local government buildings, State water project)
	M4	'08	Key relevant RD&D results and strategies from Germany and Japan are identified and recommendations made for application in CA
	M5	'08	Module certification in CA is closely aligned with national and international standards, resulting in more robust and accurate ratings
	M6	'09	Differences in policies/regulations between Western states are identified and recommendations made to address differences that impede market growth in CA
	M7	'09	Key barriers to moving CA to Performance Based Incentives (PBI - kWh) from capital rebates (kW) are addressed
	M8	'11	Building standards established that require sufficient PV-ready roof space in new construction
	M9	'10	Options for including PV as part of CA residential building efficiency standards are developed and vetted with industry and policy makers

Figure 13 continued

Note: The milestones added during the stakeholder interviews are not included in the priority ranking.

## Tier 1 Priority RD&D Milestones

The Steering Committee used the stakeholder prioritized milestones in Figure 13 to define Tier 1 (highest priority) and Tier 2 (high priority) milestones. The Tier 1 milestones contain the top eight milestones ranked by stakeholders plus the highest ranking production technology milestone. Stakeholder input convinced the Steering Committee to move this production technology milestone from Tier 2 to Tier 1 given the need to reduce PV installation costs.

The following is a list of the nine Tier 1 RD&D milestones for Solar PV, as well as descriptions of current activities at the Energy Commission and CPUC and preliminary research opportunities for PIER Renewables.

- **E4: Synergies between building energy efficiency and PV are identified, and business models to encourage synergies in retrofits and new construction are**

**identified by 2008.** A significant amount of research is already available for new construction energy efficiency and PV. To achieve this milestone, there needs to be a better understanding of retrofits and synergies between energy efficiency and PV. Coordination should take place with PIER Buildings.

- **E5: Potential roles for utilities in solar PV, including attractive business models, are identified and vetted with utility companies by 2008.** The Energy Commission Renewable Energy Program already has a contract with MRW to address this issue, but PIER should continue this research after the MRW work is completed. PIER ZENH and PV Market Assessment work support this issue. The milestone should focus on how to make it work for IOUs and end users over the long run.
- **E11: Improved PV economics are demonstrated using advanced metering, price responsive tariffs (for example; TOU, DR, Feed-in Tariff) and storage by 2010.** Improving PV economics is an important issue. There is a need to understand how storage and advanced metering involving different tariff structures can benefit the IOUs and PV system economics.
- **M1: Updated training for California installers and building code officials developed and vetted with industry/policy makers by 2007.** This milestone will be addressed by the Energy Commission Renewable Energy Program as part of an incentive package for builders. The CPUC might complement this milestone with training for non-builder stakeholder groups. There is a potential PIER role in conducting a “needs assessment.”
- **M9: Options for including PV as part of California residential building efficiency standards are developed and vetted with industry and policy makers by 2010.** An effort commenced a year ago for 2008 new construction standards (where PV is an option), and PIER buildings is already supporting the development of the new (Tier 2) Title 24 building standards. There is a need to assess the feasibility of requiring builders to offer PV (this is an SB 1 requirement).
- **M8: Building standards are established that require sufficient PV-ready roof space in new construction by 2011.** This milestone is part of 2011/2012 standards, not 2008 standards. There is a need to study not just the roof, but also integration of PV into other building materials.
- **G2: PV systems with storage or other technologies demonstrate better coincidence with utility system peak load by 2008.** IOUs have expressed the importance of this milestone, but there is very limited research underway. This work is supported by PIER Energy Systems Integration (ESI) work with inverters, and PIER Industrial, Agriculture, and Water (IAW) is putting together a storage RD&D effort. This milestone is related to technology development and is distinct from milestone E11, which is an economic assessment.

- **G1: Cost/benefits of net metering (For example; rate effects) are understood for SB 1, as well as impact of raising net metering capacity to accommodate CSI goals by 2008.** There is a limited role for PIER in achieving this milestone, as the CPUC already has a legislative mandate to cover this issue through its program evaluation efforts.
- **P3: PV system design and installation procedures are enhanced to more effectively optimize system performance by 2008.** This milestone was moved from Tier 2 to Tier 1 by the Steering Committee because of input received at the stakeholder roundtable. Industry should already be undertaking this research. There is a need to pay more attention to reducing the installation costs of PV.

## Tier 2 Priority RD&D Milestones

An additional eight milestones were identified as secondary priorities (Tier 2). As with Tier 1, the majority of milestones came from the end-use, market support, and grid integration platforms. Below is a list of the eight Tier 2 RD&D milestones for Solar PV, as well as a description of current activities at the Energy Commission and CPUC, and preliminary research opportunities for PIER Renewables.

- **M2: Solar training and educational materials are developed for architects, building land-use planning, and roofing personnel by 2007.** This milestone, along with M1, will be addressed by the Energy Commission Renewable Energy Program and the CPUC. This milestone could fit with CPUC marketing and outreach efforts, but priorities are not yet defined. PIER can support this milestone with a market research piece.
- **E2: Drivers that encourage consumer adoption of PV systems are identified and prioritized by 2008.** The Energy Commission Renewables Energy Program is planning to address this issue, and it focused on new residential construction (with a budget of \$4.5 million over the next three years). This milestone could fit with CPUC marketing and outreach efforts, but priorities are not yet defined. PIER can support this milestone with a market research piece.
- **M5: Module certification in California is closely aligned with national and international standards, resulting in more robust and accurate ratings by 2008.** Module certification will be part of the Energy Commission Renewable Energy Program work regarding the New Solar Homes Partnership Program (NSHP) guidebook. There will be guidelines outlined in the NSHP guidebook. California is moving toward Standard Testing Conditions, and it is unlikely that the PVUSA Testing Conditions rating will be used. The Emerging Renewables Program provides a certified equipment list. The CPUC expects the Energy Commission to address this issue (per SB 1) and address retrofits.

- **G5: High value locations for DG PV on transmission and distribution are identified, and the impacts/benefits of large concentrations of DG PV in one location on T&D are assessed by 2008.** PIER Renewables has looked at this issue with regard to all renewables transmission, and this work can be extended to cover PV on the distribution system. PIER ESI has also funded work to demonstrate locational benefits of distributed generation on distribution systems.
- **G8: Economic viability of new PV system storage technologies are demonstrated by 2010.** This milestone complements the storage issues raised in milestones E11 and G2 (both Tier 1), but this milestone has a broader storage technology focus.
- **E7: Lower-cost, utility-grade PV system control, metering, and monitoring capacity are developed consistent with 1 percent cost parameter established by CPUC for CSI by 2008.** The CPUC assumes the market will work out this milestone under the CPUC program rules and the handbook working group; this will evolve quickly in the market over the next year.
- **E3: New/modified business models create sustained market growth by 2008.** This complements milestone E5 (Tier 1).
- **G7: Utility acceptance of protocols to allow PV system operation during grid outages achieved by 2009.** If the value of solar PV during grid outages was incorporated, this milestone would most likely have ranked higher. It received a low score because consumers today assume PV will be available during a grid outage, even though this is false.

During various review sessions with stakeholders, the need for PIER to fund additional production technology milestones was a highly debated issue. The majority of stakeholders believe that PIER should focus on grid integration, end-use, and market support issues because there is limited research by other organizations in these areas. In contrast, DOE and industry are investing in developing improved PV production technologies. However, a few stakeholders strongly supported the continued involvement of PIER in the development of improved production technologies given its importance in helping to reach the overall PV market penetration goals. The PIER PV Steering Committee decided to maintain the primary focus of the research plan on grid integration, end-use, and market support issues and will continue to evaluate production technology improvement opportunities.

## **CHAPTER 5: IMPLEMENTATION OF SOLAR PV RESEARCH PLAN**

The Solar PV Research Plan will be used by PIER Renewables in annual project planning to scope solicitations and research projects. The set of high priority milestones identified in the Solar PV Research Plan embody those issues that stakeholders from government, utilities, solar PV companies, advocacy groups, and research organizations believe are crucial to achieving the goals set out in CSI and SB 1. PIER Renewables will also select research projects based on their expected impact on reducing the cost of energy.

In implementing the Solar PV Research Plan, PIER Renewables will concentrate on a number of key issues raised by stakeholders. With regard to technological development, PIER Renewables will focus on demonstration projects instead of early research. PIER can play a major role in helping to get new technologies over the last commercialization hurdles and into the broad market. Since there are so many installations of PV systems already in California, the state can be considered as a natural laboratory for PV experiments. The state is uniquely positioned to conduct additional research and demonstration projects with actual field clusters of PV installations. PIER Renewables will take advantage of this natural laboratory in California, especially with regard to grid integration.

PIER Renewables will coordinate with other solar PV activities already underway at various research programs in the state to maximize the benefits of its RD&D investments. Specifically, PIER Renewables will coordinate with and complement RD&D from other state solar funds (for example, Energy Commission Buildings Standards and Renewable Energy Program, CPUC funds under the CSI for RD&D, marketing and outreach, and program evaluation). Activities will focus on issues unique to California that are not being adequately pursued by industry or other government agencies. PIER Renewables will also continue to inform policy as a neutral party.

PIER Renewables will also play a key role in supporting the solar industry. It will support PV module manufacturers in their efforts to attract capital to scale up production facilities and installation capacity. PIER Renewables will also seek to benchmark installation practices and costs from United States, Japan, and Germany (consistent with milestone P3) to gain knowledge from global solar initiatives related to accelerated adoption and market transformation of solar PV systems.