California Solar Initiative RD&D Program

Process Evaluation

Summary Report

May 11, 2017

Summary

The California State Legislature created the California Solar Initiative Research, Development, Demonstration and Deployment Program (the CSI RD&D Program, or the Program) in 2006 to support the broader California Solar Initiative. The CSI RD&D Program received $50 million to fund research, development and demonstration projects supporting integration of distributed solar photovoltaic (PV) into the California grid, with the longer-term goals of increasing solar technology performance, reducing solar technology costs, and filling technical knowledge gaps in the solar industry.

The CSI RD&D Program design established three target research areas:

- **Grid Integration:** Improving PV integration with transmission and distribution systems (50-65% of funding).
- **Solar Production Technologies:** Supporting commercialization of new photovoltaic (PV) technologies (10-25% of funding).
- **Business Development and Deployment:** Supporting the market and end-users (10-20% of funding).

The CSI RD&D Program funded 37 projects (35 of which were completed) across the three target research areas, with total CSI funding of $38.3 million in addition to $34.6 million in matched funding from the grantees and other sources.

In 2016, Evergreen Economics led a research team consisting of Evergreen Economics, Research Into Action, Dr. Gretchen Jordan, Dr. Varun Rai, and Advanced Survey Design to conduct a process evaluation of the CSI RD&D Program. This theory-based evaluation began with the development of a program logic model that linked the CSI RD&D Program activities to immediate outputs and to longer-term outcomes that were consistent with CPUC policy goals.

Once the Evergreen team identified metrics that would provide evidence of the Program's progress toward its goals, the evaluation team developed a data collection plan to gather information from a variety of different activities:

- ***Review of project data and documentation*** – Collecting and analyzing all relevant program reports, presentations, and project data.
- ***48 interviews with grantees and program managers*** – Obtaining additional information on the projects not included in the original documentation.
- ***15 interviews with industry experts and stakeholders*** – Collecting information on how program activities, products, and knowledge are affecting grid operators, utilities, and regulators.

- *5 interviews with other solar market actors* – Collecting information on how project activities, products, and expertise from the Program are affecting the broader solar market.
- *88 online surveys of solar market actors* – Collecting additional standardized data on the perception of Program accomplishments from the solar community.
- *Review of external data/literature* – Reviewing secondary data and literature to investigate knowledge dissemination of the Program-supported research.

In addition to the data collection and analysis, the Evergreen team completed a related network analysis task to evaluate the knowledge benefits provided to the solar community as a result of Program activities.

Based on these research activities, general conclusions from the evaluation are summarized below.

1. **The Program Manager, Itron, performed very well.** Grantees receiving funds from the Program gave universally positive feedback on Itron. Itron carried out all the required tasks of the Program Manager very competently and implemented the Program in accordance with the original Program design. Itron communicated clearly with grantees and stakeholders throughout the life of the Program, completing each phase – proposal solicitation, project selection, project implementation oversight, and final reporting – with no complaints and with high satisfaction ratings from participants. Itron also played an important and highly effective role in facilitating communication and partnerships within and between projects, as well as with the broader solar community, helping to engage key stakeholders and reduce duplication of efforts.
2. **CSI RD&D projects were mostly successful in making progress toward the long-term policy goals established for the Program.** Demonstration of short-term outcomes that are consistent with the logic model is a positive sign that projects are on a pathway to achieving the longer-term goals established for the Program. Examples of successes for each of the project groups (with details included in the full evaluation report) are summarized below.
    - *Grid Integration* was the most successful research area, with 20 completed projects. Important accomplishments for these projects included the following:
        - **Improvement to interconnection requirements.** There are a host of rules and regulations governing the interconnection, operating, and metering requirements for solar generating facilities connected to the distribution system. Eight of these projects conducted work explicitly designed to influence standards or rules relating to interconnection. Specific improvements addressed PV interconnection limits, project screening, and costs and processes for energy storage systems. These changes helped

streamline the review process for interconnection and storage projects, and played a direct role in the improvement to the interconnection process in California.

  - **Software products.** Across the 20 projects with Grid Integration components, there were over 30 outputs that included commercialized software packages, modeling methodologies, open source modeling tools, data collection tools, and databases. Grantees developed several software products that improve resource visibility, provide more accurate prediction of generation, and allow grid planners to model economic value of planned solar generation resources. Improvements in these areas add to overall system reliability, particularly in situations with high penetration PV.
  - **Improved modeling tools.** Aside from specific software applications, several projects developed modeling tools and methodologies that can be adopted or integrated into existing utility planning and operations tools. These included tools for solar irradiance forecasting, generation forecasting for individual systems and fleet systems, distribution system models, and economic value modeling tools. Each of these can be used to improve system reliability through more accurate prediction of solar generation and optimal siting of generation resources.
  - **Inverter system enhancements.** Advanced smart inverters are communication-enabled inverters that can improve communication between distributed solar resources and the grid. Improvements to inverter systems can greatly increase the penetration of PV and other renewable energy on the grid. Key accomplishments by the Program in this area included demonstration projects of advanced smart inverters, technical reports providing guidelines and inverter settings, and studies to develop optimal control methods.
  - **Permanent demonstration sites.** The Grid Integration research area accounted for six demonstration sites. Examples of these projects include demonstrations of battery packs, a showcase home for Zero Net Energy homes and their integrated technologies, a training facility, and a field demonstration of a PV penetration modeling tool.
- The ***Solar Production Technologies*** research area had a total of 12 projects, with varied success. While most of these projects met all their stated objectives, some either did not meet their objectives or invested in technology that proved not to be viable in the market at present. Significant accomplishments with this research area included:
  - A project between SolarCity and Tesla demonstrating new battery technology and control systems that led directly to development of the Tesla PowerWall product, which was predicted to have in excess of 168 MWh in sales ($44 million in revenue).

- A project by Sunlink involving seismic testing and design automation of solar mounting units. This led to Sunlink developing new software to improve design and reduce costs of mounting products, as well as a new startup company that created automated design software.

- The ***Business Development and Deployment*** research area included 10 projects and had the least success, both in terms of achieving the stated project goals as well as in demonstrating short-term progress on key metrics. There were positive contributions from this group, however, including two technology projects that did develop business models and strategies that have proved successful. These have helped support expansion of cost-competitive solar technologies, either by reducing costs or increasing value of the solar and storage technology to owners and utilities.

3. **The Program resulted in a substantial amount of knowledge benefits**. The creation and dissemination of knowledge benefits may be the most important metric of success when evaluating a research program. By this measure, the CSI RD&D Program was very successful and took an essential step toward achieving its longer-term program goals. Key examples of successful knowledge benefits include the following:
   - **The Program research has been widely cited.** A primary knowledge benefit is the degree to which research results are cited in the related literature, as this reflects its potential value outside the Program. In this regard, the Program has been very successful, with 395 total citations to date. Among the 153 papers and reports publicly released by Program teams, 26 have been cited at least one time.
   - **Collaborative team dynamics led to significant follow-on research, with more than 40 enduring partnerships resulting from the Program**. Continued research activities combined with new and sustained partnerships are positive effects of the Program and provide another solid indicator that the Program is on a pathway to achieve its longer-term policy goals. As a result of the Program, a variety of partnerships were formed among team organizations, between team organizations and stakeholders, and between team members and market actors.
   - **The Program design led to the selection of teams committed to knowledge transfer.** Most teams went beyond the minimum knowledge exchange activities required by the Program, and many created additional knowledge dissemination opportunities by releasing resources freely to the public and by developing demonstration sites. Teams identified direct stakeholder engagement, non-Program webinars, and conference presentations as the most effective knowledge exchange methods.

California Solar Initiative RD&D Program

Process Evaluation

Final Report

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May 11, 2017

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Executive Summary

The California State Legislature created the California Solar Initiative Research, Development, Demonstration and Deployment Program (the CSI RD&D Program, or the Program) in 2006 to support the broader California Solar Initiative. The CSI RD&D Program received $50 million to fund research, development and demonstration projects supporting integration of distributed solar photovoltaic (PV) into the California grid, with the longer-term goals of increasing solar technology performance, reducing solar technology costs, and filling technical knowledge gaps in the solar industry.

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- **Grid Integration:** Improving PV integration with transmission and distribution systems (50-65% of funding).
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The CSI RD&D Program funded 37 projects (35 of which were completed) across the three target research areas, with total CSI funding of $38.3 million in addition to $34.6 million in matched funding from the grantees and other sources.

In 2016, Evergreen Economics led a research team consisting of Evergreen Economics, Research Into Action, Dr. Gretchen Jordan, Dr. Varun Rai, and Advanced Survey Design to conduct a process evaluation of the CSI RD&D Program. This theory-based evaluation began with the development of a program logic model that linked the CSI RD&D Program activities to immediate outputs and to longer-term outcomes that were consistent with California Public Utilities Commission (CPUC) policy goals.

Once the Evergreen team identified metrics that would provide evidence of the Program's progress toward its goals, the evaluation team developed a data collection plan to gather information from a variety of different activities:

Primary data collection activities for the evaluation included:

- Compiling Program and project data and documentation
- In-depth interviews with grantees and program managers
- In-depth interviews with industry experts and stakeholders
- In-depth interviews with market actors
- Survey of market actors

- External data/literature

In addition to the data collection and analysis, the Evergreen team completed a related network analysis task to evaluate the knowledge benefits provided to the solar community as a result of Program activities.

Based on these research activities, general conclusions from the evaluation are summarized below.

1. **The Program Manager Itron performed very well.** Grantees receiving funds from the Program gave universally positive feedback on Itron. Itron carried out all the required tasks of the Program Manager very competently and implemented the Program in accordance with the original Program design. Itron communicated clearly with grantees and stakeholders throughout the life of the Program, completing each phase – proposal solicitation, project selection, project implementation oversight, and final reporting – with no complaints and with high satisfaction ratings from participants. Itron also played an important and highly effective role in facilitating communication and partnerships within and between projects, as well as with the broader solar community, helping to engage key stakeholders and reduce duplication of efforts.

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        - **Improvement to interconnection requirements.** There are a host of rules and regulations governing the interconnection, operating, and metering requirements for solar generating facilities connected to the distribution system. Eight of these projects conducted work explicitly designed to influence standards or rules relating to interconnection. Specific improvements addressed PV interconnection limits, project screening, and costs and processes for energy storage systems. These changes helped streamline the review process for interconnection and storage projects, and played a direct role in the improvement to the interconnection process in California.
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3. **The Program resulted in a substantial amount of knowledge benefits**. The creation and dissemination of knowledge benefits may be the most important metric of success when evaluating a research program. By this measure, the CSI RD&D Program was very successful and took an essential step toward achieving its longer-term program goals. Key examples of successful knowledge benefits include the following:

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   - **Collaborative team dynamics led to significant follow-on research, with more than 40 enduring partnerships resulting from the Program**. Continued research activities combined with new and sustained partnerships are positive effects of the Program and provide another solid indicator that the Program is on a pathway to achieve its longer-term policy goals. As a result of the Program, a variety of partnerships were formed among team organizations, between team organizations and stakeholders, and between team members and market actors.
   - **The Program design led to the selection of teams committed to knowledge transfer.** Most teams went beyond the minimum knowledge exchange activities required by the Program, and many created additional knowledge dissemination opportunities by releasing resources freely to the public and by developing demonstration sites. Teams identified direct stakeholder engagement, non-Program webinars, and conference presentations as the most effective knowledge exchange methods.

While the CSI RD&D Program was generally successful on multiple fronts, the results of the evaluation did yield some recommendations for future programs.

- **Sustained program documentation.** Some stakeholders and grantees indicated concern that the Program results have not been disseminated broadly enough and are concerned that the CSI website may not continue to be maintained in the future. The present plan is for the CSI website to remain functional in its current form until December of 2019. We recommend that when the current website is deactivated, the current website contents (including final reports and project documentation) be moved to another established website such as www.calmac.org so that access to the research results can continue.

- **Dissemination of Program results.** There is evidence that some CSI RD&D research has not reached the intended audiences. Two audiences in particular proved challenging: solar hardware and installation firms, and commercial organizations (e.g., builders, retail). To address this, some form of promotion or dissemination of program knowledge in aggregate should be considered—for example, engaging grantees or stakeholders with project knowledge to make presentations at conferences or to key working groups, or write articles in industry publications that summarize key research findings and direct readers to the Program website.
- **Program management.** The Program Manager Itron was very successful because it had sound technical knowledge and key industry contacts that allowed it to provide meaningful assistance and make critical networking connections that enhanced program success. Future RD&D programs should have similarly qualified program managers who can provide these types of benefits.
- **Reporting.** We received consistent feedback from the grantees that the reporting requirements were too demanding and difficult to coordinate. To address these concerns, future programs should consider modifying the reporting requirements to be more flexible. Other suggestions from the grantees included providing a report template early in the process, encouraging more stakeholder involvement, and making some draft reports public to elicit more feedback.
- **Best Practices manual.** There are several aspects of the program design that were critical to the success of the Program including careful consideration of project team composition, knowledge dissemination requirements, built in networking channels and events such as webinars and forums. If there are future RD&D efforts being considered by the CPUC or other agencies, consider working with Itron and CPUC staff to develop a best practices manual that captures the successful elements of program design and management based on the CSI RD&D Program experience.

1 Introduction

The California Solar Initiative Research, Development, Demonstration and Deployment Program (the CSI RD&D Program, or the Program) was created in 2006 with the passage of Senate Bill 1 (SB1) to support the broader policy goal of installing 3,000 MW of distributed solar by 2016 and placing distributed solar photovoltaic (PV) on 50 percent of all new homes in California by 2020.[1] As part of this effort, the California legislature authorized the California Public Utilities Commission (CPUC) to allocate $50 million of the CSI budget to the RD&D Program. The RD&D portion of the CSI Program was dedicated to funding research and demonstration projects with an emphasis on supporting integration of distributed solar PV into the grid, increasing solar technology performance, reducing solar technology costs, and filling technical knowledge gaps in the solar industry.

The establishment of the CSI RD&D Program in 2006 was timely, with installed distributed generation solar capacity growing more than ten-fold from approximately 350 MW in 2008 to over 4,500 MW by the end of 2016.[2] This rapid growth in installed capacity raised important concerns about the potential for California's electricity grid to integrate such high levels of penetration, increasing the relevance and need for research conducted through the CSI RD&D Program.

The CSI RD&D Program began soliciting proposals for projects in 2008, and between 2010 and 2014, funded 37 projects over five grant solicitation rounds.[3] The Program ran for eight years with the last project completed in December of 2016. To meet the focus of the Program as envisioned in SB1, the Program required that projects concentrate on four research areas:

- Grid integration, storage and metering;
- Production technologies;
- Business development and deployment; and
- Cross cutting (covering several research areas)

Of the 37 projects accepted by the CSI RD&D Program, 35 reached completion, and 2 were cancelled. Across the 37 projects, $34,177,809 in CSI funding was delivered, with project partners providing $30,839,909 in match funding.

[1] *Senate Bill 1* (Murray, Chapter 132, Statutes of 2006). http://www.energy.ca.gov/sb1/
[2] California Distributed Generation Statistics. http://californiadgstats.ca.gov
[3] In addition to the 37 CSI RD&D projects, the CSI RD&D Program also provided $10 million in funding for the Solar Energy Research Center (formerly Helios), a 39,000-sq. ft. research facility on the University of California, Berkeley campus. This research center is not addressed in this evaluation.

In January of 2016, the CPUC selected the Evergreen Economics team (the Evergreen team) through a competitive bidding process to conduct a qualitative evaluation of the CSI RD&D Program. The Evergreen team consisted of the following firms:

- **Evergreen Economics**, as the prime contractor, took the lead in designing and managing all evaluation activities and was the prime author of this evaluation report.
- **Research Into Action** assisted with the evaluation design and implementation of all data collection activities. Research Into Action also designed and conducted the network analysis and the estimation of knowledge benefits, two critical components of the evaluation.
- **Dr. Gretchen Jordan** of 360 Innovation assisted with the development of the program logic model and data collection plan.
- **Dr. Varun Rai** from the University of Texas-Austin provided assistance with the network analysis and estimation of knowledge benefits.
- **Advanced Survey Design** contributed to the data collection and analysis activities.

The overarching objective of the evaluation was to determine the effect of the CSI RD&D Program on the growing distributed solar market in California. To achieve this broader objective, the CPUC established specific research goals for the evaluation that included measuring the following:

- The sizes of the grants obtained from CSI RD&D funds;
- The benefits for California ratepayers;
- The economic value to the California grid;
- Whether and how the project expanded PV market opportunities or reduced barriers;
- Leverage from other funding sources (use of match funds);
- Institutional and regulatory acceptance of project findings or outcomes (technology transfer and follow-on use); and
- Clean jobs created through CSI RD&D funding.

The Evergreen team designed a theory-based evaluation appropriate for an RD&D program that addressed each of these research objectives, as well as additional issues identified through the program logic model.

The remainder of this evaluation report is structured as follows. First, the program background and project accomplishments are summarized to provide context for the evaluation. Next, the evaluation methods are discussed followed by a section presenting the CSI RD&D Program logic model. An assessment of overall program management is presented in the following section. Separate sections are then included that discuss the program accomplishments in each of the research pathways identified in the logic model. The report concludes with a section on evaluation conclusions and recommendations.

Given the complex and technical nature of both the CSI RD&D projects and the theory-based evaluation of program accomplishments, the main report sections are intended as a narrative summary of the evaluation results. Additional detail is relegated to multiple appendices that are included as a separate volume to the main report.

2 Program Background

2.1 Program Overview

In 2006, California's total cumulative capacity of installed distributed solar photovoltaic (PV) was approximately 150 MW, meaning a target of 3,000 MW would require a twenty-fold increase in installed solar PV.[4] An increase of this magnitude caused significant concern among California utilities, grid operators, and other stakeholders, as there was little knowledge about the potential impacts on the grid from such high levels of solar PV installations. In particular, utilities were concerned that when behind-the-meter distributed generation was connected to the grid, the variability of energy supply and demand could have significant negative impacts. To help address these concerns and support the ambitious goals of the CSI Program, the California legislature authorized the CPUC to allocate $50 million of the CSI budget to design and implement the CSI Research, Development, Demonstration and Deployment (RD&D) Program (the CSI RD&D Program, or the Program).

In September of 2007, under CPUC Decision 07-09-042, the CPUC launched the CSI RD&D Program with the goal of research, development, demonstration, and deployment to create a "sustainable and self-supporting industry for customer-sited solar in California".[5] The CSI RD&D Program design established three target research areas:

- **Grid Integration: Improving PV integration with transmission and distribution systems (50-65% of funding).**
    - Identify and address key barriers to the development of PV minigrids or central PV.
    - Demonstrate economic viability of new PV system storage technologies.
    - Identify high value locations for distributed generation (DG) PV on transmission and distribution (T&D) and assess the impacts/benefits of large concentrations of DG PV in one location on transmission and distribution.
- **Solar Production Technologies: Supporting commercialization of new PV technologies (10-25% of funding).**
    - Demonstrate economic viability of distributed concentrating PV systems.

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[4] California Distributed Generation Statistics. http://californiadgstats.ca.gov

[5] *California Solar Initiative Proposed Research, Development and Demonstration Plan*. California Public Utilities Commission Energy Division. Decision 07-09-042 Appendix A.

- Support development of integral PV products that become cost competitive with rooftop PV with key technical integration issues addressed (e.g. spacing/cooling).
- **Business Development and Deployment: Supporting the market and end-users (10-20% of funding).**
  - Identify and vet potential roles for utilities in solar PV, including attractive business models;
  - Lower cost, utility grade PV system control, metering, and monitoring capacity;
  - Perform field tests to quantify operational risks and benefits of PV.
  - Demonstrate improved PV economics using advanced metering, price responsive tariffs and storage.

In addition to funding specific research topic areas, the CSI RD&D Program has seven key principles guiding its activities. These are to:

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

In November of 2009, the CSI RD&D Program Manager Itron outlined the details for project solicitations and project selection. Each round of project solicitations followed a consistent process:

- Itron prepared and released a draft Request for Proposal (RFP);
- The final RFP was prepared following a public comment period;
- Public notice of the final RFP was issued by the CPUC; and
- Itron conducted a pre-bid workshop.

Once bids were received, the project selection followed a similar process:

- The proposal scoring team (typically consisting of Itron, the CPUC, the California Energy Commission (CEC), the US Department of Energy, and energy experts) reviewed and evaluated proposals based on project characteristics and selection criteria;
- Itron issued recommendations to the CPUC for funding;
- Itron assisted the CPUC Energy Division with preparing a resolution for Commission consideration; and
- The CPUC approved project funding through the resolution process.

Eligible technologies included solar technologies and other distributed generation technologies that employ (or could employ) solar energy for generation or electricity storage. Preferences for funding were given to in-state businesses or sponsors.

As outlined in the CPUC Decision, project selection was to adhere to the following general guidelines: 60 percent of the projects should see results/target milestones within the first one to three years, 20 percent within four to seven years, and the remaining 20 percent after eight years. The target milestones included using the RD&D funds to help move the market from the current retail solar price of $9/watt to more comparable retail prices for electricity, and to install larger volumes of solar DG that increase the current range of 40+MW per year to 350 MW or more per year.

2.2 Characteristics of Funded Projects

The Program distributed grant funds across five solicitation rounds: two rounds in 2010, one round in 2012, and two rounds in 2014.The following section presents an overview of the projects that were funded through the CSI RD&D Program, including a summary of projects across the five program solicitations and three primary research areas. Table 1 presents the details of each solicitation round.

Table 1: Solicitation Round Characteristics

Solicitation – Resolution Number	Date	# of Proposals	# of Projects Funded	Research Areas	Total CSI Funding Requested	Total CSI Funding Provided
1 - E-4317	Mar 2010	21	8	**Primary:** Grid Integration (GI)	$9,320,472	$7,019,094
2 - E-4354	Sept 2010	95	9	**Primary:** Solar Technologies (ST); Innovative Business Models (BM)	$14,630,058	$12,808,600
3 - E-4470	Mar 2012	32	7	**Primary:** Grid Integration (GI) **Secondary:** Solar Technologies (ST); Innovative Business Models (BM)	$7,624,154	$5,656,325
4 - E-4629	Feb 2014	17	6	**Primary:** Grid Integration (GI)	$6,020,145	$5,104,134
5 - E-4646	Mar 2014	28	7	**Primary:** Grid Integration (GI)	$669,160	$667,766
Total		**193**	**37**		**$38,263,989**	**$31,255,919**

Of 193 proposals, the Program accepted 37 projects across three main research topic areas. Two projects, one in Solicitation 1 and one in Solicitation 3, were cancelled prior to completion. Table 2 provides basic information about each project funded across the five solicitation rounds, including project solicitation, name, primary grantee, project size, and funding characteristics. Projects shaded in gray were cancelled prior to completion.

Table 2: CSI RD&D Project Summary

Solicitation - Project ID	Project Name	Primary Grantee	Research Areas*	Project Status	CSI Funding	Match Funding	Total Funding
1 – 1	Advanced Modeling and Verification for High Penetration PV	CPR	GI	Complete	$976,402	$295,370	$1,271,772
1 – 2	Development and Analysis of a Progressively Smarter Distribution System	UC Irvine	GI	Complete	$297,564	$100,845	$398,409
1 – 3	Planning and Modeling for High-Penetration PV	SunPower	GI	Cancelled	$280,422	$71,643	$352,065
1 – 4	Improving Economics of Solar Power Through Resource Analysis, Forecasting and Dynamic System Modeling	UCSD	GI	Complete	$548,094	$146,254	$694,348
1 – 5	High Penetration PV Initiative	SMUD	GI	Complete	$2,000,089	$1,940,793	$3,940,882
1 – 6	Analysis of High-Penetration PV Into the Distribution Grid in California	NREL	GI	Complete	$991,100	$1,538,727	$2,529,827
1 – 7	Beopt-CA (EX): A Tool for Optimal Integration of EE/DR/ES+PV for California Homes	NREL	GI, CC	Complete	$982,934	$258,653	$1,241,587
1 – 8	Integrated Energy Project Model	KW	GI, CC	Complete	$942,489	$250,000	$1,192,489
2 – 9	PV and Advanced Energy Storage for Demand Reduction	SunPower	ST	Complete	$1,385,286	$747,326	$2,132,612
2 – 10	Improved Cost, Reliability and Grid Integration of High Concentration PV Systems	Amonix	ST	Complete	$1,938,772	$988,365	$2,927,137
2 – 11	Solaria: Proving Performance of the Lowest Cost PV System	Solaria	ST	Complete	$1,092,428	$1,338,013	$2,430,441
2 – 12	Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources	Viridity Energy	BM	Complete	$1,659,999	$840,000	$2,499,999
2 – 13	Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results	BIRAenergy	ST, BM, CC	Complete	$1,000,000	$962,557	$1,962,557
2 – 14	West Village Energy Initiative: CSI RD&D Project	UC Davis	ST, BM, CC	Complete	$1,718,004	$1,300,000	$3,018,004

Solicitation - Project ID	Project Name	Primary Grantee	Research Areas*	Project Status	CSI Funding	Match Funding	Total Funding
2 – 15	Advanced Grid-Interactive Distributed PV and Storage	SolarCity	ST, BM	Complete	$1,550,867	$564,742	$2,115,609
2 – 16	Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery	SunLink	ST, BM	Complete	$996,271	$1,263,465	$2,259,736
2 – 17	Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation Technology	Cogenra	ST, BM	Complete	$1,466,973	$2,200,958	$3,667,931
3 – 18	Quantification of Risk of Unintended Islanding	GE	GI	Complete	$629,100	$1,393,646	$2,022,746
3 – 19	Screening Distribution Feeders: Alternatives to the 15% Rule	EPRI	GI	Complete	$1,669,222	$1,669,343	$3,338,565
3 – 20	Tools Development for Grid Integration of High PV Penetration	DNV GL	GI	Complete	$943,555	$901,345	$1,844,900
3 – 21	Integrating PV into Utility Planning and Operation Tools	CPR	GI	Complete	$852,620	$901,916	$1,754,536
3 – 22	High-Fidelity Solar Forecasting Demonstration for Grid Integration	UCSD	GI	Complete	$1,261,828	$1,353,707	$2,615,535
3 – 23	Solar Energy & Economic Development Fund	SEI	BM	Complete	$300,000	$304,462	$604,462
3 – 24**	Integrating Smart Inverters and Energy Storage into Zero Net Energy Demonstrations	SCE	GI, CC	Cancelled	$0	$0	$0
4 – 25	Standard Communication Interface and Certification Test Program	EPRI	GI, ST	Complete	$882,193	$1,228,919	$2,111,112
4 – 26	PV Integrated Storage - Demonstrating Mutually Beneficial Utility-Customer Business Partnerships	E3	GI, BM	Complete	$717,500	$518,864	$1,236,364
4 – 27	Demonstration of Locally Balanced ZNE Communities Using DR and Storage and Evaluation of Distribution Impacts	EPRI	GI, ST, CC	Complete	$1,484,806	$2,778,825	$4,263,631
4 – 28	Analysis to Inform California Grid Integration Rules	EPRI	GI	Complete	$297,557	$514,398	$811,955

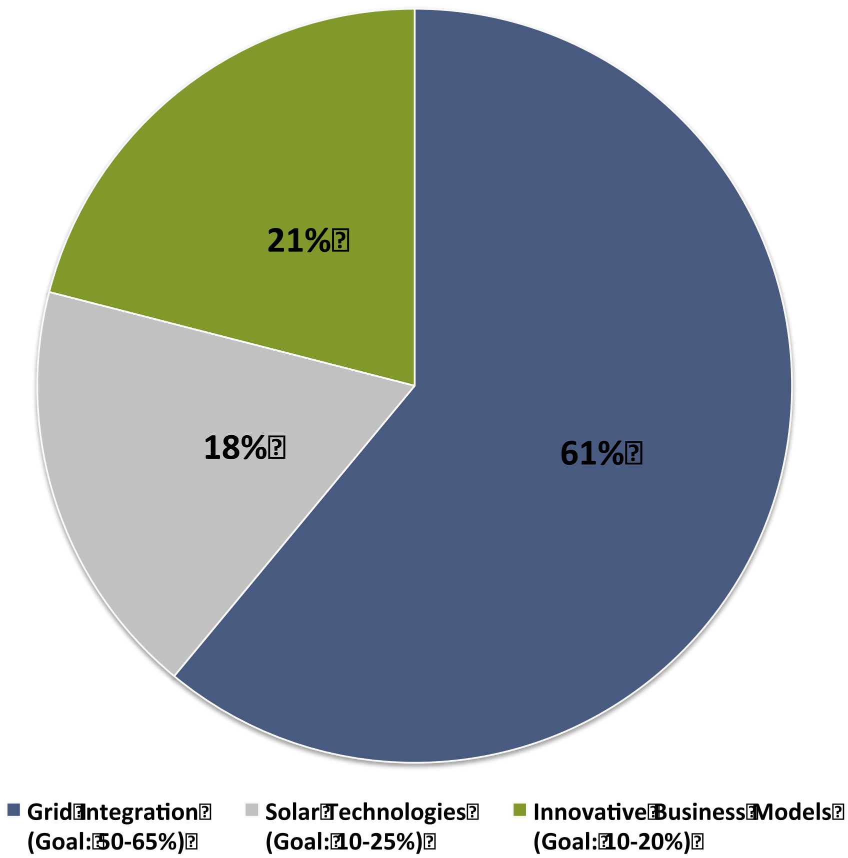
Solicitation - Project ID	Project Name	Primary Grantee	Research Areas*	Project Status	CSI Funding	Match Funding	Total Funding
	for PV						
4 – 29	Advanced Distribution Analytic Services Enabling High Penetration Solar PV	SCE	GI	Complete	$853,556	$1,644,346	$2,497,902
4 – 30	Comprehensive Grid Integration of Solar Power for SDG&E	UCSD	GI	Complete	$868,522	$1,214,850	$2,083,372
5 – 31	Sustainable Energy & Economic Development Fund	SEI	BM	Complete	$100,000	$110,616	$210,616
5 – 32	Monitoring and Evaluation of a ZNE Retrofit Home with Energy Storage, Demand Response and Home EMS	BIRAenergy	BM, CC	Complete	$74,500	$108,788	$183,288
5 – 33	Mitigation of Fast Solar Ramps Through Sky Imager Solar Forecasting and Energy Storage Control	UCSD	GI	Complete	$99,673	$35,000	$134,673
5 – 34	Supervisory Controller for PV and Storage Microgrids	Tri-Technic	GI	Complete	$96,001	$67,040	$163,041
5 – 35	BEopt Multifamily Modeling Capabilities for ZNE and IDSM in California	NREL	CC	Complete	$97,989	$75,596	$173,585
5 – 36	Comprehensive System Assessment of the Smart Grid-tied Energy Storage System Using Second-Life Lithium Batteries	UCSD	ST, CC	Complete	$99,943	$36,917	$136,860
5– 37	Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform	CPR	ST, BM, CC	Complete	$99,660	$114,229	$213,889
Total – All Projects					**$31,255,919**	**$29,780,518**	**$61,036,437**

* GI = Grid Integration; ST = Solar Technologies; BM = Innovative Business Models; CC = Cross-cutting
** Project 3-24: Integrating Smart Inverters and Energy Storage into Zero Net Energy Demonstrations was withdrawn before funding was provided. The project originally won a grant for CSI funding of $1,351,907, and had sourced $1,398,460 in match funding.

The CSI RD&D Adopted Plan established guidelines recommending allocation of funding across three RD&D target areas. The Program closely adhered to these recommendations, with actual funding landing close to the recommended allocations, based on the primary research area specified for each project:

- Grid Integration – Recommended allocation: 50-65%; Actual allocation: 61%
- Solar Production Technologies – Recommended allocation: 10-25%; Actual: 14%
- Business Development and Deployment – Recommended allocation: 10-20%; Actual: 24%

Figure 1: Funding by Research Area



In addition to the three research areas, there was a fourth research area classified as 'Cross-cutting Projects'. Cross-cutting projects included projects that covered more than one of the main research areas or involved integration with energy efficiency.[6]

[6] In all but one case, Cross-cutting projects were grouped into one of the other three target areas.

The CSI RD&D Adopted Plan identified cost sharing as an important factor in project selection and a key evaluation criterion. The Program followed the principle that the closer a project is to commercialization, the higher its cost share requirement. In other words, cost share requirements for development projects would be low, while projects reaching the demonstration and deployment phases would be required to provide a 50-75 percent cost share—a target that is fairly consistent with US Department of Energy (DOE) and other funding agency requirements.

Overall, across the three research areas, the Program saw approximately 50 percent cost sharing in aggregate, as shown in Table 3. Cost sharing was lower for Innovative Business Models and Solar Technologies projects and highest for Grid Integration projects, which aligns with the principle outlined above. The lowest project cost share was 20 percent and the highest was 65 percent.

Table 3: Funding and Cost Share Summary

Target Activity	CSI Funding	Match Funding	Total Funding	Cost Share %
Grid Integration	$17,947,659	$19,045,785	$36,993,444	51%
Solar Technologies	$5,883,459	$5,274,662	$11,158,121	47%
Innovative Business Models	$7,424,801	$5,460,071	$12,884,872	42%
Total	**$31,255,919**	**$29,780,518**	**$61,036,437**	**49%**

Additional details on program accomplishments within each of the target areas are presented in separate sections below discussing the evaluation results.

3 Evaluation Methods

3.1 Evaluation Overview

The research and demonstration focus of the CSI RD&D Program makes it fundamentally different from other programs traditionally administered by the CPUC, such as energy efficiency programs, demand response programs, or other self-generation programs such as the Self Generation Incentive Program. These programs typically have a primary goal of achieving direct impacts (e.g., energy savings, energy generation, demand reduction) along with other impacts that can be directly measured in terms of participation counts and equipment installations. Successful RD&D programs, in contrast, are focused on supporting research and demonstration projects that (by definition) are not yet at the stage to produce energy savings. Other factors that differentiate research programs from energy efficiency programs include:

- Longer timelines associated with research projects, relative to traditional efficiency programs;
- Program impacts that may be several times removed from the initial program activities;
- Research projects that fail are not necessarily indicators of an unsuccessful program; and
- Knowledge benefits and network effects (two key outputs from any successful RD&D program) are primary research program outputs and can be difficult to quantify.

Traditional energy efficiency program evaluations focus on energy savings and other market results that can be quantified using well-established analysis methods. If these traditional evaluation methods are applied to RD&D programs, however, many of the most important program benefits will be missed, as they do not manifest themselves as direct market outputs.

To guard against this, the CSI RD&D Program evaluation used analysis methods tailored specifically to capture all the potential benefits of an RD&D program. This theory-based evaluation design focusing on the underlying program logic was designed to incorporate all of the complex interrelations between program actors and external knowledge recipients. The evaluation was also designed to be consistent with two important guidance documents on evaluating RD&D programs: the California Emerging Technologies and

Market Effects Evaluation Protocols and the DOE/EERE Standard Impact Evaluation Method.[7]

As discussed previously, CPUC Decision 07-09-042 identified the following key criteria for the CSI RD&D Program, which were addressed in this evaluation:

- The sizes of the grants obtained from CSI RD&D funds;
- The benefits for California ratepayers;
- The economic value to the California grid;
- Whether and how the project expanded photovoltaic (PV) market opportunities or reduced barriers;
- Leverage from other funding sources (use of match funds);
- Institutional and regulatory acceptance of project findings or outcomes (technology transfer and follow-on use); and
- Clean jobs created through CSI RD&D funding.

The evaluation took place in 2016 at the same time as the final projects in the Program were being completed; the last project was completed in December of 2016. Given this, there were limitations to what the evaluation could identify due to the fact that 16 of the 35 CSI RD&D projects were yet to be completed at the time this evaluation started. The effects of many of these projects may not be evident for years into the future. Based in part on this challenge, the evaluation team conducted a structured, qualitative assessment of program effects. This assessment provides a sufficiently well documented preponderance of evidence from which to draw conclusions about the effect from the CSI RD&D Program on the California solar market.

Each of the major evaluation methods is described below.

3.2 Evaluation Methods

3.2.1 Program Logic Model and Progress Metric Development

The foundation of a theory-based evaluation is the development of a program logic model. This is critically important when evaluating an RD&D program, as program effects are more complex and can be missed entirely if not identified as part of the logic model that covers a timeframe and agency landscape that is appropriate for a research program. Details on the logic model are provided in Section 4 of this report.

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[7] The two documents can be found at:
http://www.calmac.org/publications/EvaluatorsProtocols_Final_AdoptedviaRuling_06-19-2006.pdf and http://www1.eere.energy.gov/analysis/pdfs/evaluating_realized_rd_mpacts_9-22-14.pdf.

The primary use of the logic model is to guide the measurement of program effects. At a high level, the logic model describes the activities and immediate outputs of the Program, as well as the expected outcomes of the Program activities and the pathways through which these will be achieved over time. The evaluation team used the logic model as a guide to define specific metrics to measure progress along the path from inputs to activities and then to outputs and outcomes. The evaluation team reviewed program and project documents, and held discussions with program management staff to develop program theory and construct the Program logic model.

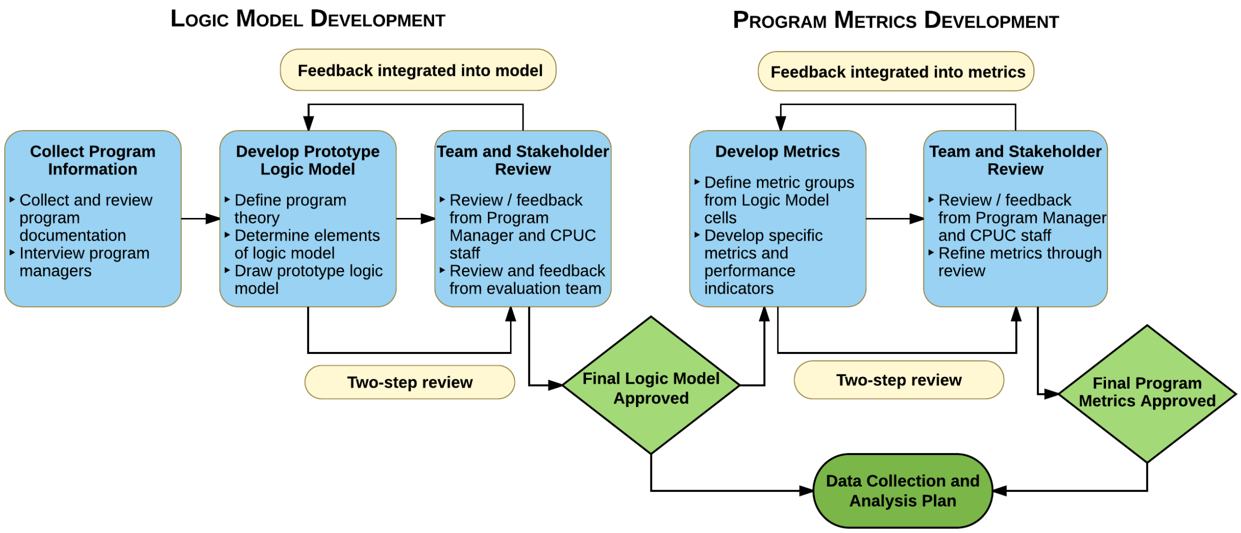
The resulting logic model uses the goals and principles of the Program as ultimate outcomes and shows pathways to these outcomes in four areas:

1. Additions to the *Knowledge Base*
2. Facilitation of *Grid Integration* through Models, Tools, and the Development of Governing Standards
3. Acceleration of New *Solar Technologies*
4. Development of *Innovative Business Models*

Once the logic model was approved, the evaluation team constructed a specific set of metrics to indicate progress along pathways to each outcome in each of the four areas listed above. These metrics were again reviewed, and program management staff and CPUC staff provided feedback and approval for the metrics. Once the metrics were approved, the evaluation team designed a data collection plan that was structured around the logic model and resulting metrics. Each metric was carefully reviewed and linked to specific data collection and analysis activities. In this way, all metrics were covered by data collection activities, and all data collection and analysis activities were explicitly linked to underlying elements of the program logic model.

Figure 2 summarizes the logic model development process and how it was used to develop program metrics addressed by the evaluation. Additional detail on the specific program metrics identified is provided in Appendix A.

Figure 2: Logic Model and Program Metrics Development Process



3.2.2 Data Collection

Once metrics were identified that would provide evidence of the Program's progress toward its goals, the evaluation team developed a data collection plan to gather information on these metrics from a variety of different sources. Primary data collection activities included:

- ***Compiling Program and project data and documentation*** – Collecting all relevant program decision and design documents, and all project-related data that were tracked for each project, including project proposals, progress reports, financial information, final project reports, and publications.
- ***In-depth interviews with grantees and program managers*** – Obtaining additional information on the projects not included in the project data, such as perceptions of program delivery, information about project execution, and opinions about the actual or predicted effect of projects.
- ***In-depth interviews with industry experts and stakeholders*** – Collecting information on how program outputs, knowledge, and expertise from the Program projects are affecting the broader solar community, grid operators, utilities, and regulators.
- ***In-depth interviews with market actors*** – Collecting information on how project outputs, knowledge, and expertise from the Program projects is affecting the broader solar market.
- ***Survey of market actors*** – Fielding an online survey to a broad variety of market actors to collect standardized quantitative data to measure the short-term outcomes of the Program.

- *External data/literature* – Collecting secondary data and literature to investigate knowledge dissemination of the Program-supported research including bibliometric and patent data to assess the reach of projects.

The evaluation team worked with the CPUC and the Itron program management staff to develop detailed interview guides for each of the in-depth interview target groups. Each interview guide was carefully designed in support of the data needs required to estimate outcome metrics in each research area.

The market actor survey was designed to measure short-term outcomes of the Program related to increasing the knowledge base of the California solar market beyond the funded projects including project awareness, new skills, acceptance, follow-on use, filling of capacity gaps, and integration of project outputs in the market. The survey targeted specific segments of the California solar market that we expected, based on evidence in the program documents, to have had early exposure to the Program or its outputs.

Table 4 presents a disposition of the interview activities and survey sample frame.

Table 4: Interview and Survey Activity Disposition

Data Collection Activity	Description	# Interviews / Surveys Planned	# Interviews / Surveys Completed
In-Depth Interviews			
Program manager/ grantee interviews	Includes interviews with CSI Program Manager, project grantees and sub-grantees	50	48
Stakeholder interviews	Includes interviews with utility staff, solar program managers, ISO staff, regulators, solar industry organization staff such as CalSEIA, CalSEPA	5-10	12
Technology expert interviews	Interviews with solar experts such as staff from national labs or research institutes	5-10	3
Market actor interviews	Interviews with market actors potentially affected by the Program such as installers, manufacturers, balance of system companies, builders, etc.	5-10	5
Total In-Depth Interviews			**68**

Market Actor Survey		Sample Size	Completes
	Individuals on the CalSolar listserv	888	57

	Individuals from teams that submitted losing proposals to the program	154	11
	Attendees of the DOE-CSI joint forums	142	17
	Individuals cited in project patent applications technical reports	105	3
Total Survey Participants		**1,289**	**88**

The Evergreen team compiled the outputs of the data collection efforts and imported them into Dedoose, a qualitative analysis software platform. The Dedoose software facilitated efficient analysis of large amounts of qualitative data, allowing the evaluation team to organize data sources based on relevant characteristics, segment and categorize data according to themes, search for and retrieve information across themes, and identify significant patterns in the data.

Table 5 provides an account of the data sources the evaluation team entered in Dedoose for analysis.

Table 5: Data Source Count

Data Source	Count
In-Depth Interviews	68
Project Final Reports	35
Project Webinars	53
Project Proposal	37
Progress Reports	64
Total Documents	**257**

Once the data were compiled into Dedoose, the evaluation team developed a comprehensive coding scheme for use by all interviewers and analysts. This qualitative coding scheme consisted of a nested set of codes or code "tree" which was used to label information in data sources according to themes or ideas. In this case, codes were directly aligned with program metrics from the logic model, along with the network analysis goals.

Due to the quantitative nature of the market actor survey, the evaluation team compiled the results of the survey separately. The survey responses were imported to SPSS, and results were tabulated and analyzed.

The resulting Dedoose and SPSS datasets provided the foundation for the main evaluation analysis tasks detailed below.

3.2.3 Network Analysis

The goal of network analysis was to evaluate the knowledge benefits that have accrued to the state of California, the solar community, and the energy industry from Program activities. The evaluation team developed a network analysis methodology that was designed to measure the following:

1. Cumulative knowledge benefits produced by the Program;
2. Trajectory of knowledge diffusion based on the fit of knowledge produced relative to the intended audience;
3. Means by which knowledge is transferred to market actors; and
4. Existing knowledge capacity that the Program drew on, and the extent to which the Program built additional knowledge capacity.

We utilized the hybrid name generator as the most appropriate network analysis method for this evaluation,[8] which involved a structured interview section where grantees and sub grantees were prompted if they interacted with actors from each of the following categories:

- Utilities or Independent System Operators (ISOs)
- Standards and testing organizations
- Research organizations, including national laboratories
- Solar hardware or installation firms
- Trade associations or non-profits

The results from this portion of the interview results were supplemented with data from several other sources, including:

- Market actor survey
- Other organizations mentioned by interviewees
- Team compositions from program documents (proposals and progress reports)
- Interactions with specific outside actors noted in program administrator progress reports

[8] Henry, A. D., Lubell, M. and McCoy, M. (2012), "Survey-Based Measurement of Public Management and Policy Networks". *J. Pol. Anal. Manage.*, 31: 432–452.

This process generated the data needed to characterize the network and determine its size. The results of the network analysis are described in more detail in Section 9 on knowledge benefits, with an expanded discussion included as Appendix F.

3.2.4 Citation Analysis

Another measure of the Program knowledge benefits and the reach of Program knowledge is the level of dissemination of project reports and publications. To this end, the evaluation team analyzed the citation of project reports and academic papers. We collected bibliographic and intellectual property data for the CSI RD&D projects through the services of Thompson Reuters, which was supplemented by using a web-scraping tool to search Google Scholar, as some projects may have resulted in Internet publications not found among the standard academic literature. Using these data, the evaluation team examined the following:

- Number of citations per project reports and paper
- The venue where a Program source was cited
- The organization type of the citing author's affiliation
- The citation pattern over time

The results of the citation analysis are also included in Section 9 in the discussion of knowledge benefits produced by the Program.

3.2.5 Delphi Panel

The final task completed by the evaluation team was to convene a Delphi panel to review the research findings and conclusions regarding the effects of the Program. The Delphi panel consisted of four experts with experience in either RD&D program evaluation or the solar industry itself. The Delphi panel was sent a summary of the research findings in the areas of Grid Integration, Solar Technologies and Innovative Business Models. Based on the summary findings in each of these areas, the Delphi panelists were asked to provide an assessment via numerical rating as to the likelihood that the projects in these areas would help meet the original CPUC goals established for the CSI RD&D Program. Following the initial assessment, the Delphi panel met via conference call to discuss the individual ratings. The panel members were then given an opportunity to revise their initial ratings based on the results of the conference call.

The Delphi results are discussed where appropriate with the evaluation conclusions, and the materials included in the Delphi panel review packets along with the final ratings are included as Appendix I.

4 Logic Model and Performance Metrics

The first step in conducting a theory-based evaluation is to develop a comprehensive program logic model that clearly illuminates the theoretical links between program activities, outputs and various downstream outcomes. As discussed in the previous section, this is especially important for an RD&D program, where program impacts can be less visible compared to more traditional energy efficiency programs.

At the start of the evaluation, the evaluation team reviewed program documents and had several meetings with Itron program staff to develop a program logic model for the CSI RD&D Program. The objective of this CSI RD&D logic model is to guide the evaluation of program impacts. At a high level, the logic model describes the expected outcomes of the program and the pathways through which they will be achieved. The evaluation team used the logic model to identify specific metrics to be measured along the path from inputs to activities and then outputs and outcomes.

As discussed previously, the ultimate goal of the CSI RD&D Program is to facilitate acceleration and expansion of grid connected solar energy resources while also providing value to California ratepayers. The Program accomplishes this by increasing the visibility and reliability of solar output, improving grid management and interconnection tools, and developing innovative supporting technologies and processes.

The logic model uses the goals and principles of the program as ultimate outcomes and shows ***pathways to these outcomes*** in four areas:[9]

- **Additions to the *Knowledge Base***. Improving the *Knowledge Base* was common to all of the RD&D projects and underlies the specific accomplishments of the other three pathways. The *Knowledge Base* is reflected in both written records and professional experience and is expressed through professional relationships, their skills, and perceptions. Related activities include building a technical body of knowledge, as well as improving R&D methodologies, networks and methods to disseminate, transfer, and exchange knowledge, and the ability to leverage past R&D experiences.
- **Facilitation of *Grid Integration* through Models, Tools, and the Development of Governing Standards.** The *Grid Integration* efforts include technical advances in modeling and tools (mostly for use in planning and management of solar T&D), as well as technical support and data useful in developing standards and guidelines for the deployment and management of solar resources. These activities contribute to improved usability, reliability, and cost-effectiveness of solar output. They also provide greater flexibility and functionality in grid integration, creating greater ease

[9] The individual grantee projects usually contributed to more than one of these areas.

for utilities, system operators, and others to implement new solar projects and manage high penetration levels of solar resources.

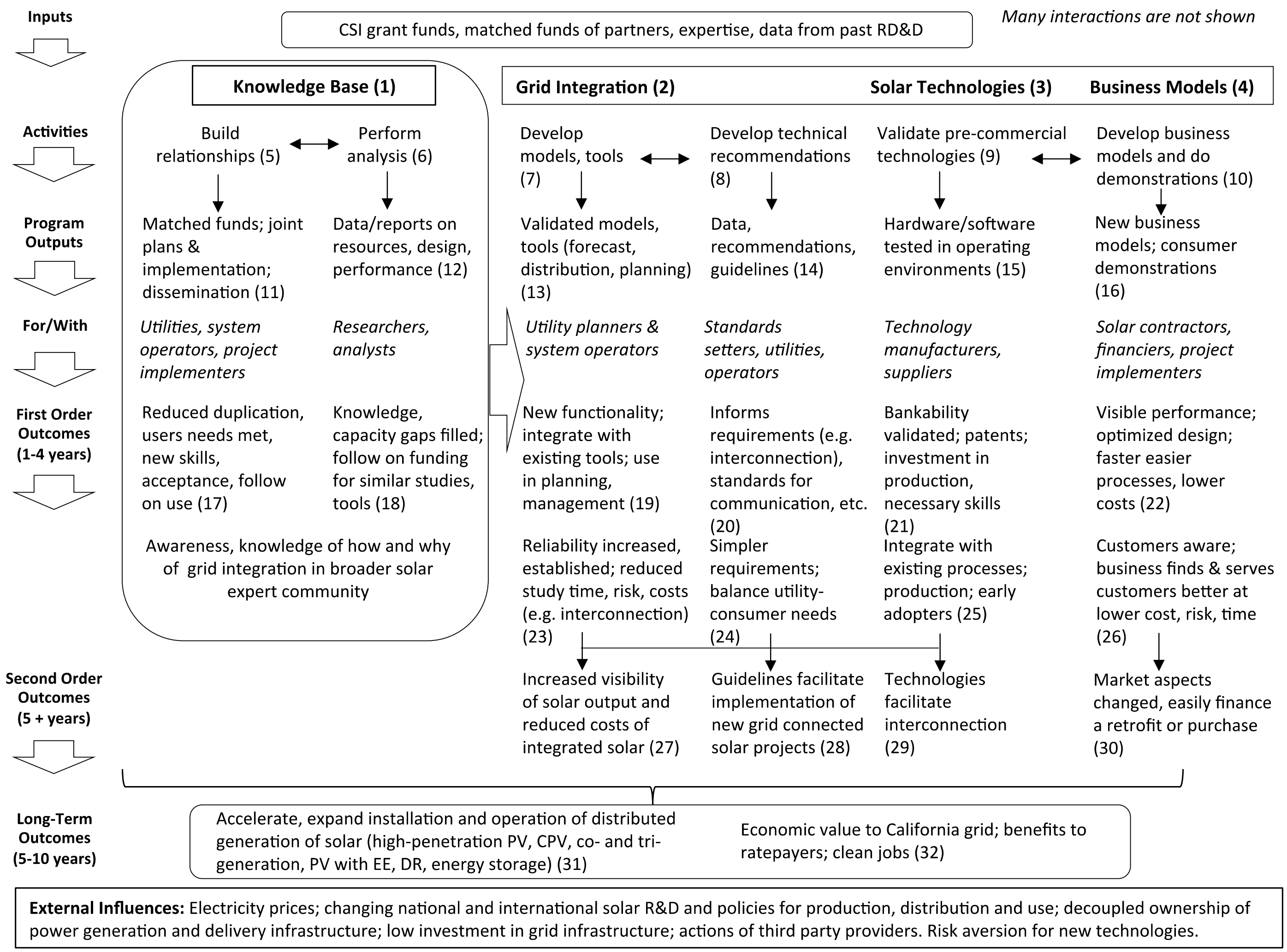
- **Acceleration of New *Solar Technologies***. The *Solar Technologies* activities focused on validating pre-commercial hardware and software designed to improve or enhance the performance, reliability and/or cost-effectiveness of solar systems and components.
- **Developing *Innovative Business Models***. The *Innovative Business Models* development effort is a smaller part of the RD&D scope in terms of budget, but combines two areas of emphasis: the development of new models for how solar business can be successfully accomplished, and performing demonstrations of new technologies or processes. The demonstration projects enhance customer acceptance and also exhibit economic benefits and potential for investors and solar companies. These can lower balance of system costs and convince market actors of the feasibility of adopting solar technology.

Figure 3 presents the CSI RD&D Program logic model covering these four pathways. Numeric labels in the figure provide a key to map the logic model components to metrics and data collection activities provided later in the following section. The development of this particular categorical structure of program activities and pathways is driven primarily by the nature of the differences in the expected outcomes for each.

For each of the core program activity areas (labeled as logic model elements #1-4), there are a series of program *Activities* that result in direct program *Outputs*. From these outputs, the program logic prescribes a series of *Outcomes* that are assumed to occur if the program is functioning properly. These *Outcomes* are defined by expected time frame, either short-term *First Order Outcomes* (1-4 years), mid-term *Second Order Outcomes* (5+ years), or *Long-term Outcomes* (5-10 years). Given the timing of this evaluation, most of the evaluation measurement will focus on the *First Order Outcomes*, as not enough time has elapsed to expect much progress for the longer-term effects.

The *"For/With"* row in the logic model is there to clarify who partners are and who are the direct users of the outputs, as these are the groups that will either help create or benefit from the desired outcomes. Finally, *External Influences* refers to contextual factors that shape the circumstances and landscape within which the program operates and the primary factors that can speed or hinder the appearance of the desired outcomes.

Figure 3: California Solar Initiative RD&D Logic Model



The final logic model was used to create a comprehensive data collection plan for the evaluation that systematically linked metrics of progress from the logic model to specific research questions. The data collection plan is structured in accordance with the four primary activity areas shown in the logic model: *Knowledge Base*, *Grid Integration*, *Solar Technologies*, and Innovative *Business Models*. Each activity area has a unique set of expected outputs and outcomes, as depicted in the logic model. Once the individual research questions were articulated, data sources were assigned to ensure that all of the important issues were addressed by the evaluation. The detailed data collection plan linking metrics, research questions, and data sources is included as Appendix A of this report.

In the data collection plan, the format for each of the data collection activities is the same. For each of the four program activities, each related program output and outcome is included in a table along with the corresponding number from the logic model diagram in Figure 3. For each output and outcome, specific metrics are provided that—when measured—can provide an indication of whether the underlying program logic is succeeding in practice. Each metric is then linked to specific data collection and analysis activities. In this way, all metrics are covered by data collection activities, and all data collection and analysis activities are explicitly linked to underlying elements of the program logic model.

As discussed in Section 3, the data collection activities consisted of the following methods:

- ***Grantee data (D)*** includes all project-related data that is tracked for each grantee. This includes items such as project descriptions, project budgets, original proposals, performance data, reports/publications, and progress reports.
- ***In-depth Interviews w/ grantees (IDI-G)*** refers to in-depth interviews with grantee project managers to obtain additional information on the projects that is not included in the project data (e.g., what worked, what did not, perceptions of the funding process, recommendations for improvement).
- ***In-depth Interviews w/ industry experts and stakeholders (IDI-E)*** collected information on how well information from the grantee projects is affecting the broader solar community.
- ***In-depth Interviews w/ market actors (IDI-MA)*** were done to collect information on how well information from the grantee projects is affecting the broader solar community (in addition to the interviews with industry experts and stakeholders).
- ***Survey of Market Actors (Su-MA)*** is an additional online survey fielded to market actors to collect more standardized information (e.g., data that are more numeric that are less in need of a less structured in-depth interview).

- ***External data/literature (S)*** includes secondary data and literature that reflect knowledge dissemination of the Program-supported research.

The following sections provide the evaluation assessment of the progress made by the Program in each of the four activity areas, based on these data collection activities. A separate section is also included discussing the overall management of the CSI RD&D Program.

5 Overall Program Administration

Part of the evaluation was devoted to collecting feedback on how the CSI RD&D Program was implemented by Itron, the CSI RD&D Program Manager. Evergreen Economics completed interviews with either the primary investigator or a project partner for 34 of the 35 completed projects. In addition to asking questions about their specific project goals, outcomes, and effect on the solar market, we asked about their experiences with the CSI RD&D Program and their interactions with Itron. Specific topics included:

- How grantees first became aware of the CSI RD&D Program;
- Grantee experiences with the solicitation process;
- Grantee experiences with the project award and contracting processes;
- Overall perceptions/feedback from interacting with Itron during the course of the project;
- Specific challenges in the project administration; and
- Suggestions for improving the design of future RD&D programs.

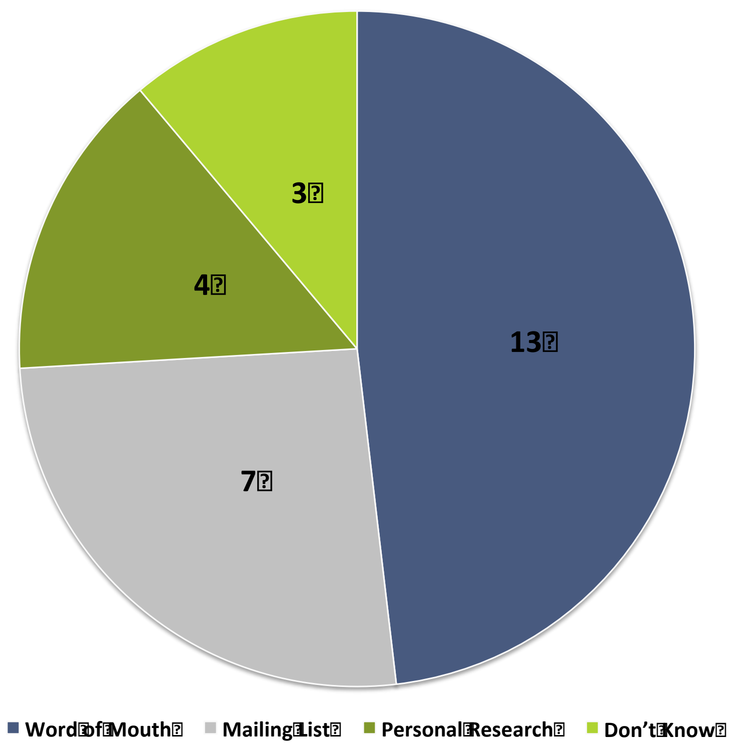
The evaluation findings relating to the CSI RD&D Program management are discussed below.

5.1 Program Awareness

In order to understand how grantees learned of the CSI RD&D funding opportunity, we asked how they first became aware of the CSI RD&D Program. Figure 4 presents the number of grantees that learned of the CSI RD&D Program across three primary methods.[10]

[10] Note that the total does not equal 34 because there were some grantees with multiple projects.

Figure 4: Count of Grantees by Method of Awareness of Program



As the figure illustrates, most of the interview awardees became aware of the CSI RD&D funding opportunities by word of mouth (13), either through conferences, past RD&D projects, project partners, or colleagues. Seven grantees stated that they first heard of funding opportunities through mailing lists (email lists, RFPs, and list serves), four noted they keep track on their own by visiting websites such as CalSolarResearch.com and PEER looking for solicitations and grant funding opportunities, and three were unable to recall where they had heard about the funding opportunity.

5.2 Experience with Solicitation and Contracting Phases

Overall, grantees were very satisfied with the solicitation phase of the CSI RD&D Program and did not have any major concerns about the program design and delivery, with many noting that it was "very straightforward" and the process was completed in a timely manner. One respondent noted that, "Overall it was a really good experience," and added "the solicitation design was flexible and targeted the research concepts well." In general, grantees did not have many difficulties meeting the requirements for solicitation applications and felt the instructions were easy to understand, and communication about the applications was clear and timely.

Once the projects were approved, they moved into the contracting and development phase. While all grantees noted that the contracting process was well managed, nine grantees expressed some level of frustration or challenge with the contracting phase, noting it as at times tedious and difficult to navigate. In general, the challenges in contracting revolved around contract wording around intellectual property rights and cost ratios. Across the nine grantees that experienced challenges, all were resolved and all projects ended up moving forward.

5.3 Experience with Program Management

The vast majority of the grantees interviewed mentioned Itron as a key source of program information, and all grantees expressed a very high level of satisfaction with the Itron program management. Key reasons given for the high level of satisfaction included that the Itron was flexible and willing to help guide any part of the solicitation and program processes, the Itron project managers were experts not just at the program management level but also in the subject matter of the projects, they had good connections to other stakeholders, and they frequently acted as conduits to facilitate networking opportunities or pass on knowledge.

One grantee stated that:

> *"From my standpoint, this was the best program that I had been involved in. It was the most realistic, at least the way it was worded for us in terms of expectation and deliverables"*, another stated that *"I manage a lot of research projects and if I could pick one entity I would like to work with again, it would be this one. I am doing projects with EPIC, Sunshot, and NREL, and this one is right on. I want to add, you know the reason I liked it was not because they were easy on me. There was a case, for example, where my team pushed back on a request from Itron concluding it was more difficult than anticipated. So I went and asked Itron about changing the scope and they came back and said no, sorry you signed up for this and if you don't want to do this that's okay, but we won't release funding. I felt like we were able to apply the dollars that were received to figure out the technical goal of the project opposed to burning it on paperwork or keeping people informed. It was the right level of oversight"*.

Finally, another grantee with significant research experience noted that:

> *"I think actually it was the best experience I have had in my life with grant management"*.

Overall, communications and coordination among Itron staff and its contractors were generally described as excellent, with regular meetings, frequent phone calls, and the ability to provide expert opinions in the research areas.

One respondent noted that:

> *"They kept overhead low and came up with special and good ideas about how to disseminate ideas that worked very well."* They added, *"I think it has been a very successful project and I think they should do it again."*

5.4 Program Challenges and Possible Suggestions for Improvement

While overall, the feedback received on the Program and Itron's management was very positive, there were some challenges and recommendations for improvement. Grantees described the following challenges about the CSI RD&D Program:

- The time period between submitting a proposal to receiving an award and beginning the work was too long; technologies and requirements change rapidly causing the scope of work to change.
- One interviewee believed that the final results were not visible enough to the public, noting that they were concerned with how the "CSI website buries the reports" and how they are not easily accessible.
- Almost universally, interviewees thought that the reporting stage of the project was cumbersome and difficult to coordinate.
- Multiple interviewees noted that the invoicing process was tedious and confusing, particularly when multiple project partners were involved.

Grantees also had the following suggestions to improve the CSI RD&D Program:

- Provide a template for the final report much earlier on in the research process.
- Introduce meetings between contractors and the CPUC in order to engage them more in the end result.
- Provide more stakeholder involvement and make some draft reports public to receive more feedback.
- Ensure that the final documents and other program documentation are publicly available, easily accessible, and well publicized.

6 Grid Integration

6.1 Grid Integration Project Accomplishments

An important area of emphasis for the CSI RD&D Program was the facilitation of solar grid integration, particularly for solar power coming from distributed consumer-based sources. Grid integration efforts are distinct from more traditional RD&D efforts focused on progress of distributed energy technologies and controls systems, and instead are focused on ensuring that these resources can be safely and efficiently tied into the existing or future electricity grids, as well as integrating solar with other resources such as energy efficiency and demand response.

The *Grid Integration* projects were very successful, with the majority (19 of 20) of projects meeting all their original objectives and having findings widely disseminated to their target audiences.

At the outset of the CSI Program in 2006, the California energy grid was looking at a future with high penetration levels of PV due to aggressive goals for renewable energy resource integration including solar PV. A major challenge facing these efforts was that the industry and utilities in particular lacked understanding and familiarity with how PV systems might impact grid operations at high penetration levels. The likelihood of sustaining high PV growth rates in some part relied on the ability, and willingness, of utilities to integrate PV systems into the electric grid, and in a way that provided benefits to both utilities and utility customers. The CPUC identified Grid Integration as a key focus area for the CSI RD&D Program that was not being served by other R&D efforts, and where the CSI RD&D Program could provide high value for grant funds.

In total, there were 20 Grid Integration projects, which are summarized earlier in Table 2:. These projects are also referred to by number in some of the subsequent tables. Prior to soliciting bids for Grid Integration projects, the CPUC identified key areas of grid integration needs and knowledge gaps, which are summarized in Table 6.

Table 6: Grid Integration Needs and Knowledge Gaps

Area of Need	Description
Planning and modeling for high-penetration PV	Utility grid operation models and planning tools lacked the capability of identifying and optimally siting and incorporating distributed generation technologies and resources. In addition methods for estimating solar resources and forecasting PV system output at high penetration levels were limited and relied on low-resolution insolation data.
Testing and development of hardware and software for high-penetration PV	Existing distribution circuits are generally capable of tolerating some variability in load, however high penetration PV introduces significantly greater variability due to geographic dispersion, impact of variable environmental factors such as intermittent cloud cover, and the fact that behind the meter generation is often invisible to behind-the-meter generation resources. These factors introduce significant challenges to grid integration and overall grid reliability. This situation requires enhanced data, improved analytical capabilities, and development of robust hardware and software resources, including protocols and formal standards, capable of dynamic interaction and communication with the grid to control, and mitigate against issues arising from, varying frequency and voltage conditions on the grid.
Addressing integration of energy efficiency, demand response and energy storage with PV	Significant opportunities exist for integration of distributed PV resources, energy storage, demand response and energy efficiency measures. Improved energy storage and controls could potentially transform distributed generation resources into reserve resources, and allow customers to avoid energy price volatility and respond to demand response events. Energy efficiency measures help reduce the energy footprint of a site and when installed with PV systems can help reduce the size and capital costs for PV systems. Lack of integration means these opportunities are often missed. This presents a need to integrate energy efficiency, demand response, energy storage and PV systems through improved efforts like guidelines on appropriate energy efficiency measures to with PV system integration, combined audits, and improved battery storage and control systems.
Demonstration Projects for Utility Interconnection and Grid Operations Tools, Technology, and Methods	Solicitations 3, 4 and 5 identified the need to move toward demonstration and operationalization of outputs. The specific areas of need included demonstrations of: PV project screening methods for interconnection, development of technology and protocols for advanced inverter technology, processes for streamlining interconnection and offsetting system upgrade costs, investigations of common challenges to interconnection and mitigation strategies to support standards and rulemaking working groups, methods for optimal siting of PV to enhance value to the grid, methods for risk quantification, enhanced distribution system modeling with capabilities for identifying risks such as islanding, methods to identify distribution line loading and congestion, interconnection of inverters with smart meters, tools with capability for utility system control and inverter dispatch, field tests of high penetration PV, and energy storage systems with capability to provide response to dynamic loads at distribution feeders.

Area of Need	Description
Demonstration of Enhanced Solar Modeling	Solar resource models with higher spatial and temporal resolution to enable better forecasting and planning by grid operators and the CAISO. Validation of estimated PV production at high temporal resolution (less than one-minute intervals) using metered PV data. Of particular interest are demonstrations where PV performance data is collected from Smart Meter/inverter applications that can be used to validate high temporal resolution PV output estimates for anticipated high PV penetration situations.

A mapping of how the 20 funded Grid Integration projects relate to the knowledge gaps and needs areas is provided in Table 7.

Table 7: Knowledge Gaps and Areas of Need Addressed by Projects

Area of Need	Project ID	Key Project Activity Examples
Planning and modeling for high-penetration PV	1, 2, 4, 5, 6, 18, 19, 21, 22, 26	• Enhancement of insolation data • Enhancement of PV system modeling methodologies and tools • Verification of modeling methods and tools against field data • Development of screening methodology to evaluate new interconnection requests • Methods to estimate impacts from high penetration PV • Modeling impact of ZNE homes • Analysis methods to inform grid integration rules and standards
Testing and development of hardware and software for high-penetration PV	1, 5, 6, 18, 20, 25, 26, 28, 29, 33, 24	• Development of software visualization tools • Enhancement of utility software tools to incorporate enhanced simulation and forecasting methodologies • Lab and field testing of advanced PV inverter technology • Testing ability of inverters to detect and react to islanding conditions • Assessing potential for open standard communication interfaces for smart inverter technology • Developing standards and protocols for hardware
Addressing integration of energy efficiency, demand response and energy storage with PV	7, 8, 27	• Enhancement of existing building modeling software to incorporate identification and implementation of balanced, optimal, and cost-effective integration of EE, DR and PV • Development of data transfer formats for information exchange between software platforms for integrated energy projects

Area of Need	Project ID	Key Project Activity Examples
		• Demonstration of cost effective strategies for ZNE homes incorporating PV
Demonstration projects for utility interconnection and grid operations tools, technology, and methods	5, 18, 19, 20, 25, 26, 27, 28, 29, 33, 34	• Deployment and testing of solar irradiance and cloud speed sensors • Demonstration and quantification of value of PV integrated storage • Demonstration of system control software for micro-grids
Demonstration of enhanced solar modeling tools	5, 21, 22, 26, 27, 29	• Field validation of PV simulation and forecasting model methods and software • Integration of PV fleet simulation methodologies into utility software tools • Development of end-to-end modeling software integrating building modeling and energy storage into distribution modeling.

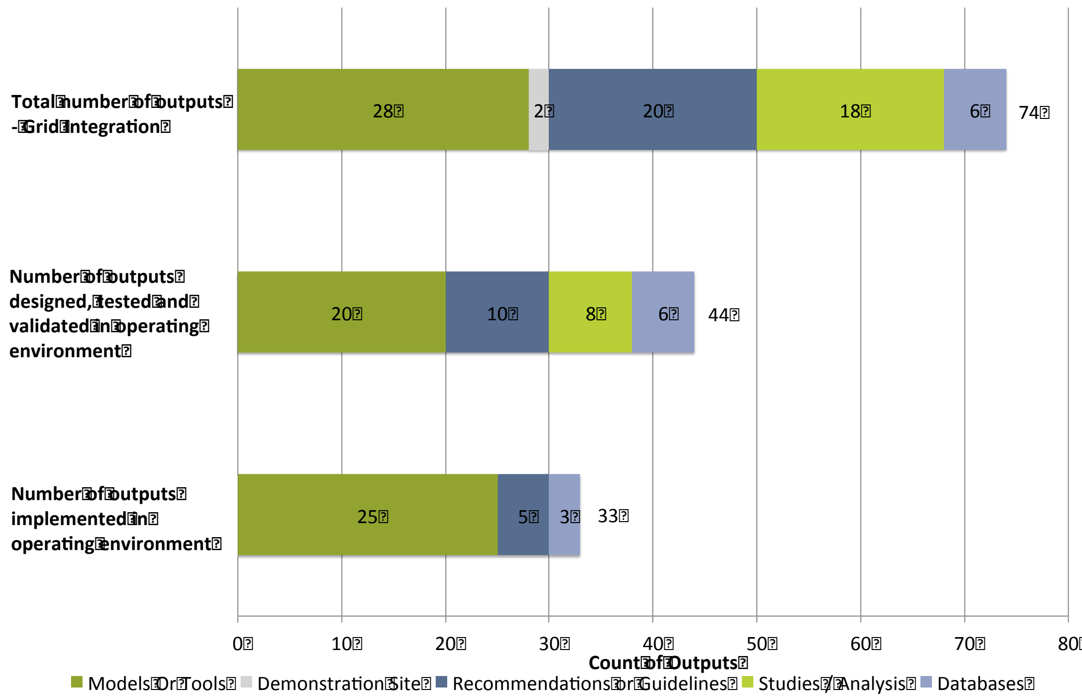
Figure 5 summarizes the Grid Integration project activities that generated 74 discrete 'outputs' relating to the logic model.[11] Examples of these outputs include:

- Databases
- Solar Project Screening Methodologies
- Modeling Tools or Algorithms
- Technical Protocols
- Field Demonstration Sites
- Grid Planning and Management Software
- Studies and Analysis

Of these 74 outputs, 44 were tested and validated in an operating environment, with 33 having documented adoption by the industry in at least one application. As discussed in the next section, the Grid Integration project results have seen a relatively high level of use within California, with project outputs being utilized by the IOUs and other utilities, the California Independent System Operator (CAISO), and standards and rulemaking organizations.

[11] See Appendix A: Data Collection Plan for a complete listing of all the logic model outputs that were considered in the evaluation for the Grid Integration projects.

Figure 5: Grid Integration Outputs (Logic Model Cell 14, 19)



6.2 Assessment of Grid Integration Project Accomplishments Relative to the Logic Model Progress Metrics

Based on the nature of the Grid Integration projects and observed project accomplishments, we identified specific areas within the logic model for assessing the impacts of these projects relative to the milestones needed for program success.

In the discussions below, the assessments of program progress were informed through several data collection activities, primarily:

- Program documentation review - including program design documents, project proposals, progress reports, final project reports, publications, and project data.
- In-depth Interviews with grantees and program managers – including primary grantees and sub-grantees. At least one project team member for each project was interviewed, except for Project 17.
- In-depth Interviews with industry experts and stakeholders – stakeholder group included representatives from organizations related to but not always directly involved in Program projects including utilities staff, solar program managers, industry organizations such as CalSEIA, regulatory agencies, and the CAISO. The expert group was comprised of industry experts from academia, public laboratory

researchers, state employees, and private sector researchers. These individuals were selected from the following sources:
  - Individuals named as stakeholders on specific projects
  - Individuals who took part in stakeholder advisory groups
  - Attendees of joint DOE-CPUC High Penetration Solar Forums in 2011 and 2013
  - Authors of literature cited in project reports

- In-depth Interviews and a survey with market actors – individuals from market facing organizations such as manufacturers, software developers, standards setting organizations and others, involved with or knowledgeable of program projects.

Our expectation during the interviews was that grantees would have strong project-level knowledge and some program-level knowledge from the other projects they were exposed to. Similarly, stakeholders would have some specific project knowledge while others would have broader program level knowledge. Solar industry experts would have broader opinions of the effects of project outputs on the wider solar market and on solar research. This turned out to typically be the case; however, there were some members of the solar expert group that had limited exposure to the Program. All respondents were provided with website details for the CSI RD&D Program where they could access project documentation prior to the interview. However, they were not explicitly instructed to review these materials. Each respondent group was asked questions across the following topics, but each was tailored specifically to the respondent group:

- Their level of engagement with the CSI RD&D Program;
- How the Program facilitated, and the effect of, networks and relationship building;
- The market relevance of projects and where project teams gathered information and how they exchanged knowledge and know-how; and
- The effect or influence of projects and outputs across the research areas, and how projects filled gaps and addressed challenges faced by the solar market.

6.2.1 Grid Integration Short-Term Outcomes

The key short-term metrics of program progress identified in the logic model are summarized in Table 8, along with the evaluation team's assessment of progress in these areas. For the short-term outcomes, the Grid Integration projects made solid progress in achieving the first stage accomplishments dictated by the program logic. These first order outcomes are accomplishments that are expected in the 0-4 year time frame and are necessary first steps toward achieving the longer-term program goals.

Table 8: Grid Integration Short-Term Outcomes – Metrics and Progress Assessment

Key Logic Model Metric	Progress Assessment
Short-Term Outcomes (0-4 years)	
Standards or rules influenced	High
Impact of recommendations on inverter system communication protocols	High
Improvement in system reliability brought by new models, tools	High
Reduced cost, saved time and lowered risk of new projects and system operations	High
Evidence of simpler/streamlined interconnection requirements	Medium
Lower transaction costs for implementing solar projects	High

Additional detail and discussion on each of these short-term metrics is included in Appendix C.

Standards and/or rules influenced

Common standards and rules provide broad benefits to any industry, ensuring the safety and quality of products and services, making product development and production more streamlined, making it easier for businesses to develop new products and access new markets, improving efficiency and reducing costs for manufacturers, and providing assurance for consumers that products and systems are safe and reliable. Targeting the development or improvement of standards is one way to have a high effect on a market; however, this requires identifying and engaging specific individuals or organizations with appropriate expertise and influence.

Eight CSI RD&D projects conducted work explicitly designed to influence standards or rules in the solar industry. Key project outcomes that relate to standards and rules include the following:

- **Revision and development of new standards for solar inverters and interconnection.** Specific projects have resulted in revisions or information for multiple standards, and testing certifications including:

- UL1741 SA - tests and certifies inverters and other utility interconnected distributed generation (DG) equipment for grid support functions enabling smarter, safer, reactive grid interconnection (Project 25).
- IEEE 1547a Amendment establishing updates to voltage regulation, response to area electric power systems abnormal conditions of voltage and frequency, and considering if other changes to IEEE Standard 1547 were necessary (Project 25).
- IEEE 1547 Full Revision providing a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). The standard provides requirements relevant to the interconnection and interoperability performance, operation, and testing, and to safety, maintenance and security considerations (Project 25).
- IEC 61850-7-420 and IEC 61850-7-520 revisions in TC57 WG17 establish communication and information exchange protocols for interconnected DER technology (Project 25).
- IEC 62108 standard for concentrated photovoltaic (CPV) module qualification testing defines testing protocols for CPV technology designed to detect CPV module failures associated with field exposure related to thermal fatigue-related failure mechanisms for the assemblies (Project 10).

- **Improvement to the existing CPUC Rule 21 (CA Rule 21).** CA Rule 21 describes the interconnection, operating, and metering requirements for generating facilities connected to the distribution system over which the CPUC has jurisdiction. The rule includes a requirement for additional screening studies to be performed on circuits where penetration of solar PV exceeds 15 percent of peak load. The additional screening studies requirements were often unclear, and the rule did not include considerations for smart inverters or battery storage. As of June 2016, the rule has been updated to include considerations of smart inverters and storage, and includes fast tracking of new solar projects meeting specific requirements. Many of the improvements were derived from CSI RD&D project research including specific improvements related to PV interconnection limits (Projects 19, 25, 28), project screening (Projects 18, 19, 25), and costs and processes for energy storage systems (Project 26). These changes helped streamline the review process for interconnection and storage projects, and played a direct role in the improvement to the existing CA Rule 21.
- **Changes to the PG&E interconnection process.** CSI projects have resulted in enabling the quick interconnection of certified inverters rated less than 1 MW, potentially streamlining and reducing the cost of applicable projects (Project 18).

Stakeholders and experts interviewed highlighted the influence of the program projects as of high importance, suggesting that these efforts have provided critically essential information and guidelines to help accelerate integration of solar PV and help California meet its renewable energy goals. Regarding new and improved protocols and standards, interview subjects suggested that these industry-led processes helped advance knowledge of advanced smart inverters among key industry personnel.

Comments from stakeholders include:

> *"They (protocols and standards) will certainly impact inverter manufacturers and communications companies, and should help other balance of systems and component manufacturers develop products in the future having standard communication language and testing protocols".* In addition, these advances *"should lead to a safer, more reliable, modernized grid and make it easier for smart inverter manufacturers … all this should reduce costs of DER".*

Concerning efforts to improve CA Rule 21, regulatory stakeholders noted that in 2008, at the start of the CSI RD&D solicitation process:

> *"With regard to Rule 21 and the 15 percent peak load threshold, we didn't know … what the limits would be on the existing grid. So with aggressive mandates for increased solar on the grid there needed to be research into how much solar the grid could handle. A number of the projects were relevant to our work on Rule 21 and overall, we found a high value in terms of pushing ahead with grid integration and becoming comfortable with pushing limits on the grid."*

Another stakeholder noted:

> *"You can tell that the program had an impact because if there wasn't positive progress with these programs then we wouldn't go from a 33 percent to 50 percent penetration goal. The regulators' exposure to the outputs of CSI and other research doing this has helped the regulators, grid operators, and utilities be more sure about the impact of distributed energy resources on the grid, and I think that they feel comfortable now, and this definitely has helped advance the opportunity for higher penetration."*

Impact of recommendations on inverter system communication protocols

Advanced smart inverters are communication enabled inverters that can improve communication between distributed solar resources and the grid, helping to manage distribution of generation to the grid, cope with distribution-level voltage deviations, and provide additional protection and resiliency to the electric power system. These capabilities can be provided at potentially low cost but can greatly increase the penetration of PV and other renewable energy on the grid. Harnessing these capabilities required better understanding of the capabilities of smart inverters, how to calibrate inverters to take optimal advantage of these functions, and how smart inverter functionality can interact with distribution-level interconnection rules and regulations for electric generators and electric storage resources. Beyond the influence on specific inverter standards mentioned above, several projects provided important guidelines and recommendations for inverter systems settings and protocols to advance the integration of advanced smart inverters and help increase interconnection limits, thereby increasing the penetration potential of solar PV.

Key outcomes in this area include:

- **Demonstration projects of advanced smart inverters**. These demonstration projects provided real world evidence of how advanced communication-connected inverters and communication protocols can help progressively increase PV limits on distribution circuits, pushing limits beyond 15 percent and potentially as high as 100 percent. In some cases, they also provide ongoing test beds for future studies. (Projects 27, 29)
- **Technical reports providing guidelines and inverter settings**. Several projects developed technical reports designed to instruct utilities on how to optimally calibrate both existing inverter technology and smart inverters to integrate high levels of distributed PV. (Projects 2, 6, 18, 28)
- **Studies and analysis to develop optimal control methods**. Multiple projects conducted studies to test the application of settings of smart inverters and develop specific control methods. These control methods help mitigate against voltage variability inherent with high penetration levels of PV. (Projects 2, 6, 29)

Again, stakeholders and experts agreed that inverter system communication protocols and control methods are key to incorporating high penetration PV, and the project outputs have provided valuable data on the ability of advanced inverters and communication protocols to improve system reliability. In addition to comments mentioned in the standards section above, with regards to inverter standards, communication and control strategies and protocols were also seen as critical advancements of the Program.

One stakeholder explained:

> *"The reason this was critically important unlike other equipment in the utility industry where the utility is the buyer and owner of all equip. So there is no standard, which is ok because they simply pick one vendor and only use that one. In the case of solar or distributed resources of all types … they are owned by the customer and the customer picks. New companies are appearing and old companies are disappearing. So to be able to create a network that connects millions of these together that can monitor them cohesively and manage them consistently requires a standard communication interface."*

One solar expert, independent of the Program, stated that the industry has:

"…been looking at the communication standards in EV and inverters with building loads and with storage, indicating this is an area of importance, and the CSI projects gave us a look in to some of the challenges that we need to overcome when we start implementing these requirements for communications with smart inverters, so it has provided very valuable information for us and I think for the everyone involved".

Improvement in system reliability brought by new models, tools, and software

Across the 20 projects with Grid Integration components, there were over 30 outputs including commercialized software packages, modeling methodologies, open source modeling tools, data collection tools, and databases. These outputs have led to improvements in grid reliability in situations with high penetration PV. Examples of outputs and their effect on grid reliability include:

- **New or enhanced software products for grid planners and operators.** Several software products were developed that improve resource visibility, provide more accurate prediction of generation, and allow grid planners to model economic value of planned solar generation resources. Improvements in these areas add to overall system reliability. Some examples in this area are:
  - CPR's PVSimulator™, FleetView™, and WattPlan® tools are commercial products developed based on research from the CSI RD&D projects. According to project partners, the CSI RD&D projects "set the stage, which helped us develop a project to get to a saleable technology". Numerous utility and other stakeholders including CAISO utilize these products for grid planning and operations. Together, these tools provide single system and fleet level modeling services that use hourly resource data and defined physical system attributes in order to simulate configuration- specific PV system and fleet outputs to support utility and ISO planning and load-balancing requirements. In addition, they incorporate value analysis tools that allow users to evaluate the economic value of PV system scenarios at very low cost. A project stakeholder explained that the most important thing that this led to was "a system to help do behind the meter PV forecasting, which addresses some of the uncertainty that the ISOs feel." (Projects 1, 21, 37)
  - The Sacramento Municipal Utility District (SMUD) and Hawaiian Electric Company (HECO) with a team of industry partners developed high resolution data monitoring and evaluation efforts leading to the development of data visualization software tools that are being utilized and updated in Hawaii. These tools continued to be refined and commercialized through efforts by the U.S. DOE Sunshot program and the industry partners that have implemented some aspects into energy management systems used by a number of western utilities including the California IOUs and the CAISO, as well as utilities in Hawaii. Project partners and stakeholders believe that these products had a

highly positive impact on grid planning and grid reliability, and some of these outputs have provided significant net benefits to their organizations. (Project 5)

- Southern California Edison and its industry partners developed a process for a stochastic distribution planning process that models distribution circuits in GridLAB-D, an open source software platform, forecasting PV adoption, determining native limits, and providing mitigation strategy analysis for interconnection of new PV generation systems. These tools have been integrated into the Qado Systems software platform GridUnity that provides a user-friendly graphical interface and visualization tools. Utility stakeholders using these platforms explained this software tool was something that did not exist prior to the project and is proving very useful in its ability to demonstrate mitigation processes, model native distribution circuit limits, and expedite the screening process for new projects, which all contribute to grid reliability. (Project 29)

- **Enhanced data products providing critical solar irradiance and other data** that can be integrated into existing modeling tools or software to improve generation visibility, predictive capabilities, and economic assessments, including:
  - SolarAnywhere, a solar resource database containing over 14 years of time- and location-specific, hourly insolation data throughout the continental U.S. and Hawaii. Through a series of CSI projects, these data were enhanced to provide the highest known resolution of any satellite-based irradiance data set in the world, with a 1 km x 1 km, 1- minute resolution. These data were publicly available to users and are used by a broad array of stakeholders around the world. (Project 1)
  - SMUD installed an irradiance sensor network within its territory and integrated the resulting data into its existing planning system to enhance planner visibility of solar generation capacity. Utility staff stated that the sensor network and data have been very important for increasing PV penetration in its service territory and to show utility leadership "that this could be [the] future for us". (Project 5)

- **Improved modeling tools and methodologies.** Aside from specific software applications, several projects developed modeling tools in open source modeling tool and modeling methodologies that can be adopted or integrated into existing utility planning and operations tools. These included tools and methodologies for solar irradiance forecasting, generation forecasting for individual systems and fleet systems, distribution system models, and economic value modeling tools. Each of these types directly or indirectly lead to benefits in system reliability through, for example, more accurate predicting of solar generation and optimal siting of generation resources. Some specific examples of outputs include:

- A PV performance model that can be applied to satellite solar irradiance data to simulate PV power output taking into account local weather conditions. The model uses SolarAnywhere data and is shown to accurately predict power output to within 3 percent of actual output. The model is provided in MATLAB and can facilitate power conversion modeling for large datasets for variability or forecasting applications. (Project 4)
- Cloud speed algorithms to help forecast transient cloud cover, which is an important variable in estimating PV power output. Two different methods to determine cloud speed were developed by a series of projects as well as innovative cloud speed sensor hardware. (Projects 4, 22, 30, 33)
- A novel PV adoption methodology was developed that estimated the probability of adoption of distributed solar attached behind the meter in residential and commercial applications. The method was developed to simulate allocation of new solar PV installations as penetration levels increased, in order to inform forecasts of future states of distribution systems. The method was shown to provide more accurate PV adoption in terms of installed size and location than has been modeled before at scale. (Project 29)

Discussion with stakeholders, experts, and market actors indicate that these program outputs have led to greater system reliability, or a better understanding of actual system reliability that has led to a higher degree of confidence in the ability of the California grid to integrate higher penetrations of distributed PV.

One stakeholder noted that:

> *"Projects I was involved in had a major impact with understanding risks, lots of grants did work with simulating higher penetrations than what is currently being absorbed and allowed utilities and stakeholders to understand the grid impacts as solar penetrations continue to increase."*

Another stakeholder stated:

> *"The generation mix has potentially changed as a direct result of projects increasing the reliability of the grid."*

Reduced cost, saved time, and lowered risk of new projects and system operations

Upfront costs are the single largest barrier to widespread adoption of solar distributed generation technologies. A major component of up-front solar costs are soft costs, which the DOE estimates at 64 percent of total solar costs.[12] Three areas of potential soft cost reduction from the customer side are optimized solar project design and integration with energy efficiency or demand response measures, faster approval and interconnection of new solar projects, and reduced costs of interconnection studies. From the utility side, soft costs can be reduced through improved system operations to incorporate new solar PV, as well as potential maintenance and repair costs that can be avoided through mitigating the risk of new solar projects.

A goal of the CSI RD&D Program was to identify projects that would lead to lower upfront costs to increase penetration of solar PV. Several of the outputs already mentioned have made significant advancement toward these goals either directly or indirectly in conjunction with meeting other goals. There are also outputs directed specifically at reducing the cost and time taken for new projects and lowering the risk of projects to system operations. Examples of important outputs meeting these goals include:

- **Software products promoting optimal building design and integrated projects.** In theory, optimal building design and integrated projects should help reduce the installation costs of solar PV, through ensuring buildings are energy efficient and solar PV is optimally sized. The program funded a project to enhance the NREL BeOpt building design and simulation software application to facilitate the identification and implementation of balanced, optimal, and cost-effective integrations of energy efficiency, demand response, and PV in the residential retrofit and new construction market, including multi-family housing. An important functionality of the program is appropriate sizing of solar PV systems based on cost effective energy efficiency measures installed in the home. The program also funded the Integrated Energy Project XML Schema project that developed a common data collection and communication protocol for common communication across software platforms. Both projects have the potential to significantly reduce costs and save time related to solar PV installation. (Projects 7, 8)
- **Recommendations for Interconnection Regulations and Rules**. Four projects developed recommendations updating either utility level interconnection processes, or recommended modifications for CA Rule 21 based on the technical analysis conducted as part of the projects' scopes. The recommendations from two of these projects (18 and 19) are known to have played a direct role in the improvements to the existing CA Rule 21. Other projects are likely to have influenced these changes. (Projects 6, 18, 19, 20)

[12] U.S. DOE. 2016. Soft Costs 101: The Key to Achieving Cheaper Solar Energy. https://energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy

- **Mitigation strategies to avoid or control faults related to new solar PV installations.** Interconnected solar PV projects come with risks to the grid, including voltage variation causing circuit overload or voltage drops that can negatively impact grid operations. Several projects developed mitigation strategies at system and grid levels to avoid these risks. Implementing mitigation strategies can reduce operations costs, as well as offset future maintenance or repair costs. (Projects 5, 6, 20, 29)

We asked stakeholders and experts outside the projects to discuss the value of efforts to reduce costs and risks of new projects and save time through accelerated project approval. Interviewees noted cost of solar projects as one of the primary barriers to adoption of solar PV, and soft costs of solar as one of the main potential areas of cost reduction. These interview subjects stated that the CSI project outputs have made inroads into reducing costs, saving time and lowering risk of new projects and system operations, with one stakeholder noting that:

> *"We are seeing significantly lower prices and higher performance and better configuration and training and everything to make things cheaper which wouldn't have happened without structured multi year programs like CSI".*

Evidence of simpler/streamlined interconnection requirements

A focus of several projects was developing screening methodologies and models to help simplify and streamline PV project interconnection requirements, which are a cost to solar projects. Given that only a short time had elapsed since these projects were completed, we did not observe any specific examples of where the projects had a direct effect on changing interconnection requirements. However, several projects developed tools or models that have good potential for providing improvements in these areas. Examples include:

- **Simulation models and methods to estimate power output of PV fleets or individual projects over high speed time intervals** can help grid planners perform detailed grid integration studies and identify optimal siting locations of PV. Screening studies often have to be conducted to install new solar PV projects, particularly on high penetration feeders. These methods can help streamline these efforts.
- **Detailed feeder models and new software to enhance utility planning models** have resulted in improved methods that will allow utilities to more quickly and accurately perform engineering screens for new interconnection requests of solar PV, thus reducing time and costs associated with interconnection studies.
- **Project screening methodologies and software tools** developed under the project are designed to help optimize location of new PV generation resources in a streamlined cost effective manner.

Lower transaction costs for implementing solar projects

One specific area of soft costs that has a high impact on overall solar system costs is transaction costs related to new solar projects. Transaction costs include costs of permitting and costs for interconnection studies or other reporting requirements, among others. Again, many of the outputs mentioned in previous sections have had or could have an impact on transaction costs through improved siting of projects, improvements to standards and rules, and developing a better understanding of the impact of solar PV on the grid. Many project outputs including forecasting models, improved smart inverter protocols, and screening methodologies have already or have the potential to lead to reduced transaction costs for interconnected solar projects. Some examples include:

- **Analysis conducted to inform California grid integration rules** that evaluated a set of advanced inverter methods and settings and developed a complete set of guidelines and recommendations provides a mechanism to improve the distribution system performance (as it relates to voltage) when accommodating higher levels of PV. These methods can help fast track application and therefore reduce costs and achieve higher penetrations of solar PV.
- **Improved project interconnection screening and methods for high penetration PV studies**. Projects developed detailed methodologies for performing high penetration PV studies. Utilities use these types of studies to determine interconnection approval status of new projects. (Projects 2, 5, 6, 19, 29)

We asked stakeholders and experts to discuss the value of project outputs designed to help improve costs of implementing new solar projects. These interview subjects stated that CSI projects provided needed and valuable information to help streamline approval of new solar projects, which leads to lower costs.

One stakeholder noted that the projects have made interconnection:

> *"much more simple and gave utilities tools to solve problems, [and] allowed more interconnections without expensive upgrades".*

Another explained that:

> *"The tools provided by projects are really pretty good at expediting (the approval) process and improving the time of the screening process".*

6.2.2 Grid Integration Medium-Term Outcomes

The Grid Integration projects also achieved progress with some of the medium-term logic model outcomes (5-10 years) summarized in Table 9 even though most of these projects were completed less than five years ago. Because a relatively short time has elapsed since the completion of these projects, we would not expect to see much progress on the medium-term progress metrics from the logic model. Despite the short timeframe, our evaluation research did find indications that progress was made in these areas, with good potential for continued progress in the future. For these reasons, we give a "medium" assessment of progress for these metrics in Table 9, which would likely be changed to "high" after more time elapses.

Progress on the Grid Integration medium-term metrics is summarized at a high level below, with a more detailed discussion provided for each metric in Appendix C.

Table 9: Grid Integration Medium-Term Outcomes – Metrics and Progress Assessment

Key Logic Model Metric	Progress Assessment
Medium-Term Outcomes (5-10 years)	
System improvements allowing greater visibility of solar generation	Medium
Improved project value, interconnection time, project approval	Medium
Encourage streamlined approval processes	Medium
Increased expectation of simplified rules and standards	Medium
Increased expectation of improved technical guidelines	Medium

The Grid Integration medium-term outcomes tend to focus on increasing the visibility of solar generation, improving the estimated value of new projects, and improving the perception among stakeholders that the projects will reduce costs and streamline approval and implementation processes (improved perceptions in these areas increase the likelihood that the RD&D results from these projects will be utilized in the industry). The perceived value of the Grid Integration projects was also confirmed by our broader survey of solar market actors when asked to assess the potential benefits of some representative projects. The outputs from several Grid Integration projects are being used in operational environments by multiple utilities as well as the California ISO, thus confirming their value to the industry.

We asked stakeholders and experts outside the projects to discuss the value of efforts for better visualization tools undertaken by program projects. These interview subjects highlighted generation visibility as an area of need in the industry.

One stakeholder noted that before the CSI RD&D Program began, there were:

> *"inadequate modeling and forecasting tools for distributed generation and these were needed to help predict and understand the impact of high penetration distributed generation resources".*

Another stakeholder explained that in 2008 a major barrier to high penetration PV was *"basically not having good forecast data for multiple locations at high time resolution".*

Across these interview subjects, there was a common agreement that there has been significant advancement made in this area, and the CSI RD&D program has made important contributions. One stakeholder noted *"we are at a very different point as a state as regulators and planners in our understanding of optimal siting, and in our understanding of visibility, and solar loading"* and attributed some of this advance to the CSI RD&D program projects.

We asked stakeholders and experts to discuss the value of project outputs designed to help improve or expedite the utility interconnection process. Again, these interview subjects were generally of the opinion that these CSI RD&D projects provided needed and valuable information to help improve the interconnection process and associated rules.

One stakeholder noted that the projects have made interconnection *"much more simple and gave utilities tools to solve problems, allowed more interconnections without expensive upgrades".* A utility stakeholder explained that for interconnection, utilities *"have to go through some technical screens to determine the impact of some PV stuff and what we do today is more or less manual. So I think the tools provided by projects are really pretty good at expediting that process and improving the time of the screening process".*

A regulatory stakeholder noted that *"the gap for these projects was that the existing screening practices needed improvement and weren't as effective as they could be for high penetration scenarios. Meaning that the timeliness of having screening done as well as the effectiveness of the screening practices was poor. The program helped fill this gap related to screening practices improvements".*

7 Solar Technologies

The success of the overall CSI Program depends on increasing performance and efficiency of solar technologies in the market. To support this goal, the CSI RD&D strategy adhered to seven key principles, which included improving the economics of solar technologies by reducing technology costs and/or increasing system performance, focusing on issues that directly benefit California that may not be funded by others, and overcoming significant barriers to technology adoption. Barriers include high up-front cost, which remains the single largest barrier to widespread adoption of solar technologies, as well as other barriers such as unproven technological performance, and proof of economic value. By targeting RD&D activities at those barriers or opportunities that promise high impact but are currently under-funded, distributed solar applications could become more widespread.

The *Solar Technologies* projects had varying levels of success with several projects meeting all their stated objectives. Other projects, however, did not meet their objectives or invested in technology that proved not to be viable in the market.

To address these market challenges, the CSI RD&D Program looked to improve and support commercialization of technologies that were at a near commercial stage, rather than prototype technology. The CPUC identified solar production technology development (Solar Technologies) as a key focus area for the CSI RD&D Program, where the CSI RD&D Program could provide high value for grant funds. By supporting these technologies, the overall goal to increase performance and efficiency of solar technologies and reduce barriers to market adoption should be met.

Solar technology was a primary focus in Solicitation round 2, and a secondary focus in rounds 4 and 5. These program solicitations instructed applicants to engage in activities focused on the needs or areas of knowledge gaps detailed in Table 10. In total, there were 12 Solar Technologies projects funded through the CSI RD&D Program. The following tables summarize these Solar Technologies project characteristics and accomplishments.

Table 10: Solar Technologies Needs And Knowledge Gaps

Area of Need	Description
Projects demonstrating "economic viability of distributed concentrating PV systems"	The CSI RD&D strategy identified CPV systems as an important technology for the success of the CSI program. Distributed solar is currently constrained by the size of a roof or available land to site the system. More efficient solar cells, inverters, and wiring solutions will decrease the overall size of the system thus allowing greater potential for more generation.
Projects that help "building integral PV products (BIPV) become competitive with rooftop PV" and which address "key technical integration issues"	Developing innovative PV materials or methods of integrating PV into buildings are also highly promising methods of reducing the cost of PV systems and/or expanding the market for them, by, among other things, reducing material and production costs and allowing more of a building's surface to be used.
Testing and demonstrating inverter technologies that improve reliability or performance of solar systems and help lower costs	Inverter technology has potential to enhance adoption of solar technology through mitigating the impact of solar penetration on the grid, and increasing control over power flow from solar PV to provide value to utilities and ratepayer. The CSI RD&D Program focused on advancing inverters that demonstrate longer periods between failures, demonstrate lifetimes approaching the expected twenty-year lifetimes for modules, have lower capital costs and lower operating and maintenance costs, and have better integration with smart meters
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems and that allow the end user or utility to capture higher value from the energy produced (e.g., provide energy during peak).	Solar storage technology has the potential to convert solar PV resources into reserve resources. To support progress to this goal, and to improve value of solar to utilities and ratepayers the CSI RD&D Program encouraged near-term testing and demonstration of innovative energy storage technologies, storage technologies suitable for community or multi-user applications, and solar thermal/electricity storage systems recently developed under DOE funding
Field-testing and demonstration of innovative hybrid-solar technologies. Possible examples include:	Solar thermal/solar electric technologies that can increase the economic or greenhouse gas benefits being provided by current solar technologies Concentrating solar systems that can increase production for larger commercial applications. Solar/non-solar combinations (e.g., fuel cells/solar applications) may help competitively extend energy benefits provided to end users

A total of 12 of the 34 completed projects included a solar technology improvement or advancement component (see Table 2). Across the 12 projects, 27 discrete outputs were delivered to meet the identified industry needs. Table 11 presents a summary of the program identified needs and the projects that developed outputs that were designed to meet those needs.

Table 11: Knowledge Gaps and Areas of Need and Corresponding Project Activities

Area of Need or Knowledge Gap	Project ID	Key Project Activity Examples
Projects demonstrating "economic viability of distributed concentrating PV systems"	10, 17	• Manufacture and installation of concentrating PV systems, • Modeling and analysis tools developed for concentrating PV • International standard developed • Installation and demonstration of innovative concentrating photovoltaic / thermal co-generation (CPV/T-2G) technology,
Projects that help "building integral PV products (BIPV) become competitive with rooftop PV" and which address "key technical integration issues"	27, 35	• Enhancement of existing building modeling software • Construction of demonstration sites of 20 ZNE homes
Testing and demonstrating inverter technologies that improve reliability or performance of solar systems and help lower costs	25	• Development of smart inverters and accompanying communication protocol
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems	9, 14, 15, 26, 36	• Development and demonstration of new energy storage technology • Development and deployment of control software
Field-testing and demonstration of innovative hybrid-solar technologies	9, 11, 14, 37	• Development and demonstration of hybrid solar technologies Installed and monitored a 110 kWp photovoltaic tracking system • Field testing performance of hybrid solar technology
Other	13, 16	• Development and demonstration of other innovative solar technology • Development and deployment of software system that automates the BOS component engineering and documentation for optimized PV array

A summary of some of the key Solar Technologies project outputs is provided in Table 12. Outputs include 11 hardware technologies, including Concentrated PV, storage, and hybrid PV technologies; five software platforms; and eight demonstration sites.

Table 12: Solar Technologies Outputs by Project

Solicitation - Project ID	Output Type	Output Description
2 – 9	Technology - Hardware	Advanced energy storage system: ice energy (thermal storage).
	Demonstration	Demonstration and field test for Ice Energy thermal storage.
2 – 10	Technology - Hardware	Amonix high concentration photovoltaic (HCPV) system
	Demonstration	Amonix manufactured and installed 2 CPV units rated at 113 kw as demonstration sites at UC Irvine
	Modeling Tool	UCI's APEP developed a central power plant and CPV dynamic models for system operation.
	Standard	International standard defines a test sequence to detect CPV module failures associated with field exposure to thermal cycling
2 – 11	Technology - Hardware	Solaria modules: single axis, dual axis and polar axis
	Demonstration	Two demonstration sites with solaria modules, a 110 kWp system at the solaria manufacturing facility in Fremont, CA and a 240 kWp system installed at alameda county Santa Rita jail in Dublin ca.
2 – 13	Technology - Hardware	Low-cost P&P PV Kit - "plug & play" AC micro-inverter PV system.
	Demonstration	Installation in six test homes. Updates to installation protocol and P&P PV kit after prototype install. Installation, monitoring and performance evaluation of the installations
2 – 14	Technology - Hardware	Battery buffered electric vehicle charging station
	Technology - Hardware	Second-life batteries for application in single family homes
	Technology - Hardware	Innovative hybrid photovoltaic/thermal (PVT) technologies and designs for solar hot water in multifamily and single family applications
	Demonstration	Demonstration site with installations of three technologies
2 – 15	Technology - Hardware	Develop advanced stationary battery product combining tesla motors' vehicle battery with Solarcity's SolarGuard dispatch and monitoring platform, to create a firm, dispatchable, grid-interactive,

Solicitation - Project ID	Output Type	Output Description
	Technology - Software	Advance communication and control technology platform.
	Demonstration	Demonstration of communication and control technology platform and advanced lithium-ion battery storage technology at six sites
2 – 16	Technology - Software	Automated array design and engineering software for rooftop solar installations - Sunlink Design Studio (SLDS)
	Study	Seismic testing and analysis of rooftop solar arrays
2 – 17	Technology - Hardware	Hybrid concentrating PV/thermal tri-gen (CPV/T-3G) technology
	Demonstration	Demonstration system installed at Sonoma Wine Company in Graton, CA rated at 272kw.
4 – 25	Technology - Software	Inverter communication driver software that bridges the field bus protocol used by the inverters (Modbus) to the wide area network protocols used by the utility network (IEEE 2030.5 and OpenADR).
	Technology - Software	Test framework software, including test scripts and test lab automation technology, to test inverters complying with CA Rule 21
	Technology Hardware	Prototype advanced smart inverter
4 – 27	Demonstration	Demonstration of cost effective technology pathways for ZNE communities
5 – 36	Technology - Hardware	Comprehensive system assessment of the smart grid-tied energy storage system using second-life lithium batteries
5 – 37	Technology - Software	Development and delivery of an interactive software platform that provides actionable insights regarding plug-in electric vehicles

Overall, the CSI RD&D Program projects had varied success in developing and demonstrating viable pre-commercial solar technologies and helping them advance to market. Of 12 projects that included a solar technology improvement or advancement component, two are likely to have long-term market impacts in terms of direct sales of new technology, with several others having the potential to have indirect impacts on the market in terms of knowledge transfer. However, the two projects that are likely to have long-term impacts are likely to have significant impacts on the development of battery storage and on reducing soft costs of mounting units and permitting.

While CSI RD&D Grid Integration projects nearly all met or exceeded their objectives, some of the Solar Technologies research area projects struggled to meet their objectives for a variety of reasons. This is not entirely surprising, as development and demonstration of technology can often face more hurdles than some of the more research-oriented outputs associated with the Grid Integration projects. While there were some projects that struggled, there were also some notable strong successes.

Project outputs all have a development lifecycle that includes initial concept development, testing, and validation of performance in operational environments and industry adoption. Once adopted, the outputs should have effects on the adopting organizations and the industry more broadly, including lower generation costs, increased competition in the market, and clean jobs. However, identification of solar technology project effects on the CSI RD&D Program is made difficult due to the varying development stages of the outputs due to the design of the program, with projects from earlier solicitations available to the industry for longer than outputs from later solicitations, including some outputs that have been available for less than one year. Despite these challenges, we are able to identify projects with significant success and subsequent market uptake, as well as projects that were less successful.

Below, we provide a summary assessment of how well the Solar Technologies projects performed relative to the market outputs identified in the logic model for this research area. The remainder of this section provides a summary, with a more detailed version of this section included as Appendix D.

7.1 Assessment of the Solar Technologies Project Outputs Relative to the Logic Model Progress Metrics

7.1.1 Solar Technologies Short-Term Outcomes

The short-term (0-4 years) outcomes are those milestones identified in the logic model that signify early progress toward achieving the overall program goals. Progress made in these initial areas for the Solar Technologies projects would indicate that the Program is on the right track, at least for this project group.

Table 13 summarizes our assessment of the progress made on the short-term Solar Technologies metrics, with additional discussion for each metric following the table.

Table 13: Solar Technologies Short-Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
Number of technology outputs with documented performance characteristics in operating environment	16
Number of technology outputs installed or applied commercially	11
Stakeholder acceptance/perceived reliability.	High
Validation of objective performance characteristics in operating environment	High
Sales / transfer of ownership of hardware/software (i.e., sales of product license –for open/free public use or privately held)	Medium
Increased technology production, sales, and/or revenues, and installations	Medium
Full scale technology production, ongoing growth of installations	Medium

Number of technology outputs with documented performance characteristics in operating environment, number of technology outputs installed or applied commercially

The Solar Technologies project results (outputs) have a development lifecycle that includes development, testing, and validation of performance in operational environments, and industry adoption. Of the 16 hardware and software technologies investigated under the CSI RD&D projects, 11 were specific products being field tested and improved with a view to some form of dispersion to the wider market, either as proprietary products, or as open source or public resources. The remaining five technologies were being field tested to determine viability in specific applications. Of the 11, which include six hardware technologies and five software technologies, all have had some form of broader installation in the market. However, three of the hardware technologies—Amonix CPV, Cogenra's Tri-Generation technology, and GE's Plug-and-Play AC PV panels—have been discontinued. The three remaining hardware technologies, the SolarCity/Tesla lithium ion battery storage technology, Solaria's low cost solar PV panels, and Ice Energy's ice battery have all seen high degrees of market adoption relative to their applications. The five software technologies have each been applied commercially to some extent.

Stakeholder acceptance or perception of reliability

Where possible, the evaluation team asked stakeholders and experts for their assessment of the technologies, whether they perceived the technology as reliable or not, and whether they accepted the results of the studies as reliable, based on the project outputs. It was not always possible to identify a specific stakeholder for each technology, in which case we relied on the combined perception of the grantees and the Program Manager, Itron.

Stakeholders and experts were provided with website details for the CSI RD&D Program where they could access project documentation prior to the interview. They were not explicitly instructed to review these materials, however. Stakeholders were asked to answer the following questions:

> *How successful were the projects in addressing and resolving the knowledge gaps they intended to close?*
>
> *Have any of the projects you were involved in led to, or are likely to lead to, new technologies, new services or businesses, new methods of manufacturing, marketing or delivering technologies?*

Interviewers probed further with stakeholders who mentioned technology projects to ascertain their perception of the technology reliability and potential.

Table 14 below presents an assessment of stakeholder, grantee, or program manager acceptance or perception of reliability. Each project received a score of 1 to 3, where a score of 1 represents low acceptance or perception of reliability and a score of 3 represents high acceptance or perception of reliability. The scores assigned to stakeholders and grantees were assigned by the Evergreen team based on the qualitative response from the interview subject. The score provided by Itron staff is an actual numeric score provided by the project manager.

Table 14: Stakeholder Acceptance or Perception of Reliability Score

Solicitation - Project ID	Stakeholder Score	Grantee Score	Itron Score	Average Score
2 – 9		2	1	1.5
2 – 10	2		1	1.5
2 – 11		3	2	2.5
2 – 13		3	3	3
2 – 14	3		2	2.5
2 – 15	3	3	3	3
2 – 16	3	3	3	3
2 – 17			3	3
4 – 25	3	3	3	3
4 – 27	3	3	3	3
5 – 36		2	2	2
5 – 37		3	3	3
Average Score	**2.83**	**2.77**	**2.42**	**2.58**

With the exception of five projects, stakeholders, grantees, and the program manager, on average perceived the results of the projects, as well as the technologies, to be reliable.

Validation of objective performance characteristics in operating environment

Each of the technologies in the 12 projects underwent field-testing and validation either in an operational or demonstration site environment. The only exception is Project 25, which is a recently completed project for which the software outputs have to date only been applied in a laboratory testing environment.

Ten of the 12 projects performed as expected by the project teams. Some notable findings and progress include:

- Producing the first international lifetime reliability standard for CPV. (Project 10)
- Showing that Solaria's Low Concentration PV technology works best in high irradiance environments by design, but still performs in cloudy or overcast environments when a high concentration ratio technology would shut down, and proved that soiling does not affect the Solaria module in any manner that would be

quantifiably different from standard modules, as far as power output is concerned. (Project 11)

- Providing a solid proof of concept and practical implementation for Grid-Ready Plug-and-Play PV Kits and demonstrating that this technology can be installed entirely by a trained roofing contractor. The GE version was estimated to have an installed cost below $4/watt, assuming a 1,000-unit production volume, this being well below the target cost. Testing also found that AC P&P PV Kit arrays are relatively insensitive to shading, compared with the typical DC string arrays. This could be a very important factor to energy production and cost-effectiveness in the retrofit market, where shading is a prevalent problem. (Project 13)
- SolarCity and Tesla were able to design, develop, and install both residential and commercial advanced lithium ion products. Throughout the process, there were many insights gathered on important product specifications, code requirements, installation processes, and customer feedback. These insights have influenced various policy and regulatory settings that are currently determining the future of paired PV and energy storage products, including conducting a series of UL site certifications, leading to draft standards for integrated storage products. (Project 15)

Sales/transfer of ownership of hardware/software (i.e., sales of product license–for open/free public use or privately held)

As noted in the proposed CSI RD&D Plan, "success of the CSI program depends on increasing performance and efficiency of solar technologies in the market." In the adopted CSI RD&D Plan, production technologies are those "supporting commercialization of new PV technologies." An indicator of success of production technologies is whether they progress to being commercialized technologies, and experience some sales volume or licensing. This metric (and the following three metrics) addresses the level of commercialization of products from initial sales and/or transfer of ownership of products, to increased technology production, and on to full-scale production. This metric measures if there have been any initial sales of technology, use of software, or transfers of ownership or technology licenses for the sharing of knowledge or technologies, with a wider range of users who can then further develop and exploit the technology into new products or processes.

Table 15 shows which projects have either had initial sales of products or have engaged in any form of licensing or knowledge transfer leading to development of products by other parties.

Table 15: Initial Sales Of Products Or Licensing or Transfer Of Knowledge

Solicitation - Project ID	Product Has Commercial Sales	Project Output has Licensing or Transfer Of Knowledge Leading to Other Product Development
2 – 9	Yes	No
2 – 10	Yes	Yes
2 – 11	Yes	Unknown
2 – 13	Yes	Yes
2 – 14	No	No
2 – 15	Yes	Unknown
2 – 16	Yes	Yes
2 – 17	Yes	Unknown
4 – 25	No	Yes
4 – 27	N/A	N/A
5 – 36	No	No
5 – 37	Yes	Unknown

Eight of the twelve projects have had at least one commercial sale of a product indicating a high initial success rate (~66%) of moving pre-commercial technology to validated commercial technology.

Increased technology production, sales, and/or revenues

The next stage of assessment is whether a technology has moved beyond initial commercial sales and experienced increased investment in production, increased sales, or increased revenues. Because of the late stage of several projects, we only assessed the progress in this metric for projects from Solicitation 2. We reviewed the project final documentation, spoke with stakeholders and market actors, and conducted Internet research to determine if technology experienced increased sales or production beyond initial commercial sales. Table 16 presents an assessment of increases in sales after the program participation ended, for each project in Solicitation 2.

Table 16: Initial Sales Of Products Or Licensing or Transfer Of Knowledge

Solicitation - Project ID	Increased Production or Sales	Description of Increased Production or Sales
2 – 9	No	While Ice Energy continues to manufacture and sell its technology successfully (over 1000 units installed), Sunpower did not partner with any of the storage partners to develop technology. Sunpower did take lessons learned from the project and apply it to new technology but there were sales connected to this project explicitly.
2 – 10	Partial	From the start of the project Amonix installed approximately 50MW of CPV globally, however, Amonix was liquidated in 2014 before the end of the project and assets purchased by Arzon Solar.
2 – 11	Yes	Developments in the project led to installation of approximately 30MW worldwide, but only 1 MW installed in California. Solaria developed additional products partly based on lessons learned in this project including NEXTracker
2 – 13	No	GE stopped production of the Grid-Ready Plug-and-Play PV Kits before commercialization. Other industry manufacturers have similar products such as LG.
2 – 14	No	No
2 – 15	Yes	SolarCity and Tesla partnered to deploy 350 units of combined PV and battery storage units based directly on outputs of this project through the CA SGIP incentive program.
2 – 16	Yes	Sunlink developed a rack mounting system for flat commercial roofs that can avoid roof penetrations as a result of this project. The project provided an AutoCAD add-in tool to design the racking and tested for seismic stability, resulting in a reduction of BOS costs. The data from the seismic tests support revisions to the standards for rack mounts throughout the industry
2 – 17	Yes	The Cogenra SunPack product was installed at approximately 20 sites after the project. Sunpower acquired Cogenra in 2015 and discontinued the SunPack product. Technology developed through SunPack development is used in SunPower products including their Performance line of products.

Of the eight projects in Solicitation 2 that had a solar technology component, four saw increased production and sales after the project with products related to project research. Two of these companies were acquired by other solar companies that discontinued their products but used the technology in other commercially available products. Two Solar Technologies projects, Project 15 and Project 16, saw significant sales increases and commercially viable products. Project 15 in particular, a partnership between SolarCity and Tesla, developed technology that has led directly to Tesla's PowerWall product—their flagship residential storage product—and SolarCity's GridLogic platform and storage control software, both of which are widely used.

Full scale technology production, ongoing growth of installations

As noted above, two projects have led to full-scale technology production and ongoing growth of installations (Project 15 and Project 16). Two other projects (Project 11 and Project 17) have contributed to other technologies.

Project 15 - Advanced Grid-Interactive Distributed PV and Storage. As noted above, the technology deployed and demonstrated in this project has led directly to new products from Tesla and SolarCity. According to a stakeholder, during the grant project lifetime, Tesla took the battery storage pack and control software through one and a half generations, which led to a product that was installed in 350 homes under the SGIP program. This technology then led directly into the PowerWall and PowerWall 2.0 products from Tesla that have been available for sale since the beginning of 2015. This same stakeholder noted that:

> *"the key impact is that because of this grant funding, the deployment of residential power storage at scale was likely accelerated by some amount – arguably by a couple of years, it is a product that came to fruition that much earlier at scale"* and through the grant *"we were able to learn what were the meaningful product requirements and system level requirements for a successful residential energy storage deployment and we absolutely view energy storage as a technology that adds value to the operation of solar on the grid, it very clearly defined for us what is necessary for a battery system to be designed, owned and operated and how to reduce soft costs. Even fundamental things like that battery packs may be wall mounted in residential applications. A lot of the details that are ultimately the difference between $1000 kWh energy storage and $200 kWh energy storage".*

Another innovation was that this project saw the initial genesis of SolarCity's communication and control platform for energy storage, and learning what are the features necessary for fleet aggregate control of energy storage.

Project 16 - Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery. The project led to new and improved Sunlink products as well as products other racking system manufacturers. One stakeholder noted that:

> *"our experimental data got traction and got published and other racking manufacturers were able to use that approach as well. So we were not the only racking system on the market that could use the method – it became an option for any manufacturer to use so systems in CA became cheaper and easier to install based on our work".*

In addition, a startup company that was formed as a result of the project developed automated design software that incorporated lessons learned from the project.

Growth in solar company profitability, stock price, or improved investor sentiment

It is difficult to directly tie growth in solar company profits to CSI RD&D Program projects. One stakeholder noted that the relationship between Tesla and SolarCity that developed around the joint work on energy storage is certainly one of the reasons why Tesla has offered to buy SolarCity, which has an impact on the performance of Tesla. Tesla was expected to sell 168.5 megawatt-hours of energy storage systems to SolarCity in 2016, up from 25.8 megawatt-hours in 2015, which represents a revenue increase from $8 million to $44 million. Other companies such as SunPower and Sunlink that have developed products from the CSI RD&D Program project research are likely to see increased revenues and therefore improved company performance, but attributing any improvements directly to CSI RD&D Program projects is not possible.

7.1.2 Solar Technologies Medium-Term Outcomes

The medium-term (or second order) outcomes refer to the effects that project accomplishments have in the mid term (5-10 years). We primarily rely on a qualitative assessment based on our interviews with the grantees, industry experts, and stakeholders.

Table 17 provides a summary of our assessment of the medium-term progress for the Solar Technologies project group. In general, progress on the medium-term outcomes has been low, largely due to the fact that not enough time has passed since project completion for much progress to be made in these areas.

Table 17: Solar Technologies Medium-Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems.	Medium
Funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software	Low
New financing options offered/new business models arise for technology distribution.	Low
Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process.	Low/Medium

Higher penetration of solar technologies, greater cost-effective applicability of solar systems

While there are only two projects with organizations actively moving forward with technologies directly related to the CSI RD&D Program project outputs (Project 15 and Project 16), these two projects have the potential to have a significant impact on the penetration of solar technologies.

In particular, the Tesla/SolarCity partnership (Project 15) has led to development of one of the industry-leading storage products on the market that is seeing significant increases in penetration. The advancements made in this project that are likely to impact solar and battery storage penetration in the future include:

- Moving the industry toward lithium ion battery technology. As noted by a stakeholder with knowledge of the Tesla/SolarCity project, the industry

  "was not focused on lithium ion batteries (LI Ion) but were focused on other chemistries – lead acid, flow batteries and a few other tech. We found that the charge cycling and weight and form factor benefits were immensely beneficial from going to LI Ion."

- Identification of key areas of cost savings. One of the important innovations according to a grant partner was

  "a lot of cost, rather than coming from the cost of the cells themselves, comes from how the system as a whole was packaged, by that I mean not just putting cells into a battery pack but then taking that DC battery pack and pairing with an inverter, and then integrating with the grid or an energy control system. We found that there were many other groups trying to do energy storage that were two to four times the cost of what we

thought it should be and were able to prove that it should have been. It was very beneficial to SolarCity and the team, not just in things we were publicly publishing in papers but just in many, many private conversations with manufacturers across the industry….equipment, inverter, battery, cell makers: we were able to have conversations with these folks and share an example of where they should be. This has informed products that are becoming available now".

- Development of certification testing and standards for battery storage. A project partner noted:

  "when we started, the National Electric Code almost had nothing in it about certain types of energy storage especially LI Ion based energy storage systems. They had lead acid systems but these are different with regards to voltages, exposure and service. This project and our communication with NEC has informed how we asked for future changes to NEC. And same thing with UL especially on the Tesla side, there were not UL testing standards for energy storage of the type we were building. So in the project, for the first few systems we built we had to do a series of UL site certifications; these were product certifications because there wasn't a standard. So coming out of that, there are now draft standards, and the way Tesla and SolarCity have interacted with the standards bodies and advised how to form standards has come out of this work. This is a key step in commercialization of the products and outputs of the project and allows the standards body to be able to do a factory listing of the products".

In addition to this project, there were other projects that could impact future penetrations of solar technologies including work on CPV technologies in testing and developing standards around these products. For example, if silicon prices increase and/or other market factors change so that CPV technology becomes economically viable again, a lot of groundwork has been laid to help advance penetration of these products.

Funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software

Aside from the startup created to commercialize output from the Sunlink Project 16 discussed above, we are not aware of any new projects being planned to develop supporting or ancillary hardware or software to support these products. It is possible that there will be further spinoff technology or research, particularly in the software and inverter protocol sphere that will be needed to support further integration of battery storage or other technologies.

New financing options offered/new business models arise for technology distribution

We are not aware of any new financing options or business models arising from these projects aside from the Tesla/SolarCity model that is already in place.

Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process

The Solar Technologies projects have shown some very early progress (and the potential for progress in the near future) toward these metrics. Specifically:

- Advancement in battery storage technology increases the scope of using solar generation by potentially converting solar generation to a reserve resource.
- Standards developed through these projects can help improve the interconnection process.

8 Innovative Business Models

The adopted CSI RD&D Plan describes Business Development and Deployment projects as those "supporting the market and end-users." Within this category, the Plan also focuses on "activities that enhance the competitiveness of new technologies, or help reach a 'tipping point' into widespread commercialization." This can include projects that involve testing of technologies or measures that enable streamlining of regulatory processes or standards in ways that allow new products to come to market more quickly and at lower costs.

The *Innovative Business Models* projects had limited success, with several projects not meeting their stated objectives. The project outputs for this group also tended to have lower penetration with targeted audiences and less potential to develop clear market applications.

Specific categories of Business Development and Deployment activities identified in the Plan for possible grant funding include:

- Projects where "potential roles for utilities in solar PV, including attractive business models, are identified and vetted with utility companies;"
- Projects involving "lower cost, utility grade PV system control, metering, and monitoring capacity developed consistent with *(the)* 1% cost parameter established by the California Public Utilities Commission (Commission) for CSI;"
- Projects that "perform field tests to quantify operational risks and benefits of PV;" and
- Projects that "demonstrate improved PV economics using advanced metering, price responsive tariffs (e.g., Time of Use—TOU, Feed in Tariff), and storage."

The CSI RD&D Program identified Business Development and Deployment as a key focus area, where the Program could provide high value for grant funds. Business Development and Deployment was a primary focus in Solicitation 2 and a secondary focus in rounds 4 and 5. These program solicitations instructed applicants to engage in activities focused on the needs or areas of knowledge gaps detailed in Table 18.

Table 18: Business Development and Deployment Needs And Knowledge Gaps

Area of Need or Knowledge Gap	Description
Demonstrations of innovative ways to lower installation or operations and maintenance costs	Standardization of installation techniques or new approaches for warehousing of parts. Testing and demonstration of low-cost maintenance approaches and trade-offs between automated and manual approaches
Testing and demonstration of virtual net metering approaches	Projects that cut across different geographical/socio-economic strata in such a way that benefits and costs are demonstrated to be shared appropriately among users; and pinpoint significant issues necessary to expand the approach more broadly including but not limited to residential housing developments and the commercial arena and (by testing) help determine appropriate tariffs
Testing and assessment of economic aspects of PV using price responsive tariffs and storage	Projects that meter the energy use and delivery aspects of energy storage used in conjunction with solar systems; and test price responsive tariffs that provide appropriate pricing to higher value energy and can potentially be expanded to the commercial market place rapidly
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems and that allow the end user or utility to capture higher value from the energy produced (e.g., provide energy during peak).	Testing and evaluation of the economics associated with "unloading" of distribution feeders across more than just a peak hour of a peak day and taking into account capacity values used by utilities in determining feeder upgrades or expansion. Testing that quantifies the extent to which increasing the number of solar systems leads to "flow back"[13] on distribution feeders and the capital and operations and maintenance (O&M) costs incurred by utilities to prevent "flow back". Testing of solar system technologies developed to prevent "flow back" and how their costs compare to utility-based solutions.

A total of 10 of the 35 completed projects included a Business Development and Deployment component. Across the 10 projects, 12 discrete outputs were delivered that fall under the category of Innovative Business Models development and deployment. Table 19 presents a summary of the market needs identified in the program design, the projects that developed outputs that were designed to meet those needs, and examples of project activities.

[13] "Flow back" refers to the movement of electricity from the end user to the utility, which is different from the historically typical flow of electricity from the utility to the end user.

Table 19: Knowledge Gaps and Areas of Need and Corresponding Project Activities

Area of Need or Knowledge Gap	Project ID	Project Activity Examples
Demonstrations of innovative ways to lower installation or operations and maintenance costs	13, 16, 17, 23, 31. 37	• Business models and research for new products to lower installation costs and increase PV penetration. • Demonstrations and tools to lower installation and O&M costs of existing products. • Shared, collaborative, funding and procurement mechanism to lower installation costs.
Testing and demonstration of virtual net metering approaches	14	• Demonstration and recommendations for virtual net metering approaches
Testing and assessment of economic aspects of PV and storage using price responsive tariffs including with storage	12, 14, 15, 26	• Case studies of business strategies for optimal tariff decision making (e.g. peak load shifting, PV firming) • Analysis of pricing mechanisms to improve the cost and quality of frequency regulation • Business model development for construction, ownership and operation of community energy systems.
Testing and demonstration of energy storage technologies that allow capture of higher value from the energy produced	15, 26	• Testing and demonstration of financing mechanisms for PV and storage • Testing control strategies for energy storage to absorb renewable production variability

A summary of the 12 unique outputs from the Innovative Business Models projects is provided below in Table 20. Outputs include 11 hardware technologies covering Concentrated PV, storage, and hybrid PV technologies; five software platforms; and eight demonstration sites.

Table 20: Innovative Business Models Outputs by Project

Solicitation - Project ID	Output Type	Output Description
2 – 12	**Testing price responsive tariffs**	Optimize and manage DER dispatch schedules in real time; investigate changes in incentives and tariffs, to determine cost-effective strategies to support integration of high penetrations of solar. The project was delayed and did not meet its original objectives.
2 – 13	**Innovative ways to lower costs**	The goal of this project was development of a business model for deployment of a nascent PV technology, AC Plug-and-Play Solar PV Kits that can be installed by roofing contractors without an on-roof electrician. The project was successful. The actual test product is no longer in production but similar products are commercially available.
2 – 14	**Virtual net metering approaches**	Business models that incorporate virtual net metering for community level solar resources connected to single-family ZNE homes. The models were completed, benefits shown and policy recommendations made.
	Innovative ways to lower costs	Alternative business models for the construction, ownership and operations of the UC Davis West Village Energy Initiative system, especially as related to achieving Zero-Net-Energy (ZNE) for the single family homes for faculty and staff. Financial modeling and analysis was completed, however, real world implementation, which was planned, did not occur.
2 – 15	**Testing energy storage technologies to capture higher value**	The project identified and designed pre-commercial technology and demonstrated installation requirements, cost, permitting, and interconnection requirements. The project team designed a control platform that enabled remote control of energy storage devices. The project analyzed potential market mechanisms to reduce barriers and increase adoption and provides policy recommendations.
	Testing price responsive tariffs	Optimal rate designs and ISO Services for maximizing the value of combined PV and storage. Three studies were conducted that 1) investigated the effects of deployment of PV power on the grid and estimated economic impacts of PV, 2) identified pricing mechanisms to improve the cost and quality of frequency regulation, 3) analyzed strategic behavior between non-generating resources (NGRs) providing fast regulation in reserve markets.
2 – 16	**Innovative ways to lower costs**	Study to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. The project conducted seismic testing of arrays, created a suite of integrated design tools that reduces time to produce accurate, original PV array layouts, and developed document databases.

Solicitation - Project ID	Output Type	Output Description
2 – 17	**Innovative ways to lower costs**	Validated energy models and economic models to calculate the return on investment of Cogenra's cogeneration solar technology. The project validated energy models and developed an ROI tool that uses the energy models to provide financial information internally and to customers.
4 – 23	**Innovative ways to lower costs**	This project aimed to develop and implement an innovative financing mechanism for regional sustainability projects for municipalities, schools and public agencies to help reduce costs through seed funding, resources and training, and collaborative procurement. The funding mechanism, a revolving loan fund, and formation of an LLC was developed, and 37 public agencies engaged in the process, with 14 public partners signing MOUs to participate. Almost 150 sites were prescreened; 41 of those sites received full feasibility assessments; and 130 MW of viable solar projects were identified across all prescreened sites. 6.8MW of viable solar projects were included in a collaborative RFP representing 13 public agencies; 4 qualified vendors submitted bids on SEED Fund projects and 4.3 MW of solar were installed or are under contract. A second round of funding began in 2016.
4 – 26	**Testing price responsive tariffs**	A goal of this project was to develop tangible policy and planning recommendations for high penetration PV and energy storage dispatch and to develop tariffs and incentives, program designs and customer outreach strategies for behind-the-meter energy storage. A demonstration site of 34 homes containing Sunverge Solar Integration Systems (SIS) – a 2.25 kW PV system integrated with a 4.5kW/11.7 kWh battery – was established to test SMUD's DRMS to dispatch the SIS units, including over nine critical peak pricing events and eight test demand response. Based on the demonstration the project team developed models to analyze the costs and benefits of PV integrated storage from customer, regional and utility ratepayer perspectives and provided recommendations for program design.
5 – 31	**Innovative ways to lower costs**	This project was the second phase of Project 4 – 23.
5 – 37	**Innovative ways to lower costs**	The purpose of this project was to modify and enhance Clean Power Research's existing solar sustained vehicle (SSV) web service and develop an intuitive user interface to include integration of personalized driving and charging habits, separation of technology financing methods, and integration of smart meter (e.g., Green Button) data. These additions are aimed at adding value to detailed analytics and collated market statistics helping to drive action by end-users. The project was completed as planned.

Some of the Innovative Business Models research area projects struggled to meet their objectives for a variety of reasons. While there were some projects that struggled, there were also some notable strong successes. Below is a brief summary of projects that did not meet all objectives.

- **Project 2–12: Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources.** The original goal of this project included demonstration of optimization and dispatch strategies in real time, and development of a public cost benefit tool. Due to project delays including delayed availability of demonstration site data and lengthy software debugging and validation efforts, neither of these activities was completed.
- **Project 2–13: Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results.** This project met all stated objectives, and the project partners demonstrated and documented the potential for innovative business opportunities related to this technology. However, the specific product tested was discontinued by GE and is no longer available on the market. There are other similar products now available that could benefit from the findings of this project.
- **Project 2–14: West Village Energy Initiative: CSI RD&D Project.** The original goals of this project included developing viable business models for deployment of community scale solar, and then working with a third party investor to design, build, and operate a community scale solar resource at West Village. The project successfully developed and assessed business models; however, the construction of the housing development that would serve as the customer for the solar project was delayed. Therefore, the second part of the project did not move forward, and the business model could not be implemented.
- **Project 2–17: Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology.** This project met all stated objectives. Cogenra demonstrated the benefits of tri-generation technology, and the commercialized Cogenra product is installed at over 10 sites in California. However, SunPower has since acquired Cogenra, and this hybrid PV/T product has been discontinued. Despite this, some of the technology developed through the research project forms the basis of a new, lower cost panel line for SunPower.

Project outputs all have a development lifecycle that includes initial concept development, testing, and validation of performance in operational environments and industry adoption. Once adopted, the outputs should have effects on the adopting organizations and the industry more broadly, including lower generation costs, increased competition in the market, and clean jobs.

8.1.1 Innovative Business Models Short-Term Outcomes

Based on the nature of the Innovative Business Models projects, we identified particular areas of potential effects in our metrics from the logic model. Table 21 summarizes our assessment of the Innovative Business Models projects for each metric.

Table 21: Innovative Business Models Short-Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
# business models designed and tested, and validated	6
# models with documented adoption or likely to be adopted and # stakeholders adopting models	6
Stakeholders reached / attending demonstrations; percent of target audience reached	Low
Documented evidence that business models will support expansion of cost-effective solar	Medium
Performance of business model in operating environment documented	Medium
Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk	Medium
Increased customer awareness of solar projects; increase in sales growth	Medium

Number of business models designed and tested, and validated

The 12 Innovative Business Models outputs developed under the CSI RD&D Program projects reached different stages of development from theoretical design to testing and validation in a demonstration or operating environment. The evaluation team reviewed program documentation and results of in-depth interviews with grantees and market actors to categorize the development stage of outputs from each project, among three stages:

- Design only
- Design and testing either through simulation or demonstration
- Design, adoption, and validation in operating environment

Table 22 presents the stage of each output by project.

Table 22: Business Development and Deployment Output Stage

Solicitation - Project ID	Output Type	Development Stage
2 – 12	**Testing price responsive tariffs including with storage**	Design only
2 – 13	**Innovative ways to lower costs**	Design and Test
2 – 14	**Testing and demonstration of virtual net metering approaches**	Design Only
	Innovative ways to lower costs	Design Only
2 – 15	**Testing energy storage technologies to capture higher value**	Design, Adopt, Validate
	Testing price responsive tariffs including with storage	Design Only
2 – 16	**Innovative ways to lower costs**	Design, Adopt, Validate
2 – 17	**Innovative ways to lower costs**	Design, Adopt, Validate
3 – 23	**Innovative ways to lower costs**	Design, Adopt, Validate
4 – 26	**Testing price responsive tariffs including with storage**	Design and Test
5 – 31	**Innovative ways to lower costs**	Design, Adopt, Validate
5 – 37	**Innovative ways to lower costs**	Design, Adopt, Validate

Three projects (Projects 12, 14, 15) produced outputs that were in the design stage at the completion of the project. Project 12 designed and conducted very limited testing of three strategies of high penetration PV integration—peak load shifting, PV firming, and grid support—and provided recommendations for future studies and potential tariff or rate structures. Project 14 developed alternative business models for community solar projects and developed financial models to test and validate business model designs. Project 14 also provided recommendations for adoption of virtual net metering in single-family residential applications for community solar projects. Project 15 identified and designed utility retail and ISO wholesale rate structures, tariffs, and market mechanisms that could help bring combined PV and storage to new markets, and help optimize the value of these products.

Two projects included outputs that were designed and then tested in either a simulated or small demonstration environment. Project 13 developed a comprehensive business model design for "plug and play" ready-to-install PV system-kits including detailed market analysis, value proposition and business strategies, and market surveys, as well as a detailed best practices training program and financial options for residential solar PV and energy efficiency. These outputs were tested through market surveys and a small demonstration activity, and showed promise. Based on a 34-home demonstration site, Project 26 developed and analyzed highly detailed use case studies, including cost effectiveness and optimal rate design for a combined PV and storage technology. These studies provided important insights into the value of solar and storage systems to utilities and rate payers, in particular showing that the value of the systems is highly dependent on location and how the systems are operated and controlled.

Below are some additional details on the six Innovative Business Models projects that had their performance tested in operating environments.

- **Project 15: Advanced Grid-Interactive Distributed PV and Storage.** The primary goal of this project was to test a new energy storage technology, demonstrate strategies to integrate these technologies with existing solar assets and into the solar market, analyze the value streams that these systems could provide, and identify market mechanisms by which this value can be accessed. Key achievements included demonstration of net benefits to the grid and customers of the technology, technology developments and best practices that lowered the cost of installation, and development of important insights into product specification, code requirements and other aspects of the technology. Since the end of the project, the project partners have leveraged the findings of this grant to develop fully commercial products with hundreds of residential and commercial installations in California. One project partner stated that the project "*very clearly defined for us what is necessary for a battery system to be designed, owned and operated*" and ultimately was highly influential in the development of widely used commercial technology including software control platforms and storage technology.
- **Project 16: Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery.** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. The outputs of the project have been implemented by the project partners in their business operations in product development and design that has helped reduce balance of systems costs for the project partner. Findings from the project have also been operationalized in that they have been used to inform building code for unattached

solar arrays, and helped other market actors develop and refine products to reduce overall cost of solar installation.

- **Project 17: Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology.** This project validated energy models and developed a return-on-investment tool that uses the energy models to provide detailed and comprehensive project financials internally and to customers. These outputs were used by Cogenra to demonstrate the financial viability of its products. The company has since been acquired by SunPower, and the products have been discontinued.
- **Project 23 / Project 31: Solar Energy & Economic Development Fund (SEED Fund).** This project developed and implemented an innovative financing mechanism and collaborative project identification and procurement model for regional sustainability projects for municipalities, schools, and public agencies. The goal of this project is to help reduce costs through seed funding, resources and training, no-cost solar assessments, and collaborative procurement. Two rounds of funding have occurred across two grants. The project was moderately successful and achieved the performance goals set forth in the grant proposal. A second round of funding began in 2016.
- **Project 37: Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources.** This project modified and enhanced Clean Power Research's existing solar sustained vehicle (SSV) web service and developed an intuitive user interface to integrate driving and charging habits, financing methods, and smart meter data. The end product, WattPlan, was operationalized, and California ratepayers can access the PV+EV calculator and enter specific information about themselves and get information that can help them make decisions about purchasing and installing PV systems and purchasing electric vehicles. The PV+EV calculator developed for CSI was launched on September 23, 2015 and was freely available to ratepayers for one year. It is included as part of WattPlan, which is used by several California utilities. Clean Power Research continues to expand and enhance its software offerings, and the knowledge and insights gained from this project have influenced its software offerings.

Evidence of models with documented adoption or likely to be adopted and # stakeholders adopting models outside project

Aside from two projects (Projects 16 and 37), there is little evidence of adoption or awareness of project outputs beyond the project partners. Below is a description of the documented adoptions for Projects 16 and 37.

- **Project 2–16: Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery.** Outputs of this project have been adopted outside the project in two areas. First**,** the outputs have provided basic data and analysis essential for improvements in building codes that have led to improvements made by the ASCE 7 committee on seismic testing of building components in building codes. Secondly, roadmaps provided by the project can help facilitate the process for other solar companies in the state. One project partner noted that while he could not provide explicit information on other companies using the outputs, he was aware that other manufacturers were using their work to improve their systems resulting in cheaper and easier installation.
- **Project 2–37: Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition.** Outputs of this project have been widely adopted by CPR utility customers, as well as ratepayers. The software was available to California IOU customers for one year ending in September of 2016 and has seen very widespread use with over 10,000 customers using the tool within the first three months of it being available.[14] All three IOUs as well as SMUD and other utilities in California and nationwide are continuing to offer Wattplan to their customers.

In addition to these two projects, Projects 23 and 31, the Solar Energy and Economic Development fund saw some strong engagement with municipalities. Similar organizations or schemes have developed such as RE-volv, but there is no evidence that this project influenced those schemes.[15] Beyond these projects, there was little adoption or evidence of project awareness outside the project teams. Stakeholders we interviewed did not raise Innovative Business Models projects as projects of which they were aware. One stakeholder who was involved in CSI Program implementation noted that prior to being interviewed as part of the evaluation, he was not aware of the Innovative Business Models projects, but having reviewed the documentation, noted that the

> *"Business Models work is pretty well aligned with what my organization does generally and what I do specifically. I looked at the (CSI RD&D) website having been prompted by this interview, I went and looked and found some stuff that would have been important for our work that I wasn't aware of"*.

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[14] WattPlan Revealing Savings of Electric Vehicles and Solar in California, New York, Arizona. http://www.cleanpower.com/resources/pr-wattplan-reveals-electric-vehicles-and-solar-savings/

[15] RE-volv is a 501(c)(3) nonprofit organization with a mission to help communities to invest collectively in renewable energy.

This interviewee was particularly interested in projects related to electric vehicles and virtual net metering strategies.

Documented evidence that business models will support expansion of cost-effective solar

Across the 10 Innovative Business Models projects, there is a varying degree of evidence that the outputs will support the expansion of cost-effective solar. Because the outputs of each project are different, we assess the level of evidence for each project individually:

- **Project 2–12: No evidence that business models will support expansion of cost-effective solar.**
- **Project 2–13: Limited evidence that business models will support expansion of cost-effective solar.** Market research conducted as part of the project indicated that the Grid-Ready Plug-and-Play PV kits can provide a valuable addition to the PV market, based on their performance and relatively low cost, estimated to be $3.99/W installed. In addition, the AC-module design provides the opportunity to open a new sales channel in the retrofit market via roofing contractors. Because the specific product has been discontinued, there is little ongoing work on this technology, with one stakeholder saying that they

  > *"are not aware of any significant development of AC systems but the market seems to be going in the other direction if anything, which is driving everyone to DC. But I think I still stand by my statement that there is a lot of benefit from an AC PV system in the retrofit market".*

- **Project 2–14: Limited evidence that business models will support expansion of cost-effective solar.** The project evaluated various business models to determine an "optimal" model that would allow for the deployment of community scale solar. While the evaluations were not achieved in an operational setting, there was some evidence that innovative business models could help achieve ZNE homes with community scale solar for close to the cost of traditional housing. A stakeholder in the project explained that although the project did not complete all its objectives, it

  > *"laid all that groundwork and did a deep dive when we did the grant; it will make it much more likely that we will be able to achieve it as we actually build the single family development going forward"*

  According to this stakeholder, the project also helped answer the question

  > *"how do we allow for this deep penetration of community distributed solar without breaking the backs of the IOUs because their business model wouldn't allow for it … and I think the CSI program is very valuable to continuing to explore that".*

- **Project 2–15: Strong evidence that business models will support expansion of cost-effective solar.** As part of the project, the project team conducted consumer research and investigated finance options for combined PV and battery storage systems. The project found that a combination of PV and grid interactive storage can achieve substantial cost savings for utilities and end customers, and a key to unlocking the benefits is overcoming the barriers to adoption including upfront costs. The project suggests that similar innovative finance mechanisms that have enabled recent growth in the distributed solar PV industry may help growth in deployments of distributed energy storage systems. Since the project completion, the project partners have experienced high uptake of their products indicating that their business models can help support expansion of cost-effective solar solutions. However, we can only make this case for the project partners specifically, not for the wider market.
- **Project 2–16: Strong evidence that business models will support expansion of cost-effective solar.** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. A major component of up-front solar costs are these balance of system costs, which the DOE estimates at 64 percent of total solar costs.[16] The design automation tools and research contributing to building codes in this project have already or will lead to decreased installation costs, which reduces upfront cost of solar systems supporting the expansion of cost effective solar.
- **Project 2–17: Limited evidence that business models will support expansion of cost-effective solar.** This project demonstrated a business model and emerging technology that presents a financially viable cogeneration solar system. These findings are specific to this technology. Cogenra was acquired by SunPower, and the product has been discontinued. However, some research from this technology is being applied as part of a new lower cost product from SunPower. Given this, we cannot say there is strong evidence that the business model-related outputs of this project will have significant impact.
- **Project 3–23 / Project 5–31: Strong evidence that business models will support expansion of cost-effective solar.** These projects have supported the installation and expansion of cost-effective solar through collaborative project identification and procurement and financing. Two rounds of funding have occurred across two grants. The project engaged 37 Marin, Napa, and Sonoma County public agencies in

[16] U.S. DOE. 2016. "Soft Costs 101: The Key to Achieving Cheaper Solar Energy". https://energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy

the collaborative procurement process, and included 143 high-level site assessments and 41 full feasibility studies. The site-screening process identified potential for over 130 MW of solar power installation, including several sites with the potential for utility-scale PV installations. Twenty-five sites across 12 public agencies have entered, or are planning to enter, into purchase or power purchase agreement (PPA) contracts with the selected vendor with a combined total of approximately 5 MW capacity. The fund is being replenished, and a second round of projects was initiated in 2015; according to a project partner, SEI and Optony are engaging jurisdictions for a third round of projects which will result in at least 12 MW of installed solar.

- **Project 2–26: Limited evidence that business models will support expansion of cost-effective solar.**
- **Project 5–37: Strong evidence that business models will support expansion of cost-effective solar.** This project's output has seen high adoption by utility customers seeking to purchase PV systems or electric vehicles. While this product is relatively new, the project partners and stakeholders suggest that there is some evidence of increased adoption of solar. One key finding from this project was that 75 percent of surveyed customers indicated that they would rather get information about solar equipment or electric vehicles from the utility and would trust them more than contractors.

Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk

Similar to previous metrics, there is limited evidence that the business development and deployment projects have led to reduced costs of solar projects or reduced risk, and it is difficult to quantify the value of any reduced costs that have been realized. As noted previously, there are six outputs that have been adopted in some form, so we focus on these six projects to identify evidence of reduced cost or business risk associated with the projects.

- **Project 2–15: Strong evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities.** This project suggested similar business models and financing that enabled adoption and deployment of PV be applied to solar storage. Specifically, SolarCity adopted a zero-down, cash-flow positive finance mechanism as the business model for PV product installation, directing private sector tax equity investments toward financing PV system installations, that allow customers to benefit from PV for no upfront cost, with an accompanying monthly finance payment that may be lower than their offset utility bill. This helps negate what is regularly seen as the key barrier to deployment of solar PV—a high upfront cost. In addition, third party ownership models, such as solar leases and power purchase agreements (PPAs), allow households who cannot afford to own a PV system to go solar. SolarCity adopted a similar model for combined PV and storage using Tesla's Powerwall product, and with the merger of Tesla and SolarCity, these products are now combined. This structure reduces the upfront cost of these technologies to customers. Battery storage integration provides risk mitigation for homeowners. There is also strong evidence that in theory the combination of PV and grid interactive storage can achieve substantial cost savings for utilities by decreasing reliance on other energy sources, and provision of backup power for an energy user with the potential to shift time of use energy and demand charges.

- **Project 2–16: Strong evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities.** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. While we cannot assess the actual impact on array costs of this specific project, one stakeholder noted that the work from this project was "available to any manufacturer to use, so systems in California became cheaper and easier to install based on their work".
- **Project 2–17: Limited evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities.** This project demonstrated a business model and emerging technology that presents a financially viable cogeneration solar system. According to project documentation, the project led to a 50 percent reduction in materials, installation, and operational cost of the Cogenra product. The product was installed at 20 other sites after this project; however, Cogenra was acquired by SunPower and the product has been discontinued. However, some research from this technology is being applied as part of a new lower cost product from SunPower. Given this, we cannot say there is strong evidence that the business model-related outputs of this project will have significant impact.
- **Project 3–23 / Project 5–31: Strong evidence that business models will reduce cost of solar projects and increase value of solar PV for municipalities and utilities, and have positive benefits for residents and businesses.** As noted, these projects have supported the installation and expansion of cost-effective solar through collaborative project identification and procurement and financing. According to project partners, the project has documented evidence that the SEED fund and assistance can reduce administration costs for jurisdictions by up to 75 percent and reduce procurement costs of solar technology by 10-12 percent due to reaching economies of scale through collaborative procurement. In total, the project team estimated a total installed cost reduction of 10 percent for jurisdictions. These

savings, as well as ongoing savings or payment for generation, accrue to the jurisdiction general funds, improving their overall bottom line which has broad benefits for jurisdictions and their residents.

- **Project 5–37: Limited evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities.** While there is not strong evidence that this project and the resulting software would reduce costs of solar or EVs for customers, the goal of the project is to improve the value of solar and EVs for customers by providing customers with accurate data and recommendations.

Increased customer awareness of solar projects; increase in sales growth

There is very limited evidence that the business development and deployment projects have led to increased customer awareness of solar projects or increases in sales growth of products. Of the six outputs that have been adopted in some form, two are likely to have increased customer awareness and increased sales growth, and one is likely to have contributed to increased sales growth. The remaining three have little evidence of effect.

- **Project 2–15: Evidence of product specific sales growth and customer awareness, although uncertain if this has or will lead to broader industry sales growth or customer awareness of solar PV and storage.** The product developed in this project has gone on to have strong and self-sustained penetration in the solar market. SolarCity and Tesla have adopted the business models developed as part of this project, which took the lessons from PV financing and applied them to create a finance program for distributed storage installations. The success of the product and increased sales growth suggest that the business models developed in this project may have contributed to this success, but to what extent is not possible to determine. In addition, based on our research and interviews with stakeholders and project partners, it is not possible to determine if there is spillover from this research to the broader market that has increased sales or customer awareness for other similar products.
- **Project 5–37: Evidence of product specific sales growth and customer awareness, although uncertain if this has or will lead to broader industry sales growth or customer awareness of solar PV and storage.** Research from this project helped develop the WattPlan software platform that allows utility customers to analyze potential savings from electric vehicles, rooftop solar systems, or both, to assist with purchase decisions. Furthermore, the research indicated that provision of this software through utility platforms and branding increases customer confidence in results and likelihood of adoption. There has been a high level of utility customer use of the platform in California, which likely has led to increased sales of EVs and solar systems, as well as raised awareness of these products among utility customers.

- **Project 2–16: Limited evidence that business models will support sales growth cost of solar projects.** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. Upfront cost of solar projects is regularly cited as the primary barrier to adoption. As costs decrease due to the influence of this project, there is likely to be associated sales growth, but the magnitude of this growth is not possible to determine.

8.1.2 Innovative Business Models Medium-Term Outcomes

Medium-term outcomes refer to results or effects of project outputs on the market that are expected to occur after five years based on the program logic model. We primarily rely on qualitative metrics that are informed by project personnel and stakeholders to identify and assess second order outcomes from the program projects.

Table 23: Innovative Business Models Medium-Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
Documented (or predicted) changes to grid-connected distributed generation solar market (supply, demand, market infrastructure)	Low
Predicted influence on expansion of PV market opportunities	Low
Likelihood of easier financing of solar projects	Low
Potential for reduction in balance of system costs	Low

Documented (or predicted) changes to grid-connected distributed generation solar market (supply, demand, market infrastructure)

As discussed previously, across the 10 Innovative Business Models projects, there were varying levels of immediate project success. At least two projects resulted in business model outputs that have already impacted the solar market. The first of these projects provided a business model and financing approach for combined solar storage and solar PV that has pushed sales of a particular product from SolarCity and Tesla, leading to both increased supply and increased demand for this product (Project 15). The business model and financing approach was based on SolarCity's successful models for Solar PV including loan programs and power purchase agreements. If similar success is seen with solar storage products, which appears to be occurring given the general success of the product, it is possible the project will impact the overall market structure. The second project, Project 16, developed automated design approaches, and recommendations for permitting and building codes, that are likely to positively impact the overall cost of solar arrays. Reduced costs resulting from these innovations should increase overall demand for solar PV.

Across the remaining projects, there is limited evidence of direct impacts on long-term supply and demand or changes to the market infrastructure. Projects 37, 23, and 31 could have indirect impact on long-term market structure through increasing demand for solar products among utility customers and municipalities. Other projects that conducted research of rates and tariffs could also contain valuable information that could impact the structure of the energy market, but there is little indication that the intended audience has adopted these outputs.

Predicted influence on expansion of PV market opportunities

There is limited evidence to allow us to determine the influence on expansion of PV market opportunities resulting from Innovative Business Models projects specifically. Interviewed stakeholders and experts did not feel like they could definitively predict influence based on these projects. The exception was Project 15, which several interviewees noted as being very successful at developing and promoting behind-the-meter storage. As we have already documented, sales of these products have been high, indicating that there is potential for expansion in this product area.

Potential for reduction in balance of system costs

There is limited evidence to allow us to determine the influence on reduced balance of system costs resulting from Innovative Business Models projects specifically. Again, interviewed stakeholders and experts were reluctant to predict influence based on these projects. The exception was Project 16, which several interviewees noted as impacting the cost of solar arrays.

9 Knowledge Benefits

The CSI RD&D Program was designed to produce benefits to the California solar market through expanding the knowledge base of the solar industry, including filling existing knowledge gaps to enable successful, wide-scale deployment of solar distributed technologies. Knowledge benefits produced by development of the knowledge base, however, are often not accounted for when communicating results of programs and the program value to stakeholders.

There were significant *Knowledge Benefits* achieved by the grantee research activities through contributions to the overall solar energy knowledge base. These knowledge benefits occurred across all project categories and reflect the most important outputs of the CSI RD&D Program.

As emphasized throughout this report, a comprehensive evaluation of any RD&D program must be structured to capture those impacts related specifically to research projects. Foremost among these is the RD&D contributions to the knowledge base. Having a theory-based evaluation plan that has knowledge base contributions incorporated into the logic model helps ensure that these critical program impacts are addressed in the evaluation research.

To explore the different types of knowledge benefits produced by the Program, we have organized the discussion in this section around several different types of related impacts:

- Relationship building
    - Team composition
    - Team working dynamics
    - Project partnerships
- Knowledge dissemination
    - Knowledge exchange activities
    - Efficacy and fit of exchange activities
    - Knowledge spillover and external interest
    - Influential knowledge disseminators
- Knowledge gaps filled and follow-on production
    - Knowledge gaps and application
    - Target audience and knowledge recipients
    - Intellectual property and intention to use
- Citation analysis
- Market actor awareness and perceptions

Positive activity in these areas provides solid evidence that knowledge benefits are being produced and disseminated in such a way that will help achieve the longer-term program goals.

The original goals of knowledge base development for the CSI RD&D Program are detailed in Table 24. Given the RD&D focus of the program, all projects produced some form of knowledge with associated benefits.

Table 24: Knowledge Base Development Goals

Area of Need	Description
1) Fill existing knowledge gaps in research areas	Identify and fill knowledge gaps in three primary research areas - Grid Integration, Solar Technologies, and Innovative Business Models - while ensuring knowledge produced is not duplicative and leverages existing knowledge where possible.
2) Engage in knowledge exchange activities that transfer knowledge effectively to appropriate audiences and enhance knowledge capacity among stakeholders as well as industry more broadly	Identify and require engagement in formal knowledge exchange activities to transfer knowledge to appropriate audiences. Required activities include, required interactions with partners, webinars, and reports. Encourage other non-required or informal knowledge transfer activities, such as writing academic papers and developing conference presentations to transfer knowledge to actors outside of project team occurred. Optimize the impact of the knowledge exchange activities through thoughtful planning and timing of outreach efforts at different stages of the project. Document the most effective activities for future R&D programs.
3) Develop new relationships and partnerships among industry actors to facilitate future innovation	Promote formation of project teams that include partners with unique, complimentary skills and knowledge, and reach and influence to disseminate knowledge effectively. Encourage creation of partnerships with key stakeholders outside the project teams to disseminate knowledge. Develop enduring partnerships and relationships that can help facilitate future innovation and transfer of knowledge.

Table 25 presents examples of project activities that helped meet the knowledge base development goals.

Table 25: Knowledge Benefits Areas of Need and Project Activities

Area of Need	Project Activity Examples
1) Fill existing knowledge gaps in research areas	Projects addressed knowledge gaps across 15 distinct categories - forecast modeling, solar design tools, improved PV technology, improved CPV technology, innovative business and financial models, gaps related to interconnection rules, electric vehicles, solar regulations, solar resource modeling, energy storage, transmission and distribution modeling, tariff and incentive design, risk mitigation of high penetration PV, utility planning tools, and zero net energy buildings and integrated demand side management. The knowledge gaps were addressed by projects across Grid Integration (12 projects), Solar Technologies (3 projects), Innovative Business Models (5 projects) and cross cutting projects (9 projects).
2) Engage in knowledge exchange activities	The Program's focus on knowledge transfer resulted in a diverse set of activities. High buy-in to Program goals among project personnel led to many more knowledge exchange activities beyond what was explicitly required. Required activities were kick-off webinars, interim reports and webinars, stakeholder engagement, and final webinars. Non-required activities varied by project and included conference presentations, academic papers, and participation in industry working groups.
3) Develop or enhance relationships and partnerships	Program projects brought together well-known and deeply experienced teams, most of whom were already active in the California solar and utility market, had been involved with publicly sponsored RD&D programs, and had existing relationships with other key solar actors in the State. Project partners also worked with the Program Manager and independently to engage external stakeholders. Over forty partnerships formed that persisted after project activities ceased.

The knowledge benefits impacts in each category were assessed through the network analysis completed as part of this evaluation. Grantee and sub-grantee interviews were a primary source of information for the knowledge benefits assessment, as was the analysis of the grantee project data that included a review of how the research results were disseminated and used by external parties.

The remainder of this section provides a summary discussion of these knowledge benefits, with an expanded discussion included in Appendix F.

9.1.1 Relationship Building

Team composition

Understanding the composition of the grantee teams is critical for assessing how well the grantee projects will be able to produce knowledge benefits that can be sustained once the initial project has ended. This includes examining the team size along with the reach and influence of the individual team members. Large, diverse teams that function well share know-how, and over the long term, there are more opportunities for knowledge to spill over in diverse applications throughout the market. While knowledge can be packaged and transferred, know-how is less transferrable. The experience and professional reach of team personnel affects how much know-how developed during the Program and then how much additional is absorbed and will be available in the future.

One aspect of team composition is diversity, and a diverse set of experiences will generally improve the overall competency of the team. Thus, we assessed the diversity and unique competencies of Program teams. A less intuitive but important factor is the degree to which partnerships include a mix of public and private actors. Private sector actors are essential to project success as they bring market insight and cutting-edge capabilities. Public organizations, however, play an essential part in ensuring mid- and long-term knowledge benefits. Public organizations tend to be much more stable over the long-term than private companies, and their underlying strategies tend both to be less volatile and more dedicated to open knowledge resources. The latter was true of many of the public research organizations in the Program.

Based on our review, it is readily apparent that the CSI RD&D Program brought together well-known and deeply experienced teams, most of whom were already active in the California solar and utility market, had been involved with publicly sponsored RD&D programs, and had existing relationships with other key solar actors in California.

By reviewing the individual project documents and interviewing grantees, we were able to gain a deeper understanding of the team characteristics. Grid Integration projects tended to be larger and more diverse than projects under the other three funding areas. Teams with Grid Integration and Solar Technologies projects had high representation of research organizations, like national labs and industry research groups. By contrast, no Innovative Business Models or Cross-cutting projects included research organizations among their ranks. Universities, software firms, and consulting firms were well represented across the Program.

Teams led by solar hardware or installation firms were more likely to include organizations from outside the solar and utility sectors, including builders and retail organizations. Trade organizations were not well represented in the Program, even though they tend to possess significant market and policy understanding and access to information distribution channels.

Descriptions of team experience in many cases went beyond expert competency. One subject described their team members as market leaders. This sentiment was expressed independently across numerous respondents. One way that teams differentiated their team organizations from the market was by including organizations that had developed first-of-kind products or methodologies. Several teams included academics who had recently proved concepts relevant to the project scope of work. Alternatively, some teams enlisted organizations that had developed hardware or software that are new to the market. For example, some teams included leading smart inverter companies, and others brought in firms that owned potentially useful proprietary software. In each case, the teams indicated that these rare competencies were paramount to the project success.

Based on our analysis, we believe that the typical team composition was near-optimal for facilitating long-term knowledge benefits across the program, particularly for the Grid Integration projects. Teams leveraged rare skills, strong market position, and operational know-how; and included a mix of private sector firms and public research organizations. The benefits of strong team composition were strengthened by collaborative working relationships, as discussed below.

Team working dynamics

Another important area for investigation was the working dynamics that occurred during project implementation. Nearly all respondents praised the Program Manager Itron for facilitating stakeholder and market actor relationships, and supporting a vibrant research culture. This, according to grantees, is unique for RD&D programs. Several subjects with prior RD&D program experience conveyed that the flexibility to work through project bottlenecks and respond to discoveries and obstacles during implementation improved their capacity to leverage team resources.

The majority of large and small teams described explicitly collaborative team dynamics. Among respondents who felt their team was collaborative, most described the collaborative aspects in terms of feedback. Teams routinely drew on competencies and know-how in other organizations. In particular, teams were better able to prepare for the applied stages of projects by consulting the experiences of other organizations across the team.

Respondents described intra-team communication as structured, and most indicated consistently frequent communication during the active stages of projects. Many teams had weekly calls, most had some sort of structured expectations for checking in. One respondent exemplified the overall tone regarding partner organizations, commenting, *"I treated it as though they were staff at [my firm] and it was an internal project".*

There were a handful of exceptions, mostly with Solar Technologies and Innovative Business Models projects. Respondents described the working dynamic as more siloed, with different organizations working on discrete tasks, with little sharing of information or providing feedback. Respondents did not cast this independent approach in a negative light, however, indicating that it was largely a consequence of very significant differences in the types of work assigned to each of the partners.

In general, a spirit of collaboration typified the project team dynamics. Working dynamics and robust team composition set the stage for strong knowledge and absorptive capacity benefits; the high number follow-on RD&D and applied partnerships are early evidence that the benefits will follow.

Project partnerships

During the actual CSI RD&D Program implementation period, over 40 partnerships formed that persisted after the initial project activities ended. Partnerships formed between team organizations, between team organizations and stakeholders, and between team members and market actors.

Grid Integration projects formed many more partnerships on average, nearly two partnerships per project. By contrast, Cross-cutting and Innovative Business Models projects produced closer to one partnership per every two projects. The greater number of partnerships per project for Grid Integration may be in part due to the larger average team size. In may also be due in part to the newness or acuteness of the issue during the period of Program implementation. Finally, we saw no indication that enduring partnerships formed out of the Solar Technologies area projects.

Most enduring partnerships formed by Grid Integration projects were with stakeholders or other utilities, continuing and extending work similar to that of the original project funded through the Program. Partnerships also formed between research organizations in the teams—for instance, national labs and EPRI—and other technical team members. Enduring Grid Integration partnerships tended to focus on demonstration or application as opposed to continued research and development.

Enduring partnerships stemming from the Cross-cutting area took two general forms; several were partnerships with project stakeholders or with team members, others were with industry partners who have existing supply chain access. Partnerships with team members tended to be extensions of partnerships that predated the Program.

Team organizations that formed enduring partnerships with other project partners comprised most new partnerships in the Innovative Business Models area. The nature of these partnerships generally centered on research and development and data sharing.

9.1.2 Knowledge Dissemination

Knowledge exchange activities

Teams engaged in a variety of knowledge exchange activities, some of which were generated by the teams and went beyond the requirements of the Program. These exchange activities typically fell into three categories: stakeholder engagement, reports, and webinars. Stakeholder engagement includes: sharing data with stakeholders, formal and informal meetings, direct or ongoing outreach to stakeholders, presentations of findings to stakeholders, and project review meetings with stakeholders. The reports and webinars categories include both interim and final reports and webinars.

Teams found value in engaging stakeholders for feedback and in disseminating project knowledge into the broader field. Each project team participated in multiple stakeholder engagement activities, but usually produced one report and held one webinar.

Interview respondents explained that—because the Program reports followed a structured, expansive format—there was little reason to complete more reports. Some grantees felt that the standardized reports were not user friendly enough to capture an audience. Developing the reports was a major time commitment for the teams, and a few grantees suggested that they could have done more research or engaged in more effective knowledge transfer with the time it took to produce the required Program reports.

The Program-required webinars had similar issues. Respondents indicated that the webinars required a huge time commitment, and many felt that the return on time spent was producing and delivering the webinar was not high. Although some appreciated the experiences, many felt that the audiences were too small and too poorly matched to their project.

Teams were given license to pursue a variety of other knowledge exchange activities. Presenting at conferences was the most common non-required activity, reported by 89 percent of the projects, with Innovative Business Models projects least likely to have a conference presentation. About half of the projects published findings in academic peer-reviewed journals or as white papers.

Direct outreach to the intended audience and to stakeholders was reported by about half of the project teams. Grantees described this outreach as "spreading the word," going on "a roadshow," and "web outreach," with one grantee specifying the use of LinkedIn, and "email blasts to registered users." In addition to the required webinars, 14 projects reported conducting additional webinars to share project findings, using webinar distribution channels outside of the Program.

Many projects (74%), created resources that are available to the public as a result of the CSI RD&D project research. Tools and software included open source algorithms that can be downloaded from websites, formal data sets that can be downloaded, a training video that demonstrates how to use a tool, and a handbook for distribution engineers working with PV assessment and modeling. Maps that can be downloaded included irradiance maps that took into account variable cloud cover and maps of the feeders to show what areas could accommodate higher penetration of distributed energy resources.

The non-required information exchange activities provided a way for the project teams to inform their intended audience of project developments, obtain feedback from stakeholders to guide project research, and to promote the tools and methodologies developed in these projects. Project teams in the Cross-cutting and Grid Integration funding areas reported presenting information about their projects at trade conferences specific to their research areas. Examples included the Energy Efficiency Building Coalition conference, Electric Vehicles Association (EVA), American Council for an Energy-Efficient Economy (ACEEE), and Institute of Electrical and Electronics Engineers (IEEE). Interviewees from four Grid Integration projects reported that a main purpose of talking about their CSI project with those outside the Program was to get feedback from stakeholders or the broader industry to help inform the project research. As one Grid Integration grantee stated,

> *"Getting that feedback from the industry along the way helps steer some things. When the broader industry provides some of that feedback and input, frankly, it helps to strengthen and bolster the research."*

One Cross-cutting project used these non-required knowledge dissemination activities to announce when the California version of the BEopt tool was available, and another let the public know when resources became available for download from their individual websites.

In total, there were 11 reported demonstration sites across all 35 projects. The Grid Integration funding area accounted for more than half of these demonstration sites, as five of those projects combined for a total of six sites. Examples of demonstration projects given in interviews includes demonstrations of battery packs, a showcase home for ZNE homes and their integrated technologies, a field demonstration of the Qado tool for modeling PV penetration, and a training facility for people to learn how to use the project outputs.

Efficacy and fit of knowledge exchange activities

Project teams did not view the knowledge exchange activities as equally effective. Webinars and conferences targeted at the intended audience were viewed as effective by more than half of the projects. By contrast, one-third of projects found the final reports an effective method of spreading information about their project findings. Interviewees discussed the effectiveness of these activities mostly by describing what they found as effective, while few commented on what activities were less effective.

Grantees who explicitly mentioned activities they found to be less effective at disseminating project findings focused on Program-required reports and webinars, as discussed above. The grantee who mentioned reports said that "*most people don't sit around and read those.*" The other grantee was disappointed with the number of attendees at his webinar.

The presence of stakeholder engagement, webinars (primarily non-Program related), and conferences at the top of the effectiveness scale for respondents across the funding areas reinforces the importance of audience and time spent in preparation. Numerous respondents expressed sensitivity to the time it takes to reach the right audience. One contact pointed out that—given the very technical nature of the topics covered by the Program—teams needed to find key people in organizations (like utilities) that really dealt with the topic, as there was little value to others.

Knowledge spillover and external knowledge interest

The Program generated substantial interest from stakeholders and other outside actors. We inquired directly during interviews about occasions where requests for information came directly from stakeholders or market actors. Fifty-six percent of Grid Integration projects and 44 percent of Cross-cutting projects received direct interest in their work from utilities[17] or ISOs, more than the other funding areas. These market actor-to-team overtures came in the form of requests for data, or explanations of methodologies after research presentations. A few projects noted that they pointed these interested stakeholders to the GoSolarCalifornia website, where reports and other information were available. Two project teams even noted interest from outside the US, one from Italy and one from the Caribbean.

Innovative Business Models and Solar Technologies projects received interest from public agencies or municipalities, as well solar hardware or installation firms, and community-based organizations. Examples of solar hardware and installation firms include SolarCity and other manufacturers of inverters, batteries, and modules. The CEC as well as

[17] Several respondents described "system planners and operators", which we included in the utility category.

standards and testing organizations each expressed interest in various Cross-cutting projects.

Influential knowledge disseminators

Many (but not all) grantees described individuals from team organizations or stakeholders as highly active and effective in disseminating project findings. These types of actors are referred to as knowledge disseminators. We found that all mentions of Itron as an influential knowledge disseminator were by project teams in Solicitation 1 (4 of 7 projects). Project team members conducted more knowledge dissemination in later solicitations.

Five projects called out the joint DOE/CEC High Penetration PV forum as one of the most valuable aspects of the Program. Project team members also made important contacts during occasions when the Program administrator arranged for meetings between different active Project teams. In fact, six project teams reported that a key way the Program helped with knowledge exchange was facilitating connections to other researchers and organizations within the Program.

Only two project teams identified a way that the program hindered knowledge exchange activities, both of which were in Solicitation 4 and in the Grid Integration Funding area. Their critiques related to the rules around how the project budget could be spent, which reportedly limited their ability to attend conferences. One said that he desired greater flexibility with how projects can spend dollars for things other than labor, like travel to conferences, and thought the documentation requirements were a bit excessive. The other reported being constrained by the deadline by which he had to use the grant funds. He desired more time after completing the research to disseminate the findings.

9.1.3 Assessment of Knowledge Gaps Filled and Follow-on Knowledge Production

At the outset of the Program, team proposals were evaluated in part based on the reasonableness of the case made that the project outputs would address one of the knowledge gaps identified in the resolution. The teams identified specific knowledge gaps that were specific, narrow, and tailored to their skillsets. We reviewed the original project proposals to get a sense of how subjects envisioned critical gaps in the market and how they planned to close them. During interviews, we asked grantees and sub grantees to retrospectively define the knowledge gap they had sought to close, their target audience, and the innovative project outputs that resulted from project activities. We also asked them to explain how they leveraged existing public and proprietary resources to complete their projects. We then explored how program participation directly affected the teams and outside actors, in terms of follow-on research and changes in firm, product, or market strategy.

In this section, we discuss how effectively the Program addressed the needs and knowledge gaps project teams targeted. In order to accelerate the California PV market, Program knowledge needed to do each of the following:

- Produce outputs that closed knowledge gaps;
- Develop outputs into deliverables suitable for the habits and expectations of the intended audience; and
- Identify, reach, and transfer Program knowledge to market actors

Knowledge gaps and application

Through our analysis of grantee interviews and program documents, we identified 15 distinct categories of knowledge gaps that project teams attempted to address through their research. Knowledge gaps related to forecast modeling and design tools were most prevalent. For projects in the Cross-cutting funding area, gaps related to improved PV technologies were most common. Grid Integration projects largely focused on gaps related to forecast modeling, design tools, Interconnection Rule 21, and solar resource modeling.

Knowledge gaps differed somewhat across the four Program funding areas, though many overlapped. A large number of the knowledge gaps addressed by projects in the Cross-cutting funding area centered around the intersection of technology integration (e.g., energy storage) and energy analysis and optimization. While there were common strands across several projects within this funding area, they varied in how and where in the value chain their outputs matter.

Knowledge gaps articulated by Innovative Business Models projects were the most eclectic, sharing little in common with other funding areas. Knowledge gaps ranged from advanced solar hardware that needed demonstration and commercialization, to procurement challenges at public agencies, to inadequate rate and tariff structures. In this area, knowledge gaps tended to focus much more on major market gaps, as opposed to the nuanced technical, skill, and process gaps evident in the other funding areas.

Generally, projects addressed multiple complementary knowledge gaps, which enabled the project scopes to evolve in tandem with the teams' understanding. Many subjects credited the program managers for working with them to revise the focus of projects in order to emphasize efforts that would be more likely to succeed, would have greater near-term impact, or would lead to more opportunities for follow-on knowledge creation after the Program. While the orientation of knowledge gaps guided Program activities, teams had flexibility during Program implementation to act strategically and pursue high-impact opportunities.

Additional detail on how specific projects address knowledge gaps is provided in the previous sections summarizing each funding area.

Target audience and knowledge recipients

Project teams identified a range of potential audiences for their research, including utilities and ISOs as the primary audience for most projects, followed by public-facing and commercial organizations. Regulators and standards and testing organizations were a primary audience for each funding area, except Cross-cutting. System planners were a significant focus for Grid Integration projects. Conversely, public organizations (such as academics, community-based organizations, and municipalities) and commercial organizations (especially consultants and program implementers) were a high priority for all funding areas, except for Grid Integration projects.

We found that knowledge recipients differed slightly from the intended audience. For example, while utilities and ISOs represented both a target audience and a primary knowledge recipient, national labs and research organizations were more likely to be targeted as knowledge recipients than targeted as audiences. Additionally, we found the volume of knowledge recipients was significantly higher for projects in the Solar Technologies funding area compared to other funding areas.

Multiple respondents described ongoing efforts by program administrator Itron to make connections and facilitate meetings among project teams and key market actors. Several respondents expressed appreciation for this role, suggesting they would not have been able to obtain such broad audiences were it not for Itron. Respondents also credited Itron's staff for having widespread connections through the California market and federal agencies, due to their significant experience working in state agencies.

Respondents also noted that Itron helped to facilitate joint workshops with the U.S. Department of Energy, as well as periodic meetings among the project teams. The required knowledge exchange activities also standardized the immediate knowledge recipients. Webinars and Program sources (i.e., reports and papers) were posted on the GoSolarCalifornia website, and announcements were made through an opt-in email list. These Program attributes help explain why projects across the funding areas shared many knowledge recipients, even though intended audiences varied.

To assess the extent to which projects successfully reached their intended audience, we drew upon interview data to compare the target audience for each project with the organizations who ended up receiving knowledge from the project. This brief analysis reinforces the role that program design played in determining the composition of Program knowledge recipients. Teams interacted directly with a large number of knowledge recipients who had not been identified as target audiences. This, however, does not necessarily indicate a mismatch between the target audiences and knowledge recipients. Projects were able to make connections with their target audiences in every funding area.

The over-representation of knowledge recipients who were not part of the target audiences is likely a consequence of the formalized Program knowledge exchange activities. A second factor we identified that may have contributed to non-targeted knowledge recipients derived from subject responses, suggesting they changed the scope of their research as they learned and gained expertise during Program implementation. Changes in the research scope would reasonably change the intended audiences.

Our analysis did uncover challenges that some projects had in connecting with certain target audiences. Two audiences in particular proved challenging: solar hardware and installation firms, and commercial organizations (for instance, builders, retail). The difficulty to connect with solar hardware and installation firms, in particular, is surprising, considering that several subcontractors were from this subsector, as were a few of the principal organizations.

Intellectual property and intention to use program knowledge

We asked grantees to explain any intellectual property strategy that developed around the Program outputs. Twenty-one respondents from 19 projects provided responses. Overall, six grantees indicated that they did not have an intellectual property strategy at all. An additional 11 grantees reported that all project-related results were open source. In these cases, respondents explained that the research effort was not developed in a manner that easily lends itself to an intellectual property strategy.

A few projects stand out as exceptions. Five grantees reported they developed intellectual property strategies to commercialize some of what they learned during the Program. The intellectual property strategies centered on patent application. Four of the five were Grid Integration projects, and the fifth was an Innovative Business Models project.

No respondent mentioned other explicit intellectual property strategies, such as trade secrets, copyrights, or joint partnerships. The teams submitted patents around specific components of their outputs. For instance, one indicated they filed patents around software control methodologies; another indicated that the project prime had some IP already in place prior to the project for some of the hardware components developed. One subject indicated there was some resistance from another project team member to give away testing and validation software due to proprietary information.

Intention to use: team and non-team

We reviewed program documents and asked grantees about their plans to apply the knowledge gained after the end of the project. Grantees from 16 teams reported that they would leverage Program knowledge with follow-on RD&D funding, primarily by the U.S. DOE and the CEC. Four grantees and sub-grantees interviewed provided details on the follow-on research funding amounts they received, with follow-on research funding totaling $5,722,500 and ranging from $90,000 to $13,000,000.

Although the CEC invested in follow-on projects, several individuals who participated in the Program indicated that they would not pursue additional RD&D funding from California. These firms are located outside of California and mentioned that the contractual obligations of the EPIC program—the successor to the CSI RD&D Program—were too onerous and resulted in greater uncertainty.

The Program has been effective in stimulating other forms of follow-on use, apart from RD&D funding. According to interviews with project grantees, two-thirds (66%) of projects resulted in some type of follow-on research. Grid Integration projects were more likely to result in follow-on research compared to projects in the Innovative Business Models and Solar Technologies projects funding areas.

Utilities and ISOs were the main external organizations that expressed interest in using project knowledge operationally after the Program. This included utilities within California and throughout the U.S. The Innovative Business Models and Solar Technologies projects had a more limited range of organizations that expressed interest in using project knowledge compared to projects in the Cross-cutting and Grid Integration funding areas. Apart from experiencing more overall outside interest, Grid Integration and Cross-cutting projects made inroads with regulators, and with standards and testing organizations.

Overall, both market actors internal and external to the Program expressed a significant degree of interest in leveraging their Program experience to conduct follow-on work. The diverse spectrum of external actors planning to or already using Program knowledge sets in motion several distinct trajectories into the market. For instance, the application of knowledge by technology developers addresses a different market niche than does application by grid management experts or standards and testing organizations. This benefit is especially true for knowledge produced by the Cross-cutting and Grid Integration funding areas.

Grid Integration team members are currently well positioned to leverage Program knowledge directly. Application of Program knowledge directly by project teams carries with it several implications for knowledge benefits. First, the team members have the benefit of direct experience and “learning by doing”, thus improving the ease and cost of leveraging Program knowledge. Second, the project team members have diverse networks of partners and clients, who become likely beneficiaries and recipients of Program knowledge. Finally, research has begun to show that solar sector knowledge produced in

California by firms based in California or working in California localizes the benefits of innovation to the state. It is reasonable to assume that follow-on innovation from the Program by firms based, working, or demonstrating in California will lead to accumulation knowledge benefits over time.

9.1.4 Citation Analysis

In this section, we discuss evidence of knowledge receipt by analyzing citation of program outputs. The Program produced at least 153 original papers and reports, with more forthcoming from several projects. Teams developed interim and final reports in compliance with Program requirements, and many teams published additional journal articles or technical reports to highlight specific aspects or implications of their findings.

As one measure of the reach of Program knowledge, we analyzed the citation of project reports and papers. We collected data and examined the following:

- Number of citations per project reports and paper
- The venue where a Program source was cited
- The organization type of the citing author's affiliation
- The citation pattern over time

Details of our analysis in each of these areas are included in Appendix F, with a summary of our findings provided below.

Among the 153 papers and reports publicly released by Program teams, 26 have been cited at least one time as of the time we collected data during Fall 2016. The 26 Program sources have been cited 395 times to date; though a single Solicitation 1 Grid Integration project accounts for 315 citations (80%). This unique project had published four of its seven papers in *Solar Energy* (n = 3) and *Energy Policy* (n = 1). The papers published in these high impact journals reached a combined total of 303 citations. The project's three other papers, two published in less well-known journals and one Program report, reached a combined total of only 13 citations. This strongly suggests that publication in high impact venues increased visibility of findings and drove a signification citation. Further supporting this observation, across all cited Program sources, papers that were self-published or published by the Program only accounted for 11 percent of citations. It is worth noting, however, that team members from universities and national laboratories released a number of reports beyond what the Program required, and it is too early to determine the long-term impact of these sources. At this stage, it does seem that uptake of self-published and Program released sources is slower than publication in high-impact journals.

Most of the sources that have been cited were produced by projects in Solicitation 1. A few projects from Solicitation 3 and one project from Solicitation 2 have also been cited.

Program sources released in later solicitations likely have not yet had sufficient time to be cited, especially when considering the lag time associated with peer review.

It is notable that only one project outside the Grid Integration funding area has been cited. No projects from the Cross-cutting or Innovative Business Models areas have been cited. Solicitations 1 and 2 had multiple projects from each funding area. The lack of citation suggests that the knowledge produced by Grid Integration projects is more relevant to market actors who cite research in the course of their work.

9.1.5 Market Actor Awareness and Perceptions

As part of our assessment of knowledge benefits, we developed a market actor survey to collect additional perceptions on the potential impacts of the CSI RD&D Program.

The market actor survey was designed to address three project outcomes:

- Awareness of program and project outputs
- Awareness of new ideas
- Adoption of program knowledge

Market actor Program awareness

Overall, the majority of the market actors we surveyed (91%) across the variety of the organization types reported they were aware that the state of California has funded RD&D to stimulate the state's solar market. Figure 6 below shows that more than half of the market actors (56%) even knew about specific projects that were funded by the program, although there were some organization types that were less aware of specific projects than others, including utilities, manufacturers, and installation contractors.

Figure 6: Awareness of the Program and Projects by Organization Type

Organization types	Aware of CSI RD&D program / Aware of CSI RD&D projects
Government (n=17)	100%
	65%
Private research and consulting company (n=16)	94%
	63%
University or nonprofit (n=15)	100%
	67%
Utility (n=12)	92%
	33%
Hardware manufacturer (n=11)	73%
	36%
Installation contractor (n=9)	67%
	44%
3P program implementer or software developer (n=8)	100%
	75%
Total (n=88)	**91%**
	56%

Perceived value of Program

To assess how these market actors perceive the value of the Program funded projects, we asked a set of questions about each of four actual projects that had completed their intended activities. Each project was presented with two pieces of information: 1) the particular barrier or challenges the California solar industry faced to which the project attempted to address, and 2) the project's outcome. Two projects fell under the Grid Integration focus area, and the other two projects fell under the Cross-cutting focus area as follows:

- Project 1: Development of optimal smart inverter setting (Grid Integration)
- Project 2: Software development for custom system design (Cross-cutting)
- Project 3: Understanding the effects of geographically dispersed PV system (Grid Integration)
- Project 4: Software development that optimizes energy efficiency, DR, storage with PV (Cross-cutting)

We presented one randomly selected set of two projects to each respondent—Project 1 and Project 2, or Project 3 and Project 4.

Figure 7 summarizes the responses to each of the four projects.

Figure 7: Perceived Value of Program by Project

	Project 1 (n=46) Grid integration	Project 2 (n=46) Cross cutting	Project 3 (n=42) Grid integration	Project 4 (n=42) Cross cutting
a) Project outcome "very relevant" to your organization's work	59%	30%	67%	60%
b) Project findings "very needed" for the CA solar market	67%	52%	74%	64%
c) "Very effective" in reducing knowledge gaps that exist in the CA solar market	57%	33%	50%	57%
d) "Very effective" in improving understanding and capacity of regulators, grid operators, and standard setters	50%	26%	74%	52%
e) "Very effective" in improving your organization's ability to provide services or develop products	33%	28%	36%	36%
f) "Very effective" in accelerating the integration of distiributed solar power into the CA grid	54%	39%	60%	55%

All of the above items were asked using 5-point scales with similar expression of degrees – for instance a) 'not at all relevant', 'a little relevant', 'somewhat relevant', 'very relevant', and 'extremely relevant'. The percentages show a combination of 'very' and 'extremely'.

Overall, the respondents reacted favorably to the outcomes of Project 1, 3, and 4, while slightly less so to Project 2. Across Projects 1, 3, and 4, more than half of the market actors thought that the project outcomes were 'very relevant' to their organizations (a) and about a third thought those projects 'very effectively' improved their organization's ability to provide services or develop products (e). Regarding these three projects, more than half of the market actors also thought the outcomes were 'very needed' for California's solar market (b), and 'very effective' in reducing knowledge gaps that exist in California's solar market (c). Additionally, more than half of the market actors thought these three projects were 'very effective' in increasing the capacity of regulators, grid operators, and other standard setters (d). As a whole, more than half of the market actors surveyed appraised that these projects' contribution to the acceleration of the solar power integration into the California grid was 'very effective' (f).

Although the perceived value of the Project 2 outcome was not as great as other projects, more than half of the market actors thought the project outcome as 'very needed' for the California solar market.

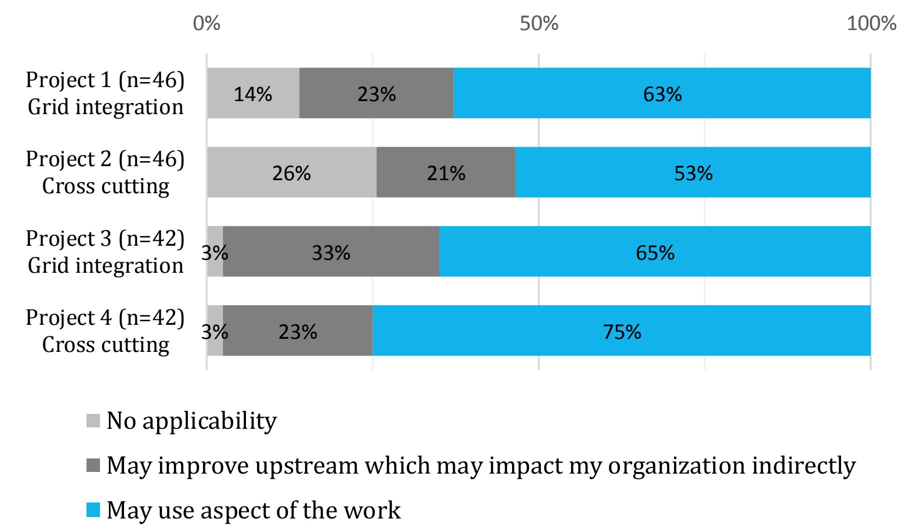
Generally, across the four projects, market actors who are engaged in research and development, grid operation and management, or third party services tended to hold higher opinions of the value of Program outputs. Contacts of hardware manufacturers were the least impacted group by these projects.

Intention and early indication of program knowledge use

Using the same four projects as concrete examples, we asked the market actors some questions that assessed the early indications that Program knowledge is being adopted.

Regarding all four projects, more than half of the market actors reported they are likely using Program outputs, findings, and tools for their organization's future work (Figure 8). The Project 4 outcomes in particular were viewed as directly relevant to their work. Even if they do not see these project outcomes to be directly useful to their work, about a quarter to a third of the market actors thought their work will indirectly benefit as these project outcomes influence the upstream. Overall, market actors thought Projects 3 and 4 produced the outcomes they are likely using.

Figure 8: Intention to Use Program Knowledge by Project



Of the market actors surveyed, 41 percent reported that their work has already used or benefitted from program outputs, clearly indicating early impacts of the program outside of the project teams (Figure 9). Contacts of government, university/nonprofit, and private research and consulting companies or those who are engaged in the research and development or policy analysis are the leading users of the Program outputs so far. Few of the hardware manufacturers have yet found ways to adopt the project knowledge.

Figure 9: Early Indication of Program Knowledge Use by Organization Type

Organization types	Have used or benefitted from CSI RD&D projects outcomes
Government (n=17)	53%
Private research and consulting company (n=16)	44%
University or nonprofit (n=15)	53%
Utility (n=12)	33%
Hardware manufacturer (n=11)	18%
Installation contractor (n=9)	33%
3P program implementer or software developer (n=8)	38%
Total (n=88)	**41%**

We also asked market actors who reported having used or benefited from Program outputs how their organizations have used the information (Figure 10). Most commonly, market actors reported Program outputs are used to educate their clients or audience, for their research and development activities or for improving their projects and services. Another use of the Program outputs reported was to apply for other research funding, for which a few of them have been awarded.

Figure 10: Ways Program Knowledge Used (n=36)

Ways CSI RD&D project information used	
Educating clients and audience	69%
Research and development	69%
Improving products and services	58%
Applying for funding	39%
Increasing sales or market	31%
Other	14%

9.1.6 Knowledge Benefits Summary

Follow-on applications of Program knowledge are already under way, and many of these include direct support from grant awardees. The presence of team members in follow-on use of Program knowledge accrues to the benefit of their partners and client networks. Follow-on projects include RD&D, client services, expansion of products and services, and use by outside partners. The high degree of evident follow-on uses of Program knowledge is in part due to the flexibility afforded to teams by the Program administrator, which worked with teams to revise research emphases as new information came to light. Teams felt this Program aspect was atypical for public RD&D programs, and helped match outputs with market needs.

Program design led to selection of teams committed to knowledge transfer. Most teams went beyond Program-required knowledge exchange activities, and many created knowledge spillover opportunities by releasing resources freely to the public and by developing demonstration sites. Teams identified direct stakeholder engagement, non-Program webinars, and conference presentations as the most effective knowledge exchange methods. Many projects relied on non-required knowledge exchange opportunities to reach key audiences.

The Program Manager Itron worked closely with teams to cultivate audiences for the research outputs, but some struggled to make the right connections. The time it took to produce Program-required webinars and reports was viewed by grantees to be incommensurate with effectiveness of knowledge transfer. As a consequence, some teams emphasized one-off and non-required knowledge exchange activities. Some teams noted that restrictions on how the Program could be used for knowledge exchange complicated pursuit of effective knowledge exchange activities.

Teams connected with knowledge recipients throughout the California market; however, many of the knowledge recipients for some projects did not align with the intended audiences the teams set out to reach. Teams praised Itron for facilitating stakeholder and market actor relationships, reducing the time spent for teams to reach key audiences. The mismatch between knowledge recipients and target audiences, however, appears to be due to the formalized Program knowledge exchange activities, which centralized a lot of Program outreach through the GoSolarCalifornia websites, the opt-in email list, and existing contacts of teams and the Program manager. Teams may have better reached their intended audiences with a more exact and individualized approach for market actor and stakeholder engagement, and for knowledge exchange efforts.

California market actors were familiar both with the Program and with specific projects. Market actors engaged in research and development, grid operation and management, and third-party electricity market services held the highest opinion of the value of Program outputs. Market actors are currently using Program outputs primarily to educate their clients, for their own research and development, and to improve products and services. Even market actors who do not see an immediate direct use for Program outputs in their own work viewed outputs as needed and likely to benefit them indirectly.

10 Conclusions and Recommendations

10.1 General Evaluation Conclusions

Overall, the CSI RD&D Program has been successful on multiple fronts. Feedback on program management by the grantees has been almost universally positive, with a few relatively minor suggestions for improvement. The Program also achieved significant progress on the short-term progress metrics identified in the logic model for most of the research areas. Note that while some individual grantee projects did not achieve their goals or ended early, this is not necessarily a poor reflection on the Program. Research programs that are truly pushing the envelope in terms of exploring new technologies will have some projects that fail. This is arguably better than a research program that chooses 'safer' projects that are less likely to fail, as these projects tend to involve technologies that are closer to commercialization and therefore in less need of research dollars to become viable in the market.

The overarching conclusions drawn from the evaluation are presented below. The conclusions are first discussed relative to the program management and then for each of the major project types discussed in the earlier report sections. Following this, a discussion is presented of how well the Program achieved the original goals the CPUC established for the CSI RD&D Program and this evaluation.

Overall Program Management

The feedback received on Itron's program management was very positive across multiple criteria. Specific accomplishments include the following:

- **The Program design was clearly communicated to relevant stakeholders and the Program was executed as designed.**
- **The Program Manager Itron performed very well and carried out all functions and duties of the Program Manager outlined in the CSI RD&D Adopted Plan.**
    - **The proposal solicitation and selection phases were completed with no complaints from participants.** All project grantees interviewed who participated in the proposal solicitation and selection phases expressed high satisfaction with the process, expressing that instructions were easy to understand and communication about the applications was clear and timely.
    - **The Program Manager effectively managed the grant agreement and contracting phases.** All grantees expressed satisfaction with the contracting process, explaining that it was professionally managed. Grantees from nine projects did note challenges with contracting, but all issues were resolved satisfactorily.

- Oversight of project implementation was excellent with all grantees and relevant stakeholders expressing high satisfaction with the process.** Evidence suggests that Itron regularly monitored project progress and provided essential feedback and project coordination.
    - **The Program Manager went above and beyond the formal role.** Many grantees and stakeholders detailed valuable project assistance beyond what was required under the contract, which directly led to more successful projects.
- **Program data were well maintained and available with all but one project completing all the required documentation.**
- **The Program Manager and CPUC staff communicated well with other research entities and agencies to reduce duplication of efforts** according to respondents from other research agencies (the California Energy Commission, the US Department of Energy, National Renewable Energy Laboratory, etc.)
- **Projects demonstrated strong adherence to key principles of the CSI RD&D Program.** The Program design incorporated adherence to the Program principles as a component of proposal scoring and selection. The design was successful and the evaluation found that projects aligned with the Program principles**:**
    - Improve the economics of solar technologies by reducing technology costs and increasing system performance – there is strong evidence that the Program led to reduced costs of some solar technologies and balance of system costs, as well as developed innovations that will have a positive impact on technology and grid performance.
    - Focus on issues that directly benefit California, and that may not be funded by others – the Program selected projects designed to produce outputs with direct benefits to California including innovations specific to the California climate, and designed for the California grid. Outputs of these projects have demonstrated benefits to California and the broader solar community. The Program adds to the pool of research conducted in California that is likely to attract innovators and businesses to the State.
    - Fill knowledge gaps to enable successful, wide-scale deployment of solar distributed generation technologies – the Program projects targeted specific, important knowledge gaps in the areas of Grid Integration, Solar Technologies, and Innovative Business Models. Stakeholders and experts agreed that many successful projects helped fill these gaps.
    - Overcome significant barriers to technology adoption – projects successfully focused on technology improvement, development and improvement of regulations and standards, and streamlined product development to reduce costs, all of which have reduced or are likely to reduce barriers to technology adoption.
    - Take advantage of California's wealth of data from past, current, and future installations to fulfill the above – projects successfully leveraged and in some

cases improved on a vast range of existing information including data sources, academic research, and the outputs of previous research and development efforts.
  - Provide bridge funding to help promising solar technologies transition from a pre-commercial state to full commercial viability – several projects took promising solar technology from a pre-commercial state to close to or actual full commercial viability including products from Tesla, SolarCity, General Electric, and Cogenra.
  - Support efforts to address the integration of distributed solar power into the grid in order to maximize its value to California ratepayers – several projects were highly successful in producing outputs that improve and advance the integration of distributed solar resources into the California grid, which have led to or are likely to lead to a more robust grid, improved energy security, and improved rates and tariffs which will benefit California ratepayers.

10.2 Research Area Conclusions

Grid Integration

Grid Integration was the most successful research area, with the vast majority (18 of 19) of the projects meeting all the original objectives and having findings widely disseminated to their relevant audiences.

Key accomplishments and evaluation conclusions for these projects relative to logic metrics and original Program goals include the following:

- **Grid integration projects produced highly valuable outputs that have seen high rates of adoption with 33 unique outputs being adopted across 19 projects.**
- **Grid integration project outputs have or will improve economics and enhance integration of high penetration PV.** Some key successes included:
  - **Research projects demonstrating the viability of high penetration PV on the California grid.** Several studies indicate that native limits of grid feeders can exceed the 15 percent limit set under CA Rule 21 and with advanced inverter controls and appropriate mitigation strategies, there is potential for very high penetration of PV.
  - **Planning and modeling tools for high-penetration PV** including enhanced insolation data, improved PV system modeling methodologies and tools to improve visibility of distributed solar resources to grid operators and planners, and new screening methodologies to efficiently evaluate new interconnection requests.
  - **Testing and development of hardware and software for high-penetration PV** including development of software visualization tools, enhancement of utility

software tools to incorporate enhanced simulation and forecasting methodologies, and lab and field testing of advanced PV inverter technology.
    - **Demonstration of enhanced solar modeling tools** including field validation of PV simulation and forecasting model methods and software, and integration of PV fleet simulation methodologies into utility software tools.
    - **Permanent demonstration sites addressing integration of energy efficiency, demand response and energy storage, and demonstrating best practices and modeling impacts of ZNE homes.**
    - **Analysis and research to inform grid integration rules and standards as well as to develop industry standards and protocols for solar technology and hardware.**

Each of these accomplishments is a demonstration of a positive impact of the Program that relates directly to the short-term logic model outcomes. This signifies that the Grid Integration projects are on the correct pathway for helping achieve the Program's longer-term goals.

The Delphi panel reviewed information on the Grid Integration projects and came to similar conclusions. Of all project areas reviewed, the Delphi panel gave the Grid Integration project area the highest ratings, and it was also the research area where there was the most agreement, with each reviewer rating each category either a 3 or 4 on a 0-4 scale. On a 0-4 scale, the panelists agreed that the selected projects had a significant impact in addressing the CPUC research needs (average rating = 3.75). Similarly, the panel agreed that the Grid Integration projects were likely to create ratepayer benefits (3.63), provide economic value to the grid (3.75), expand market opportunities/decrease barriers (3.88), and gain regulatory and institutional acceptance (3.75).

Solar Technologies

The Solar Technologies project group had varied success, with most projects meeting all project objectives but some projects either not meeting stated objectives or investing in technology that proved not to be viable in the market at present.

Examples of the varying success of these projects include the following:

- **Two projects conducted research into highly successful new technology.**
    - A project between SolarCity and Tesla demonstrating new battery technology and control systems led directly to development of the Tesla PowerWall product, which was predicted to have in excess of 168 MWh in sales this year ($44 million in revenue). The relationship between Tesla and SolarCity that developed during the project was a factor leading to Tesla acquiring SolarCity in 2016.

- A project by Sunlink involving seismic testing and design automation of solar mounting units. This led to:
  - Sunlink developing new software to improve design and reduce costs of mounting products.
  - A new startup company that has created automated design software.
  - Industry-wide improvements in mounting tech and cost reductions through knowledge transfer and influencing building codes.
- **Three concentrated photovoltaic (CPV) projects were successful, but the technology is not economically viable at this point.** A stated focus of the Program for Solar Technologies was to assist development of concentrated solar technologies, which at the time of the program design was a technology with the potential to compete with silicon solar PV. Three projects focused on concentrated PV technology and had successful outcomes. However, falling silicon prices have reduced the competitiveness of CPV, and most CPV companies have gone out of business. All three technologies are not actively being produced at present.
- **The remaining projects were either not successful in achieving their objectives (1 project), the investigated technology is no longer being produced (1 project), or the projects met their objectives but their success is not determinable given the short amount of time since project completion (5 projects).**

Despite these issues, the Solar Technologies projects typically had positive benefits for the project partners, and potentially for the overall penetration of distributed solar. It is not clear if the project outputs were accessed or leveraged outside of project teams, however. The combined effect was a somewhat limited achievement of the metrics identified in the logic model for this project pathway.

The Delphi panel had slightly lower ratings for the Solar Technologies group, and there was less agreement across panelists with the rating scores. On the 0-4 point scale, there was general agreement that the selected projects appeared to address the CPUC research needs for the Solar Technologies area (average rating = 3.5). The ratings were somewhat lower when the panel was asked to rate the likelihood of creating ratepayer benefits (3.25), providing economic value to the grid (3.25), and expanding market opportunities/ decreasing barriers (3.38). The lowest rating was given when assessing the likelihood that the Solar Technologies projects would gain regulatory and institutional acceptance (2.88).

Innovative Business Models

Of all the project groups, the Innovative Business Models projects had the least success, both in terms of achieving the stated project goals as well as in demonstrating short-term progress on key outcomes identified in the logic model. There were also issues with project knowledge having limited penetration with targeted audiences and lower potential to develop into concrete models with clear market application.

Examples of both the successes and challenges for this group included:

- **Two highly successful technology projects also developed business models and strategies that have proved successful** and have helped support expansion of cost-competitive solar technologies by reducing costs or increasing value of the solar and storage technology to owners and utilities by:
  - Lowering solar system installation or operating and maintenance (O&M) costs.
  - Testing and demonstrating the economic value of storage systems and developing financing models for these systems.
- **Two projects developed comprehensive business models and economic valuation tools for deployment of nascent PV technologies with the potential to help lower solar system installation and O&M costs; however, the products have been discontinued.**
- **Two projects worked to develop and implement a collaborative procurement and revolving loan program.** These projects met the stated goals, and the fund continues to function beyond the projects; however, the overall reach of the fund was not as broad as project partners and stakeholders had hoped.
- **Multiple projects conducted studies and analysis that was either inconclusive or has not found traction in the broader market**. Projects conducted analysis to test virtual net metering approaches, tariffs that reflect the time dependent value of energy storage to system owners and/or utilities, and economic value associated with solar systems. In several cases, these tests were incomplete or inconclusive. In some cases, projects produced potentially valuable results; however, there is little evidence of this knowledge reaching intended audiences.

The results of the Delphi panel also reflected the varied success of the Innovative Business Models project group, with lower ratings and less consensus on the ratings for each issue covered. In the follow up discussion with the panelists, part of the disparity of ratings was due to the fact that the Innovative Business Models category covered the widest range of project types. Additionally, this was also the category that was least consistent with more traditional RD&D topic areas. Despite this, the panelists did give a relatively high rating on whether the funded Innovative Business Models projects addressed the research needs identified by the CPUC (average rating = 3.25). It was less clear to the Delphi panel that the Innovative Business Models projects were likely to produce ratepayer benefits (3.0), provide economic value to the grid (3.0), or expand market opportunities/decrease barriers (2.5). The Innovative Business Models group also received the lowest ratings for gaining regulatory and institutional acceptance (2.67). In general, panelists mentioned that the lower ratings were due in part to limited evidence that the Innovative Business Models had much application or acceptance beyond the original project team.

Knowledge Benefits

The CSI RD&D Program was very successful in creating knowledge benefits, which may be the most important metric of success when evaluating a research program. Improving the knowledge base by producing a range of knowledge benefit outcomes was also the dominant feature of the program logic model. The success of the CSI RD&D Program in creating numerous knowledge benefits is an essential step toward achieving the longer-term program goals.

Specific knowledge benefit achievements included the following:

- **Team composition was near-optimal for long-term knowledge benefits across the Program, highest among Grid Integration projects**. Teams leveraged rare skills, strong market position, and operational know-how; and included a mix of private sector firms and public research organizations. The benefits of strong team composition were strengthened by collaborative working relationships.
- **Collaborative team dynamics were the norm across projects, leading to many follow-on collaborations, with more than 40 enduring partnerships stemming from the Program**. Partnerships formed among team organizations, between team organizations and stakeholders, and between team members and market actors. Working dynamics and robust team composition set the stage for strong knowledge and absorptive capacity benefits; the high number follow-on RD&D and applied partnerships are early evidence that the benefits will follow.
- **Many follow-on applications of Program knowledge are already under way, many of which include direct support from grant awardees**. The presence of team members in follow-on use of Program knowledge accrues to the benefit of their partners and client networks. Follow-on projects include RD&D, client services, expansion of products and services, and use by outside partners. The high degree of evident follow-on uses of Program knowledge is in part due to the flexibility afforded to teams by the Program administrator, which worked with teams to revise research emphases as new information came to light. Teams felt this Program aspect was atypical for public RD&D programs, and helped match outputs with market needs.
- **Program design led to selection of teams committed to knowledge transfer. Most teams went beyond Program-required knowledge exchange activities, and many created knowledge spillover opportunities by releasing resources freely to the public and by developing demonstration sites**. Teams identified direct stakeholder engagement, non-Program webinars, and conference presentations as the most effective knowledge exchange methods. Many projects relied on non-required knowledge exchange opportunities to reach key audiences.

- **The Program administrator worked closely with teams to cultivate audiences for their outputs, but some struggled to make the right connections**. The time it took to produce Program-required webinars and reports was viewed to be incommensurate with effectiveness of knowledge transfer by some project teams. Thus, teams emphasized one-off and non-required knowledge exchange activities. Some teams noted that restrictions on how the Program could be used for knowledge exchange complicated pursuit of effective knowledge exchange activities.
- **Teams connected with knowledge recipients throughout the California market; however, many of the knowledge recipients for some projects did not align with the intended audiences the teams set out to reach**. Teams praised the Program administrator for facilitating stakeholder and market actor relationships, reducing the time spent for teams to reach key audiences. The mismatch between knowledge recipients and target audiences, however, appears to be due to the formalized Program knowledge exchange activities, which centralized a lot of Program outreach through the GoSolarCalifornia websites, the opt-in email list, and existing contacts of teams and the Program Manager. Teams may have better reached their intended audiences with a more exact and individualized approach for market actor and stakeholder engagement, and for knowledge exchange efforts.
- **California market actors were familiar both with the Program and with specific projects**. Market actors who were engaged in research and development, grid operation and management, and third-party electricity market services held the highest opinion of the value of Program outputs. Market actors are currently using Program outputs primarily to educate their clients, for their own research and development, and to improve products and services. Even market actors who do not see an immediate direct use for Program outputs in their own work viewed outputs as beneficial to the California market and ratepayers as a whole.

10.3 Performance Relative to Evaluation Goals

The CPUC established several overarching research goals for this evaluation, and our assessment of the Program performance relative to each of these goals is summarized below.

Size of grant obtained from CSI RD&D funds

The CSI RD&D Adopted Plan established guidelines for the recommended allocation of funding across three RD&D target areas. As shown in Table 26, the Program adhered to these recommendations, with actual funding amounts close to the original targets for each research area.[18]

Table 26: Funding by Research Area

Target Activity	Goal %	Actual Funding	Actual %
Grid Integration	**50-65%**	$17,947,659	51%
Solar Technologies	**10-25%**	$5,883,459	47%
Innovative Business Models	**10-20%**	$7,424,801	42%
Total		**$31,255,919**	**49%**

Leverage from other funding sources (use of match funds)

The CSI RD&D Adopted Plan identified cost sharing as an important factor in project selection and a key evaluation criterion in part because it encourages project discipline. The CSI RD&D Adopted Plan guided the Program to follow the principle that the closer a project is to commercialization, the higher its cost share requirement. In other words, cost share requirements for development projects would be low, around 10 percent, while projects reaching the demonstration and deployment phases would be required to provide a 50-75 percent cost share—a target that is fairly consistent with DOE and other funding agency requirements.

The amount of total funding and cost sharing is summarized in Table 27. Itron and the proposal selection teams were careful to consider cost sharing as a key component of project selection. Overall, across the three research areas, the Program saw approximately 50 percent cost-sharing in aggregate as shown in the table below. Cost sharing was lower for Innovative Business Models and Solar Technologies projects and higher for Grid Integration projects, which aligns with the principle outlined above. The lowest project cost share was 20 percent and the highest was 65 percent.

Table 27: Funding and Cost Share Summary

Target Activity	CSI Funding	Match Funding	Total Funding	Cost Share %
Grid Integration	$17,947,659	$19,045,785	$36,993,444	51%
Solar Technologies	$5,883,459	$5,274,662	$11,158,121	47%
Innovative Business Models	$7,424,801	$5,460,071	$12,884,872	42%

[18] In these calculations, we use the primary research area for each project. There were nine Cross-cutting projects that conducted activities across research areas. If funds are allocated evenly across research areas for these projects, the allocations are: Grid Integration = 53%; Solar Technologies = 23%; Innovative Business Models = 24%.

Total	**$31,255,919**	**$29,780,518**	**$61,036,437**	**49%**

Benefits for California ratepayers

An important overarching goal of the CSI Program is to provide benefits to California ratepayers, and in this area, the Program had a significant positive impact. All projects had the majority of their activities conducted in California (in most cases, all activities were conducted solely in California), and all projects involved at least one major project partner or sponsor based in California. Likewise, projects were selected that targeted issues or barriers that particularly affect California.

The project outputs activities are also on a path that is consistent with providing longer-term ratepayer benefits in the future, as identified through the program logic model. Important benefits that have accrued or are likely to accrue to California ratepayers include:

- **Increased penetration of solar generation resources included distributed solar PV leading to cleaner energy generation, avoided energy generation costs, increased grid resiliency, environmental benefits, and economic benefits:**
  - The CSI RD&D Program projects directly led to installation of approximately 5.2 MW of installed generation in California with 5 MW coming from projects funded through one project.
  - Several projects contributed to a significant level of installed solar generation and storage in California after completion of the project including:
    - Installation of Tesla/SolarCity storage and PV technology that led to installation of 350 units of combined PV and battery storage units in the year after the project. This technology then led directly into the PowerWall and PowerWall 2.0 products from Tesla that have been available for sale since the beginning of 2015, with Tesla expected to sell 168.5 megawatt-hours of energy storage systems to SolarCity in 2016, up from 25.8 megawatt-hours in 2015. This represents a revenue increase from $8 million to $44 million.
    - The Cogenra SunPack product was installed at approximately 20 sites after the project. Sunpower acquired Cogenra in 2015 and discontinued the SunPack product. Technology developed through SunPack development is used in SunPower products including their Performance line of products.
    - Other companies including SunPower and Sunlink have developed products from the CSI RD&D Program project that have seen high market adoption.
- **Improved electric grid reliability with higher penetrations of solar and other renewable resources**. Grid Integration projects were successful in developing important outputs such as improved solar data, forecasting models, simulation tools, and risk mitigation strategies that have or are likely to:

- Improve visibility of solar generation for system operators.
- Enhance the ability of system planners to optimize the value to the grid and ratepayers of new solar installations.
- Reduce the risk of negative impacts on the California electricity grid from high penetration levels of solar generation resources.
- Improve overall system reliability through reduced unintentional islanding, inverter trips, voltage variation, and other common issues that can arise from high penetration PV.

- **Helped utilities and grid operators understand the risks and benefits of high penetration PV.** This research has been beneficial to a number of utilities in California, helping to allay some of the concerns associated with this variability. It has also highlighted the conditions under which such variability has the potential to occur: in situations where PV is highly concentrated in one location (i.e., large, single PV facilities or highly concentrated PV on a distribution system). This will have planning benefits at both the transmission and distribution levels.
- **More efficient locating and installation of solar generation resources improving grid economics.** Examples of these improvements include:
    - Improved identification of optimal locations for high penetration levels of PV.
    - Simpler or more streamlined interconnection.
    - Reduction in the need for costly ad hoc load flow studies to determine whether the PV installation creates unacceptable circuit conditions, (2) increasing the value of PV installations by enabling ancillary services such as active power filtering and controlled reactive power support, and (3) improving circuit efficiency and equipment lifetime as a result of those services.
    - Decreased overall cost of solar generation which led to improvements in rates and tariffs.

The Delphi panel reviewers also agreed that the CSI RD&D projects had good potential for providing ratepayer benefits, although their assessment varied across project types. For Grid Integration, the Delphi panelists provided the highest rating of the likelihood of providing ratepayer benefits, rating this as 3.63 on average on the 0-4 scale. This was followed by Solar Technologies (3.25) and Innovative Business Models (3.0).

Economic value to the California grid

The CSI RD&D Program (particularly with the Grid Integration projects) was also successful in providing economic value to the California grid, and Program examples of this are closely tied to those listed above for providing benefits to California ratepayers (see list of above for more details).

Given that the short-term outputs observed so far are consistent with those identified in the logic model (in addition to the large amount of knowledge benefits observed), the Program appears to be on track for achieving the desired medium- and long-term outputs that will lead to increased economic benefit to the grid.

The Delphi panel confirmed this positive outlook for most of the project groups. Not surprisingly, the Grid Integration projects were rated the highest in terms of potential for providing economic value to the grid, with an average rating of 3.75 using the 0-4 scale. This was followed by Solar Technologies projects (3.25) and Innovative Business Models (3.0).

Whether and how the project expands photovoltaic (PV) market opportunities or reduces barriers

A closely related benefit to those described above is the expansion of PV market opportunities and reduction of market barriers. In general, those factors that provide ratepayer benefits or improvements to the grid are in some sense either expanding opportunities and/or reducing barriers. The examples of Program accomplishments listed above, therefore, are also relevant for this criterion. Examples discussed previously that relate specifically to reducing barriers include achievements in streamlining interconnection, improving balance of system and other soft costs, and reducing the upfront costs to solar technology. Additionally, the Grid Integration and Innovative Business Models project groups by definition are designed to expand market opportunities and reduce barriers, and the Grid Integration projects in particular were judged as successful in achieving their goals.

The Delphi panel also confirmed the positive effects of these projects in expanding PV markets and reducing barriers. When asked to rate the positive effects in these areas, the panelists rated the Grid Integration projects 3.88 on average, followed by Solar Technologies (3.38) and Innovative Business Models (2.5).

Institutional and regulatory acceptance of project findings or outcomes

It is still too early to determine the overall effect the CSI RD&D projects will have in terms of institutional and regulatory acceptance, but the early indicators are encouraging. Some important examples of accomplishments already achieved in this area include the following:

- **Improvements to CA Rule 21.** Many of these improvements were derived from CSI RD&D project research, including specific improvements related to PV interconnection limits, project screening, and costs and processes for energy storage systems. In part due to these project outputs, CA Rule 21 was updated in 2016 to include considerations of smart inverters and storage, and included fast tracking of new solar projects meeting specific requirements. These changes helped streamline the review process for interconnection and storage projects, and played a direct role in the improvements to the existing CA Rule 21.

- **Revision and development of new standards for solar inverters and interconnection.** Specific projects have resulted in revisions or information for multiple standards, and testing certifications. These standards are described in the Grid Integration section and include changes to UL1741 SA, IEEE 1547a, IEEE 1547, IEC 61850-7-420 & 520, and IEC 62108.

Furthermore, the significant amount of knowledge benefits—particularly with the amount of follow-on research, new partnerships and publications—are all early indicators of progress that may eventually translate into formal acceptance by institutions and regulatory bodies.

The Delphi panel also believed that at least the Grid Integration projects had the potential for achieving this acceptance, with an average rating of 3.75 on the 0-4 point scale. The Solar Technologies and Innovative Business Models projects were viewed to have less potential in this area (with average ratings of 2.88 and 2.67, respectively), which is not surprising as these projects tended to be more focused on commercialization and management and less oriented toward the regulatory side.

Clean jobs created through CSI RD&D funding

There was limited evidence that the CSI RD&D projects led directly to an increase in clean jobs. This lack of evidence was due in large part to the fact that the evaluation occurred just as these projects were ending, so there was no immediate evidence one way or the other that the Program was having an incremental effect on creating new jobs (a longer-term effect). Given the research focus, any significant new job creation would be expected to occur further in the future once the research results have been more fully integrated and commercialized within the solar industry.

Timing issues not withstanding, there are indications that the CSI RD&D projects have the potential for creating clean jobs in the future. As discussed above, the Program is achieving related positive impacts in terms of providing benefits to California ratepayers and economic value to the grid, which in turn can be expected to eventually result in an increase in jobs. Some of the grantees also reported follow on research and increases in production since the original project that will presumably have positive employment impacts, or at least help sustain current employment levels.

10.4 Recommendations

While the CSI RD&D Program was generally successful in achieving its goals, the results of the evaluation did yield some recommendations for future programs.

- **Sustained program documentation.** Some stakeholders and grantees indicated concern that the Program results have not been disseminated broadly enough and are concerned that the CSI website may not continue to be maintained in the future. The present plan is for the CSI website to remain functional in its current form until December of 2019. We recommend that when the current website is deactivated, the current website contents (including final reports and project documentation) be moved to another established website such as www.calmac.org so that access to the research results can continue.
- **Dissemination of Program results.** There is evidence that some CSI RD&D research has not reached the intended audiences. Two audiences in particular proved challenging: solar hardware and installation firms, and commercial organizations (e.g., builders, retail). To address this, some form of promotion or dissemination of program knowledge in aggregate should be considered—for example, engaging grantees or stakeholders with project knowledge to make presentations at conferences or to key working groups, or write articles in industry publications that summarize key research results and direct readers to the Program website.
- **Program management.** The Program Manager Itron was very successful because it had sound technical knowledge and key industry contacts that allowed it to provide meaningful assistance and make critical networking connections that enhanced program success. Future RD&D programs should have similarly qualified program managers who can provide these types of benefits.
- **Reporting.** We received consistent feedback from the grantees that the reporting requirements were too demanding and difficult to coordinate. To address these concerns, future programs should consider modifying the reporting requirements to be more flexible. Other suggestions from the grantees included providing a report template early in the process, encouraging more stakeholder involvement, and making some draft reports public to elicit more feedback.
- **Best Practices manual.** There are several aspects of the program design that were critical to the success of the Program including careful consideration of project team composition, knowledge dissemination requirements, built-in networking channels and events such as webinars and forums. If there are future RD&D efforts being considered by the CPUC or other agencies, consider working with Itron and CPUC staff to develop a best practices manual that captures the successful elements of program design and management based on the CSI RD&D Program experience.

California Solar Initiative RD&D Program

Process Evaluation

Final Report - Appendices

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360 Innovation LLC

Dr. Varun Rai

May 11, 2017

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Appendix A: Data Collection Plan

Introduction

The overall objective of the Evergreen evaluation team's process evaluation research is to assess the success of the CSI RD&D Program (the CSI RD&D Program); this data collection plan builds upon the evaluation framework submitted earlier in our CSI RD&D Process Evaluation Research Plan (May 27, 2016).

From the evaluation plan (and summarized below in Table 1), the evaluation team utilized a variety of data collection and analysis activities to measure the effects of the program.

Table 1: Data Collection Activities

Data Collection Activity	Description	# Interviews / Surveys (if applicable)
Itron & Grantee interviews	In-depth interviews with the Itron, grantees and sub-grantees	50-70
Technology expert interviews	LBNL, NREL, CEC, DOE SunShot Program	5-10
Stakeholder interviews	Investor-owned and publicly-owned utility solar program managers, CalSEIA, Four Energy Solar, IEPA, Solar Alliance, SEPA	5-10
Market actor interviews/survey	Market actors potentially affected by the RD&D efforts such as installers, manufacturers, balance of system companies, builders, contractors, grid planners and operations staff, and utility program managers	20-80
Program Documentation Analysis	In-depth review and analysis of program documents, including proposals, progress reports, final reports and other key documents	
Data assembly (knowledge, economic, market, and other data)	Bibliometric and patent research to assess reach of CSI RD&D. Longitudinal data on production costs, labor and material requirements, product characteristics including reliability metrics Secondary sources and data such as energy related law and policy, trade journals, energy consumption and solar generation statistics, solar market and employment data (e.g. price, volume, revenue, investment capital, market entrants/exits, employment statistics)	
Delphi Panel	To fine tune estimates of effects	

Table 2 summarizes the types of projects funded through the CSI RD&D Program, which will be the primary focus for our data collection activities. Currently, there are 35 projects approved for Program funding. Based on our most recent discussions with Itron, the Program Manager, approximately one-third of these projects are still underway and some have only recently been completed.

Table 2: Target Research and Focus Areas

Projects Funded*	Resolution				
	E-4317	E-4354	E-4470	E-4646	E-4629
Grid Integration					
Planning and modeling for high-penetration PV	4				
Testing and development of hardware and software for enabling high penetration PV	3				
Addressing the near-term integration of energy efficiency, demand response, and energy storage with PV	2				
Overcoming existing barriers to integrating high-penetration PV into the electricity grid, and accelerating the integration and interconnection of high-penetration PV into the grid			5	6	5
Solar Technologies					
Testing and demonstration of new solar technologies with improved performance/reliability or lower costs		7			
Improving the economics of solar technologies and increasing system performance, and addressing key market barriers.			1		
Innovative Business Models					
Testing and demonstration of innovative business models that help support expansion of cost-competitive solar technologies by reducing costs or increasing value of the solar system to owners or utilities		9			
Improving the economics of solar technologies and increasing system performance, addressing key market barriers			1		
Overcoming existing barriers to integrating high-penetration PV into the electricity grid and accelerating the integration and interconnection of high-penetration PV into the grid					2

* Some projects represented more than one resolution focus area.

The remainder of this document presents our Data Collection Plan that expands on these data collection activities and shows how they are linked to key metrics of program performance. The first section presents the program logic model developed by the evaluation team, which shows the program activities and expected outcomes. This one-page model serves as a guide for describing the underlying program theory and for developing researchable questions and metrics. The second section summarizes the data collection activities and maps these activities to specific elements of the logic model. This mapping of data collection and metrics will serve as the guide for developing interview guides and other survey instruments for each targeted group. Because the network analysis associated with knowledge benefits is a critical part of the evaluation, additional discussion is provided on that component. The final section provides our estimated timeline for completion of the data collection activities.

Appendix B provides additional tables that reorganize the data collection activities. These tables are arranged by data collection activity (rather than logic model element), and show which metrics are addressed by each data collection method.

CSI RD&D Program Logic

Earlier this year, the evaluation team reviewed program documents and held discussions with Itron program staff to develop a unique program logic model. The objective of this CSI RD&D logic model is to guide the evaluation of program impacts. At a high level, this logic model describes the expected outcomes of the program and the pathways through which these have and will be achieved. The evaluation team used the logic model as a guide to define specific metrics to be measured along the path from inputs to activities and then outputs and outcomes.

The ultimate goal of the CSI RD&D Program is to facilitate acceleration and expansion of grid connected solar energy resources while also providing value to California ratepayers. The program accomplishes this by increasing the visibility and reliability of solar output; improving grid management and interconnection tools, and developing innovative supporting technologies and processes.

The original CPUC Decision 07-09-042 that has guided the CSI RD&D Program lists the following seven overarching principles leading to this goal.

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

The logic model uses the goals and principles of the program as ultimate outcomes and shows ***pathways to these outcomes*** in four areas (projects typically address more than one):

- **Additions to the *Knowledge Base***, which is common to all of the RD&D projects and underlies the specific accomplishments of the other three pathways. The *Knowledge Base* is both written/digital and held in people's heads. It is expressed in their professional relationships, their skills and perceptions. Related activities include building a technical body of knowledge, as well as improving R&D methodologies, networks and methods to disseminate, transfer and exchange knowledge, and the skills to effectively leverage past R&D experiences, the particular skillsets of R&D organizations and personnel, and concurrent R&D funding and research projects.

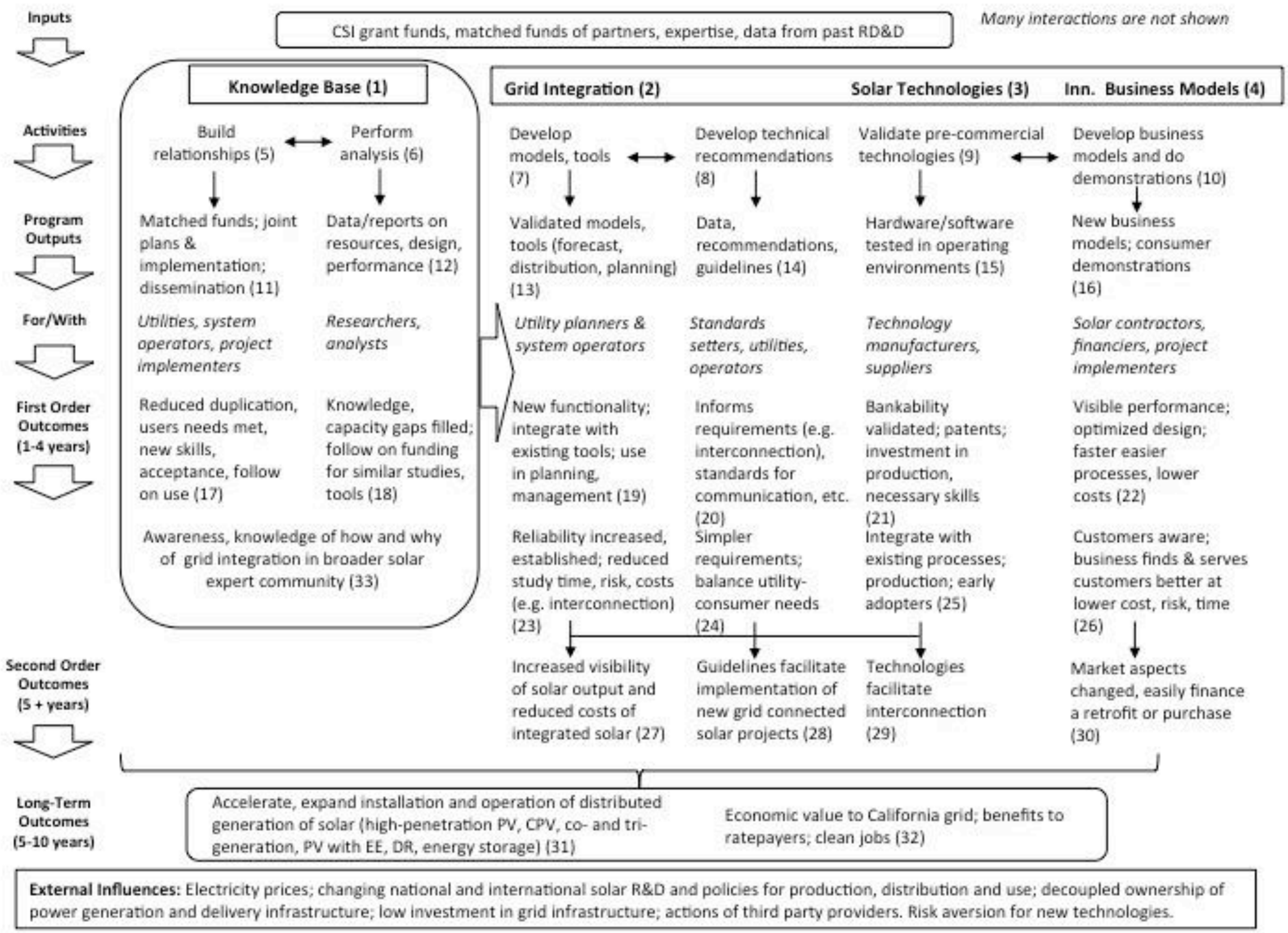
- **Facilitation of *Grid Integration* through Models, Tools and the Development of Governing Standards.** The *Grid Integration* efforts include technical advances in modeling and tools (mostly for use in planning and management of solar T&D); technical support and data useful in developing standards and guidelines for the deployment and management of solar resources. These activities contribute to improved usability, reliability and cost-effectiveness of solar output. They provide greater flexibility and functionality in grid integration, creating greater ease for utilities, system operators and others to implement new solar projects and manage high-penetration levels of solar and other renewable resources.
- **Acceleration of New *Solar Technologies***. The *Solar Technologies* activities focused on validating pre-commercial hardware and software designed to improve or enhance the performance, reliability and/or cost-effectiveness of solar systems and components.
- **Developing *Innovative Business Models***. The *Innovative Business Models* development effort is a smaller part of the RD&D scope in terms of budget, but combines two areas of emphasis: the development of new models for how solar business can be successfully accomplished, and the demonstration of new technologies or processes that enhance customer acceptance/demand, and also exhibit economic benefits and potential for investors and solar companies. These can lower balance of system costs and convince market actors of the feasibility of adopting solar technology.

Error! Reference source not found. on the following page presents the program logic model. Numeric labels in the figure provide a key to map the logic model components to metrics and data collection activities provided later in the following section. The development of this particular categorical structure of program activities and pathways is driven primarily by the nature of the differences in the expected outcomes for each. These in turn will each require different metrics and measurement techniques.

For each of the core program activity areas (labeled as logic model elements #1-4), there are a series of program *Activities* that results in direct program *Outputs*. From these outputs, the program logic prescribes a series of *Outcomes* that are assumed to occur if the program is functioning properly. These *Outcomes* are defined by expected time frame, either short-term *First Order Outcomes* (1-4 years), mid-term *Second Order Outcomes* (5+ years), or *Long-term Outcomes* (5-10 years). Given the timing of this evaluation, must of the evaluation measurement will focus on the *First Order Outcomes*, as not enough time has elapsed to expect much progress for the longer term effects.

The *"For/With"* row in the logic model is there to clarify who partners are and who are the direct users of the outputs, as these are the groups that will either help create or benefit from the desired outcomes. Finally, *External Influences* refers to contextual factors that shape the circumstances and landscape within which the program operates and the primary factors that can speed or hinder the appearance of the desired outcomes. The evaluation research will determine whether or not the outcomes projected in the logic model have occurred, and will investigate both program and other plausible explanations for those observed outcomes.

Figure 1: California Solar Initiative RD&D Logic Model



Data Collection Plan

This section summarizes the data collection plan derived from the logic model and expected outcomes discussed in the previous section. The data collection plan is structured in accordance with the four primary activity areas shown in the logic model: *Knowledge Base*, *Grid Integration*, *Solar Technologies*, and *Innovative Business Models*. Each activity area has a unique set of expected outputs and outcomes, as depicted in the logic model.

The format for each of the data collection tables is the same. For each program activity, each related program output and outcome is included in the table along with the corresponding number from the logic model diagram in **Error! Reference source not found.**. For each output and outcome, specific metrics are provided that—when measured—can provide an indication of whether the underlying program logic is succeeding in practice. Each metric is then linked to specific data collection and analysis activities. In this way, all metrics are covered by data collection activities, and all data collection and analysis activities are explicitly linked to underlying elements of the program logic model.

All of the data collection activities will rely on the following methods:

- ***Grantee Data (D)*** includes all project-related data that is tracked for each grantee. This includes items such as project descriptions, project budgets, original proposals, performance data, reports/publications and progress reports.
- ***In-depth Interviews with Grantees (IDI-G)*** refers to in-depth interviews with grantee project managers to obtain additional information about the projects that is not included in the project data (e.g., what worked, what did not, perceptions of the funding process, recommendations for improvement).
- ***In-depth Interviews with Industry Experts and Stakeholders (IDI-E)*** will collect information on how well information from the grantee projects is affecting the broader solar community.
- ***In-depth Interviews with Market Actors (IDI-MA)*** will also collect information on how well information from the grantee projects is affecting the broader solar community (in addition to the interviews with industry experts and stakeholders).
- ***Survey of Market Actors (Su-MA)*** is an additional online survey that will be fielded to market actors to collect more standardized information (e.g., data that are more numeric that are less in need of a less structured in-depth interview).
- ***External Data/Literature (S)*** includes secondary data and literature that reflects knowledge dissemination of the Program-supported research.

In all the tables that follow, these data sources are assigned to each logic model metric.

Knowledge Base (Logic Model #1)

We refer to the outputs and outcomes of the *Knowledge Base* activities collectively as the knowledge benefits. This component of the data collection plan is focused on investigating the current and potential reach of knowledge benefits emanating from the Program.

Based on the objectives of the evaluations and the program logic model, the following tables summarize *Knowledge Base* activities, outputs, and metrics that the knowledge diffusion research will investigate. Each metric group is then mapped to one or more data collection activities with primary data collection efforts. Although there is overlap with other evaluation topics for this project, the focus of the network analysis is on knowledge benefits; additional discussion of the network analysis is included following the tables.

Table 3 provides the first example of the mapping process that links program logic model elements to metrics and data collection activities. The table presents outputs from the "Build Relationships" activity from the logic model and is labeled in the diagram as component #5. For this activity, three outputs are identified: matched funds, joint plans and implementation, and dissemination. All three of these activities are included as logic model component #11. For each of the metrics, multiple data sources are included and are color coded as either a main information source or supporting source. Similar tables are included for all other logic model elements.

Table 3: Outputs for Build Relationships (Logic Model Activity #5)

Outputs	Metrics	Data Source
Matched funds (#11)	Dollars/budgets provided by grantee partners	D, IDI-G
Joint Plans & Implementation (#11)	# of new and existing partnerships	D, IDI-G
	Unique skills/experience of partners	IDI-G, IDI-E, D
	# of additional grant applications, teaming	IDI-G, IDI-E
Dissemination (#11)	Use of existing/past research	IDI-G, S, D
	# of workshops, webinars, memos, presentations, publications	D, IDI-G, IDI-E, IDI-MA
	Direct outreach activities by team to other solar entities (number and description)	IDI-G, IDI-E, IDI-MA, D

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 4: First Order Outcomes (1-4 Years) for Build Relationships (Logic Model Activity #5)

Outcomes	Metrics	Data Source
Reduced Duplication (#17)	Perception of industry experts on unnecessarily duplicative projects	IDI-E, IDI-G
Users needs met (#17)	Perception of industry experts, stakeholders, and market actors that projects address users' needs and knowledge gaps, and were relevant.	IDI-E, IDI-MA, Su-MA
New skills developed & accepted (#17)	Awareness of CSI RD&D findings	IDI-E, IDI-MA, Su-MA, S
	Citations of research results in publications	S, IDI-E, D
	Patent applications filed/received	S, IDI-G
	Other intellectual property created (copyright, license, etc.), granted based on funded projects	IDI-G
	Involvement of utility partners (funding, management involvement)	IDI-G, IDI-E
Follow on use (#17)	New project funding	IDI-E, IDI-MA
	Adoption by industry experts, market actors	IDI-E, IDI-MA
	Adoption into industry protocols/guidelines	IDI-E, IDI-MA, S

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 5: Outputs for Perform Analysis (Logic Model Activity #6)

Outputs	Metrics	Data Source
Data/reports on resources, design, performance (#12)	Number of researchers involved in projects	D, IDI-G
	Project database(s)/documentation	D, IDI-G
	Technical reports/memos	D, IDI-G
	Publications, papers, articles	D, S, IDI-G
	Meetings with researchers and stakeholders to discuss research	IDI-G, IDI-S
	Results presentations and size/composition of audience	D, IDI-G
	Website postings, website hits and downloads	D, IDI-G
	Webinars/workshops/meetings/events	D, IDI-G
	Demonstration projects and reports	D, S, IDI-G

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 6: First Order Outcomes (1-4 Years) for Perform Analysis (Logic Model Activity #6)

Outcomes	Metrics	Data Source
Knowledge/capacity gaps filled (#18)	Perception of industry experts, stakeholders, and market actors that projects address knowledge/capacity gaps, are relevant	**IDI-E, IDI-MA, Su-MA**
	Documentation of knowledge growth (new findings)	**IDI-E, IDI-MA**
	Integration of knowledge sets/perspectives	**IDI-E, IDI-MA**
Follow on funding for similar studies/tools (#18)	Funding opportunities (# and $ amounts)	**IDI-E, IDI-MA, IDI-G, D, S**
	Funding awarded (# and $ amounts)	**IDI-E, IDI-MA, IDI-G, S**

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 7: Combined First Order Outcomes (1-4 Years) for Build Relationships (Logic Model Activity #5) and Perform Analysis (Logic Model Activity #6)

Outcomes	Metrics	Data Source
Awareness/knowledge of how and why of grid integration in broader solar expert community	Awareness and perception of those exposed to results of program	**IDI-E, IDI-MA, Su-MA**

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Knowledge Benefits and Network Analysis

The knowledge benefits component of the data collection plan will investigate the current and potential reach of knowledge benefits emanating from the Program. Although grid impacts and economic benefits are an indirect consequence of the Program's knowledge outputs, the knowledge benefits portion of the larger study aims to answer these major evaluation questions:

Has the Program filled important knowledge gaps, and how was this knowledge and know-how useful to stakeholders?

- Understand the ideas (novel and ordinary) and know-how generated by the Program.
- Assess knowledge diffusion beyond the project teams; including awareness of ideas and know-how, acceptance and follow-on knowledge production.

Were the requirements for collaboration (project partners who matched funding) and dissemination of results effective in stimulating diffusion of the knowledge produced?

- Understand the efficacy of knowledge transfer efforts.
- Assess the current reach of knowledge transfer and exchange.

How might knowledge production, exchange and diffusion be improved?

- Understand the various processes of knowledge origination across the Program, including team dynamics and absorptive capacity, project and partners' goals and objectives, and formal and informal knowledge exchange activity.

Knowledge Benefit Researchable Questions and Metrics

Based on the objectives of the evaluations and the program logic, Table 8 expands on the metrics presented in the previous tables and summarizes knowledge benefit activity, output and impact questions and sub questions that the knowledge diffusion research will investigate. Although there is overlap with other evaluation topics, the focus of the network analysis is on knowledge benefits.

Table 8: Knowledge Benefits Target Research and Focus Areas

<table>
<tr><th>Principal Question</th><th>Sub Questions</th><th>Metrics</th></tr>
<tr><td rowspan="3">What knowledge exchange activities (formal and informal) took place?</td><td>What formal knowledge exchange activities did each project produce? (interactions with partners, patent applications, webinars, reports, articles, conference presentations, press releases, workshops, etc.)</td><td rowspan="3">• Count of formal knowledge exchange activities (e.g., patent applications, webinars, reports, etc.)
• Extent of informal knowledge exchange activities (this can be measured in survey of project teams)</td></tr>
<tr><td>What informal knowledge transfer activities to people outside of project team occurred? (e.g., overlap with other business unit, seeking outside input, seeking partners who can fill gaps, etc.)</td></tr>
<tr><td>How did outreach efforts vary at different stages of the project?</td></tr>
<tr><td rowspan="6">What knowledge exchange activities most effectively transferred awareness or knowledge?</td><td>How did activities vary in the extent to which they spurred interest from outside actors?</td><td rowspan="6">• Perceived value of knowledge produced, of knowledge exchange activities
• Intention of using the knowledge
• Names of key stakeholders (individuals or organizations), their roles, how/if they were utilized
• Views/downloads from website
• Number of inquiries received about project output
• Consultations by teams with stakeholders
• Number of citations in industry publications</td></tr>
<tr><td>How did activities vary in the extent they were effective in transferring
the knowledge/awareness to outside actors?</td></tr>
<tr><td>Who are the influential individuals and organizations to disseminate the knowledge/awareness? Did the project work with those individuals and organizations?</td></tr>
<tr><td>Did the market applicability of projects improve or hinder interest from stakeholders?</td></tr>
<tr><td>Did the nature of projects affect the fit of some knowledge/utility transfer activities and their effectiveness?</td></tr>
<tr><td>What stakeholders and audiences did the projects have in mind?</td></tr>
<tr><td rowspan="5">What relationships did projects build between/within the solar, utility, and research sectors?</td><td>Who were the project partners?</td><td rowspan="5">• Names of project partners and organizations
• Project partners' roles in organizations
• Business units of team organizations/firms participating in projects
• Unique skills/expertise of project teams</td></tr>
<tr><td>What relationships were built with non-project partners?</td></tr>
<tr><td>How did project teams vary in terms of the reach and influence of/on partners?</td></tr>
<tr><td>What was the working dynamic between partners? (Close collaboration, independent contributions; is there a shared site or virtual)</td></tr>
<tr><td>Do partnerships continue after project ends?</td></tr>
</table>

Principal Question	Sub Questions	Metrics
	Have partners joined other efforts due in part to their CSI experience?	• Presence of demonstration project • Availability of tools developed • Project online presence • Co-organized workshops and other knowledge exchange events • Program level coordination • Joint efforts planned
	Did projects have ongoing physical or otherwise public presence, such as community sites?	
What knowledge was produced?	How did projects enhance the knowledge capacity among the project team and stakeholders? (Utility/ISO staff, public researchers, advocates, heads of business units, program managers, downstream firms, upstream firms, financing entities)	• Knowledge gaps identified • Knowledge gaps filled • Follow-on knowledge produced (by project and non-project actors) • New insights and conclusions • New market solutions available • New research or partnering skills taking root or expected to • Resources from existing/current research engaged for continuing or new related work
	What new knowledge did the projects produce?	
	Have the project teams changed their near- or long-term strategy, or market interests, as a result of knowledge gained from the projects? Have non-project teams?	
	To what areas of the solar, utility, and research sectors does the new knowledge apply?	
	To what extent did projects enhance the knowledge capacity among the solar, utility, and research sectors?	

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Knowledge Benefits Network Analysis Approach

This evaluation will complete the assessment of knowledge benefits using a network analysis approach. The research design borrows from knowledge spillover and diffusion research, integrates approaches for looking progressively at increasing "social distances" from the Program, and investigates the program impacts in terms of follow-on knowledge production.

The network analysis is composed of three unique research levels, reflecting our consideration of distance from the Program. At each level, we investigate the knowledge benefits questions (Table 8) to the extent applicable, and include a cluster of analytical objectives meant to facilitate a systematic and reasoned response to the study objectives. Each level produces unique and complementary insights while also producing insights that, when taken together with those from the other levels, complete the network-based understanding of knowledge diffusion and knowledge benefit impacts. The three levels are:

1. Immediate – Project teams and their outputs
2. Intermediate – Short-term and mid-term outcomes of projects
3. Distant – Effects on non-project actors

Knowledge Production and Absorption – Immediate

In this step, we will document the relational dynamics of project teams and intentional and unintentional knowledge dissemination and exchange activities, and characterize core project activities according to their impacts on knowledge absorption (by the teams) and incidental knowledge exchange (to actors outside the teams). We will also investigate and characterize the knowledge gaps that projects sought to address, and seek to understand the knowledge recipients (the audience) that project teams imagined would benefit from filling the gaps.

Analytical Objectives:

- Understand and characterize the diversity of transferrable knowledge created across projects, and the need for such knowledge in the solar, utility and research sectors;
- Discover and characterize any deepening absorptive capacity of project team members and organizations; and
- Understand and characterize the efficacy and potential reach of intentional knowledge exchange activities, and the potential reach and impact of unintentional knowledge transfer.

Knowledge Production, Awareness and Absorption – Intermediate

During this step, we will focus on investigating knowledge exchange with stakeholders and other non-Program actors. The 35 completed or in-progress projects produced knowledge of varying degrees of usefulness and complexity, and breadth of applicability. Some projects have been more successful than others in raising awareness or use among their target audiences. This is not, however, necessarily indicative of the relative success of projects in producing impactful knowledge, because factors such as complexity, immediacy, and applicability likely affect the rate at which knowledge is absorbed and lead to follow-on production of knowledge.

We will identify several projects from at least two funding areas and gauge the extent to which they have stirred the interests of stakeholders or key audiences during and after the project period. We will investigate the absorption of knowledge by these audiences, perceptions of value, intent to apply received knowledge and intent to invest in follow-on knowledge production.

Analytical Objectives:

- Characterize the efficacy of various exchange channels; identify the extent of current follow-on knowledge production and the likely extent of forthcoming knowledge production.
- Assess how successfully projects filled the knowledge gaps they intended to address.
- Assess the impact trajectory of knowledge benefits from the case projects and the extent to which it is reasonable to assume other Program projects will achieve similar results.

Knowledge Reach and Impact – Distant

In this step, we will investigate the reach of knowledge exchange that is observable in non-project segments of the solar, utility and research sectors. We will develop numerous unique search routines drawn from project outputs, including terms of art, project report titles, key findings and other indicators. We will conduct a database search (U.S. patent office, Web of Science, Google Scholar), and identify and characterize the evident knowledge recipients. To the best of our ability, we will use these insights to backwards-map impacts to Program focus areas and projects.

Analytical Objectives:

- Characterize the reach of measurable knowledge transfer to non-project actors.
- Assess the implications for Program knowledge benefit impacts.

Typologies and Assumptions / Data Collection

Many of the metrics will reveal granular insights for characterizing key aspects of the Program. We will formalize these insights by developing typologies for the following aspects:

- Knowledge exchange activities including efficacy, reach and function.
- Knowledge recipients including role in market, influence and potential to utilize or produce follow-on knowledge.
- Knowledge types including complexity, novelty.

After characterizing these aspects of the Program, we will develop assumptions to improve our ability to perform analysis to answer the primary research questions.

Grid Integration (Logic Model #2)

The Grid Integration component of the logic model is concerned with the present and future impact of projects focused on developing modeling, data and other tools to improve and accelerate grid integration of distributed solar. The focus of this section is on measuring the direct impacts of these program activities on grid integration. Of particular interest is how projects that developed modeling and data tools and technical support for standards and guidelines for use in integration of distributed solar generation contribute to increased visibility of solar output to grid planners, reduced cost of grid integration, reduced time in bringing new solar generation online, and improvement in the ability of utilities and system operators to bring new solar projects online.

Table 9: Outputs from Develop Models and Tools (Logic Model Activity #7)

Outputs	Metrics	Data Source
Validated models, tools (forecast, distribution, planning) (#13)	# of models and tools designed, tested and validated in operating environment	D, IDI-G
	Unique needs met by models and tools	D, IDI-G, IDI-MA
	# of tools that perform better than existing tools or that fill gap.	IDI-G, IDI-E, D
	Estimated costs of model or tool implementation	IDI-G, IDI-E, D
	# of unique stakeholders using tool	IDI-G, D

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 10: Outputs from Develop Technical Recommendations (Logic Model Activity #8)

Outputs	Metrics	Data Source
Data, recommendations, guidelines (#14)	# of databases, technical recommendations and guidelines, by field	D, IDI-G
	# stakeholders involved in development	D, IDI-G, IDI-MA
	Unique needs met	D, IDI-G, IDI-MA
	# of dissemination activities, workshops, webinars, websites	D, IDI-G
	# of unique individuals or organizations reached and description of audience reached	IDI-G, D

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 11: First Order Outcomes for Develop Models and Tools (Logic Model Activity #7)

Outcomes	Metrics	Data Source
New functionality (#19)	# of models, tools with documented performance characteristics in operating environment	IDI-G, D
	# of models, tools that provide new functionality or improvement over status quo	IDI-G, D, IDI-MA
	Details of new or improved performance (improved estimate precision, more accurate forecasting, etc.)	IDI-G, IDI-E, D
	Estimated costs of model or tool implementation	IDI-G, IDI-E, D
Integrate with existing tools (#19)	# of models, tools officially implemented (or planned) in operating environment.	IDI-G, IDI-MA, D
	# of models, tools officially implemented (or planned) in regulatory procedures, standards, policy	IDI-G, IDI-MA, D
Use in planning and management (#19)	# of models, tools officially implemented (or planned) in planning and grid management.	IDI-G, IDI-MA, D
Reliability increased, established (#23)	Improvement (actual or estimated) in system reliability brought by new models, tools (reduced unintentional islanding, etc.)	IDI-G, IDI-E, D
Reduced study time, risk, costs (e.g. interconnection) (#23)	Improvement (actual or estimated) brought by new models, tools in saved time, lower cost, reduced risk	IDI-G, IDI-E, D

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 12: First Order Outcomes for Develop Technical Recommendations (Logic Model Activity #8)

Outcomes	Metrics	Data Source
Informs Requirements and Standards for Communication (e.g. interconnection) (#20)	# mandatory and voluntary implementations of recommendations (names of standards, rules)	IDI-G, D
	# of unique entities that invest in skills to implement recommendations (actual and predicted)	IDI-G, D, IDI-MA
	Dollars spent on training (actual and predicted)	IDI-G, IDI-E, D
	Standards and/or rules influenced (actual and predicted) (number and description)	IDI-G, IDI-E, D
	Impact of recommendations (geographic influence, economic influence, improved rates, lowered transaction costs, changes to interconnection standards)	IDI-G, IDI-MA, IDI-E, D
	Impact of recommendations on inverter system communication protocols	IDI-G, IDI-MA, D
Simpler requirements; balance utility-consumer needs (#24)	Evidence of simpler/streamlined interconnection requirements	IDI-MA, IDI-E, IDI-G, D, S
	Estimated or actual improvements to rates and tariffs	IDI-MA, IDI-E, IDI-G, D, S
	Lower transaction costs for implementing solar projects	IDI-MA, IDI-E, IDI-G, D, S

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 13: Second Order Outcomes for Develop Models, Tools (Logic Model Activity #7)

Outcomes	Metrics	Data Source
Increased visibility of solar output (#27)	Estimates of system improvements allowing greater visibility of solar generation: increased temporal resolution of data, improved predictive ability and economic analytics	IDI-E, IDI-MA, IDI-G, D, S
	Estimates of improvements in estimated value of new projects, interconnection time, project approval and interoperability	IDI-E, IDI-MA, IDI-G, D, S
	# of stakeholders estimated to be impacted by new and improved models, tools	IDI-E, IDI-MA, IDI-G, D, S
	Estimated increased penetration and proportion of load of solar generation attributable to models, tools	IDI-E, IDI-MA, IDI-G, D, S
Reduced costs of integrated solar (#27)	Estimated cost reductions related to models, tools	IDI-E, IDI-MA, IDI-G, D, S
	Improved efficiencies in system resulting in lower costs of integrated solar	IDI-E, IDI-MA, IDI-G, D, S

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 14: Second Order Outcomes for Develop Technical Recommendations (Logic Model Activity #8)

Outcomes	Metrics	Data Source
Guidelines facilitate implementation of new grid connected solar projects (#28)	Perceptions on whether standards and rules will be simplified by recommendations resulting in lower cost, greater penetration of grid connected solar	IDI-E, IDI-MA, IDI-G, D, S
	Perceptions on whether recommendations can contribute to improved technical guidelines resulting in lower cost, greater penetration of grid connected solar	IDI-E, IDI-MA, IDI-G, D, S
	Perceptions on whether recommendations encourage streamlined approval processes that reduce time and cost of new projects	IDI-E, IDI-MA, IDI-G, D, S

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Solar Technologies (Logic Model #3)

The Solar Technologies section will investigate the current and long-term impact of projects focused on testing and demonstration of pre-commercial solar technologies. Technology development projects were funded where there was an expectation of the potential for improved performance and reliability, and/or lower costs. Of particular interest is how these projects developed supporting technologies that continue to improve and accelerate the ability to effectively manage an electric grid with high-penetration of renewables. Expected outcomes include a reduced cost of solar energy, greater reliability and usability of solar technologies, and reduced cost and greater ease of grid integration. Some examples of these technologies include energy storage technology, distributed concentrating PV systems, building integrated PV products, improved performance of PV inverters and integration with smart meters.

There are eight funded projects that fall into this category. Seven of these were approved in the Solicitation round 2 (Resolution E-4354) in August of 2010. One project was funded in the Solicitation round 3 (Resolution E-4470) in March of 2012.

Data collection to support metrics for shorter-term outputs will seek data that document project activities, such as reports or data reflecting testing protocols, demonstrations and outcomes. The primary sources for these data include grantee interviews and their project data. We will also collect data to gauge the level of stakeholder involvement, perceptions of project validity, and the size and composition of the immediate audience for tests and demonstration. For these components, interviews with stakeholders, market actors and industry experts will also play a role.

For the first order outcomes, data collection focuses on several things. We will collect data and evidence that the technology progressed to a new stage of development, and the timing of the progression relative to the project implementation. We will also gauge the additionality of the Program on that progression. For these elements, the investigation will rely on project data as well as secondary sources such as technology and stock prices, investment capital data, technology specifications, solar company data, and other economic data. We will also look to the grantee interviews, industry experts and market actors to understand their perceptions of additionality and to request their input on where to focus our review of secondary sources and data.

Our investigation of second-order, longer-term outcomes (5+ years) seeks evidence of industry growth and prosperity. We will seek documentation of a higher penetration of solar energy; a greater breadth and volume of solar projects; a simpler, faster and more automated interconnection process; and lowered demands on grid operations related to solar energy. For this, we will use interviews with industry experts and stakeholders as well as secondary data sources such as energy price and consumption data, interconnection records, solar industry sales and employment data, materials stock prices, technology prices and related product specifications.

As further evidence of second-order outcomes, we will also look for evidence that technologies have been fully accepted in the marketplace. For this, we will look through secondary sources and leverage grantee interviews to find evidence of more recent projects that develop supporting or ancillary products building on the technologies supported by the Program. Similarly, we will investigate whether new innovative business models have been introduced to the marketplace that facilitate technology distribution.

The following three tables summarize project activities to develop pre-commercial solar production technologies, the output of these activities, impact questions and metrics.

Table 15: Outputs for Validate Pre-Commercial Technologies (Logic Model Activity #9)

Outputs	Metrics	Data Source
Funding provided for development of promising pre-commercial hardware /software (#15)	Documentation of specific needs, gaps filled by selected projects	IDI-E, D, S, IDI-G
Test and validate the performance characteristics of promising pre-commercial hardware/software in operating environments (#15)	Documentation of performance testing strategies, including testing protocols and planning documents	IDI-G, D, IDI-E
	Documentation that verifies technology testing was completed in operating environments (or near-to operating environments)	IDI-G, D, IDI-MA, IDI-E
	Documentation of the performance characteristics that were tested	IDI-G, D
	Documentation of testing outcomes	IDI-G, D,
	Documentation of improvements made to testing strategies and/or improvements made to technologies resulting from testing outcomes	IDI-G, D, IDI-MA, S
Validate the performance of pre-commercial hardware/software (#15)	Documentation of stakeholder involvement/ input in testing and validation activities	IDI-MA, IDI-G, D, IDI-E, S
	Documentation of stakeholder acceptance/perceived reliability	IDI-MA, IDI-E, D, S
	Documentation of stakeholder awareness /dispersion of testing and validation activities and results (# related events, publications, references and websites visited by stakeholders)	IDI-MA, D, IDI-G, IDI-E, S

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 16: First Order Outcomes (1 – 4 years) for Validate Pre-Commercial Technologies (Logic Model Activity #9)

Outputs	Metrics	Data Source
Accelerate the stages of development of pre-commercial solar production hardware/software (#21)	Documentation confirming successful validation of objective performance characteristics in operating environment	IDI-G, D, S, IDI-E, IDI-MA
	Sales/transfer of ownership of hardware/software (i.e., sales of product license–for open/free public use or privately held)	S, IDI-G, D, IDI-E, IDI-MA
	Documents confirming scaled deployment of technology/full integration with larger system	D, IDI-G, S, IDI-E, IDI-MA
	Increased technology production, sales, and/or revenues	S, IDI-MA, D, IDI-G, IDI-E
	Full scale technology production, ongoing growth of installations	S, IDI-MA, D, IDI-G, IDI-E
Validate Bankability /Acceptance by stakeholders	Investment in production equipment/materials, necessary skills. Investments in integration with existing processes	S, IDI-MA, D, IDI-G, IDI-E
	Perceptions of clear commercial viability by stakeholders. Percent of targeted stakeholders using or considering use	IDI-MA
	Growth in # of new investors. Growth in amount of investment	S, D, IDI-E, IDI-G
	Growth in solar company profitability, stock price, or improved investor sentiment	S, D, IDI-E, IDI-G, IDI-G
	Growth in production, sales, installations	S, D, IDI-E, IDI-G, IDI-G

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 17: Second Order Outcomes (5+ years) for Validate Pre-Commercial Technologies (Logic Model Activity #9)

Outcomes	Metrics	Data Source
Increased visibility of solar output and reduced costs of integrated solar (#27)	Growth in solar industry size/profitability, stock price, investor sentiment	S, IDI-E, IDI-MA, IDI-G, D, IDI-MA
	Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems	S, IDI-E, IDI-MA, IDI-G, D
	Reduced time, cost and risk to determine value of a grid connected DG solar project	S, IDI-E, IDI-MA, IDI-G, D
Facilitate implementation of new (more) grid connected solar projects (#28)	Funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software	S, IDI-E, IDI-MA, IDI-G, D
	New financing options offered/new innovative business models arise for technology distribution	S, IDI-E, IDI-MA, IDI-G, D
	Increased efficiencies (e.g., lower costs of distribution, production, grid integration)	IDI-E, IDI-MA, S, IDI-G, D
	Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process	S, IDI-E, IDI-MA, S, IDI-G, D

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Innovative Business Models (Logic Model #4)

This section will investigate the current and long term impact of projects focused on testing and demonstrating innovative business models that support the expansion of cost-competitive solar technologies. Moreover, the intent of testing and demonstrations is to address and reduce non-price barriers to adoption by demonstrating value to contractors, solar companies and/or financiers. Some examples of these innovative business models include sales of integrated PV and battery systems, alternative system ownership and financing arrangements, and testing and development of tariffs and incentives to promote integrated operation of distributed generation technologies.

The following three tables summarize project activities to develop the market for solar technologies through testing and demonstrations. The table also shows the output of these activities, impact questions and metrics.

Table 18: Outputs From Develop Business Models And Do Demonstrations (Logic Model Activity #10)

Outputs	Metrics	Data Source
New business models (#16)	# of business models designed and tested, and validated	D, IDI-G
	Unique needs met by business models by topic area (name and description of business models)	D, IDI-G, IDI-MA
	Performance of business model in operating environment documented	D, IDI-G, IDI-MA
	Outcomes of cost-benefit analysis of business models	D, IDI-G, IDI-MA
Consumer demonstrations (#16)	# of demonstrations performed by business model topic area	D, IDI-G
	# stakeholders reached/attending demonstrations; percent of target audience reached	D, IDI-G, IDI-MA
	Documented evidence that business models will support expansion of cost-effective solar	D, IDI-G, IDI-MA

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 19: First Order Outcomes for Develop Business Models And Do Demonstrations (Logic Model Activity #10)

Outcomes	Metrics	Data Source
Visible performance (#22)	# of replicated demonstrations and # of stakeholders exposed to business models in 1-4 year timespan	D, IDI-G
	# of business models progressing to larger scale implementation and validation in operating environment	IDI-G, IDI-MA, D
	# of models with documented adoption or likely to be adopted and # of stakeholders adopting models	IDI-G, IDI-MA, D
Optimized design (#22)	Evidence of operational compatibility with existing system/business operations it fits into	IDI-MA, IDI-G, D
	Evidence of relative advantage compared to existing business models	IDI-MA, IDI-G, D
Lower costs (#22)	Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk	IDI-G, IDI-MA, D
Customers aware (#26)	Increased customer awareness of solar projects; increase in sales growth	IDI-MA, IDI-G, IDI-E D
Business finds and serves customers better at lower cost, risk, time (#28)	Faster, easier market intelligence; decreased cost of solar projects to customers; increased speed of delivery of solar projects	IDI-MA, IDI-G, D

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Table 20: Second Order Outcomes for Develop Technical Recommendations (Logic Model Activity #10)

Outcomes	Metrics	Data Source
Guidelines facilitate implementation of new grid connected solar projects (#28)	Documented (or predicted) changes to grid-connected DG solar market (supply, demand, market infrastructure)	**IDI-E, IDI-MA, IDI-G, D, S**
	Predicted influence on expansion of PV market opportunities	**IDI-E, IDI-MA, IDI-G, D, S**
	Likelihood of easier financing of solar projects	**IDI-E, IDI-MA, IDI-G, D, S**
	Potential for reduction in balance of system costs	**IDI-E, IDI-MA, IDI-G, D, S**
	Potential for easier market entry and exit of firms, increased competition, reduced costs and improved services	**IDI-E, IDI-MA, IDI-G, D, S**

Data source key: D=Grantee data, IDI-G=In-depth interview w/ grantees, IDI-E=In-depth interview w/ industry experts and stakeholders, S=External data/literature, IDI-MA=In-depth interview w/ market actors, Su-MA=Survey of market actors. **Green text** indicates main source, **orange text** indicates supporting source.

Appendix B: Data Collection Methods Tables

This appendix provides tables showing each data collection method and the information that each will be used to collect. This is the same information provided early in the report, but organized by data collection method rather than by logic model element. These tables served as the foundation for developing the individual data collection instruments.

Table 21: Program Documentation – Knowledge Base Metrics Addressed (Logic Model #1)

Primary Metrics	Secondary Metrics
• Dollars/budgets provided by grantee partners (#11) • # of new and existing partnerships (#11) • # of workshops, webinars, memos, presentations, publications (#11) • Number of researchers involved in projects (#12) • Project database(s)/documentation (#12) • Technical reports/memos (#12) • Publications, papers, articles (#12) • Results presentations and size/composition of audience (#12) • Website postings, website hits and downloads (#12) • Webinars/workshops/meetings/events (#12) • Demonstration projects and reports (#12)	• Unique skills/experience of partners (#11) • Use of existing/past research (#11) • Direct outreach activities by team to other solar entities (number and description) (#11) • Citations of research results in publications (#17) • Funding opportunities (# and $ amounts) (#18)

Table 22: Program Documentation – Grid Integration Metrics Addressed (Logic Model #2)

Primary Metrics	Secondary Metrics
• # of models and tools designed, tested and validated in operating environment (#13) • Unique needs met by models and tools (#13) • # of databases, technical recommendations and guidelines, by field (#14) • # stakeholders involved in development • Unique needs met (#14) • # of dissemination activities, workshops, webinars, websites (#14)	• # of tools that perform better than existing tools or fill gap (#13) • Estimated costs of model or tool implementation (#13) • # of unique stakeholders using tool (#13) • # of unique individuals or organizations reached and description of audience reached (#14) • # of models, tools with documented performance characteristics in operating environment (#19) • # of models, tools that provide new functionality or improvement over status quo (#19) • Details of new or improved performance (improved estimate precision, more accurate forecasting, etc.) (#19) • Estimated costs of model or tool implementation (#19) • # of models, tools officially implemented (or planned) in operating environment (#19) • # of models, tools officially implemented (or planned) in regulatory procedures, standards, policy (#19) • # of models, tools officially implemented (or planned) in planning and grid management (#19) • Improvement (actual or estimated) in system reliability brought by new models, tools (reduced unintentional islanding, etc.) (#23) • Improvement (actual or estimated) brought by new models, tools in saved time, lower cost, reduced risk (#23) • # mandatory and voluntary implementation of recommendations (names of standards, rules) (#20) • # of unique entities that invest in skills to implement recommendations (actual and predicted) (#20)

Primary Metrics	Secondary Metrics
	• Dollars spent on training (actual and predicted) (#20) • Standards and/or rules influenced (actual and predicted) (number and description) (#20) • Impact (actual or estimated) of recommendations (geographic influence, economic influence, improved rates, lowered transaction costs, changes to interconnection standards) (#20) • Impact (actual or estimated) of recommendations on inverter system communication protocols (#20) • Evidence of simpler/streamlined interconnection requirements (#24) • Estimated or actual improvements to rates and tariffs (#24) • Lower transaction costs for implementing solar projects (#24) • Estimates of system improvements allowing greater visibility of solar generation: increased temporal resolution of data, improved predictive ability and economic analytics (#27) • Estimates of improvements in estimated value of new projects, interconnection time, project approval and interoperability (#27) • # of stakeholders estimated to be impacted by new and improved models, tools (#27) • Estimated increased penetration and proportion of load of solar generation attributable to models, tools • Estimated cost reductions related to models, tools • Improved efficiencies in system resulting in lower costs of integrated solar

Table 23: Program Documentation – Solar Technologies Metrics Addressed (Logic Model #3)

Primary Metrics	Secondary Metrics
• Document specific needs, gaps filled by selected projects (#15) • Documentation of performance testing strategies, including testing protocols and planning documents (#15) • Data, reports and documentation that verifies technology testing was completed in operating environments (or near-to operating environments) (#15) • Reports and documentation of the performance characteristics that were tested (#15) • Data and documentation of testing outcomes (#15) • Data, reports and documentation of improvements made to testing strategies and/or improvements made to technologies resulting from testing outcomes (#15) • Reports, data and documentation of stakeholder involvement/input in testing and validation activities (#15) • Data, reports and documentation confirming successful validation of objective performance characteristics in operating environment (#21) • Sales/transfer of ownership of hardware/software (i.e. Sales of product license–for open/free public use or privately held) (#21) • Increased technology production, sales, and/or revenues (#21) • Data, reports and documentation indicating commercialized (#21) • Full scale technology production, ongoing growth of installations (#21) • Investment in production equipment/materials, necessary skills. Investments in integration with existing processes (#21) • Growth in # of new investors. Growth in	• Reports, data and documentation of stakeholder awareness/dispersion of testing and validation activities and results (#15) • Reports, data and documentation of stakeholder acceptance/perceived reliability (#15) • Growth in solar industry size/profitability, stock price, investor sentiment (#27) • Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems (#27) • Reduced time, cost and risk to determine value of a grid connected DG solar project (#27) • The funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software (#28) • New financing options offered/new business models arise for technology distribution (#28) • Increased efficiencies, e.g. lower costs of distribution, production, grid integration (#28) • Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process (#28)

Primary Metrics	Secondary Metrics
amount of investment capital/venture capital (#21) • Growth in solar company profitability, stock price, or improved investor sentiment (#21) • Growth in production, sales, installations (#21) • Growth in solar industry size/profitability, stock price, investor sentiment (#27)	

Table 24: Program Documentation – Business Models Metrics Addressed (Logic Model #4)

Primary Metrics	Secondary Metrics
• # of business models designed and tested, and validated (#16) • Unique needs met by business models by topic area (name and description of business models) (#16) • Performance of business model in operating environment documented (#16) • Outcomes of cost-benefit analysis of business models (#16) • # of demonstrations performed by business model topic area (#16) • # of stakeholders reached/attending demonstrations; percent of target audience reached (#16) • Documented evidence that business models will support expansion of cost-effective solar (#16) • # of replicated demonstrations and # of stakeholders exposed to business models in 1-4 year timespan (#22)	• # of business models progressing to larger scale implementation and validation in operating environment (#22) • # of models with documented adoption or likely to be adopted and # of stakeholders adopting models (#22) • Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk (#22) • Evidence of operational compatibility with existing system/business operations it fits into (#22) • Evidence of relative advantage compared to existing business models (#22) • Increased customer awareness of solar projects; increase in sales growth (#22) • Faster, easier market intelligence; decreased cost of solar projects to customers; increased speed of delivery of solar projects (#22) • Documented (or predicted) changes to grid-connected dg solar market (supply, demand, market infrastructure) (#22) • Predicted influence on expansion of PV market opportunities (#22) • Likelihood of easier financing of solar projects (#22) • Potential for reduction in balance of system costs (#22) • Potential for easier market entry and exit of firms, increased competition, reduced costs and improved services (#22)

Table 25: In-depth Interviews w/ Grantees – Knowledge Base Metrics Addressed (Logic Model #1)

Primary Metrics	Secondary Metrics
• Unique skills/experience of partners (#11) • # of additional grant applications, teaming (#11) • Use of existing/past research (#11) • Direct outreach activities by team to other solar entities (number and description) (#11) • Other intellectual property created (copyright, license, etc.), granted based on funded projects. (#17) • Involvement of utility partners (funding, management involvement) (#17) • Meetings with researchers and stakeholders to discuss research (#12)	• Dollars/budgets provided by grantee partners (#11) • # of new and existing partnerships (#11) • # of workshops, webinars, memos, presentations, publications (#11) • Perception of industry experts on unnecessarily duplicative projects (#17) • Patent applications filed/received (#17) • Number of researchers involved in projects (#12) • Project database(s)/documentation (#12) • Technical reports/memos (#12) • Publications, papers, articles (#12) • Results presentations and size/composition of audience (#12) • Website postings, website hits and downloads (#12) • Webinars/workshops/meetings/events (#12) • Demonstration projects and reports (#12) • Funding opportunities (# and $ amounts) (#18) • Funding awarded (# and $ amounts) (#18)

Table 26: In-depth Interviews w/ Grantees – Grid Integration Metrics Addressed (Logic Model #2)

Primary Metrics	Secondary Metrics
• # of tools that perform better than existing tools or fill gap (#13) • Estimated costs of model or tool implementation (#13) • # of unique stakeholders using tool (#13) • # of unique individuals or organizations reached and description of audience reached (#14) • # of models, tools with documented performance characteristics in operating environment (#19) • # of models, tools that provide new functionality or improvement over status quo (#19) • Details of new or improved performance (improved estimate precision, more accurate forecasting, etc.) (#19) • Estimated costs of model or tool implementation (#19) • # of models, tools officially implemented (or planned) in operating environment (#19) • # of models, tools officially implemented (or planned) in regulatory procedures, standards, policy (#19) • # of models, tools officially implemented (or planned) in planning and grid management (#19) • Improvement (actual or estimated) in system reliability brought by new models, tools (reduced unintentional islanding, etc.) (#23) • # of mandatory and voluntary implementation of recommendations (names of standards, rules) (#20) • # of unique entities that invest in skills to implement recommendations (actual and predicted) (#20) • Dollars spent on training (actual and predicted) (#20) • Standards and/or rules influenced (actual and	• # of models and tools designed, tested and validated in operating environment (#13) • Unique needs met by models and tools (#13) • # of databases, technical recommendations and guidelines, by field (#14) • # of stakeholders involved in development (#14) • Unique needs met (#14) • # of dissemination activities, workshops, webinars, websites (#14) • Evidence of simpler/streamlined interconnection requirements (#24) • Estimated or actual improvements to rates and tariffs (#24) • Lower transaction costs for implementing solar projects (#24) • Estimates of system improvements allowing greater visibility of solar generation (#27) • Estimates of improvements in estimated value of new projects, interconnection time, project approval and interoperability (#27) • # of stakeholders estimated to be impacted by new and improved models, tools (#27) • Estimated increased penetration and proportion of load of solar generation attributable to models, tools (#27) • Estimated cost reductions related to models, tools (#27) • Improved efficiencies in system resulting in lower costs of integrated solar (#27) • Expert and stakeholder opinion on whether standards and rules will be simplified by recommendations resulting in lower cost, greater penetration of grid connected solar (#28) • Expert and stakeholder opinion on whether recommendations can contribute

Primary Metrics	Secondary Metrics
predicted) (number and description) (#20) • Impact (actual or estimated) of recommendations (geographic influence, economic influence, improved rates, lowered transaction costs, changes to interconnection standards) (#20) • Impact (actual or estimated) of recommendations on inverter system communication protocols (#20)	to improved technical guidelines resulting in lower cost, greater penetration of grid connected solar (#28) • Will recommendations encourage streamlined approval processes reducing time and cost of new projects (#28)

Table 27: In-depth Interviews w/ Grantees – Solar Technologies Metrics Addressed (Logic Model #3)

Primary Metrics	Secondary Metrics
• Documentation of performance testing strategies, including testing protocols and planning documents (#15) • Data, reports and documentation that verifies technology testing was completed in operating environments (or near-to operating environments) (#15) • Reports and documentation of the performance characteristics that were tested (#15) • Data and documentation of testing outcomes (#15) • Data, reports and documentation of improvements made to testing strategies and/or improvements made to technologies resulting from testing outcomes (#15) • Reports, data and documentation of stakeholder involvement/input in testing and validation activities (#15) • Data, reports and documentation confirming successful validation of objective performance characteristics in operating environment (#21) • Sales/transfer of ownership of hardware/software (i.e. sales of product license–for open/free public use or privately held) (#21) • Data, reports and documents confirming scaled deployment of technology/full integration with larger system (#21)	• Document specific needs, gaps filled by selected projects (#15) • Reports, data and documentation of stakeholder awareness /dispersion of testing and validation activities and results. (#15) • Increased technology production, sales, and/or revenues (#21) • Data, reports and documentation indicating commercialized status (need to lookup definition of commercialized to refine this) (#21) • Full scale technology production, ongoing growth of installations (#21) • Investment in production equipment/materials, necessary skills. Investments in integration with existing processes (#21) • Growth in # of new investors. Growth in amount of investment capital/venture capital (#21) • Growth in solar company profitability, stock price, or improved investor sentiment (#21) • Growth in production, sales, installations (#21) • Growth in solar industry size/profitability, stock price, investor sentiment (#27) • Higher penetration of solar technologies (#27) • Greater breadth and volume of cost-effective applicability of solar systems (#27) • Reduced time, cost and risk to determine value of a grid connected dg solar project (#27) • The funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software (#28) • New financing options offered/new

Primary Metrics	Secondary Metrics
	business models arise for technology distribution (#28) • Increased efficiencies, e.g. lower costs of distribution, production, grid integration (#28) • Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process (#28)

Table 28: In-depth Interviews w/ Grantees – Business Models Metrics Addressed (Logic Model #4)

Primary Metrics	Secondary Metrics
• # of business models designed and tested, and validated (#16) • Unique needs met by business models by topic area (name and description of business models) (#16) • Performance of business model in operating environment documented (#16) • Outcomes of cost-benefit analysis of business models (#16) • # of replicated demonstrations and # of stakeholders exposed to business models in 1-4 year timespan (#22) • # of business models progressing to larger scale implementation and validation in operating environment (#22) • # of models with documented adoption or likely to be adopted and # stakeholders adopting models (#22) • Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk (#22)	• # of demonstrations performed by business model topic area (#16) • # of stakeholders reached/attending demonstrations; percent of target audience reached (#16) • Documented evidence that business models will support expansion of cost-effective solar (#16) • Evidence of operational compatibility with existing system/business operations it fits into (#22) • Evidence of relative advantage compared to existing business models (#22) • Increased customer awareness of solar projects; increase in sales growth (#22) • Faster, easier market intelligence; decreased cost of solar projects to customers; increased speed of delivery of solar projects (#22) • Documented (or predicted) changes to grid-connected dg solar market (supply, demand, market infrastructure) (#22) • Predicted influence on expansion of PV market opportunities (#22) • Likelihood of easier financing of solar projects • Potential for reduction in balance of system costs (#22) • Potential for easier market entry and exit of firms, increased competition, reduced costs and improved services (#22)

Table 29: In-Depth Interview W/ Industry Experts And Stakeholders – Knowledge Base Metrics Addressed (Logic Model #1)

Primary Metrics	Secondary Metrics
• Perception of industry experts on unnecessarily duplicative projects (#17) • Perception of industry experts, stakeholders, and market actors that projects address users needs, knowledge gaps, were relevant (#17) • Awareness of CSI RD&D findings (#17) • New project funding (#17) • Adoption by industry experts, market actors (#17) • Adoption into industry protocols/guidelines (#17) • Perception of industry experts, stakeholders, and market actors that projects address knowledge/capacity gaps, are relevant (#18) • Documentation of knowledge growth (new findings) (#18) • Integration of knowledge sets/perspectives (#18) • Funding opportunities (# and $ amounts) (#18) • Funding awarded (# and $ amounts) (#18) • Awareness and perception of those exposed to results of program	• Unique skills/experience of partners (#11) • # of additional grant applications, teaming (#11) • # of workshops, webinars, memos, presentations, publications (#11) • Direct outreach activities by team to other solar entities (number and description) (#11) • Citations of research results in publications (#17) • Involvement of utility partners (funding, management involvement) (#17)

Table 30: In-Depth Interview W/ Industry Experts And Stakeholders – Grid Integration Metrics Addressed (Logic Model #2)

Primary Metrics	Secondary Metrics
• Evidence of simpler/streamlined interconnection requirements (#24) • Estimated or actual improvements to rates and tariffs (#24) • Lower transaction costs for implementing solar projects (#24) • Estimates of system improvements allowing greater visibility of solar generation: increased temporal resolution of data, improved predictive ability and economic analytics (#27) • Estimates of improvements in estimated value of new projects, interconnection time, project approval and interoperability (#27) • # of stakeholders estimated to be impacted by new and improved models, tools (#27) • Estimated increased penetration and proportion of load of solar generation attributable to models, tools (#27) • Estimated cost reductions related to models, tools (#27) • Improved efficiencies in system resulting in lower costs of integrated solar (#27) • Expert and stakeholder opinion on whether standards and rules will be simplified by recommendations resulting in lower cost, greater penetration of grid connected solar (#28) • Expert and stakeholder opinion on whether recommendations can contribute to improved technical guidelines resulting in lower cost, greater penetration of grid connected solar (#28) • Will recommendations encourage streamlined approval processes reducing time and cost of new projects (#28)	• # of tools that perform better than existing tools or fill gap (#13) • Estimated costs of model or tool implementation (#13) • Details of new or improved performance (improved estimate precision, more accurate forecasting, etc.) (#19) • Estimated costs of model or tool implementation (#19) • Improvement (actual or estimated) in system reliability brought by new models, tools (reduced unintentional islanding, etc.) (#23) • Improvement (actual or estimated) brought by new models, tools in saved time, lower cost, reduced risk (#23) • Dollars spent on training (actual and predicted) (#20) • Standards and/or rules influenced (actual and predicted) (number and description) (#20)

Table 31: In-Depth Interview W/ Industry Experts And Stakeholders – Solar Technologies Metrics Addressed (Logic Model #3)

Primary Metrics	Secondary Metrics
• Document specific needs, gaps filled by selected projects (#15) • Reports, data and documentation of stakeholder acceptance/perceived reliability (#15) • Growth in # of new investors. Growth in amount of investment capital/venture capital (#21) • Growth in solar company profitability, stock price, or improved investor sentiment (#21) • Growth in production, sales, installations (#21) • Growth in solar industry size/profitability, stock price, investor sentiment (#27) • Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems (#27) • Reduced time, cost and risk to determine value of a grid connected DG solar project (#27) • The funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software (#28) • New financing options offered/new business models arise for technology distribution (#28) • Increased efficiencies, e.g. lower costs of distribution, production, grid integration (#28) • Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process (#28)	• Documentation of performance testing strategies, including testing protocols and planning documents (#15) • Data, reports and documentation that verifies technology testing was completed in operating environments (or near-to operating environments) (#15) • Reports, data and documentation of stakeholder involvement/input in testing and validation activities (#15) • Reports, data and documentation of stakeholder awareness/dispersion of testing and validation activities and results (#15) • Data, reports and documentation confirming successful validation of objective performance characteristics in operating environment (#15) • Sales/transfer of ownership of hardware/software (i.e. sales of product license–for open/free public use or privately held) (#15) • Data, reports and documents confirming scaled deployment of technology / full integration with larger system (#21) • Increased technology production, sales, and/or revenues (#21) • Data, reports and documentation indicating commercialized status (need to lookup definition of commercialized to refine this) (#21) • Full scale technology production, ongoing growth of installations (#21) • Investment in production equipment/materials, necessary skills. Investments in integration with existing processes (#21)

Table 32: In-Depth Interview W/ Industry Experts And Stakeholders – Business Models Metrics Addressed (Logic Model #4)

Primary Metrics	Secondary Metrics
• Documented (or predicted) changes to grid-connected DG solar market (supply, demand, market infrastructure) (#28) • Predicted influence on expansion of PV market opportunities (#28) • Likelihood of easier financing of solar projects (#28) • Potential for reduction in balance of system costs (#28) • Potential for easier market entry and exit of firms, increased competition, reduced costs and improved services (#28)	• Increased customer awareness of solar projects; increase in sales growth (22)

Table 33: External Data/Literature – Knowledge Base Metrics Addressed (Logic Model #1)

Primary Metrics	Secondary Metrics
• Use of existing/past research (#11) • Citations of research results in publications (#17) • Patent applications filed/received (#17) • Publications, papers, articles (#12) • Demonstration projects and reports (#12)	• Awareness of CSI RD&D findings (#17) • Adoption into industry protocols/guidelines (#17) • Meetings with researchers and stakeholders to discuss research (#12) • Funding opportunities (# and $ amounts) (#18) • Funding awarded (# and $ amounts) (#18)

Table 34: External Data/Literature – Grid Integration Metrics Addressed (Logic Model #2)

Primary Metrics	Secondary Metrics
	• Evidence of simpler/streamlined interconnection requirements (#24) • Estimated or actual improvements to rates and tariffs (#24) • Lower transaction costs for implementing solar projects (#24) • Estimates of system improvements allowing greater visibility of solar generation: increased temporal resolution of data, improved predictive ability and economic analytics (#27) • Estimates of improvements in estimated value of new projects, interconnection time, project approval and interoperability (#27) • # of stakeholders estimated to be impacted by new and improved models, tools (#27) • Estimated increased penetration and proportion of load of solar generation attributable to models, tools (#27) • Estimated cost reductions related to models, tools (#27) • Improved efficiencies in system resulting in lower costs of integrated solar (#27) • Expert and stakeholder opinion on whether standards and rules will be simplified by recommendations resulting in lower cost, greater penetration of grid connected solar (#28) • Expert and stakeholder opinion on whether recommendations can contribute to improved technical guidelines resulting in lower cost, greater penetration of grid connected solar (#28) • Will recommendations encourage streamlined approval processes reducing time and cost of new projects (#28)

Table 35: External Data/Literature – Solar Technologies Metrics Addressed (Logic Model #3)

Primary Metrics	Secondary Metrics
• Document specific needs, gaps filled by selected projects (#15) • Sales/transfer of ownership of hardware/software (i.e. sales of product license–for open/free public use or privately held) (#21) • Data, reports and documents confirming scaled deployment of technology/full integration with larger system (#21) • Increased technology production, sales, and/or revenues (#21) • Data, reports and documentation indicating commercialized status (need to lookup definition of commercialized to refine this) (#21) • Investment in production equipment/materials, necessary skills. Investments in integration with existing processes (#21) • Growth in # of new investors. Growth in amount of investment capital/venture capital (#21) • Growth in solar company profitability, stock price, or improved investor sentiment (#21) • Growth in production, sales, installations (#21) • Growth in solar industry size/profitability, stock price, investor sentiment (#27) • Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems (#27) • Reduced time, cost and risk to determine value of a grid connected DG solar project (#27) • The funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software (#28) • New financing options offered/new business models arise for technology distribution (#28)	• Data, reports and documentation of improvements made to testing strategies and/or improvements made to technologies resulting from testing outcomes (#15) • Reports, data and documentation of stakeholder involvement/input in testing and validation activities (#15) • Reports, data and documentation of stakeholder acceptance/perceived reliability (#15) • Reports, data and documentation of stakeholder awareness /dispersion of testing and validation activities and results (#15) • Data, reports and documentation confirming successful validation of objective performance characteristics in operating environment (#21) • Increased efficiencies, e.g. lower costs of distribution, production, grid integration (#21)

Primary Metrics	Secondary Metrics
• Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process (#28)	

Table 36: External Data/Literature – Business Models Metrics Addressed (Logic Model #4)

Primary Metrics	Secondary Metrics
	• Documented (or predicted) changes to grid-connected DG solar market (supply, demand, market infrastructure) (#28) • Predicted influence on expansion of PV market opportunities (#28) • Likelihood of easier financing of solar projects • Potential for reduction in balance of system costs (#28) • Potential for easier market entry and exit of firms, increased competition, reduced costs and improved services (#28)

Table 37: In-Depth Interview W/ Market Actors – Knowledge Base Metrics Addressed (Logic Model #1)

Primary Metrics	Secondary Metrics
• Perception of industry experts, stakeholders, and market actors that projects address users needs, knowledge gaps, were relevant (#17) • Awareness of CSI RD&D findings (#17) • New project funding (#17) • Adoption by industry experts, market actors (#17) • Adoption into industry protocols/guidelines (#17) • Perception of industry experts, stakeholders, and market actors that projects address knowledge/capacity gaps, are relevant (#18) • Documentation of knowledge growth (new findings) (#18) • Integration of knowledge sets/perspectives (#18) • Funding opportunities (# and $ amounts) (#18) • Funding awarded (# and $ amounts) (#18) • Awareness and perception of those exposed to results of program	• # of workshops, webinars, memos, presentations, publications (#11) • Direct outreach activities by team to other solar entities (number and description) (#11)

Table 38: In-Depth Interview W/ Market Actors – Grid Integration Metrics Addressed (Logic Model #2)

Primary Metrics	Secondary Metrics
• Evidence of simpler/streamlined interconnection requirements (#24) • Estimated or actual improvements to rates and tariffs (#24) • Lower transaction costs for implementing solar projects (#24) • Estimates of system improvements allowing greater visibility of solar generation, increased temporal resolution of data, improved predictive ability and economic analytics (#27) • Estimates of improvements in estimated value of new projects, interconnection time, project approval and interoperability (#27) • # of stakeholders estimated to be impacted by new and improved models, tools (#27) • Estimated increased penetration and proportion of load of solar generation attributable to models, tools (#27) • Estimated cost reductions related to models, tools (#27) • Improved efficiencies in system resulting in lower costs of integrated solar (#27) • Expert and stakeholder opinion on whether standards and rules will be simplified by recommendations resulting in lower cost, greater penetration of grid connected solar (#28) • Expert and stakeholder opinion on whether recommendations can contribute to improved technical guidelines resulting in lower cost, greater penetration of grid connected solar (#28) • Will recommendations encourage streamlined approval processes reducing time and cost of new projects (#28)	• Unique needs met by models and tools (#13) • # of stakeholders involved in development (#13) • Unique needs met (#13) • # of models, tools that provide new functionality or improvement over status quo (#19) • # of models, tools officially implemented (or planned) in operating environment (#19) • # of models, tools officially implemented (or planned) in regulatory procedures, standards, policy (#19) • # of models, tools officially implemented (or planned) in planning and grid management (#19) • # of unique entities that invest in skills to implement recommendations (actual and predicted) (#20) • Impact (actual or estimated) of recommendations (geographic influence, economic influence, improved rates, lowered transaction costs, changes to interconnection standards) (#20) • Impact (actual or estimated) of recommendations on inverter system communication protocols (#20)

Table 39: In-Depth Interview W/ Market Actors – Solar Technologies Metrics Addressed (Logic Model #3)

Primary Metrics	Secondary Metrics
• Reports, data and documentation of stakeholder involvement/input in testing and validation activities (#15) • Reports, data and documentation of stakeholder acceptance/perceived reliability (#15) • Reports, data and documentation of stakeholder awareness/dispersion of testing and validation activities and results (#15) • Data, reports and documentation indicating commercialized status (need to lookup definition of commercialized to refine this) (#21) • Full scale technology production, ongoing growth of installations (#21) • Investment in production equipment/materials, necessary skills. Investments in integration with existing processes (#21) • Perceptions of clear commercial viability by stakeholders. Percent of targeted stakeholders considering use, or use (#21) • Growth in solar industry size/profitability, stock price, investor sentiment (#27) • Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems (#27) • Reduced time, cost & risk to determine value of a grid connected DG solar project (#27) • The funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software (#28) • New financing options offered/new business models arise for technology distribution (#28) • Increased efficiencies, e.g. lower costs of distribution, production, grid integration (#28) • Increased applicability/usability of solar generation. Growth in types of projects (#28)	• Data, reports and documentation that verifies technology testing was completed in operating environments (or near-to operating environments) (#15) • Data, reports and documentation of improvements made to testing strategies and/or improvements made to technologies resulting from testing outcomes (#15) • Data, reports and documentation confirming successful validation of objective performance characteristics in operating environment (#21) • Sales/transfer of ownership of hardware/software (i.e. sales of product license–for open/free public use or privately held) (#21) • Data, reports and documents confirming scaled deployment of technology/full integration with larger system (#21) • Increased technology production, sales, and/or revenues (#21)

Primary Metrics	Secondary Metrics
• Shorter and more automated interconnection process (#28)	

Table 40: In-Depth Interview W/ Market Actors – Business Models Metrics Addressed (Logic Model #4)

Primary Metrics	Secondary Metrics
• Evidence of operational compatibility with existing system/business operations it fits into (#22) • Evidence of relative advantage compared to existing business models (#22) • Increased customer awareness of solar projects; increase in sales growth (#22) • Faster, easier market intelligence; decreased cost of solar projects to customers; increased speed of delivery of solar projects (#22) • Documented (or predicted) changes to grid-connected DG solar market (supply, demand, market infrastructure) (#28) • Predicted influence on expansion of PV market opportunities (#28) • Likelihood of easier financing of solar projects (#28) • Potential for reduction in balance of system costs (#28) • Potential for easier market entry and exit of firms, increased competition, reduced costs and improved services (#28)	• Unique needs met by business models by topic area (name and description of business models) (#16) • Performance of business model in operating environment documented (#16) • Outcomes of cost-benefit analysis of business models (#16) • # of stakeholders reached/attending demonstrations; percent of target audience reached (#16) • Documented evidence that business models will support expansion of cost-effective solar (#16) • # of business models progressing to larger scale implementation and validation in operating environment (#22) • # of models with documented adoption or likely to be adopted and # of stakeholders adopting models (#22) • Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk (#22)

Table 41: Survey W/ Market Actors – Knowledge Base Metrics Addressed (Logic Model #1 and Network Analysis)

Primary Metrics	Secondary Metrics
• Awareness of CSI RD&D findings (#17) • Perception of industry experts, stakeholders, and market actors that projects address knowledge/capacity gaps, are relevant (#18) • Awareness and perception of those exposed to results of program	• Perception of industry experts, stakeholders, and market actors that projects address users needs, knowledge gaps, are relevant (#17)

Appendix C: Grid Integration Analysis Detail

Introduction and Background

The goals of the CSI RD&D Program include acceleration and expansion of grid integration of distributed generation solar photovoltaics (PV), to add economic value and clean energy benefits to the California grid and ratepayers. A primary focus is facilitating grid integration of solar coming from distributed consumer-based sources. Grid integration is primarily aimed at supporting efforts to enhance the integration of distributed solar into the grid and to maximize the value of distributed solar power for California ratepayers. Grid integration efforts are distinct from more traditional R&D efforts focused on progress of distributed energy technologies and controls systems, and instead is focused on ensuring that these resources can be safely and efficiently tied into the existing, or future electricity grids, as well as integrating solar with other resources such as energy efficiency and demand response.

At the outset of the Program, in 2006, the California energy grid was looking at a future with high penetration levels of PV due to aggressive goals for renewable energy resource integration including solar PV. A major challenge facing these efforts was that the industry and utilities in particular lacked understanding and familiarity with how PV systems might impact grid operations at high penetration levels. The likelihood of sustaining high PV growth rate in some part relied on the ability and willingness of utilities to integrate PV systems into the electricity system, and in a way that provided benefits to both utilities and utility customers. The CPUC identified grid integration as a key focus area for the CSI RD&D Program that was not being served by other R&D efforts, and where the CSI RD&D Program could provide high value for grant funds. Grid integration was a primary focus in Solicitation rounds 1, 3, 4 and 5. These program solicitations instructed applicants to engage in activities focused on the needs or areas of knowledge gaps detailed in Table 44 below.

Table 42: Grid Integration Needs And Knowledge Gaps

Area of Need	Description
Planning and modeling for high-penetration PV	Utility grid operation models and planning tools lacked the capability of identifying and optimally siting and incorporating distributed generation technologies and resources. In addition, methods for estimating solar resources and forecasting PV system output at high penetration levels were limited and relied on low-resolution insolation data.
Testing and development of hardware and software for high-penetration PV	Existing distribution circuits are generally capable of tolerating some variability in load; however, high penetration PV introduces significantly greater variability due to geographic dispersion, impact of variable environmental factors such as intermittent cloud cover, and the fact that behind-the-meter generation is often invisible to behind-the-meter generation resources. These factors introduce significant challenges to grid integration and overall grid reliability. This situation requires enhanced data, improved analytical capabilities, and development of robust hardware and software resources, including protocols and formal standards, capable of dynamic interaction and communication with the grid to control, and mitigate against issues arising from varying frequency and voltage conditions on the grid.
Addressing integration of energy efficiency, demand response and energy storage with PV	Significant opportunities exist for integration of distributed PV resources, energy storage, demand response and energy efficiency measures. Improved energy storage and controls could potentially transform distributed generation resources into reserve resources, and allow customers to avoid energy price volatility and respond to demand response events. Energy efficiency measures help reduce the energy footprint of a site and when installed with PV systems can help reduce the size and capital costs for PV systems. Lack of integration means these opportunities are often missed. This presents a need to integrate energy efficiency, demand response, energy storage and PV systems through improved efforts like guidelines on appropriate energy efficiency measures to with PV system integration, combined audits, and improved battery storage and control systems.
Demonstration projects for utility interconnection and grid operations tools, technology, and methods	Solicitations 3, 4 and 5 identified the need to move toward demonstration and operationalization of outputs. The specific areas of need included demonstrations of PV project screening methods for interconnection, development of technology and protocols for advanced inverter technology, processes for streamlining interconnection and offsetting system upgrade costs, investigations of common challenges to interconnection and mitigation strategies to support standards and rulemaking working groups, methods for optimal siting of PV to enhance value to the grid, methods for risk quantification, enhanced distribution system modeling with capabilities for identifying risks such as islanding, methods to identify distribution line loading and congestion, interconnection of inverters with smart meters, tools with capability for utility system control and inverter dispatch, field tests of high penetration PV, and energy storage systems with capability to provide response to dynamic loads at distribution feeders.
Demonstration of enhanced solar modeling	Solar resource models with higher spatial and temporal resolution to enable better forecasting and planning by grid operators and the CAISO. Validation of estimated PV production at high temporal resolution (less than one-minute intervals) using metered PV data. Of particular interest are demonstrations where PV performance data is collected from Smart Meter/inverter applications that can be used to validate high temporal resolution PV output estimates for anticipated high PV penetration situations.

Many activities were encouraged to meet these needs and fill these gaps, including but not limited to:

- Developing distribution and PV system load models to evaluate impacts of high penetration PV;
- Developing methodologies for appropriate screening and optimal selection of high penetration PV projects to ensure safe, efficient installation of high penetration PV;
- Conducting studies on actual distribution feeders in the field to understand the native limits of existing grid infrastructure and the true impact of distributed PV on the grid to inform protocols and standards determining limits on PV penetration such as California Rule 21;
- Developing methods and strategies for mitigating potential risks of high penetration PV such as unintentional islanding and voltage or power factor variability;
- Establishing protocols and standards, conducting lab and field testing, and developing new technologies for inverter systems manage distributed PV; and
- Creating tools for grid operators to improve visibility, forecasting and control of distributed generation resources such as high penetration PV.

A total of 20 of the 34 completed projects included a Grid Integration component. These projects listed along with their funding amount in Table 43 below:

Table 43: Grid Integration Project List

Solicitation - Project ID	Project Name	Grantee	CSI Funding	Match Funding	Total Funding
1 – 1	Advanced Modeling and Verification for High Penetration PV	CPR	$976,392	$543,000	$1,519,392
1 – 2	Development and Analysis of a Progressively Smarter Distribution System	UC Irvine	$300,000	$100,000	$400,000
1 – 4	Improving Economics of Solar Power Through Resource Analysis, Forecasting and Dynamic System Modeling	UCSD	$548,148	$137,037	$685,185
1 – 5	High Penetration PV Initiative	SMUD	$2,073,232	$1,623,859	$3,697,091
1 – 6	Analysis of High-Penetration PV Into the Distribution Grid in California	NREL	$1,600,000	$1,400,000	$3,000,000
1 – 7	Beopt-CA (EX): A Tool for Optimal Integration of EE/DR/ES+PV for California Homes	NREL	$985,000	$329,000	$1,314,000
1 – 8	Integrated Energy Project Model	KW	$942,500	$250,000	$1,192,500
3 – 18	Quantification of Risk of Unintended Islanding and Re-assessment of Interconnection Requirements in High-Penetration of Customer-Sited Distributed PV Generation	GE	$629,100	$632,700	$1,261,800
3 – 19	Screening Distribution Feeders: Alternatives to the 15% Rule	EPRI	$1,978,239	$1,978,239	$3,956,478
3 – 20	Tools Development for Grid Integration of High PV Penetration	DNV GL	$964,500	$1,077,100	$2,041,600
3 – 21	Integrating PV into Utility Planning and Operation Tools	CPR	$852,260	$875,000	$1,727,260
3 – 22	High-Fidelity Solar Forecasting Demonstration for Grid Integration	UCSD	$1,548,148	$1,548,148	$3,096,296
4 – 25	Standard Communication Interface and Certification Test Program	EPRI	$885,675	$1,016,693	$1,902,368
4 – 26	PV Integrated Storage - Demonstrating Mutually Beneficial Utility-Customer Business Partnerships	E3	$815,500	$1,072,980	$1,888,480
4 – 27	Demonstration of Locally Balanced ZNE Communities Using DR and	EPRI	$1,485,476	$2,155,000	$3,640,476

Solicitation - Project ID	Project Name	Grantee	CSI Funding	Match Funding	Total Funding
	Storage and Evaluation of Distribution Impacts				
4 – 28	Analysis to Inform California Grid Integration Rules for PV	EPRI	$399,494	$399,494	$798,988
4 – 29	Advanced Distribution Analytic Services Enabling High Penetration Solar PV	SCE	$934,000	$934,000	$1,868,000
4 – 30	Comprehensive Grid Integration of Solar Power for SDG&E	UCSD	$1,057,050	$1,057,050	$2,114,100
5 – 33	Mitigation of Fast Solar Ramps Through Sky Imager Solar Forecasting and Energy Storage Control	UCSD	$100,000	$35,000	$135,000
5 – 34	Supervisory Controller for PV and Storage Microgrids	Tri-Technic	$100,000	$60,000	$160,000

Across the 20 projects, 74 discrete outputs were delivered to meet the identified industry needs. Table 46 below presents a summary of the Program identified needs and the projects that developed outputs designed to meet those needs.

Table 44: Knowledge Gaps and Areas of Need and Corresponding Project Activities

Area of Need	Project ID	Key Project Activity Examples
Planning and modeling for high-penetration PV	1, 2, 4, 5, 6, 18, 19, 21, 22, 26	• Enhancement of insolation data • Enhancement of PV system modeling methodologies and tools • Verification of modeling methods and tools against field data • Development of screening methodology to evaluate new interconnection requests • Methods to estimate impacts from high penetration PV • Modeling impact of ZNE homes • Analysis methods to inform grid integration rules and standards
Testing and development of hardware and software for high-penetration PV	1, 5, 6, 18, 20, 25, 26, 28, 29, 33, 24	• Development of software visualization tools • Enhancement of utility software tools to incorporate enhanced simulation and forecasting methodologies • Lab and field testing of advanced PV inverter technology • Testing ability of inverters to detect and react to islanding conditions • Assessing potential for open standard communication interfaces for smart inverter technology • Developing standards and protocols for hardware
Addressing integration of energy efficiency, demand response and energy storage with PV	7, 8, 27	• Enhancement of existing building modeling software to incorporate identification and implementation of balanced, optimal, and cost-effective integration of EE, DR and PV • Development of data transfer formats for information exchange between software platforms for integrated energy projects • Demonstration of cost effective strategies for ZNE homes incorporating PV
Demonstration projects for utility interconnection and grid operations tools, technology, and methods	5, 18, 19, 20, 25, 26, 27, 28, 29, 33, 34	• Deployment and testing of solar irradiance and cloud speed sensors • Demonstration and quantification of value of PV integrated storage • Demonstration of system control software for micro-grids
Demonstration of enhanced solar modeling tools	5, 21, 22, 26, 27, 29	• Field validation of PV simulation and forecasting model methods and software • Integration of PV fleet simulation methodologies into utility software tools • Development of end-to-end modeling software integrating building modeling and energy storage into distribution modeling

A complete description of all outputs is not practical in this report, but some key examples of outputs are provided below:

- **Databases:**
  - A state-of-the-art database providing the highest known resolution of any satellite-based irradiance data set in the world, with a 1 km x 1 km spatial resolution and one-minute temporal resolution accessible via API. (Project ID 1, 21)
  - A database of all PV systems in California as of 2014 representing approximately 1.8 GW of solar capacity (Project 1)
  - One year of measured production data and forecast data from seven Sacramento Municipal Utility District (SMUD) feed in tariff PV sites totaling 100 MW capacity (Project 5)
- **Methodologies**
  - Improved method to help utilities more quickly and accurately perform engineering screens for new interconnection requests of solar PV (Project 20)
  - A bottom-up approach to quantifying "hosting capacity" for PV on representative distribution feeders was developed and tested. Through this analysis, alternative screens that are believed to be more accurate than the CPUC Rule 21 15% rule were created to accelerate interconnection of PV (Project 19)
- **Modeling Tools or Algorithms**
  - A new analog based forecasting algorithm called Taylor Expanded Solar Analog Forecasting (TESLA) applied to observations and numerical weather prediction output from coastal California (Project 30)
  - Forecasting tools consisting of very high resolution numerical weather prediction and statistical modeling (Project 4)
- **Technical Protocols**
  - Draft certification protocol for advanced inverter and interoperability functions leading to accelerated development of UL 1741 SA test procedures (Project 25)
  - Test protocols to evaluate the electrical performance and interoperability of DER inverters (Project 25)
- **Field Demonstration Sites**
  - 34 home Zero Net Energy (ZNE) community demonstration sites designed to provide a benchmark in determining whether or not combined energy storage, distributed generation, and demand response could be controlled and aggregated beneficially to the utility and the customer (Project 27)

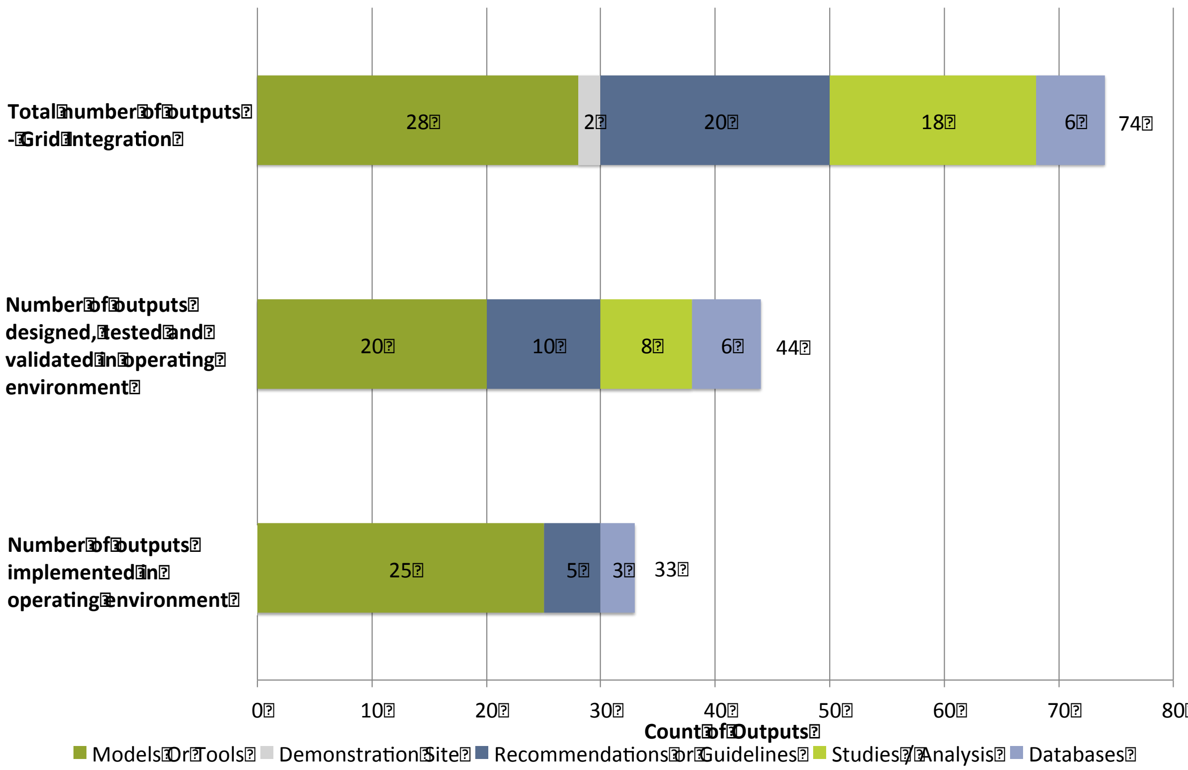
- **Software**
  - NREL's BEopt program has been completely redesigned to better accommodate the particulars of retrofit analysis and incorporation of PV in single- and multi-family applications.
  - Development of an online software tool incorporating models and visualization tools that can be used to proactively determine feeder upgrades or adjustments that will increase native limits of distribution circuits.
- **Hardware**
  - Development of advanced smart inverter prototypes as part of an effort to develop standardized inverter communication protocols.
  - Development of a cloud speed sensor designed to provide self-contained cloud motion vector measurements at utility-scale solar power plants.
- **Studies and Analysis**
  - Analysis of the effect of geographically dispersed PV systems on output variability finding that output variability reduces as PV systems are more geographically dispersed.
  - Analysis of various scenarios to study the impacts of high penetration residential PV and the effect of the mitigation measures.

These project outputs all have a development lifecycle that includes initial concept development, testing and validation of performance in operational environments and industry adoption. Once adopted, the outputs will have effects on the adopting organizations and the industry more broadly. The nature of many of the outputs from the Grid Integration projects, such as data, recommendations and modeling tools, make quantification of effects challenging, as their effects are more nebulous and diffuse than effects from commercialized products or other outputs with distinct impacts that can be tracked more closely. Another challenge to identifying the effects of the CSI projects is the varying development stages of the outputs due to the design of the Program, with projects from earlier solicitations available to the industry for longer than outputs from later solicitations, including some outputs that have been available for less than one year. Despite these challenges, we can see that there has been broad adoption of many program outputs that have or are likely to result in real and lasting effects. The outputs of these efforts will also be of importance to researchers and academics conducting innovative research in grid integration.

Assessment Stage – First Order Outcomes – Short Term

First order outcomes refer to results or effects of the unique project outputs on the market in the immediate to short term (0-4 years). We identified a mix of quantifiable and qualitative metrics by which to identify and measure first order outcomes from program projects. Project outputs all have a development lifecycle that includes development, testing and validation of performance in operational environments and industry adoption. Figure 2 below presents a count of Grid Integration project outputs by key stage of development.

Figure 2: Grid Integration Outputs (Logic Model Cell 14, 19)



Program Grid Integration outputs have experienced high uptake from the industry within California including from the IOUs and other utilities, the California Independent System Operator, and standards and rulemaking organizations. As illustrated in Figure 2, the Grid Integration projects generated 74 discrete outputs across five categories. Of these 74 outputs, 44 were tested and validated in an operating environment, with 43 having documented adoption by the industry in at least one application. The operationalized outputs were generated from 10 of the 19 projects with a Grid Integration component. Of the nine projects without output uptake to date, five are from the final two program solicitations; their outputs have only been available for a short period of time. We would expect, over time, that later solicitation outputs will also see higher levels of adoption similar to the outputs from early solicitations.

Based on the nature of the grid integration projects, we identified particular areas of potential effects in our metrics. Table 47 below summarizes our progress assessment of the program portfolio in each area of potential effect. Following the table, we summarize the areas of effect and how the outputs from the Grid Integration project portfolio have influenced or may influence each area in the short term.

Table 45: Grid Integration Short Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
Standards or rules influenced	High
Impact of recommendations on inverter system communication protocols	High
Improvement in system reliability brought by new models, tools	High
Reduced cost, saved time and lowered risk of new projects and system operations	High
Evidence of simpler/streamlined interconnection requirements	High
Lower transaction costs for implementing solar projects	High

Standards and/or rules influenced (Logic Model Cell #20)

Progress Assessment – High

Common standards and rules provide broad benefits to any industry, ensuring the safety and quality of products and services, making product development and production more streamlined, making it easier for businesses to develop new products and access new markets, improving efficiency and reducing costs for manufacturers, and providing assurance for consumers that products and systems are safe and reliable. Targeting the development or improvement of standards is one way to have a high effect on a market; however, this requires identifying and engaging specific individuals or organizations with appropriate expertise and influence. Eight CSI RD&D projects conducted work explicitly designed to influence standards or rules in the solar industry. Key project outcomes that relate to standards and rules include the following:

- **Revision and development of new standards for solar inverters and interconnection.** Specific projects have resulted in revisions or information for multiple standards, and testing certifications including:
    - UL1741 SA - Tests and certifies inverters and other utility interconnected distributed generation (DG) equipment for grid support functions enabling smarter, safer reactive grid interconnection. (Project 25)
    - IEEE 1547a - Amendment establishing updates to voltage regulation, response to area electric power systems abnormal conditions of voltage and

frequency, and considering if other changes to IEEE Standard 1547 were necessary. (Project 25)

- IEEE 1547 - Full Revision providing a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). The standard provides requirements relevant to interconnection and interoperability performance, operation and testing, as well as to safety, maintenance and security considerations. (Project 25)
- IEC 61850-7-420 and IEC 61850-7-520 revisions in TC57 WG17 establish communication and information exchange protocols for interconnected DER technology. (Project 25)
- IEC 62108 standard for concentrated photovoltaic (CPV) module qualification testing defines testing protocols for technology designed to detect CPV module failures associated with field exposure related to thermal fatigue-related failure mechanisms for the assemblies. (Project 10)

- **Improvement to the existing CPUC Rule 21 (CA Rule 21).** CPUC Rule 21 describes the interconnection, operating and metering requirements for generating facilities connected to the distribution system over which the CPUC has jurisdiction. The rule includes a requirement for additional screening studies to be performed on circuits where penetration of solar PV exceeds 15 percent of peak load. The additional screening study requirements were often unclear, and the rule did not include considerations for smart inverters or battery storage. As of June 2016, the rule has been updated to include considerations of smart inverters and storage, and includes fast tracking of new solar projects meeting specific requirements. Many of the improvements were derived from CSI RD&D project research including specific improvements related to PV interconnection limits (Projects 19, 25, 28), project screening (Projects 18, 19, 25) and costs and processes for energy storage systems (Project 26). These changes helped streamline the review process for interconnection and storage projects, and played a direct role in the improvement to the existing CPUC Rule 21.
- **Changes to the PG&E interconnection process.** CSI projects have resulted in enabling the quick interconnection of certified inverters rated less than 1MW, potentially streamlining and reducing the cost of applicable projects. (Project 18)

Stakeholders and experts interviewed highlighted the influence of the program projects as of high importance, suggesting that these efforts have provided critically essential information and guidelines to help accelerate integration of solar PV and help California meet its renewable energy goals. Regarding new and improved protocols and standards, interview subjects suggested that these industry-led processes helped advance knowledge of advanced smart inverters among key industry personnel, and, as one stakeholder said, *"will certainly impact inverter manufacturers and communications companies, and should help other balance-of-systems and component manufacturers develop products in the future having standard communication language and testing protocols. In addition, these advances "should lead to a safer, more reliable, modernized grid and make it easier for smart inverter manufacturers … all this should reduce costs of DER".*

Another stakeholder suggested that industry-led standards development is a critically important endeavor and is *"important instead of it being regulated top down".*

Concerning efforts to improve CPUC Rule 21, regulatory stakeholders noted that in 2008, at the start of the CSI RD&D process,

"with regard to Rule 21 and the 15% peak load threshold, we didn't know … what the limits would be on the existing grid. So with aggressive mandates for increased solar on the grid there needed to be research into how much solar the grid could handle. A number of the projects were relevant to our work Rule 21 and overall we found a high value in terms of pushing ahead with grid integration and becoming comfortable with pushing limits on the grid".

Another stakeholder noted,

"you can tell that the program had an impact because if there wasn't positive progress with these programs then we wouldn't go from a 33 percent to 50 percent penetration goal. The regulators exposure to the outputs of CSI and other research doing this has helped the regulators, grid operators, and utilities be more sure about the impact of distributed energy resources on the grid, and I think that they feel comfortable now and this definitely has helped advance the opportunity for higher penetration".

Impact of recommendations on inverter system communication protocols (Logic Model Cell #20)

Progress Assessment – High

Advanced smart inverters are communication enabled inverters that can improve communication between distributed solar resources and the grid, helping to manage distribution of generation to the grid, cope with distribution-level voltage deviations, and provide additional protection and resiliency to the electric power system. These capabilities can be provided at potentially low cost but can greatly increase the penetration of photovoltaic and other renewable energy on the grid. Harnessing these capabilities required better understanding of the capabilities of smart inverters, how to calibrate inverters to take optimal advantage of these functions, and how smart inverter functionality can interact with distribution-level interconnection rules and regulations for electric generators and electric storage resources. Beyond the influence on specific inverter standards mentioned above, several projects provided important guidelines and recommendations for inverter systems settings and protocols to advance the integration of advanced smart inverters and help increase interconnection limits, thereby increasing the penetration potential of solar PV. Key outcomes in this area include:

- **Demonstration projects of advanced smart inverters**. These demonstration projects provided real world evidence of how advanced communication-connected inverters and communication protocols can help progressively increase PV limits on distribution circuits, pushing limits beyond 15 percent and potentially as high as 100 percent. In some cases, they also provide ongoing test beds for future studies. (Projects 27, 29)
- **Technical reports providing guidelines and inverter settings**. Several projects developed technical reports designed to instruct utilities on how to optimally calibrate both existing inverter technology and smart inverters to integrate high levels of distributed PV. (Projects 2, 6, 18, 28)
- **Studies and analysis to develop optimal control methods**. Multiple projects conducted studies to test the application of settings of smart inverters and develop specific control methods. These control methods help mitigate against voltage variability inherent with high penetration levels of PV. (Projects 2, 6, 29)

Again, stakeholders and experts agreed that inverter system communication protocols and control methods are key to incorporating high penetration PV, and the project outputs have provided valuable data on the ability of advanced inverters and communication protocols to improve system reliability. In addition to comments already mentioned in the standards section above, with regards to inverter standards, communication and control strategies and protocols were also seen as critical advancements of the Program. One stakeholder explained that

> *"the reason this was critically important unlike other equipment in the utility industry where the utility is the buyer and owner of all equipment. So there is no standard, which is OK because they simply pick one vendor and only use that one. In the case of solar or distributed resources of all types … they are owned by the customer and the customer picks. New companies are appearing and old companies are disappearing. So to be able to create a network that connects millions of these together that can monitor them cohesively and manage them consistently requires a standard communication interface".*

One solar expert, independent of the Program, stated that

> *"the industry has been looking at the communication standards in EV and inverters with building loads and with storage, indicating this is an area of importance, and the CSI projects gave us a look in to some of the challenges that we need to overcome when we start*

implementing these requirements for communications with smart inverters, so it has provided very valuable information for us and I think for the everyone involved".

Improvement in system reliability brought by new models, tools, and software (Logic Model Cell #23)

Progress Assessment – High

Across the 19 projects with Grid Integration components, there were over 30 outputs including commercialized software packages, modeling methodologies, open source modeling tools, data collection tools, and databases. These outputs have led to improvements in grid reliability in situations with high penetration PV. Examples of outputs and their effect on grid reliability include:

- **New or enhanced software products for grid planners and operators.** Several software products were developed that improve resource visibility, provide more accurate prediction of generation, and allow grid planners to model economic value of planned solar generation resources. Improvements in these areas add to overall system reliability. Some examples in this area are:
    - CPR's PVSimulator™, FleetView™ and WattPlan® tools are commercial products developed based on research from the CSI RD&D projects. According to project partners, the CSI RD&D projects *"set the stage, which helped us develop a project to get to a saleable technology*". Numerous utility and other stakeholders including the California Independent System Operator (CAISO) utilize these products for grid planning and operations. Together these tools provide single system and fleet level modeling services that use hourly resource data and defined physical system attributes in order to simulate configuration-specific PV system and fleet outputs to support utility and ISO planning and load-balancing requirements. In addition, they incorporate value analysis tools that allow users to evaluate the economic value of PV system scenarios at very low cost. A project stakeholder explained that the most important thing that this led to was *"a system to help do behind the meter PV forecasting, which addresses some of the uncertainty that the ISOs feel."* (Projects 1, 21, 37)
    - The Sacramento Municipal Utility District (SMUD) and the Hawaii Public Utilities Commission, along with a team of industry partners, developed high resolution data monitoring and evaluation efforts leading to the development of data visualization software that is being utilized and updated in Hawaii. These tools continued to be refined and commercialized through efforts by the US Department of Energy Sunshot program and the industry partners who have implemented some aspects into energy management systems used by a number of Western utilities including the California IOUs and the CAISO, as well as utilities in Hawaii. Project partners and stakeholders believe that these products had a highly positive

impact on grid planning and grid reliability, and that some of these outputs have provided significant net benefits to their organizations. (Project 5)
    - Southern California Edison and its industry partners developed a process for a stochastic distribution planning process that models distribution circuits in GridLAB-D, an open source software platform, forecasting PV adoption, determining native limits, and providing mitigation strategy analysis for interconnection of new PV generation systems. These tools have been integrated into the Qado Systems software platform GridUnity, which provides a user-friendly graphical interface and visualization tools. Utility stakeholders using these platforms explained that this software tool was something that did not exist prior to the project and is proving very useful in its ability to demonstrate mitigation processes, model native distribution circuit limits, and expedite the screening process for new projects, which all contribute to grid reliability. (Project 29)
- **Enhanced data products providing critical solar irradiance and other data** that can be integrated into existing modeling tools or software to improve generation visibility, predictive capabilities and economic assessments, including:
    - SolarAnywhere, a solar resource database containing over 14 years of time- and location-specific, hourly insolation data throughout the continental US and Hawaii. Through a series of CSI projects, these data were enhanced to provide the highest known resolution of any satellite-based irradiance data set in the world, with a 1 km x 1 km, 1-minute resolution. These data were publicly available to users and are used by a broad array of stakeholders around the world. (Project 1)
    - SMUD installed an irradiance sensor network within its territory and integrated the resulting data into its existing planning system to enhance planner visibility of solar generation capacity. Utility staff stated that the sensor network and data have been very important for increasing PV penetration in its service territory and to show utility leadership *"that this could be the future for us".* (Project 5)
- **Improved modeling tools and methodologies.** Aside from specific software applications, several projects developed modeling tools in open source methodologies that can be adopted or integrated into existing utility planning and operations tools. These included tools and methodologies for solar irradiance forecasting, generation forecasting for individual systems and fleet systems, distribution system models, and economic value modeling tools. Each of these types directly or indirectly lead to benefits in system reliability through, for example, more accurate predicting of solar generation and optimal siting of generation resources. Some specific examples of outputs include:

- A PV performance model that can be applied to satellite solar irradiance data to simulate PV power output taking into account local weather conditions. The model uses SolarAnywhere data and is shown to accurately predict power output to within 3 percent of actual output. The model is provided in MATLAB and can facilitate power conversion modeling for large datasets for variability or forecasting applications (Project 4).
- Cloud speed algorithms to help forecast transient cloud cover which is an important variable in estimating PV power output. Two different methods to determine cloud speed were developed by a series of projects as well as innovative cloud speed sensor hardware (Projects 4, 22, 30, 33).
- A novel PV adoption methodology was developed that estimated the probability of adoption of distributed solar attached behind the meter in residential and commercial applications. The method was developed to simulate allocation of new solar PV installations as penetration levels increased, in order to inform forecasts of future states of distribution systems. The method was shown to provide more accurate PV adoption in terms of installed size and location than has been modeled before at scale (Project 29).

Discussion with stakeholders, experts and market actors indicate that these program outputs have led to greater system reliability, or a better understanding of actual system reliability that has led to a higher degree of confidence in the ability of the California grid to integrate higher penetrations of distributed PV. One stakeholder noted that

> *"projects I was involved in had a major impact with understanding risks, lots of grants did work with simulating higher penetrations than what is currently being absorbed and allowed utilities and stakeholders to understand the grid impacts as solar penetrations continue to increase."*

Another stakeholder stated that

> *"the generation mix has potentially changed as a direct result of projects increasing the reliability of the grid".*

Reduced cost, saved time and lowered risk of new projects and system operations (Logic Model Cell #23)

Progress Assessment – High

Up-front costs are the single largest barrier to widespread adoption of solar DG technologies. A major component of up-front solar costs are soft costs, which the DOE estimates at 64 percent of total solar costs.[1] Three areas of potential soft cost reduction from the customer side are optimized solar project design and integration with energy efficiency or demand response measures, faster approval and interconnection of new solar projects, and reduced costs of interconnection studies. From the utility side, soft costs can be reduced through improved system operations to incorporate new solar PV, as well as potential maintenance and repair costs that can be avoided through mitigating the risk of new solar projects. A goal of the CSI RD&D Program was to identify projects that would lead to reduced up-front costs to increase penetration of solar PV. Several of the outputs already mentioned have made significant advancement toward these goals either directly or indirectly in conjunction with meeting other goals. There are also outputs directed specifically at reducing the cost and time taken for new projects and lowering the risk of project to system operations. Examples of important outputs meeting these goals include:

- **Software products promoting optimal building design and integrated projects.** In theory, optimal building design and integrated projects should help reduce the installation costs of solar PV, through ensuring that buildings are energy efficient and that solar PV is optimally sized. The program funded a project to enhance the NREL BeOpt building design and simulation software application to facilitate the identification and implementation of balanced, optimal, and cost- effective integrations of energy efficiency, demand response and PV in the residential retrofit and new construction market, including multi-family housing. An important functionality of the Program is appropriate sizing of solar PV systems based on cost effective energy efficiency measures installed in the home. The Program also funded the Integrated Energy XML Schema project that developed a common data collection and communication protocol for communication across software platforms. Both projects have the potential to significantly reduce costs and save time related to solar PV installation. (Projects 7, 8)
- **Recommendations for Interconnection Regulations and Rules**. Four projects developed recommendations updating either utility level interconnection processes, or recommended modifications for CPUC Rule 21 based on the technical analysis conducted as part of the projects' scopes. The recommendations from two of these projects (18 and 19) are known to have played a direct role in the improvements to the existing CPUC Rule 21. Other projects are likely to have influenced these changes. (Projects 6, 18, 19, 20)

[1] U.S. DOE. 2016. Soft Costs 101: The Key to Achieving Cheaper Solar Energy. https://energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy

- **Mitigation strategies to avoid or control faults related to new solar PV installations.** Interconnected solar PV projects come with risks to the grid, including voltage variation causing circuit overload or voltage drops that can negatively impact grid operations. Several projects developed mitigation strategies at system and grid levels to avoid these risks. Implementing mitigation strategies can reduce operations costs, as well as offset future maintenance or repair costs. (Projects 5, 6, 20, 29)

We asked stakeholders and experts outside the projects to discuss the value of efforts to reduce costs and risks of new projects and save time through accelerated project approval. Interviewees noted the cost of solar projects as one of the primary barriers to adoption of solar PV, and soft costs of solar as one of the main potential areas of cost reduction. These interview subjects stated that the CSI project outputs have made inroads into reducing costs, saving time and lowering risk of new projects and system operations, with one stakeholder noting that

> *"we are seeing significantly lower prices and higher performance and better configuration and training and everything to make things cheaper which wouldn't have happened without structured multi year programs like CSI".*

Lower transaction costs for implementing solar projects (Logic Model Cell #24)

Progress Assessment – High

One specific area of soft costs that has a high impact on overall solar system costs is transaction costs related to new solar projects. Transaction costs include costs of permitting, costs for interconnection studies or other reporting requirements, among others. Again, many of the outputs mentioned in previous sections have had or could have an impact on transaction costs through improved siting of projects, improvements to standards and rules, and development of a better understanding of the impact of solar PV on the grid. Many project outputs including forecasting models, improved smart inverter protocols, and screening methodologies have already or have the potential to lead to reduced transaction costs for interconnected solar projects. Some examples include:

- **Analysis conducted to inform California grid integration rules** that evaluated a set of advanced inverter methods and settings and developed a complete set of guidelines and recommendations provides a mechanism to improve the distribution system performance (as it relates to voltage) when accommodating higher levels of PV. These methods can help fast track applications and therefore reduce costs and achieve higher penetrations of solar PV.
- **Improved project interconnection screening and methods for high penetration PV studies**. Projects developed detailed methodologies for performing high

penetration PV studies. Utilities use these types of studies to determine interconnection approval status of new projects. (Projects 2, 5, 6, 19, 29)

We asked stakeholders and experts to discuss the value of project outputs designed to help improve costs of implementing new solar projects. These interview subjects stated that CSI projects provided needed and valuable information to help streamline approval of new solar projects, which leads to lower costs. One stakeholder noted that the projects have made interconnection *"much more simple and gave utilities tools to solve problems, allowed more interconnections without expensive upgrades"*. Another explained that *"the tools provided by projects are really pretty good at expediting that (the approval) process and improving the time of the screening process".*

Evidence of simpler/streamlined interconnection requirements (Logic Model Cell #24)

Progress Assessment – High

A focus of several projects was developing screening methodologies and models to help simplify and streamline PV project interconnection requirements. At present interconnection studies and associated requirements are costly to solar projects. Several of these projects have developed tools or models that have already or are likely to influence interconnection requirements including:

- **Simulation models and methods to estimate power output of PV fleets or individual projects over high speed time intervals**. These methodologies can help grid planners perform detailed grid integration studies and identify optimal siting locations of PV. Screening studies often have to be conducted to install new solar PV projects, particularly on high penetration feeders. These methods can help streamline these efforts.
- **Detailed feeder models and new software to enhance utility planning models.** These have resulted in improved methods that will allow utilities to more quickly and accurately perform engineering screens for new interconnection requests of solar PV, thus reducing time and costs associated with interconnection studies.
- **Project screening methodologies and software tools. These methodologies and tools** developed under the project are designed to help optimize location of new PV generation resources in a streamlined costs effective manner

Assessment Stage – Second Order Outcomes

Second order outcomes refer to results or effects of project outputs on the market in the long- to mid-term to short-term (5-10 years). We primarily rely on qualitative metrics informed by project personnel and stakeholders to identify and assess second order outcomes from the Program projects.

System improvements allowing greater visibility of solar generation: increased temporal resolution of data, improved predictive ability and economic analytics (Logic Model Cell #27)

Progress Assessment – High

Distributed solar resources are highly variable, and often are not visible to grid planners and operators, making it difficult to predict their impact on distribution circuits and potentially increasing risk to grid reliability. Individually, distributed PV systems are typically orders of magnitude smaller, measured in kilowatts of generation, when compared with more traditional generation, usually measured in megawatts of generation. However, when taken in aggregate, distributed solar generation resources account for over 4,000 MW in installed capacity in California, making distributed solar resources on some circuits as large as other generation resources.

A critical difference between distributed solar and other resources is that traditional generation resources are "in front of the meter", meaning they are visible and controllable by grid operators, whereas distributed resources are "behind-the-meter", meaning they are typically invisible to system operators. Another critical difference is that distributed solar resources, in aggregate, provide highly variable generation to distribution circuits based on weather conditions, usage patterns, and other often unknown variables. Distribution circuits with high PV penetration can see significant increases or decreases of generation simultaneously, leading to situations that incur additional cost or challenges for the system operator to ensure that sufficient flexibility and reserves are available for reliable operations.

In a future predicted to have high penetrations of distributed PV, improving the visibility and value of solar generation is critical. There are three important areas of development that impact visibility of solar generation:

1. **Solar generation forecasting across various time horizons allows grid operators to appropriately plan for solar input on the grid**, reducing risks and improving grid reliability. Solar forecasting is also important for other aspects of grid operation including resource planning and price setting. While there are no comprehensive studies on the quantitative value of solar forecasting, it is generally agreed that the

value of accurate forecasting is large relative to the costs of solar forecasting.[2] Forecasting has been shown to have high value in other areas such as wind power.[3]

2. **Development or enhancement of software visualization tools to improve predictive ability and understanding.** Power grid visualization software enables users to view large amounts of information in intuitive graphical images, with the goal that users can interpret the data more rapidly and more accurately. These software tools are critical for grid planners and operators as electricity grids become more complex with the addition of distributed generation, and are integrated over ever-larger areas. These software tools improve visibility of power generation and problems on the grid, reducing system risk, improving response time to outages, increasing system reliability, and improving system efficiency. These systems can also help expedite decision-making for new projects. A 2012 research study by GTM Research predicted a six-fold return on investment for utilities deploying grid analytics software.[4]
3. **Advanced "smart" inverter protocols can improve communication and control of distributed generation resources for grid operators**. Enhanced communication and control functions in smart inverter technology can provide better responsiveness and visibility to grid operators.

As noted previously, several projects developed outputs to help improve generation visibility. In particular, seven projects developed tools in one of the three areas discussed above. Important innovations from these projects include:

- a state-of-the-art satellite-based irradiance database - 1 km x 1 km, half-hour and 15 second resolution. (Project 1)
- A novel methodology to simulate the power output of any PV fleet over any high speed time interval. (Project 1)
- A PV performance model provided in MATLAB that can facilitate power conversion modeling for large datasets and variable forecasting applications. The error between modeled and measured power output was found to be less than 3 percent except near sunrise and sunset, and mean absolute errors for 30 minute data were less than 5 percent, which compared favorably to other tools. (Project 4)

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[2] Letendre et al. "Predicting Solar Power Production: Irradiance Forecasting Models, Applications and Future Prospects". SEPA. March 2014. http://www.sepapower.org/media/144099/sepa-forecastreport-2014.pdf
[3] Wang et al. "The value of improved wind power forecasting: Grid flexibility quantification, ramp capability analysis, and impacts of electricity market operation timescales". NREL. Applied Energy 2016.
[4] Leeds, D. 2012. "The Soft Grid 2013-2020: Big Data & Utility Analytics for Smart Grid". GTM Research. https://www.greentechmedia.com/research/report/the-soft-grid-2013

- PV simulation software services that can be used for fault location identification and evaluating the effect of load transfer, PV interconnection studies and utility system design, and calculation of location-specific economic value of distributed PV generation from the utility perspective. (Project 1, 5, 29)
- Visualization tools that can be used to proactively determine feeder upgrades or adjustments that will increase native limits of distribution circuits. (Project 1, 5, 29)

The outputs from these projects are being used in operational environments by multiple utilities as well as the California ISO.

We asked project partners and stakeholders in these projects if there was evidence that outputs from their projects had made, or were likely to make, improvements in grid visibility for system operators. Table 48 below presents the results of this question.

Table 46: Evidence of Improvement in Solar PV Generation Visibility

Solicitation - Project ID	Output Type	Has Improved	Will Improve
1 – 1	Forecasting; Visualization Software	Y	Y
1 – 4	Forecasting	Maybe	Y
1 – 5	Forecasting; Visualization Software	Y	Y
3 – 21	Forecasting; Visualization Software	Y	Y
3 – 22	Forecasting	Maybe	Y
4 – 25	Inverter Protocols	-	Y
4 – 29	Forecasting; Visualization Software	-	Y

We asked stakeholders and experts outside the projects to discuss the value of efforts for better visualization tools undertaken by Program projects. These interview subjects highlighted generation visibility as an area of need in the industry. One stakeholder noted that before when the CSI Program began in 2006, there *"were inadequate modeling and forecasting tools for distributed generation and these were needed to help predict and understand the impact of high penetration distributed generation resources"*. Another stakeholder explained that in 2006, a major barrier to high penetration PV was *"basically not having good forecast data for multiple locations at high time resolution"*.

Among these interview subjects, there was common agreement that there has been significant advancement made in this area, and the CSI Program has made important contributions. One stakeholder noted that *"we are at a very different point as a state as regulators and planners in our understanding of optimal siting, and in our understanding of visibility, and solar loading"* and attributed some of this advance to the CSI Program projects. Another explained that

> *"the California ISO needing to be able to better integrate solar and wind into their market operation though better forecasting, better telemetry, and better planning models – those are all things that have been happening over the past 10 years and some of the project outputs are key tools meeting these needs for the California ISO. I think the CSI Program has been very effective at eliminating those past barriers or helping to reduce those, but I have not seen as much work that is focused on the issues I mentioned."*

Overall, several CSI projects related to Grid Integration developed outputs that have made significant advancements in increased temporal resolution of data, improved predictive ability and economic analytics.

Improvement in estimated value of new projects, including improved interconnection time, project approval and interoperability (Logic Model Cell #27)

Progress Assessment – High

Estimating the value of new distributed PV projects, including costs of interconnection, project approval and the costs and benefits of interoperability of solar resources, is a challenge for system planners for several reasons:[5]

- Distributed PV systems are different from traditional generation resources like coal or natural gas power plants in terms of assessing value.
- Distributed PV output is variable and includes an element of uncertainty.
- Typically, homeowners, business or third party companies like SolarCity, rather than utilities, own and operate distributed PV systems.
- Distributed PV systems require no fuel and produce no emissions, and generate electricity at or near the point of consumption.
- Distributed generation resource value will be dependent on penetration levels. At low penetration, costs to the system are relatively low; at higher penetrations, the value of distributed resources may change.

[5] Denholm et al. 2014. Methods for Analyzing the Benefits and Costs of Distributed Photovoltaic Generation to the U.S. Electric Utility System. NREL. http://www.nrel.gov/docs/fy14osti/62447.pdf

These unique characteristics as well as the lack of visibility of solar resources can make estimation of the value of distributed PV projects to both customers and utilities challenging. Two of the seven key principles of the CSI RD&D Program were to improve the economics of solar technologies and to support efforts to address the integration of distributed solar power into the grid in order to maximize its value to California ratepayers. Nine projects produced outputs designed to help improve the project approval and interconnection process, increase interoperability, improve the value of new solar projects, and better estimate the value of new solar projects. Important innovations from these projects include the following:

- **Economic Value Modeling Tools**. Clean Power Research developed a tool under this grant agreement to assist in the economic evaluation of distributed PV systems. The tool provides a medium to incorporate PV value analysis methodologies into software services The resulting software service calculates location-specific economic value of distributed PV generation from the utility perspective of the utility, including energy value, generation capacity value, environmental value, fuel price hedge value, T&D capacity value, and loss savings. The tool greatly simplifies the approach of calculating the economic value of PV. It has been made available to a variety of stakeholders in California with a particular focus on utility planners. (Project 1)
- **Grid-integration Economic Value Studies**. Several projects conducted studies that included economic value analysis of grid integration of distributed PV, including how distribution feeder loading changes with PV penetration level, the impact of increased PV penetration on system losses and the cost of system losses, the cost of voltage fluctuations due to changing generation levels of PV on voltage regulator operation, and cost effectiveness calculations for new PV projects and storage technology, as well as the impact of rates and tariffs. These studies have provided valuable results and methodologies for assessing value. (Projects 1, 4, 26, 27)
- **PV Inverter Communications Studies And Protocols**. Cost effective integration and interoperability of high penetrations of PV systems requires some level of communication and direct control of PV inverters. Identifying low-cost solutions allowing control and communications with residential systems has the potential to significantly impact the value of solar PV. Several projects conducted studies and developed communication protocols to develop low-cost communications and controls of distributed PV, which could reduce the costs of PV integration, increase PV integration, increase overall grid reliability and enable customers to benefit through grid services and improved response to potential utility grid pricing. These advances can also offset costs invested in metering and interconnection studies, as well as increased investment by utilities in mitigation solutions. (Projects 5, 6, 25, 26)

- **Software and Protocols to Enhance Value of Integrated Energy Projects (Energy Efficiency, Demand Response and Distributed Generation projects)**. Two projects focused on software development and data protocols for integrated energy projects. The first project adapted and extended a widely-used building design platform, NREL's BEopt Program, to develop a modeling tool with capabilities to facilitate the identification and implementation of a balanced, optimal and cost- effective integration of energy efficiency, demand response and distributed generation in the residential retrofit market and new construction markets. The second project developed a standardized data format and protocol that can integrate building energy assessment and analysis processes and tools with assessment, quoting and implementation of energy efficiency and renewable energy projects, enabling stakeholders in integrated energy projects to easily collect, transmit and store information through various software tools used within the energy ecosystem. These tools have the potential to improve the value of distributed PV projects by reducing project costs and ensuring efficient sizing and installation of integrated energy components. These outputs are in use to varying degrees in California and national programs and protocols. (Projects 7, 8)

We asked project partners and stakeholders in these projects if there was evidence that outputs from their projects had made, or were likely to make, the solar projects easier or cheaper and made the value of solar projects easier to determine. Table 49 below presents the results of this question.

Table 47: Partner and Stakeholder Assessment of Project Effect on Solar Project Cost and Value

Solicitation - Project ID	Output Type	Has Made Solar Easier or Cheaper	Will Make Solar Easier or Cheaper	Has Made Solar Project Value Easier to Determine	Will Make Solar Project Value Easier to Determine
1 – 1	Value Analysis Tool	Unsure	Unsure	Unsure	Unsure
1 – 4	Grid Integration Study	Y	Y	Y	Y
1 – 5	Inverter Protocols for Interoperability	Unsure	Unsure	-	-
1 – 6	Interconnection Recommendations; Inverter Protocols	Unsure	Y	-	-
1 – 7	Integrated Project Software	Y	Y	Y	Y
1 – 8	Integrated Project Data Protocol	-	Unsure – Dependent on adoption	N	N
2 – 25	Inverter Protocols for Interoperability	Y	Y	-	-
2 – 26	Value Analysis Tool; Demonstration Site	-	Y	-	Y
2 – 27	Demonstration Site; Grid Integration Study	-	Y	-	Y

We asked stakeholders and experts outside the projects to discuss the value of efforts to improve the value of new projects, improve interconnection time, accelerate project approval and advance interoperability. Interview subjects across the board highlighted the cost of solar projects as a primary barrier to adoption and high penetrations of PV. All interviewees also acknowledged that the costs of solar have decreased significantly and that CSI projects have helped reduce the costs and increase the value of solar projects. Some notable quotes from stakeholders and experts include:

> *"Cost is another barrier that existed of course, but these projects are bringing the costs down…and I think some of the advances are attributable to the program. Training, reduced costs, best practices, developing standards and regulations, all these things have helped advance the solar industry."*

> *"I would say the cost of solar especially the reduction in ancillary costs as well as technology was prohibitive. Performance of products especially on the storage side just wasn't there 10*

years ago. Lack of investment in solar technology was a challenge and I don't think we could get to where we are today without programs like this. Clearly in the solar industry if you take a ten or fifteen year window or less, we are seeing significantly lower price and higher performance and better configuration and training and everything to make things cheaper wouldn't have happened without structured multi-year programs like CSI."

"The solar market has so much more sophistication on not just how to put solar in but how to integrate it to use it as a system resource and how to combine this with their own resources and bid into the ISO market. The solar market is much more sophisticated and advanced. Doing cause and effect between the (CSI) program and the market is hard but I can do so based on the partners I see participating in the research and they are much more sophisticated."

"If we are talking about bankability of large scale utility projects or in terms of builders installing rooftop PV, I think this (CSI) has a causal impact in getting utilities and builders more comfortable with the value of solar."

Overall, nine CSI projects related to Grid Integration developed outputs that have made significant advancements to improve the value of new projects, including improved interconnection time, project approval and interoperability. Project partners and external stakeholders and experts believe that these projects have, or will impact the market.

Will recommendations encourage streamlined approval processes reducing time and cost of new projects (Logic Model Cell #28)

Progress Assessment – High

As noted above, a primary factor in the cost of new solar projects, whether they are distributed PV projects or concentrated, utility scale projects, is the time and cost involved in obtaining project approval. The proliferation of incentive programs, and mandated goals for renewable generation, have increased the number of solar PV system interconnection requests in California. The California utilities evaluate these interconnection requests to ensure proper operation of the grid is maintained. To quickly evaluate these requests, various screens have been developed that help identify when issues may or may not arise. The most common screening method takes into account the ratio of solar PV to peak load; known as the California Rule 21, this screen requires an additional interconnection study if a project will mean the ratio of solar PV to peak load exceeds 15 percent. This rule, and other screens, have often been seen as conservative and often do not take into account other factors that may indicate higher levels of PV penetration are possible—for example, the locational impact of distributed PV on a distribution circuit, feeder-specific characteristics that can impact whether issues may occur, or the presence and effect of inverter settings or communications. Several CSI projects focused on developing more advanced screening methodologies and tests, conducting studies to determine the correlation between distribution circuit characteristics and native PV penetration limits, and developing mitigation strategies for common faults related to high penetration PV. The ultimate goal of these outputs is to better understand the true impact of distributed PV and streamline the approval process for interconnection of distributed PV.

Specific outputs from these projects include:

- **Baseline Modeling and High Penetration Studies of Operational Distribution Feeders**. Multiple studies conducted baseline modeling of operational distribution feeders to determine the native limits of PV penetration on these circuits. These project studies comprehensively covered feeders in all three IOU territories as well as SMUD's territory and feeders in all Hawaii utility regions. Using a cluster analysis approach, Projects 19 and 29 sampled representative feeders from the population of feeders in the three IOU service territories and representative feeders from the population of feeders in SCE service territory respectively. The results of the baseline modeling suggested that there is no set penetration limit for feeders, but that penetration limits vary widely based on load, locations, configuration and other factors. All studies suggested that most feeders could hand over 15 percent penetration with some feeder native limits being as high as 100 percent penetration. These studies also simulated high penetration scenarios on the feeders studied to identify potential enhancements or mitigation strategies to extend the native limits of the feeders. (Projects 2, 5, 19, 29)
- **Methods for Performing High Penetration PV Studies**. As part of or in addition to the above studies, projects also developed detailed methodologies for performing high penetration PV studies. Utilities use these types of studies to determine interconnection approval status of new projects. Across the four projects that developed these methodologies, the outputs ranged from methodologies presented in the final program documentation to development of fully documented approaches including model development and instructional guides, such as the NREL High-Penetration PV Integration Handbook for Distribution Engineers.[6] Several of these methodologies have been adopted by California utilities as well as other utilities nationwide, and internationally. (Projects 2, 5, 6, 19, 29)
- **Software or Modeling Tools to Conduct High Penetration PV Studies.** As part of or in addition to the above studies, projects also developed software or modeling tools for performing high penetration studies. Three projects developed some form of software or computer modeling tool. All three produced open source code to conduct these studies in commonly used platforms including OpenDSS, Synergi,

[6] Mather et al. National Renewable Energy Laboratory. 2016. "High-Penetration PV Integration Handbook for Distribution Engineers". http://www.nrel.gov/docs/fy16osti/63114.pdf

and GridLab-D. One project worked with a software developer to incorporate the modeling into a proprietary software platform that added a graphical user interface to the system. Several of these methodologies have been adopted by California utilities as well as other utilities nationwide, and internationally. (Projects 5, 19, 29)

- **Mitigation Strategies for High Penetration PV Impacts**. Three projects developed detailed mitigation strategies for a variety of impacts potentially related to high penetration PV under a comprehensive variety of hypothetical scenarios of future high PV penetration. Mitigation strategies ranged from enhanced smart inverter communication and control settings to utility side mitigation strategies such as requiring separate feeders, transfer trips or reconfiguring circuitry. Findings have been integrated into instructional guides and are in use with several California utilities. Projects (6, 20, 29)
- **Recommendations for Interconnection Regulations and Rules**. Four projects developed recommendations updating either utility level interconnection processes, or recommended modifications for CPUC Rule 21 based on the technical analysis conducted as part of the projects' scopes. The recommendations from two of these projects (18 and 19) are known to have played a direct role in the improvements to the existing CPUC Rule 21. Other projects are likely to have influenced these changes. (Projects 6, 18, 19, 20)
- **PV Inverter Communications Studies And Protocols**. Inverter technology can play a critical role in increasing the penetration potential of solar PV. Two projects in particular developed outputs that could help advance inverter technology and protocols for communication and controls to increase penetration of PV. Project 25 developed a certification path for the new CPUC Rule 21 Test Protocols for Advanced Inverter Function requirements, and developed and published US requirements to meet this need. Project 28 assessed the impact of PV inverters on system stability and how the impacts could be controlled via frequency and voltage ride-through inverter settings, and developed methods to determine optimal distribution focused settings. (Projects 25, 28)

We asked project partners and stakeholders in these projects if there was evidence that outputs from their projects had made, or were likely to make, solar project interconnection more streamlined. Table 50 below presents the results of this question.

Table 48: Partner and Stakeholder Assessment of Project Effect on Interconnection Requirements

Solicitation - Project ID	Output Type	Has Made Interconnection More Streamlined	Will Make Interconnection More Streamlined
1 – 2	Baseline Modeling and High Penetration Studies; Interconnection Study Methodology	Y	Y
1 – 5	Baseline Modeling and High Penetration Studies; Interconnection Study Methodology; Software or Modeling Tools	Unknown	Unknown
1 – 6	Baseline Modeling and High Penetration Studies; Mitigation Strategies; Interconnection Study Methodology; Recommendations for Interconnection Regulations	Y	Y
1 – 18	Interconnection Study Methodology; Recommendations for Interconnection Regulations	Y	Y
1 – 19	Baseline Modeling and High Penetration Studies; Interconnection Study Methodology; Software or Modeling Tools; Recommendations for Interconnection Regulations	Y	Y
1 – 20	Mitigation Strategies; Interconnection Study Methodology	Y	Y
2 – 25	PV Inverter Communications	Y	Y
2 – 28	PV Inverter Communications	Y	Y
2 – 29	Baseline Modeling and High Penetration Studies; Interconnection Study Methodology; Software or Modeling Tools; Mitigation Strategies	Y	Y

We asked stakeholders and experts to discuss the value of project outputs designed to help improve or expedite the utility interconnection process. Again, these interview subjects were generally of the opinion that these CSI projects provided needed and valuable information to help improve the interconnection process and associated rules. One stakeholder noted that the projects have made interconnection *"much more simple and gave utilities tools to solve problems, allowed more interconnections without expensive upgrades"*. A utility stakeholder explained that for interconnection, utilities *"have to go through some technical screens to determine the impact of some PV stuff and what we do today is more or less manual. So I think the tools provided by projects are really pretty good at expediting that process and improving the time of the screening process"*. A regulatory stakeholder noted that *"the gap for these projects was that the existing screening practices needed improvement and weren't as effective as they could be for high penetration scenarios. Meaning that the timeliness of having screening done as well as the effectiveness of the screening practices was poor. The program helped fill this gap and related to screening practices improvements".*

Another stakeholder who had worked on CPUC Rule 21 explained that

"a number of the (CSI) projects were relevant to our work as I remember and Rule 21, overall, found a high value from these projects in terms of pushing ahead with grid integration and becoming comfortable with pushing limits on the grid. The program definitely has had value."

Overall, nine CSI projects related to Grid Integration developed outputs that have helped streamline and improve the process of interconnecting solar PV, which has led to reduced application time and lower costs. These advances improve the value of new projects, and are likely to lead to higher penetration levels of solar PV.

Expert and stakeholder opinion on whether standards and rules will be simplified by recommendations resulting in lower cost, greater penetration of grid connected solar (Logic Model Cell #28)

Progress Assessment – High

As discussed in previous sections, several Grid Integration projects intended to streamline or simplify standards or rules with the goal of lowering the cost and increasing the penetration of solar generation. Three projects in particular have demonstrated impacts on standards and rules that are likely to lower costs and increase penetration. These projects and their impacts are:

- **Project 18 - Quantification of Risk of Unintended Islanding**. The main goal of this project was to improve understanding of impacts of unintended islanding. The need to prevent sustained islanding is recognized in the industry and the UL 1741 standard includes a set of tests to evaluate the ability of inverters to detect islanding conditions and subsequently disconnect from the system. This project performed islanding tests across several thousand inverters in the laboratory enabling the capture of a vast library of islanding experiments. These results and the analysis code used to distill them into insights are in the public domain to accelerate and inspire future work. The findings from the project were shared with the utility industry at Distributech 2016, and PG&E has already modified some of its interconnection guidelines to make use of the insights from the project. A PG&E stakeholder explained that the project *"gives us additional information on potential impacts … it is going to allow more of them (solar PV projects) to be interconnected and have higher penetration by reducing the streamlining requirements and reducing the cost allowing more solar to be interconnected".*

- **Project 19 - Screening Distribution Feeders: Alternatives to the 15% Rule**. CPUC Rule 21 is an interconnection procedure for California utilities to follow for distributed generation application reviews. The goal of this project was to conduct detailed feeder analysis to help improve CPUC Rule 21 as penetration levels and interconnection requests continue to increase. The "Alternatives to the 15% Rule" found in this project more properly address the impacts from distributed generation than the existing CPUC Rule 21, and several improvements were suggested. Several of these recommendations were adopted in subsequent improvements to CPUC Rule 21.
- **Project 25 - Standard Communication Interface and Certification Test Program.** This project was conceived in reaction to the proposed revision of CPUC Rule 21, and revision of the IEEE P1547 standard, which has served as the basis for grid codes throughout North America. The project sought to assess the potential for solar inverter manufacturers to mass-produce and certify products that could use a common communication interface to improve interoperability of products on the market. As a direct result of this project, revisions either have been made or are being planned for several key standards related to inverter technology and interconnection including:

    - UL1741 SA - tests and certifies inverters and other utility interconnected distributed generation (DG) equipment for grid support functions enabling smarter, safer, reactive grid interconnection. (Project 25)
    - IEEE 1547a - Amendment establishing updates to voltage regulation, response to area electric power systems abnormal conditions of voltage and frequency, and considering if other changes to IEEE Standard 1547 were necessary. (Project 25)
    - IEEE 1547 - Full Revision providing a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). The standard provides requirements relevant to the interconnection and interoperability performance, operation and testing, and to safety, maintenance and security considerations. (Project 25)
    - IEC 61850-7-420 and IEC 61850-7-520 - revisions in TC57 WG17 establish communication and information exchange protocols for interconnected DER technology. (Project 25)

We spoke with stakeholders from utilities and regulatory agencies, as well as industry stakeholders, with knowledge of these and other CSI projects to elicit their opinions about the impact of the Program on standards and rules resulting in lower cost solar projects and higher penetration of solar PV. Overall, the interviewees believed that the CSI Program projects led to improved rules and regulations that have decreased costs and led to or will lead to higher penetration of solar resources. Once stakeholder noted that:

> *"you can tell that the program had an impact because if there wasn't positive progress with these programs then we wouldn't go from 33 percent to 50 percent penetration goals. The regulators' exposure to the outputs of CSI and other research doing this has helped the regulators, grid operators, and utilities be more sure about the impact of DERs on the grid, and I think that they feel comfortable now, and this opportunity (CSI) definitely has helped advance the opportunity for higher penetration."*

Another regulatory stakeholder with strong knowledge of the CPUC Rule 21 process stated that

> *"a number of the (CSI) projects were relevant to our work as I remember and Rule 21, overall, found a high value from these projects in terms of pushing ahead with grid integration and becoming comfortable with pushing limits on the grid".*

Lastly, an industry stakeholder from a prominent standards organization stated that

> *"I am sure that everybody who participated in the program had some really good exposure to excellent projects and not only the participation but also having big knowledge gains in those participating. All the participants are probably going to be looked at as some of the experts and working on the early implementation will help with … it (CSI) will certainly impact inverter manufacturers and communications companies and should help other BOS and other component manufacturers develop products in the future having standard communication language and testing protocols. I think it has been a very valuable program and has impacted the DER market positively. You know a lot of other states and PUCs follow California's lead and in this case, other states will be impacted by this research. You look at Hawaii as a test case and they are going through what California is planning for, so I think the project overall was excellent and it did very well and is very timely".*

Overall, experts and stakeholders generally expressed opinions that Grid Integration project outputs have simplified or improved or will simplify or improve standards and rules, resulting in lower cost and greater penetration of grid connected solar.

Expert and stakeholder opinion on whether recommendations can contribute to improved technical guidelines resulting in lower cost, greater penetration of grid connected solar (Logic Model Cell #28)

Progress Assessment – High

Several grid integration projects developed recommendations to improve technical guidelines and interconnection processes for solar projects to lower costs and increase penetration levels. Similar to opinions about changes to standards and rules, stakeholders from utilities and regulatory agencies, as well as industry stakeholders, suggested that the Program projects resulted in important recommendations that would improve technical guidelines. One regulatory stakeholder had the opinion that

> *"I think definitely there has been (a change in the level of awareness, or visibility, of the progress being made in solar RD&D at my organization), and I think this also comes back to the synergistic relationship between the programs like CSI, PIER, and EPIC and the relationship to the policy environment in California. I think the projects help inform policy recommendations at the energy commission and regulatory decisions at the CPUC, and help inform the integrated resource plans that look at increasing DERs or other renewables on the grid. The foundational work that CSI did has helped significantly and you can really point to the movement now of the levels of DERs on distribution systems and attribute a lot of that progress to the CSI program and programs like PIER and EPIC as well. I think this type of research is essential to providing information to policy makers and regulators to help make these decisions".*

Overall, experts and stakeholders generally expressed opinions that Grid Integration project recommendations have contributed or will contribute to improved technical guidelines resulting in lower cost and greater penetration of grid-connected solar.

Appendix D: Solar Technologies Analysis Detail

Introduction and Background

The success of the overall CSI program depends on increasing performance and efficiency of solar technologies in the market. The CPUC CSI RD&D strategy adhered to seven key principles which included improving the economics of solar technologies by reducing technology costs and/or increasing system performance, focusing on issues that directly benefit California and that may not be funded by others, and overcoming significant barriers to technology adoption. Barriers include high up-front cost, which remains the single largest barrier to widespread adoption of solar technologies, and the innovation "valley of death." By targeting RD&D activities at those barriers or opportunities that promise high impact but are currently under-funded, distributed solar applications could become more widespread.

In particular, the CSI RD&D Program looked to improve and support commercialization of technologies that were at a near commercial stage, rather than prototype technologies. One CPUC staff member involved in the original program design noted that

> *"CSI Program staff tried very hard to embody the idea that we are using ratepayer funds and we want to make a lot of difference with a little money. A part of this philosophy was we tried to leverage money being spent by DOE or CEC or others and build on those projects but take a different approach or different aspect of the research to not duplicate efforts. We had modest expectations and knew we weren't going to be changing things hugely but thought we could target funds and make a large impact for our dollars. So we tried to focus on projects that weren't early and find things that were closer to market and push toward the overall market transformation of the industry".*

By supporting these technologies the overall goal is to increase performance and efficiency of solar technologies in the market to improve the economic value of solar technologies and reduce barriers to market adoption of promising technologies should be met.

Overall, the CSI RD&D projects had varied success in developing and demonstrating viable pre-commercial solar technologies and helping them advance to market. Of 12 projects, two are likely to have long-term market impacts in terms of direct sales of new technology, with several others having the potential to have indirect impacts on the market in terms of knowledge transfer. However, the two projects that are likely to have long-term impacts are also likely to have significant impacts on the development of battery storage and on reducing soft costs of mounting units and permitting.

The CPUC identified Solar Technologies development as a key focus area for the CSI RD&D Program, where the Program could provide high value for grant funds. Solar Technologies was a primary focus in Solicitation round 2, and a secondary focus in rounds

4 and 5. These program solicitations instructed applicants to engage in activities focused on the needs or areas of knowledge gaps detailed in Table 49 below.

Table 49: Solar Technologies Needs And Knowledge Gaps

Area of Need	Description
Projects demonstrating "economic viability of distributed concentrating PV systems"	The CSI RD&D strategy identified concentrating photovoltaic (CPV) systems as an important technology for the success of the CSI Program that depended on increasing performance and efficiency of solar technologies in the market. Distributed solar is currently constrained by the size of a roof or available land to site the system. More efficient solar cells, inverters, and wiring solutions will decrease the overall size of the system, thus allowing greater potential for more generation.
Projects that help "building integral PV products (BIPV) become competitive with rooftop PV" and which address "key technical integration issues"	Developing innovative PV materials or methods of integrating PV into buildings are also highly promising methods of reducing the cost of PV systems and/or expanding the market for them, by, among other things, reducing material and production costs and allowing more of a building's surface to be used.
Testing and demonstrating inverter technologies that improve reliability or performance of solar systems and help lower costs	Inverter technology has the potential to address barriers to adoption of solar technology in terms of mitigating the impact of solar penetration on the grid, and increasing control over power flow from solar PV to provide value to utilities and ratepayers. In particular, the CSI RD&D Program focused on advancing inverters that demonstrate longer periods between failures, that demonstrate lifetimes approaching the expected twenty-year lifetimes for modules, that have lower capital costs and lower operating and maintenance costs, and have the potential for better integration with smart meters.
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems and that allow the end user or utility to capture higher value from the energy produced (e.g., provide energy during peak).	Solar storage technology has the potential to convert solar PV resources into reserve resources. To support progress to this goal, and to improve the value of solar to utilities and ratepayers, the CSI RD&D Program encouraged near-term testing and demonstration of innovative energy storage technologies, storage technologies suitable for community or multi-user applications, and solar thermal/electricity storage systems recently developed under DOE funding.
Field-testing and demonstration of innovative hybrid-solar technologies.	Possible examples of hybrid-solar technologies include: • Solar thermal/solar electric technologies that can increase the economic or greenhouse gas benefits being provided by current solar technologies • Concentrating solar systems that can increase production for larger commercial applications • Solar/non-solar combinations (e.g., fuel cells/solar applications) that may help extend the energy benefits provided to the end user in a cost-competitive manner

A total of 12 of the 34 completed projects included a solar technology improvement or advancement component. These projects are listed along with their funding amount in Table 50.

Table 50: Solar Technologies Project List

Solicitation - Project ID	Project Name	Grantee	CSI Funding	Match Funding	Total Funding
2 – 9	PV and Advanced Energy Storage for Demand Reduction	SunPower	$1,475,000	$937,990	$2,412,990
2 – 10	Improved Cost, Reliability and Grid Integration of High Concentration PV Systems	Amonix	$2,139,384	$3,157,000	$5,296,384
2 – 11	Solaria: Proving Performance of the Lowest Cost PV System	Solaria	$1,217,500	$1,217,500	$2,435,000
2 – 13	Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results	BIRAenergy	$1,000,000	$932,500	$1,932,500
2 – 14	West Village Energy Initiative: CSI RD&D Project	UC Davis	$2,500,000	$1,245,000	$3,745,000
2 – 15	Advanced Grid-Interactive Distributed PV and Storage	Solar City	$1,774,657	$931,187	$2,705,844
2 – 16	Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery	SunLink	$996,269	$927,031	$1,923,300
2 – 17	Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology	Cogenra	$1,467,125	$2,773,304	$4,240,429
4 – 25	Standard Communication Interface and Certification Test Program	EPRI	$885,675	$1,016,693	$1,902,368
4 – 27	Demonstration of Locally Balanced ZNE Communities Using DR and Storage and Evaluation of Distribution Impacts	EPRI	$1,485,476	$2,155,000	$3,640,476
5 – 36	Comprehensive System Assessment of the Smart Grid-tied Energy Storage System Using Second-Life Lithium Batteries	UC Davis	$100,000	$36,917	$136,917
5 – 37	Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition	CPR	$99,660	$99,660	$199,320

Across the 12 projects, 27 discrete outputs were delivered to meet the identified industry needs. Table 53 below presents a summary of the program identified needs and the projects that developed outputs that were designed to meet those needs:

Table 51: Knowledge Gaps and Areas of Need and Corresponding Project Activities

Area of Need	Project ID	Key Project Activity Examples
Projects demonstrating "economic viability of distributed concentrating PV systems"	10, 17	• Manufacture and installation of concentrating PV systems • Modeling and analysis tools developed for concentrating PV • International standard developed • Installation and demonstration of innovative concentrating photovoltaic/thermal co-generation (CPV/T-2G) technology
Projects that help "building integral PV products (BIPV) become competitive with rooftop PV" and which address "key technical integration issues"	27, 35	• Enhancement of existing building modeling software • Construction of demonstration sites of 20 ZNE homes
Testing and demonstrating inverter technologies that improve reliability or performance of solar systems and help lower costs	25	• Development of smart inverters and accompanying communication protocol
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems	9, 14, 15, 26, 36	• Development and demonstration of new energy storage technology • Development and deployment of control software
Field-testing and demonstration of innovative hybrid-solar technologies	9, 11, 14, 37	• Development and demonstration of hybrid solar technologies • Installed and monitored a 110 kWh photovoltaic tracking system yield testing performance of hybrid solar technology
Other	13, 16	• Development and demonstration of other innovative solar technologies • Development and deployment of software system that automates the BOS component engineering and documentation for optimized PV array

A complete description of all outputs is not practical in this report, but a summary of the 27 unique outputs is provided in Table 52 below. Outputs include 11 hardware technologies including concentrated PV, storage, and hybrid PV technologies; five software platforms; and eight demonstration sites.

Table 52: Solar Technologies Outputs by Project

Solicitation - Project ID	Output Type	Output Description
2 – 9	Technology - Hardware	Advanced energy storage system: Ice Energy (thermal storage)
	Demonstration	Demonstration and field test for Ice Energy thermal storage
2 – 10	Technology - Hardware	Amonix high concentration photovoltaic (HCPV) system
	Demonstration	Amonix manufactured and installed 2 CPV units rated at 113 kw as demonstration sites at UC Irvine
	Modeling Tool	UCI's APEP developed a central power plant and CPV dynamic models for system operation
	Standard	International standard defines a test sequence to detect CPV module failures associated with field exposure to thermal cycling
2 – 11	Technology - Hardware	Solaria modules: single axis, dual axis and polar axis
	Demonstration	Two demonstration sites with Solaria modules, a 110 kWp system at the Solaria manufacturing facility in Fremont, CA and a 240 kWp system installed at Alameda County Santa Rita jail in Dublin, CA
2 – 13	Technology - Hardware	Low-cost P&P PV Kit - "plug & play" AC micro-inverter PV system
	Demonstration	Installation in six test homes. Updates to installation protocol and P&P PV kit after prototype install. Installation, monitoring and performance evaluation of the installations
2 – 14	Technology - Hardware	Battery buffered electric vehicle charging station
	Technology - Hardware	Second-life batteries for application in single-family homes
	Technology - Hardware	Innovative hybrid photovoltaic/thermal (PVT) technologies and designs for solar hot water in multifamily and single-family applications
	Demonstration	Demonstration site with installations of three technologies
2 – 15	Technology - Hardware	Develop advanced stationary battery product combining Tesla Motors' vehicle battery with SolarCity's SolarGuard dispatch and monitoring platform, to create a firm, dispatchable, grid-interactive storage solution
	Technology - Software	Advance communication and control technology platform
	Demonstration	Demonstration of communication and control technology platform and advanced lithium-ion battery storage technology at six sites
2 – 16	Technology - Software	Automated array design and engineering software for rooftop solar installations - Sunlink Design Studio (SLDS)

Solicitation - Project ID	Output Type	Output Description
	Study	Seismic testing and analysis of rooftop solar arrays
2 – 17	Technology - Hardware	Hybrid concentrating PV/thermal tri-gen (CPV/T-3G) technology
	Demonstration	Demonstration system installed at Sonoma Wine Company in Graton, CA rated at 272kw
4 – 25	Technology - Software	Inverter communication driver software that bridges the field bus protocol used by the inverters (Modbus) to the wide area network protocols used by the utility network (IEEE 2030.5 and OpenADR)
	Technology - Software	Test framework software, including test scripts and test lab automation technology, to test inverters complying with CPUC Rule 21
	Technology Hardware	Prototype advanced smart inverter
4 – 27	Demonstration	Demonstration of cost effective technology pathways for ZNE communities
5 – 36	Technology - Hardware	Comprehensive system assessment of the smart grid-tied energy storage system using second-life lithium batteries
5 – 37	Technology - Software	Development and delivery of an interactive software platform that provides actionable insights regarding plug-in electric vehicles

While CSI RD&D Grid Integration projects nearly all met or exceeded their objectives, some of the Solar Technologies research area projects struggled to meet their objectives for a variety of reasons. This is not entirely surprising, as development and demonstration of technology can often face more hurdles than some of the more research-oriented outputs associated with the Grid Integration projects. While there were some projects that struggled, there were also some notable strong successes. Below is a brief summary of projects that did not meet all objectives.

Projects with Challenges During Or Shortly After Project

- **Project 2-9: PV and Advanced Energy Storage for Demand Reduction**. The original objective of this project was to demonstrate solar PV combined with three different energy storage technologies; however, the project experienced some technical and contractual difficulties. The initial installation site partner withdrew from the project, requiring a search for other sites. Two other sites were identified. One of those two sites provided data of limited value, while the second site experienced several technical difficulties, with the host ultimately asking that the equipment be removed from the site and the demonstration be cancelled. Ultimately, only one technology from Ice Energy was demonstrated with limited success.

- **Project 2-10: Improved Cost, Reliability and Grid Integration of High Concentration PV Systems.** Amonix (now Arzon Solar) was able to complete most grant tasks, demonstrating the technical viability of concentrating photovoltaic (CPV) technology, making progress into addressing some of the barriers to adoption of CPV, and developing an international standard for fault detection in CPV systems. However, the CPV industry in general was faced with significant economic challenges with the precipitous drop in the cost of solar PV, resulting in an inability for CPV systems to compete in the present market. This has resulted in a decline in the CPV industry that resulted in Amonix declaring bankruptcy. Arzon Solar is still in the marketplace.
- **Project 2–17: Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology.** This project met all stated objectives, with Cogenra demonstrating the benefits of tri-generation technology. The commercialized Cogenra product is installed at over 10 sites in California. However, SunPower has since acquired Cogenra, and this hybrid PV/T product has been discontinued. Despite this, some of the technology developed through the research project forms the basis of a new, lower cost panel line for SunPower.

Project outputs all have a development lifecycle that includes initial concept development, testing and validation of performance in operational environments, and industry adoption. Once adopted, the outputs should have effects on the adopting organizations and the industry more broadly, including lower generation costs, increased competition in the market, and clean jobs. However, identifying the effects of CSI RD&D Solar Technologies projects is made difficult by the varying development stages of the outputs; project outputs from earlier solicitations have been available to the industry for longer than outputs from later solicitations, including some outputs that have been available for less than one year. Despite these challenges, we are able to identify projects with significant success and subsequent market uptake, as well as projects that were less successful.

Assessment Stage – First Order Outcomes (Short Term)

'First order outcomes' refers to results or effects of the unique project outputs on the market in the immediate to short term (0-4 years). We identified a mix of quantifiable and qualitative metrics by which to identify and measure first order outcomes from Program projects.

Based on the nature of the Solar Technologies projects, we identified particular areas of potential effects in our metrics. Table 53 summarizes our progress assessment of the program portfolio in each metric. Following the table, we summarize the progress in each key metric and how the outputs from the Solar Technologies project portfolio have or may influence each area in the short term.

Table 53: Solar Technologies Short Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
# of technology outputs with documented performance characteristics in operating environment	16
# of technology outputs installed or applied commercially	11
Stakeholder acceptance/perceived reliability	High
Validation of objective performance characteristics in operating environment	High
Sales / transfer of ownership of hardware/software (i.e., sales of product license – for open/free public use or privately held)	Mid
Increased technology production, sales, and/or revenues, and installations	Mid
Full scale technology production, ongoing growth of installations	Mid

# of technology outputs with documented performance characteristics in operating environment / # of technology outputs installed or applied commercially

Project outputs have a development lifecycle that includes development, testing and validation of performance in operational environments, and industry adoption.

Of the 16 hardware and software technologies investigated under the CSI RD&D projects, 11 were specific products being field tested and improved with a view to some form of dispersion to the wider market, either as proprietary products or as open source or public resources. The remaining five technologies were being field tested to determine viability in specific applications. Of the 11, which include six hardware technologies and five software technologies, all have had some form of broader installation in the market. However, three of the hardware technologies—Amonix CPV, Cogenra's Tri-Generation technology, and GE's Plug and Play AC PV panels—have been discontinued. The three remaining hardware technologies—the Solar City/Tesla lithium ion battery storage technology, Solaria's low cost solar PV panels, and Ice Energy's ice battery—have all seen high degrees of market adoption relative to their applications. The five software technologies have each been applied commercially to some extent.

Stakeholder acceptance or perception of reliability

Progress Assessment – High

Where possible, the evaluation team asked stakeholders and experts for their assessment of the technologies, whether they perceived the technology as reliable or not and whether they accepted the results of the studies as reliable, based on the project outputs. It was not always possible to identify a specific stakeholder for each technology, in which case we relied on the combined perception of the grantees and the program manager, Itron. Table 54 below presents an assessment of stakeholder, grantee or program manager acceptance or perception of reliability. We give each project a score of 1 to 3 where a score of 1 represents low acceptance or perception of reliability and a score of 3 represents high acceptance or perception of reliability.

Table 54: Stakeholder Acceptance or Perception of Reliability Score

Solicitation - Project ID	Stakeholder Score	Grantee Score	Itron Score	Average Score
2 – 9		2	1	1.5
2 – 10	2		1	1.5
2 – 11		3	2	2.5
2 – 13		3	3	3
2 – 14	3		2	2.5
2 – 15	3	3	3	3
2 – 16	3	3	3	3
2 – 17			3	3
4 – 25	3	3	3	3
4 – 27	3	3	3	3
5 – 36		2	2	2
5 – 37		3	3	3
Score	**2.83**	**2.77**	**2.42**	**2.58**

Stakeholders, grantees and the program manager perceived the results of the projects (with the exception of five of the projects) and the technologies to be reliable.

Validation of objective performance characteristics in operating environments

Progress Assessment – High

Each of the technologies in the 12 projects underwent field-testing and validation either in an operational or demonstration site environment. The only exception is Project 25 which is a recently completed project; the software outputs have to date only been applied in a laboratory testing environment. Table 55 indicates whether a project conducted validation in an operating or other environment.

Table 55: Validation Environment

Solicitation - Project ID	Validation in Operating Environment	Validation in Other Environment
2 – 9	Yes	
2 – 10	Yes	
2 – 11	Yes	
2 – 13		Demonstration Site
2 – 14		Demonstration Site
2 – 15	Yes	
2 – 16	Yes	
2 – 17	Yes	
4 – 25		Laboratory Testing
4 – 27		Demonstration
5 – 36		Demonstration
5 – 37	Yes	

In general, performance characteristics were successfully validated with the following exceptions:

- **Project 2-9: PV and Advanced Energy Storage for Demand Reduction**. The original objective of this project was to demonstrate solar PV combined with three different energy storage technologies; however, only one technology from Ice Energy was demonstrated with limited success.
- **Project 2-11: Solaria: Proving Performance of the Lowest Cost PV System**. The original intent of this research was to install low-cost CPV panels on four different types of trackers at four locations in collaboration with the California Construction Authority (CCA). The CCA backed out of the project, so new demonstration sites had to be identified. Solaria installed and metered modules on two types of trackers (single axis and horizontal axis) at their headquarters and azimuth trackers at the

Alameda County Santa Rita jail. Performance analysis was completed, which provided the groundwork for additional Solaria products and installations.

Aside from these projects, all other projects performed according to the expectations of the project teams. Some notable findings include:

- Project 10 produced the first international lifetime reliability standard for CPV.
- Project 11 showed that Solaria's Low Concentration PV technology works best in high irradiance environments by design, but still performs in cloudy or overcast environments when a high concentration ratio technology would shut down,. Also proved that soiling does not affect the Solaria module in any manner that would be quantifiably different from standard modules, as far as power output is concerned.
- Project 13 provided a solid proof of concept and practical implementation for Grid-Ready Plug-and-Play PV Kits and demonstrated that this technology can be installed entirely by a trained roofing contractor. The GE version was estimated to have an installed cost below $4/watt (well below the target cost), assuming a 1,000-unit production volume. Testing also found that AC P&P PV Kit arrays are relatively insensitive to shading, compared with the typical DC string arrays. This could be a very important factor in energy production and cost-effectiveness in the retrofit market, where shading is a prevalent problem.
- SolarCity and Tesla were able to design, develop, and install both residential and commercial advanced lithium ion products. Throughout the process, there were many insights gathered on important product specifications, code requirements, installation process and customer feedback. These insights have influenced various policy and regulatory settings that are currently determining the future of paired PV and energy storage products, including conducting a series of UL site certifications, leading to draft standards for integrated storage products. (Project 15)

Sales/transfer of ownership of hardware/software (i.e., sales of product license – for open/free public use or privately held)

Progress Assessment – Mid

As noted in the proposed CSI RD&D Plan, *"success of the CSI program depends on increasing performance and efficiency of solar technologies in the market."* In the adopted CSI RD&D Plan, production technologies are those "supporting commercialization of new PV technologies." An indicator of success for production technologies is whether or not they progress to being commercialized and experience some sales volume or licensing. This metric and the following three metrics all address the level of commercialization of products from initial sales and/or transfer of ownership of products, to increased technology production, and on to full-scale production. This metric assesses if there have been any initial sales of technology, use of software, transfer of ownership or technology licenses, or other activities that have led to sharing knowledge or technologies with a wider range of users who can further develop and use the technology in new products or processes. Table 56 below indicates if any projects have either had initial sales of products or have engaged in any form of licensing on knowledge transfer leading to development of products by other parties.

Table 56: Initial Sales Of Products Or Licensing or Transfer Of Knowledge

Solicitation - Project ID	Product Has Commercial Sales	Project Output Has Licensing or Transfer Of Knowledge Leading to Other Product Development
2 – 9	Yes	No
2 – 10	Yes	Yes
2 – 11	Yes	Unknown
2 – 13	Yes	Yes
2 – 14	No	No
2 – 15	Yes	Unknown
2 – 16	Yes	Yes
2 – 17	Yes	Unknown
4 – 25	No	Yes
4 – 27	N/A	N/A
5 – 36	No	No
5 – 37	Yes	Unknown

Eight of twelve projects have had at least one commercial sale of a product indicating a high initial success rate (~66%) of moving pre-commercial technology to validated commercial technology. Project success rates in R&D are a function of the level of inherent risk in the projects selected; however, a success rate of 66 percent is likely to be relatively high for an R&D project.

Increased technology production, sales and/or revenues

Progress Assessment – Mid

The next stage of assessment is whether a technology has moved beyond initial commercial sales and experienced increased investment in production, increased sales or increased revenues. Because the timing of this evaluation occurs as some projects have either recently finished or have yet to finish, we will only assess the progress in this metric for projects from Solicitation 2. We reviewed the project final documentation, spoke with stakeholders and market actors, and conducted Internet research to determine if technologies experienced increased sales or production beyond initial commercial sales. Table 57 below presents an assessment of increases in sales after the program participation ended, for each project in Solicitation 2.

Table 57: Initial Sales Of Products or Licensing or Transfer Of Knowledge

Solicitation - Project ID	Increased Production or Sales	Description of Increased Production or Sales
2 – 9	No	While Ice Energy continues to manufacture and sell its technology successfully (over 1,000 units installed), Sunpower did not partner with any of the storage partners to develop technology. Sunpower did take lessons learned from the project and apply it to new technology, but there were sales connected to this project explicitly.
2 – 10	Partial	From the start of the project, Amonix installed approximately 50MW of CPV globally, however, Amonix was liquidated in 2014 before the end of the project and assets purchased by Arzon Solar.
2 – 11	Yes	Developments in the project led to installation of approximately 30 MW worldwide, but only 1 MW installed in California. Solaria developed additional products including NEXTracker, partly based on lessons learned in this project.
2 – 13	No	GE stopped production of the Grid-Ready Plug-and-Play PV Kits before commercialization. Other industry manufacturers such as LG have similar products.
2 – 14	No	N/A
2 – 15	Yes	SolarCity and Tesla partnered to deploy 350 units of combined PV and battery storage units based directly on outputs of this project through the CA SGIP incentive program.
2 – 16	Yes	Sunlink developed a rack mounting system for flat commercial roofs that can avoid roof penetrations as a result of this project. The project provided an AutoCAD add-in tool to design the racking and test it for seismic stability, resulting in a reduction of BOS costs. The data from the seismic tests support revisions to the standards for rack mounts throughout the industry.
2 – 17	Yes	The Cogenra SunPack product was installed at approximately 20 sites after the project. Sunpower acquired Cogenra in 2015 and discontinued the SunPack product. Technology developed through SunPack development is used in SunPower products, including in their Performance line of products.

Of the eight projects in Solicitation 2 that had a solar technology component, four saw increased production and sales after the project with products related to project research. Two of these companies were acquired by other solar companies, which discontinued their products but used the technology in other commercially available products. Two Solar Technologies projects, Project 15 and Project 16, developed commercially viable products. The viability of these products is evidenced by significant sales increases of the products that were direct outputs of the CSI RD&D funded projects.. Project 15 in particular, a partnership between SolarCity and Tesla, developed technology that has led directly to Tesla's PowerWall product, their flagship residential storage product, and SolarCity's GridLogic platform and storage control software, both of which are widely used.

Full scale technology production, ongoing growth of installations

Progress Assessment – Mid

As noted above, two projects have led to full-scale technology production and ongoing growth of installations—Project 15 and Project 16. Two other projects—Project 11 and Project 17—have contributed to the development of other technologies and commercial products.

Project 15 - Advanced Grid-Interactive Distributed PV and Storage. As noted above, the technology deployed and demonstrated in this project has directly led to new products from Tesla and SolarCity. According to a stakeholder, during the grant project lifetime, Tesla took the battery storage pack and control software through one and a half generations, which led to a product that was installed in 350 homes under the SGIP program. This technology then led directly into the PowerWall and PowerWall 2.0 products from Tesla that have been available for sale since the beginning of 2015. This same stakeholder noted that

> *"The key impact is that because of this grant funding, the deployment of residential power storage at scale was likely accelerated by some amount – arguably by a couple of years. It is a product that came to fruition that much earlier at scale" [*and through the grant] *"we were able to learn what were the meaningful product requirements and system level requirements for a successful residential energy storage deployment, and we absolutely view energy storage as a technology that adds value to the operation of solar on the grid. It very clearly defined for us what is necessary for a battery system to be designed, owned and operated and how to reduce soft costs. Even fundamental things like that battery packs may be wall mounted in residential applications. A lot of the details that are ultimately the difference between $1,000 kWh energy storage and $200 kWh energy storage. Another innovation was that this project saw the initial genesis of SolarCity's communication and control platform for energy storage, and learning what are the features necessary for fleet aggregate control of energy storage*".

Project 16 - Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery. The project led to new and improved Sunlink products as well other racking system manufacturers. One stakeholder noted that "our experimental data got traction and got published and other racking manufacturers were able to use that approach as well. So we were not the only racking system on the market that could use the method—it became an option for any manufacturer to use so systems in California became cheaper and easier to install based on our work”. In addition, a startup software company spun off from the project and developed an automated design software incorporating lessons learned from the project.

Growth in solar company profitability, stock price or improved investor sentiment

Progress Assessment – Low

It is difficult to directly tie growth in solar company profits to CSI projects. One stakeholder noted that the relationship between Tesla and SolarCity that developed around the joint work on energy storage is certainly one of the reasons why Tesla has offered to buy SolarCity, which has an impact on the performance of Tesla. Tesla was expected to sell 168.5 megawatt-hours of energy storage systems to SolarCity in 2016, up from 25.8 megawatt-hours in 2015. This represents a revenue increase from $8 million to $44 million. Other companies such as SunPower and Sunlink that have developed products from the CSI RD&D Program project research are likely to see increased revenues and therefore improved company performance; however, attributing any improvements to CSI projects is not possible.

Assessment Stage – Second Order Outcomes

'Second order outcomes' refers to results or effects of project outputs on the market in the long- to mid-term (5-10 years). We primarily rely on qualitative metrics informed by project personnel and stakeholders to identify and assess second order outcomes from the program projects.

Table 58: Second Order Outcome Progress Assessment

Key Metric	Progress Assessment
Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems.	Mid
Funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software.	Low
New financing options offered/new innovative business models arise for technology distribution.	Low
Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process.	Mid

Higher penetration of solar technologies. Greater breadth and volume of cost-effective applicability of solar systems.

Progress Assessment – Mid

While there are only two projects with organizations actively moving forward with technologies directly related to the CSI RD&D Program project outputs, Project 15 and Project 16, these two projects have the potential to have a significant impact on the penetration of solar technologies. The Tesla/SolarCity partnership has led to development of one of the industry-leading storage products on the market that is seeing significant increases in penetration. The advancements made in this project that are likely to impact solar and battery storage penetration in the future include:

- **Moving the industry toward lithium ion battery technology.** As noted by a stakeholder with knowledge of the Tesla/Solar City project, the industry "was not focused on lithium ion batteries (LI Ion) but were focused on other chemistries – lead acid, flow batteries and a few other tech. We found that the charge cycling and weight and form factor benefits were immensely beneficial from going to LI Ion."
- **Identification of key areas of cost savings.** One of the important innovations according to a grant partner was

  "a lot of cost, rather than coming from the cost of the cells themselves, comes from how the system as a whole was packaged; by that, I mean not just putting cells into a battery pack but then taking that DC battery pack and pairing with an inverter, and then integrating with the grid or an energy control system. We found that there were many other groups trying to do energy storage that were two to four times the cost of what we thought it should be and were able to prove that it should have been. It was very beneficial to SolarCity and the team, not just in things we were publicly publishing in papers but just in many, many private conversations with manufacturers across the industry with equipment manufacturers, inverter manufacturers, battery manufacturers, cell makers. We were able to have conversations with these folks and share an example of where they should be. This has informed products that are becoming available now."

- **Development of certification testing and standards for battery storage.** A project partner noted, "*when we started, the National Electric Code (NEC) almost had nothing in it about certain types of energy storage, especially LI Ion-based energy storage systems. They had lead acid systems, but these are different with regards to voltages, exposure and service. This project and our communication with NEC has informed how we asked for future changes to NEC. And same thing with UL, especially on the Tesla side; there were no UL testing standards for energy storage of the type we were building. So in the project for the first few systems we built, we had to do a series of UL site certifications; these were product certifications because there wasn't a standard. So coming out of that, there are now draft standards. And, the way Tesla and SolarCity have interacted with the standards bodies* *and advised how to form standards has come out of this work, this has been a key step in commercialization of the products and outputs of the project and allows the standards body to be able to do a factory listing of the products".*

In addition to this project, there were other projects that could impact future penetrations of solar technologies, including work on CPV technologies regarding testing and developing standards around these products. If there is a future in which silicon prices increase or other market factors mean that CPV technology become economically viable again, a lot of groundwork has been laid to help advance penetration of these products.

Funding of new projects to develop supporting or ancillary hardware/software, dependent on the newly commercialized hardware/software

Progress Assessment – Low

Aside from the startup created to commercialize output from Sunlink's Project 16 discussed above, we are not aware of any new projects being planned to develop supporting or ancillary hardware or software to support these products. It is possible that there will be further spinoff technology or research, particularly in the software and inverter protocol sphere, that will be needed to support further integration of battery storage or other technologies.

New financing options offered/new business models arise for technology distribution

Progress Assessment – Low

We are not aware of any new financing options or business models arising from these projects, aside from the Tesla/SolarCity model that is already in place.

Increased applicability/usability of solar generation. Growth in types of projects. Shorter and more automated interconnection process.

Progress Assessment – Mid

Advancement in battery storage technology increases the scope to use solar generation by potentially converting solar generation to a reserve resource. Standards developed through these projects can help improve the interconnection process.

Appendix E: Innovative Business Models Analysis Detail

Introduction and Background

The adopted CSI RD&D Plan describes Business Development and Deployment projects as those "supporting the market and end-users." Within this category, the Plan also focuses on "activities that enhance the competitiveness of new technologies, or help reach a 'tipping point' into widespread commercialization." This can include projects that involve testing of technologies or measures that enable streamlining of regulatory processes or standards in ways that allow new products to come to market more quickly at lower cost.

Specific categories of Business Development and Deployment activities identified in the Plan for possible grant funding include:

- Projects where "potential roles for utilities in solar PV, including attractive business models, are identified and vetted with utility companies";
- Projects involving "lower cost, utility grade PV system control, metering, and monitoring capacity developed consistent with *(the)* 1% cost parameter established by the California Public Utilities Commission (Commission) for CSI";
- Projects that "perform field tests to quantify operational risks and benefits of PV"; and
- Projects that "demonstrate improved PV economics using advanced metering, price responsive tariffs (e.g., Time of Use—TOU, Feed in Tariff) and storage."

The CPUC identified Business Development and Deployment as a key focus area for the CSI RD&D Program, where the CSI RD&D Program could provide high value for grant funds. Business Development and Deployment was a primary focus in Solicitation round 2, and a secondary focus in rounds 4 and 5. These program solicitations instructed applicants to engage in activities focused on the needs or areas of knowledge gaps detailed in Table 59 below.

Table 59: Business Development and Deployment Needs And Knowledge Gaps

Area of Need	Description
Demonstrations of innovative ways to lower installation or operations and maintenance costs	Standardization of installation techniques or new approaches for warehousing of parts. Testing and demonstration of low-cost maintenance approaches and trade-offs between automated and manual approaches
Testing and demonstration of virtual net metering approaches	Projects that cut across different geographical/socio-economic strata in such a way that benefits and costs are demonstrated to be shared appropriately among users. Pinpoint significant issues necessary to expand the approach more broadly including but not limited to residential housing developments and the commercial arena and (by testing) help determine appropriate tariffs
Testing and assessment of economic aspects of PV using price responsive tariffs and storage	Projects that meter the energy use and delivery aspects of energy storage used in conjunction with solar systems. Test price responsive tariffs that provide appropriate pricing to higher value energy and that can potentially be expanded to the commercial market place rapidly
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems and that allow the end user or utility to capture higher value from the energy produced (e.g., provide energy during peak).	Testing and evaluation of the economics associated with "unloading" of distribution feeders across more than just a peak hour of a peak day and taking into account capacity values used by utilities in determining feeder upgrades or expansion. Testing that quantifies the extent to which increasing the number of solar systems leads to "flow back"[7] on distribution feeders and the capital and operations and maintenance (O&M) costs incurred by utilities to prevent "flow back". Testing of solar system technologies developed to prevent "flow back" and how their costs compare to utility-based solutions.

A total of 10 of the 34 completed projects included a Business Development and Deployment component. These projects are listed along with their funding amount in Table 60 below:

[7] "Flow back" refers to the movement of electricity from the end user to the utility, which is different from the historically typical flow of electricity from the utility to the end user.

Table 60: Business Development and Deployment Project List

Solicitation - Project ID	Project Name	Grantee	CSI Funding	Match Funding	Total Funding
2 – 12	Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources	Viridity Energy	$1,660,000	$840,000	$2,500,000
2 – 13	Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results	Bira Energy	$1,000,000	$932,500	$1,932,500
2 – 14	West Village Energy Initiative: CSI RD&D Project	UC Davis	$2,500,000	$1,245,000	$3,745,000
2 – 15	Advanced Grid-Interactive Distributed PV and Storage	Solar City	$1,774,657	$931,187	$2,705,844
2 – 16	Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery	Sunlink	$996,269	$927,031	$1,923,300
2 – 17	Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology	Cogenra	$1,467,125	$2,773,304	$4,240,429
3 – 23	Solar Energy & Economic Development Fund (SEED Fund)	SEI	$300,000	$341,150	$641,150
4 – 26	PV Integrated Storage - Demonstrating Mutually Beneficial Utility-Customer Business Partnerships	E3	$815,500	$1,072,980	$1,888,480
5 – 31	Sustainable Energy & Economic Development Fund (SEED Fund)	SEI	$100,000	$60,000	$160,000
5– 37	Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition	CPR	$99,660	$99,660	$199,320

Across the 10 projects, 12 discrete outputs were delivered that fall under the category of Innovative Business Models development and deployment. Table 61 below presents a summary of the market needs identified in the program design, the projects that developed outputs that were designed to meet those needs, and examples of project activities.

Table 61: Knowledge Gaps and Areas of Need and Corresponding Project Activities

Area of Need	Project ID	Project Activity Examples
Demonstrations of innovative ways to lower installation or operations and maintenance costs	13, 16, 17, 23, 31. 37	• Business models and research for new products to lower installation costs and increase PV penetration • Demonstrations and tools to lower installation and O&M costs of existing products • Shared, collaborative, funding and procurement mechanism to lower installation costs
Testing and demonstration of virtual net metering approaches	14	• Demonstration and recommendations for virtual net metering approaches
Testing and assessment of economic aspects of PV and storage using price responsive tariffs including with storage	12, 14, 15, 26	• Case studies of business strategies for optimal tariff decision making (e.g. peak load shifting, PV firming) • Analysis of pricing mechanisms to improve the cost and quality of frequency regulation • Business model development for construction, ownership and operation of community energy systems
Testing and demonstration of energy storage technologies that allow capture of higher value from the energy produced	15, 26	• Testing and demonstration of financing mechanisms for PV and storage • Testing control strategies for energy storage to absorb renewable production variability

A complete description of all outputs is not practical in this report, but a summary of the 12 unique outputs is provided in Table 62 below. Outputs include 11 hardware technologies (including concentrated PV, storage, and hybrid PV technologies), five software platforms and eight demonstration sites.

Table 62: Innovative Business Models Outputs by Project

Solicitation - Project ID	Output Type	Output Description
2 – 12	Testing price responsive tariffs including with storage	This project aimed to optimize and manage DER dispatch schedules in real time, and investigated changes in incentives and tariffs to determine cost-effective strategies to support integration of high penetrations of solar. The project was delayed and did not meet its goals but did test three strategies: peak load shifting, PV firming and grid support. The energy impacts, costs and benefits for each strategy were evaluated against a base case defined by UC San Diego's micro grid status quo.
2 – 13	Innovative ways to lower costs	The goal of this project was the development of a business model for deployment of a nascent PV technology, AC Plug-and-Play Solar PV Kits, which can be installed by roofing contractors without an on-roof electrician. The project was successful and provides a business model and deployment strategies for the integrated solar PV product, and finds that there is market opportunity in the existing home market. The actual test product is no longer in production, but similar products are commercially available.
2 – 14	Testing and demonstration of virtual net metering approaches	A goal of this project was testing business models that incorporate virtual net metering for community level solar resources connected to single-family Zero Net Energy (ZNE) homes. These models may create financial incentives for purchase of community-scale systems capable of serving multiple homes. The models were completed, benefits shown and policy recommendations made.
	Innovative ways to lower costs	A goal of this project was to evaluate alternative business models for the construction, ownership and operation of the UC Davis West Village Energy Initiative system, especially as related to achieving ZNE for the single-family homes for faculty and staff. This included financial modeling of alternative business models, identifying regulatory barriers to adopting alternative business models, and recommendations for implementation of alternative business models. Financial modeling and analysis was completed; however, real world implementation, which was planned, did not occur.
2 – 15	Testing energy storage technologies to capture higher value	This project was designed to test energy storage technology, understand the value energy storage may provide, demonstrate integration of these products with existing solar PV assets, analyze value streams that these dual systems could provide, and identify finance mechanisms that could increase adoption. The project identified and designed pre-commercial technology and demonstrated installation requirements, cost, permitting, and interconnection requirements. The project team designed a control platform that enabled remote control of energy storage devices. Lastly, the project analyzed potential market mechanisms to reduce barriers and increase adoption and provides policy recommendations.
	Testing price	A goal of the project was to identify optimal rate designs and ISO

Solicitation - Project ID	Output Type	Output Description
	responsive tariffs including with storage	Services for maximizing the value of combined PV and storage. Three studies were conducted that 1) investigated the effects of deployment of high-penetration photovoltaic (PV) power on the distribution grid and estimated economic impacts of PV, 2) identified pricing mechanisms to improve the cost and quality of frequency regulation, and studied a market design that will induce regulation providers to bid regulation services competitively, and 3) analyzed strategic behavior between non-generating resources (NGRs) providing fast regulation in reserve markets.
2 – 16	Innovative ways to lower costs	This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. Combined, these efforts are directed at developing automated processes and software to provide to PV installers, allowing general and electrical contractors access to the market where previously, only higher-margin entities were able to gain entry. The project conducted seismic testing and analysis of ballasted arrays. This testing demonstrated acceptable performance, and created a suite of integrated design tools that reduces time to produce accurate, original PV array layouts and improves accuracy and efficient distribution of layout drawing information to all company departments requiring it: Sales, Project Engineering, Project Management, and Operations.
2 – 17	Innovative ways to lower costs	A goal of this project was to validate energy models and develop economic models to calculate the return on investment of Cogenra's cogeneration solar technology. The project validated energy models and developed an ROI tool that uses the energy models to provide detailed and comprehensive project financials internally and to customers.
4 – 23	Innovative ways to lower costs	This project aimed to develop and implement an innovative financing mechanism for regional sustainability projects for municipalities, schools and public agencies to help reduce costs through seed funding, resources and training, and collaborative procurement. The funding mechanism, a revolving loan fund, and formation of an LLC was developed, and 37 public agencies engaged in the process, with 14 public partners signing MOUs to participate. Almost 150 sites were prescreened; 41 of those sites received full feasibility assessments, and 130 MW of viable solar projects were identified across all prescreened sites. 6.8 MW of viable solar projects were included in a collaborative RFP representing 13 public agencies; 4 qualified vendors submitted bids on SEED Fund projects, and 4.3 MW of solar were installed or are under contract. A second round of funding began in 2016.
4 – 26	Testing price responsive	A goal of this project was to develop tangible policy and planning recommendations for high penetration PV and energy storage dispatch

Solicitation - Project ID	Output Type	Output Description
	tariffs including with storage	and to develop tariffs and incentives, program designs and customer outreach strategies for behind-the-meter energy storage. A demonstration site of 34 homes containing Sunverge Solar Integration Systems (SIS)–a 2.25 kW PV system integrated with a 4.5kW/11.7 kWh battery–was established to test SMUD's Demand Response Management System to dispatch the SIS units, including over nine critical peak pricing events and eight test demand response events. Based on the demonstration, the project team developed models to analyze the costs and benefits of PV integrated storage from customer, regional and utility ratepayer perspectives and provided recommendations for program design.
5 – 31	Innovative ways to lower costs	This project was the second phase of Project 4 – 23.
5 – 37	Innovative ways to lower costs	The purpose of this project was to modify and enhance Clean Power Research's existing solar sustained vehicle (SSV) web service and develop an intuitive user interface to include integration of personalized driving and charging habits, separation of technology financing methods, and integration of smart meter (e.g., Green Button) data. These additions are aimed at adding value to detailed analytics and collated market statistics helping to drive action by end-users. The project was completed as planned.

While there were some notably strong successes from among the Innovative Business Models research area projects, others struggled to meet their objectives for a variety of reasons. Below is a brief summary of projects that did not meet all objectives.

Projects with Challenges During Or Shortly After Project

- **Project 2–12: Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources.** The original goal of this project included demonstration of optimization and dispatch strategies in real time, and development of a public cost benefit tool. Due to project delays including delayed availability of demonstration site data, and lengthy software debugging and validation efforts, neither of these activities were completed.
- **Project 2–13: Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results.** This project met all stated objectives, and the project partners demonstrated and documented the potential for innovative business opportunities related to this technology. However, the specific product tested was discontinued by GE and is no longer available on the market. There are other similar products now available that could benefit from the findings of this project.
- **Project 2–14: West Village Energy Initiative: CSI RD&D Project.** The original goals of this project included developing viable business models for deployment of community scale solar, and then working with a third party investor to design, build and operate a community scale solar resource at West Village. The project successfully developed and assessed business models; however, the construction of the housing development that would serve as the customer for the solar project was delayed. Therefore, the second part of the project did not move forward, and the business model could not be implemented.
- **Project 2–17: Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology.** This project met all stated objectives. Cogenra demonstrated the benefits of tri-generation technology, and the commercialized Cogenra product is installed at over 10 sites in California. However, SunPower has since acquired Cogenra and this hybrid PV/T product has been discontinued. Despite this, some of the technology developed through the research project forms the basis of a new, lower cost panel line for SunPower.

Project outputs all have a development lifecycle that includes initial concept development, testing and validation of performance in operational environments, and industry adoption. Once adopted, the outputs should have effects on the adopting organizations and the industry more broadly, including lower generation costs, increased competition in the market, and clean jobs.

Assessment Stage – First Order Outcomes (Short Term)

First order outcomes refer to results or effects of the unique project outputs on the market in the immediate to short term (0-4 years). We identified a mix of quantifiable and qualitative metrics by which to identify and measure first order outcomes from program projects.

Based on the nature of the Innovative Business Models projects, we identified particular areas of potential effects in our metrics. Table 63 below summarizes our progress assessment of the program portfolio in each metric. Following the table, we summarize the progress in each key metric and how the outputs from the Solar Technologies project portfolio have influenced or may influence each area in the short term.

Table 63: Business Development and Deployment Short Term Outcomes – Metrics and Progress Assessment

Key Metric	Progress Assessment
# of business models designed and tested, and validated	6
# of models with documented adoption or likely to be adopted and # of stakeholders adopting models	6
Stakeholders reached/attending demonstrations; percent of target audience reached	Low
Documented evidence that business models will support expansion of cost-effective solar	Mid
Performance of business model in operating environment documented	Mid
Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk	Mid
Increased customer awareness of solar projects; increase in sales growth	Mid

# of business models designed and tested, and validated

The 12 Innovative Business Models outputs developed under the CSI RD&D projects reached different stage of development from theoretical design, to testing and validation in a demonstration or operating environment. The evaluation team reviewed program documentation and results of in-depth interviews with grantees and market actors to categorize the development stage of outputs from each project, among three stages:

- Design only
- Design and testing either through simulation or demonstration
- Design, adoption and validation in operating environment

Table 64 below presents the stage of each output by project.

Table 64: Business Development and Deployment Output Stage

Solicitation - Project ID	Output Type	Development Stage
2 – 12	Testing price responsive tariffs including with storage	Design only
2 – 13	Innovative ways to lower costs	Design and Test
2 – 14	Testing and demonstration of virtual net metering approaches	Design Only
	Innovative ways to lower costs	Design Only
2 – 15	Testing energy storage technologies to capture higher value	Design, Adopt, Validate
	Testing price responsive tariffs including with storage	Design Only
2 – 16	Innovative ways to lower costs	Design, Adopt, Validate
2 – 17	Innovative ways to lower costs	Design, Adopt, Validate
3 – 23	Innovative ways to lower costs	Design, Adopt, Validate
4 – 26	Testing price responsive tariffs including with storage	Design and Test
5 – 31	Innovative ways to lower costs	Design, Adopt, Validate
5 – 37	Innovative ways to lower costs	Design, Adopt, Validate

Three projects (Projects 12, 14, 15) produced outputs that were in the design stage at the completion of the project. Project 12 designed and conducted very limited testing of three strategies for high penetration PV integration: peak load shifting, PV firming, and grid support, and provided recommendations for future studies and potential tariff or rate structures. Project 14 developed alternative business models for community solar projects and developed financial models to test and validate business model designs. Project 14 also provided recommendations for adoption of virtual net metering in single-family residential applications for community solar projects. Project 15 identified and designed utility retail and ISO wholesale rate structures, tariffs and market mechanisms that could help bring combined PV and storage to new markets and help optimize the value of these products.

Two projects included outputs that were designed and then tested in either a simulated or small demonstration environment. Project 13 developed a comprehensive business model design for "plug and play" ready-to-install PV system-kits which included detailed market analysis, value proposition and business strategies, and market surveys, as well as a detailed best practices training program and financial options for residential solar PV and energy efficiency. These outputs were tested through market surveys and a small demonstration activity, and showed promise. Project 26 developed and analyzed highly detailed use case studies based on 34 home demonstration sites, including cost effectiveness and optimal rate design for a combined PV and storage technology. These studies provided important insights into the value of solar and storage systems to utilities and ratepayers, in particular showing that the value of the systems is highly dependent on location and how the systems are operated and controlled.

Performance of business model in operating environment documented

Progress Assessment - Mid

Six projects included business development and deployment outputs that were designed, tested and then validated in an operational environment either end of or shortly after the end of the project. The definition of an operating environment in these cases is somewhat harder to determine than for solar technologies, but we classified outputs as operational if any organizations have formally adopted them in their business strategy or practices. The following points describe, by project, how outputs were operationalized and how they performed in these operating environments.

- **Project 2–15: Advanced Grid-Interactive Distributed PV and Storage.** The primary goal of this project was to test a new energy storage technology, demonstrate strategies to integrate this technology with existing solar assets and into the solar market, analyze the value streams that these systems could provide, and identify market mechanisms by which this value can be accessed. The project was highly successful, with key achievements including demonstration of net benefits to the grid and to customers of the technology, technology developments and best practices that lowered the cost of installation, and development of important insights into product specification, code requirements and other aspects of the technology. Since the end of the project, the project partners have leveraged the findings of this grant to develop fully commercialized products with hundreds of residential and commercial installations in California. One project partner stated that the project "very clearly defined for us what is necessary for a battery system to be designed, owned and operated" and ultimately was highly influential in the development of widely used commercial technology including software control platforms and storage.

- **Project 2–16: Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery.** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. The outputs of the project have been implemented by the project partners in their business operations in product development and design. Implementing the outputs has reduced balance of systems costs for the project partners. Findings from the project have also been operationalized. Findings have been used to inform building code for unattached solar arrays and to help other market actors develop and refine products to reduce overall cost of solar installation.
- **Project 2–17: Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology.** This project validated energy models and developed an ROI tool that uses the energy models to provide detailed and comprehensive project financials internally and to customers. These outputs were used by Cogenra to demonstrate the financial viability of their products. The company has since been acquired by SunPower, and the products have been discontinued.

- **Project 3–23 / Project 2–31: Solar Energy & Economic Development Fund (SEED Fund).** This project developed and implemented an innovative financing mechanism and a collaborative project identification and procurement model for regional sustainability projects for municipalities, schools and public agencies to help reduce costs through seed funding, resources and training, no-cost solar assessments, and collaborative procurement. Two rounds of funding have occurred across two grants. The project was moderately successful and achieved the performance goals set forth in the grant proposal. A second round of funding began in 2016.

- **Project 2–37: Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources.** This project modified and enhanced Clean Power Research's existing solar sustained vehicle (SSV) web service and developed an intuitive user interface to integrate driving and charging habits, financing methods and smart meter data. The end product, WattPlan, was operationalized; with it, California ratepayers can access the PV+EV calculator and enter specific information about themselves to get information that can help them make decisions about purchasing and installing PV systems and purchasing electric vehicles. The PV+EV calculator developed for CSI was launched on September 23, 2015, and was freely available to ratepayers for one year. It is included as part of WattPlan, which is used by several California utilities. Clean Power Research continues to expand and enhance their software offerings.

Across the 10 projects, there were six that resulted in operationalized business models, with the remainder either being tested on a small scale or being contained in program documentation as model designs or recommendations. Some projects appear to have been very successful or have the potential for future success, in particular Projects 15, 16 and 37. However, while these projects and their outputs have positively impacted the project partners, and potentially the broader market, there is little evidence, with the exception of Projects 16 and 37, that there has been widespread awareness or adoption of these outputs beyond the project partners.

Evidence of models with documented adoption or likely to be adopted and # stakeholders adopting models outside project

Progress Assessment - Low

As noted above, aside from Project 16 and 37, there is little evidence of adoption or awareness of project outputs beyond the project partners. The Solar Energy and Economic Development (SEED) fund (Projects 23 and 31) saw some strong engagement with municipalities. Similar organizations or schemes to the SEED fund, such as RE-VOLV have developed, but there is no evidence that this project influenced those schemes. Below is a description of the documented adoptions for Projects 16 and 37.

- **Project 2–16: Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery.** Outputs of this project have been adopted outside the project in two areas. Firstly**,** the outputs have providing basic data and analysis essential for improvements in building codes, which has led to improvements made by the ASCE 7 committee on seismic testing of building components in building codes. Secondly, roadmaps provided by this project can help facilitate the process for other solar companies in the state. One project partner noted that while he could not provide explicit information on other companies using the outputs, he was aware that other manufacturers were using their work to improve their systems, resulting in cheaper and easier installation.
- **Project 2–37: Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition.** Outputs of this project have been widely adopted by CPR utility customers as well as ratepayers. The software was available to California IOU customers for one year ending in September 2016 and has seen very widespread use with over 10,000 customers using the tool within the first three months of it becoming available.[8] All three IOUs, SMUD and other utilities in California and nationwide are continuing to offer WattPlan to their customers.

Beyond these two projects, there was little adoption or evidence of project awareness outside the project teams. Stakeholders we interviewed did not mention business model projects as projects of which they were aware. One stakeholder who was involved in CSI program implementation noted that prior to being interviewed as part of the evaluation, he was not aware of the business model projects, but having reviewed the documentation, noted that the *"business models work is pretty well aligned with what my organization does generally and what I do specifically. I looked at the (CSI RD&D) website having been prompted by this interview; I went and looked and found some stuff that would have been important for our work that I wasn't aware of".* This interviewee was particularly interested in projects related to electric vehicles and virtual net metering strategies.

Documented evidence that business models will support expansion of cost-effective solar

Progress Assessment - Mid

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[8] WattPlan Revealing Savings of Electric Vehicles and Solar in California, New York, Arizona. http://www.cleanpower.com/resources/pr-wattplan-reveals-electric-vehicles-and-solar-savings/

Across the 10 projects with business development and deployment outputs, there is a varying degree of evidence that the outputs will support the expansion of cost-effective solar. Because the outputs of each project are different, we assess the level of evidence for each project, below:

- **Project 2–12:** No evidence that business models will support expansion of cost-effective solar.
- **Project 2–13:** Limited evidence that business models will support expansion of cost-effective solar. Market research conducted as part of the project indicated that the plug and play PV kits can provide a valuable addition to the PV market, based on their performance and relatively low cost, estimated to be $3.99/W installed. In addition, the AC-module design provides the opportunity to open a new sales channel in the retrofit market via roofing contractors. Because the specific product has been discontinued, there is little ongoing work on this technology, with one stakeholder saying that they *"are not aware of any significant development of AC systems but the market seems to be going in the other direction if anything, which is driving everyone to DC, but I think I still stand by my statement that there is a lot of benefit from an AC PV system in the retrofit market".*
- **Project 2–14:** Limited evidence that business models will support expansion of cost-effective solar. The project evaluated various business models to determine an "optimal" model that would promote deployment of community scale solar. While the evaluations were not conducted in an operational setting, there was some evidence that innovative business models could promote development of ZNE homes with community scale solar for close to the cost of traditional housing. A stakeholder in the project explained that although the project did not complete all its objectives, it laid important groundwork "making it much more likely that we will be able to achieve it (ZNE) as we actually build the single family development going forward". It will also help answer the question, "how do we allow for this deep penetration of community distributed solar without breaking the backs of the IOUs because their business model wouldn't allow for it? … and I think the CSI program is very valuable for continuing to explore that".
- **Project 2–15:** Strong evidence that business models will support expansion of cost-effective solar. As part of the project, the project team conducted consumer research and investigated finance options for combined PV and battery storage systems. The project found that a combination of PV and grid interactive storage can achieve substantial cost savings for utilities and end customers, and a key to unlocking the benefits is overcoming the barriers to adoption including upfront costs. The project suggests that similar innovative finance mechanisms that have enabled recent growth in the distributed solar PV industry may help growth in deployments of distributed energy storage systems. Since the project completion, the project

partners have experienced high uptake of their products, indicating that their business models can help support expansion of cost-effective solar solutions. However, we can only make this case for the project partners specifically, not for the wider market.

- **Project 2–16:** Strong evidence that business models will support expansion of cost-effective solar. This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. A major component of up-front solar costs are these BOS costs, which the DOE estimates at 64 percent of total solar costs.[9] The design automation tools and research contributing to building codes in this project have already or will lead to decreased installation costs, which reduces upfront cost of solar systems supporting the expansion of cost effective solar.
- **Project 2–17:** Limited evidence that business models will support expansion of cost-effective solar. This project demonstrated a business model and emerging technology that presents a financially viable cogeneration solar system. These findings are specific to this technology. Cogenra was acquired by SunPower and the product has been discontinued. However, some research from this technology is being applied as part of a new lower cost product from SunPower. Given this, we cannot say there is strong evidence that the business model related outputs of this project will have significant impact.
- **Project 3–23 / Project 5–31:** These projects have supported the installation and expansion of cost-effective solar through collaborative project identification and procurement and financing. Two rounds of funding have occurred across two grants. The project engaged 37 Marin, Napa and Sonoma County public agencies in the collaborative procurement process, which included 143 high-level site assessments and 41 full feasibility studies. The site-screening process identified potential for over 130 MW of solar power installation, including several sites with the potential for utility-scale PV installations. Twenty-five sites across 12 public agencies have entered, or are planning to enter, into purchase or Power Purchase Agreement (PPA) contracts with the selected vendor with a combined total of approximately 5MW capacity. The fund is being replenished and a second round of projects was initiated in 2015; according to a project partner, SEI and Optony are engaging jurisdictions for a third round of projects which will result in at least 12MW of installed solar.

[9] U.S. DOE. 2016. Soft Costs 101: The Key to Achieving Cheaper Solar Energy. https://energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy

- **Project 2–26:** Limited evidence that business models will support expansion of cost-effective solar.
- **Project 5–37:** Strong evidence that business models will support expansion of cost-effective solar. This project's output has seen high adoption by utility customers seeking to purchase PV systems or electric vehicles. While this product is relatively new, the project partners and stakeholders suggest that there is some evidence of increased adoption of solar. One key finding from this project was that 75 percent of surveyed customers indicated that they would rather get information about solar equipment or electric vehicles from the utility and would trust them more than contractors.

Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk

Progress Assessment – Mid

Similar to previous metrics, there is limited evidence that the business development and deployment projects have led to reduced costs of solar projects or reduced risk, and it is difficult to quantify the value of any reduced costs that have been realized. As noted previously, there are six outputs that have been adopted in some form, so we focus on these six projects to identify evidence of reduced cost or business risk associated with the projects.

- **Project 2–15:** Strong evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities. This project suggested similar business models and financing that enabled adoption and deployment of PV be applied to solar storage. Specifically, SolarCity adopted a zero-down, cash-flow positive finance mechanism as the business model for PV product installation, directing private sector tax equity investments toward financing PV system installations that allow customers to benefit from PV for no upfront cost, with an accompanying monthly finance payment that may be lower than their offset utility bill. This helps negate what is regularly seen as the key barrier to deployment of solar PV—a high upfront cost. In addition, third party ownership models, such as solar leases and power purchase agreements (PPAs), allow households that cannot afford to own a PV system to go solar. SolarCity adopted a similar model for combined PV and storage using Tesla's Powerwall product, and with the merger of Tesla and SolarCity, these products are now combined. This structure reduces the upfront cost of these technologies to customers. Battery storage integration provides risk mitigation for homeowners. There is also strong evidence that in theory the combination of PV and grid interactive storage can achieve substantial cost savings for utilities by decreasing reliance on other energy sources, and provision of backup power for an energy user with the potential to shift time of use energy and demand charges.

- **Project 2–16:** Strong evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities. This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. While we cannot assess the actual impact on array costs of this specific project, one stakeholder noted that the work from this project was *"available to any manufacturer to use so systems in California became cheaper and easier to install based on their work"*.
- **Project 2–17:** Limited evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities. This project demonstrated a business model and emerging technology that presents a financially viable cogeneration solar system. According to project documentation, the project led to a 50 percent reduction in materials, installation, and operational cost of the Cogenra product. The product was installed at 20 other sites after this project; however, Cogenra was acquired by SunPower and the product has been discontinued. However, some research from this technology is being applied as part of a new, lower cost product from SunPower. Given this, we cannot say there is strong evidence that the business model related outputs of this project will have significant impact.
- **Project 3–23 / Project 5–31:** Strong evidence that business models will reduce cost of solar projects and increase value of solar PV for municipalities and utilities, and have positive benefits for residents and businesses. As noted, these projects have supported the installation and expansion of cost-effective solar through collaborative project identification and procurement and financing. According to project partners, the project has documented evidence that the SEED fund and assistance can reduce administration costs for jurisdictions by up to 75 percent and reduce procurement costs of solar technology by 10-12 percent due to reaching economies of scale through collaborative procurement. In total, the project team estimates a total installed cost reduction of 10 percent for jurisdictions. These savings, as well as ongoing savings or payment for generation, accrue to the jurisdiction general funds, improving their overall bottom line which has broad benefits for jurisdictions and their residents.
- **Project 5–37:** Limited evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities. While there is not strong evidence that this project and the resulting software would reduce costs of solar or EVs for customers, the goal of the project is to improve the value of

solar and EVs for customers by providing customers with accurate data and recommendations.

Increased customer awareness of solar projects; increase in sales growth

Progress Assessment – Low

There is very limited evidence that the business development and deployment projects have led to increased customer awareness of solar projects or increases in sales growth of products. Of the six outputs that have been adopted in some form, two are likely to have increased customer awareness and increased sales growth, and one is likely to have contributed to increased sales growth. The remaining three have little evidence of effect.

- **Project 2–15:** Evidence of product specific sales growth and customer awareness, although uncertain if this has or will lead to broader industry sales growth or customer awareness of solar PV and storage. The product developed as a result of this project has gone on to have strong, self-sustained penetration in the solar market. SolarCity and Tesla have adopted the business models developed as part of this project, which took the lessons from PV financing and applied them to create a finance program for distributed storage installations. The success of the product and increased sales growth indicate that the business models developed during this project may have contributed to this success, but to what extent is not possible to determine. In addition, based on our research and interviews with stakeholders and project partners, it is not possible to determine if there is spillover from this research to the broader market that has increased sales or customer awareness for other similar products.
- **Project 5–37:** Evidence of product specific sales growth and customer awareness, although uncertain if this has or will lead to broader industry sales growth or customer awareness of solar PV and storage. Research from this project helped develop the WattPlan software platform that allows utility customers to analyze potential savings from electric vehicles, rooftop solar systems or both, to assist with purchase decisions. Furthermore, the research indicated that provision of this software through utility platforms and branding increases customer confidence in results and likelihood of adoption. There has been a high level of utility customer use of the platform in California, which likely has led to increased sales of EVs and solar systems, as well as raised awareness of these products among utility customers.
- **Project 2–16:** Limited evidence that business models will support sales growth cost of solar projects. This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. Upfront cost of solar projects is regularly cited as the primary barrier to adoption. As costs reduce due to the influence of this project, there is

likely to be associated sales growth, but the magnitude of this growth is not possible to determine.

Assessment Stage – Second Order Outcomes

Second order outcomes refer to results or effects of project outputs on the market in the medium to long term (5-10 years). We primarily rely on qualitative metrics, and preponderance of evidence, informed by project personnel and stakeholders to identify and assess second order outcomes from the program projects.

Table 65: Second Order Outcome Progress Assessment

Key Metric	Progress Assessment
Documented (or predicted) changes to grid-connected DG solar market (supply, demand, market infrastructure)	Low
Predicted influence on expansion of PV market opportunities	Low
Likelihood of easier financing of solar projects	Low
Potential for reduction in balance of system costs	Low

Documented (or predicted) changes to grid-connected DG solar market (supply, demand, market infrastructure)

Progress Assessment – Low

As discussed previously, across the ten innovative business model projects, there was varying immediate project success. At least two projects resulted in business model outputs that have already impacted the solar market. The first of these projects provided a business model and financing approach for combined solar storage and solar PV that has pushed sales of a particular product from SolarCity and Tesla, leading to both increased supply and increased demand for this product (Project 15). The business model and financing approach was based on SolarCity's successful models for solar PV including loan programs and power purchase agreements. If similar success is seen with solar storage products, which appears to be occurring given the general success of the product, it is possible the project will impact the overall market structure. The second project, Project 16, developed automated design approaches, as well as recommendations for permitting, and building code that are likely to positively impact the overall cost of solar arrays. Reduced costs resulting from these innovations should increase overall demand for solar PV.

Across the remaining projects, there is limited evidence of direct impacts on long-term supply and demand or changes to the market infrastructure. Projects 37, 23 and 31 could have indirect impact on long-term market structure through increasing demand for solar products among utility customers and municipalities. Other projects that conducted research of rates and tariffs could also contain valuable information that could impact the structure of the energy market, but there is little indication that the intended audience has adopted these outputs.

Predicted influence on expansion of PV market opportunities

Progress Assessment – Low

There is limited evidence to allow us to determine the influence on expansion of PV market opportunities resulting from Innovative Business Models projects specifically. Interviewed stakeholders and experts did not feel like they could definitively predict influence based on these projects. The exception was Project 15, which several interviewees noted as being very successful at developing and promoting behind the meter storage. As we have already documented, sales of these products have been high, indicating that there is potential for expansion in this product area.

Potential for reduction in balance of system costs

Progress Assessment – Low

There is limited evidence to allow us to determine the influence on reduced balance of system costs resulting from Innovative Business Models projects specifically. Again, interviewed stakeholders and experts were reluctant to predict influence based on these projects. The exception was Project 16, which several interviewees noted as impacting the cost of solar arrays.

Appendix F: Knowledge Benefits and Network Analysis Detail

Introduction and Background

The California Solar Initiative RD&D Program (the CSI RD&D Program) was designed to produce benefits to the California solar market, including increased knowledge, awareness and understanding of the market, as well as new processes and supporting policies. This section describes findings covering four distinct areas of knowledge benefits.

1. Relationship building
    - Team composition and capacity
    - Team working dynamics
    - Project partnerships
2. Knowledge dissemination
    - Knowledge exchange activities
    - Efficacy and fit of exchange activities
    - Knowledge spillover and external interest
    - Influential knowledge disseminators
3. Knowledge gaps filled and follow on production
    - Knowledge gaps and application
    - Target audience and knowledge recipients
    - Intellectual property and intention to use
4. Awareness and impact of knowledge in the market
    - Awareness of knowledge among market actors beyond the project teams and stakeholders
    - Impact of knowledge created by the projects

The Evergreen team also addressed these major evaluation questions:

- Has the program filled important knowledge gaps?
- How was this knowledge disseminated and how useful was it to stakeholders?
- Were the requirements for collaboration (project partners who matched funding) and dissemination of results effective in stimulating a diffusion of knowledge?
- How might knowledge production, exchange, and diffusion be improved?

This section applies the network analysis approach described in Section 3.2.3 of the main report. We addressed the metrics and objectives of the evaluation but added two components to enrich understanding of the implications for near-, mid- and long-term knowledge impacts. First, metrics and analysis objectives are discussed outright, as well as within a framework of research questions designed to inform how the Program might induce knowledge benefits through network effects. Second, we introduce three network diagrams—we use the term Program Sociograms—that illustrate networks engaged at three levels of the program:

- Program team composition;
- Direct, immediate knowledge recipients; and
- Indirect, distant knowledge recipients.

We discuss implications for knowledge benefits illustrated by each Program Sociogram.

Relationship Building: Team Capacity, Implementation Dynamics and Partnership Formation

Introduction and Overview

The Program brought together well-known and deeply experienced teams, most of which were already active in the California solar and utility market, had been involved with publicly sponsored RD&D programs, and had existing relationships with other key solar actors in the state. Team composition set the stage for diffusion of knowledge from the Program, and affected the extent to which California's taxpayers and ratepayers will benefit from the program. We base this assumption on the near-, medium-, and long-term impacts of increased knowledge capacity. Several factors affect knowledge capacity.

A fundamental part of increasing knowledge capacity is the team size, and the reach and influence of team members. Large, diverse teams that function well share know-how, and over the long-term there are more opportunities for knowledge to spill over in diverse applications throughout the market. While knowledge can be packaged and transferred, expertise is less transferrable. The experience and professional reach of team personnel affects how much expertise developed during the Program and then how much additional expertise is absorbed and will be available in the future.

During implementation, how teams interact matters a great deal to the accumulation of Program knowledge benefits. When teams are more collaborative in nature—sharing ideas, giving feedback and building trust—greater competencies are built as a result. A secondary benefit of close coordination is a higher propensity to work together in future endeavors.

Team diversity plays an important role in knowledge benefits. One aspect of this is straightforward: a diverse set of experiences improves the net competency of the team. Thus, we assessed the diversity and unique competencies of Program teams. A less intuitive but important factor is the degree to which partnerships include a mix of public and private actors. Private sector actors are essential to project success as they bring market insight and cutting-edge capabilities. Public organizations, however, play an essential part in ensuring mid- and long-term knowledge benefits. Public organizations tend to be more stable over the long-term than private companies, and their underlying strategies tend to be both less volatile and more dedicated to open knowledge resources. The latter was true of many of the public research organizations in the Program.

Finally, we explore how teams formed partnerships with one another and with organizations outside their projects. Apart from direct application of knowledge by Program award recipients, partnerships are the most efficient means of applying and extending knowledge developed during the Program. Methods of partnership formation include leveraging pre-existing relationships, outreach to form new partnerships to continue after the program, and exploiting the network ties of partner organizations. We assessed evidence that partnerships formed, with whom, and some of the dynamics around how and why these relationships developed.

Taken together, this section establishes the framework of knowledge capacity on which the Program was built. This framework is perhaps the most important antecedent of long-term knowledge benefits. We closely examined how each of the factors described above came together and evolved over the course of the Program to determine the implications for the California solar market.

Data and Analysis

Team Composition

The primary unit of analysis across the four Program funding areas (Grid Integration, Solar Technologies, Innovative Business Models, and Cross-Cutting Projects) is the team for each project. Looking at Program documents, grantee interviews, and sub grantee interviews, we were able to gain an understanding of the team characteristics.

Grid Integration project teams tended to be larger and more diverse than projects under the other three funding areas (Table 66). Grid Integration and Solar Technologies project teams had high a representation of research organizations, like national labs and industry research groups. By contrast, no Innovative Business Model or Cross-Cutting projects (Table 67) included research organizations among their ranks. Universities, software firms, and consulting firms were well represented across all research areas and project in the Program.

Table 66: Team Composition, Grid Integration Solar Technologies Funding Areas

	Funding Area	Grid Integration																	Improved Solar Technolgoies		
Attributes	Prime Organization Type	Consulting			Eng. Firm	Research Org				SaaS	Solar Hardwr/ Installation		University					Utility		Solar Hardware/ Installation		
	Solicitation	3		4	5	1	3	4		1	2	3	1		3	4	5	1	4	2		
	Team Size	8	11	7	2	4	5	3	7	9	7	2	1	2	4	3	2	8	3	3	7	8
Sub Grantees	Research Org	1	2	1	1	1	2	2	1	1	2			1				4	1	1	1	2
	Solar Hardwr, Softwr		1	2		2	1		2						1			2				
	Consulting			2			1		1		1	1									2	3
	Utility	2	4							2					1	1	1					
	Energy Svce		2								2				1	1		1	1			
	University	2	1	1						1										1		
	Agency or Trade Assoc.	2								4		4										
	Non-Energy Svcs										1										3	1
	Testing Org								2													1

Teams led by solar hardware or installation firms were more likely to include organizations from outside the solar and utility sectors. Trade organizations were not well represented in the Program, even though they tend to possess significant market and policy understanding and access to information distribution channels.

Table 67: Team Composition, Innovative Business Models and Cross-Cutting Funding Areas

	Funding Area	Innovative Business Models					Cross-Cutting								
Attributes	Prime Organization Type	Consulting		SaaS	Solar Hardwr/ Installation		Consulting		Eng. Firm	Research Org		SaaS	University		
	Solicitation	3	5	2	2		2	5	1	1	4	5	2	5	
	Team Size	2	2	2	3	5	3	2	3	5	5	1	5	1	2
Sub Grantees	Research Org					1									
	Solar Hardwr, Softwr				1	1	1		2	1					
	Consulting	1	1	1						1	2				
	Utility									1					
	Energy Svce							1			1		2		
	University				1	1				1			1	1	
	Agency or Trade Assoc.														
	Non-Energy Svcs						1				1		1		
	Testing Org					1									

Descriptions of team experience in many cases went beyond expert competency; several interview subjects from multiple teams described their team members as market leaders. This sentiment was expressed independently by numerous respondents. One way that successful teams that won grant funding from CSI RD&D differentiated their team organizations was by including organizations that had developed first-of-kind products or methodologies. Several teams included academics who had recently proved concepts relevant to the project scope of work. Alternatively, some teams enlisted organizations that had developed hardware or software new to the market. For example, some teams included leading smart inverter companies, while others brought in firms that owned potentially useful proprietary software. In each case, the teams indicated that these rare competencies were paramount to the success of their projects.

Process experience also enriched teams. Respondents pointed to the benefit of organizations within their team possessing experience dealing with rare yet relevant situations. In a few cases, this involved personnel who were current or prior utility employees who had dealt directly with difficulties surrounding the high penetration of photovoltaics (PV). Others described the value of having experts with deep conceptual and applied engineering competencies, such as experience participating in operations planning.

Program stakeholders were primarily California utilities, standards and testing organizations, and independent system operators (ISOs). Stakeholders played various roles, from advisory roles with activities such as providing feedback on scopes of work and providing technical assistance or advice, to more active roles that included providing teams with access to data and integrated systems. Many stakeholder organizations played a role in multiple projects (Table 68), and in some cases engaged organizations from project teams to support related follow-on work after the project activities ended.

Table 68: Average Number of Stakeholders by Funding Area

Stakeholders	Grid Integration (n=18)	Solar Technologies (n=3)	Innovative Business Models (n=5)	Cross-cutting (n=9)
Total	**66**	**1**	**10**	**17**
Overall average	**3.6**	**0.3**	**2**	**1.8**
Solicitation 1 avg.	4	-	-	2
Solicitation 2 avg.	1	0.3	2.3	1.5
Solicitation 3 avg.	3.8	-	1	-
Solicitation 4 avg.	4.8	-	-	3
Solicitation 5 avg.	1	-	2	1.75

Grid Integration projects had more stakeholders overall, averaging at least double that of the other funding areas. More stakeholders for this funding area also brought in team organizations for follow-on engagements. Some relationships between grantees and stakeholders predated the program, some were developed in response to the call for proposals, and others were a result of direct efforts by the Program Administrator.

Network Assessment

Team Working Dynamics

The working dynamics that occurred during team project implementation was an important area of investigation. Nearly all respondents praised the Program Administrator for facilitating stakeholder and market actor relationships and supporting a vibrant research culture. This, according to grantees, is unique for RD&D programs. Several subjects with prior RD&D program experience conveyed that the Program Administrator demonstrated flexibility to work through project bottlenecks and respond to discoveries and obstacles during implementation. This flexibility improved project team's capacity to leverage team resources to focus on the most promising opportunities presented in projects.

The majority of teams, whether small or large, described highly collaborative team dynamics. Most respondents who felt their team was collaborative described the collaboration in terms of feedback. Teams routinely drew on competencies and expertise of other organizations. In particular, teams were better able to prepare for the applied stages of projects by drawing from the experiences of other organizations across the team.

Respondents described intra-team communication as structured, and most indicated consistently frequent communication during the active stages of projects. Many teams had weekly calls, and most had some sort of structured expectations for checking in with each other. One respondent exemplified the overall tone regarding partner organizations, commenting, "*I treated it as though they were staff at [my firm] and it was an internal project*."

There were a handful of exceptions, mostly regarding Solar Technologies and Innovative Business Models funding area projects. Respondents described the working dynamic of these project teams as more independent or siloed, with different organizations working on discrete tasks, sharing little data, information, and feedback. Respondents did not cast this independent approach in a negative light, indicating that it was largely a consequence of differences in the types of work assigned to each of the partners.

Project Partnerships

During Program implementation, more than forty partnerships formed that persisted after project activities ceased. Partnerships formed between team organizations, between team organizations and stakeholders, and between team members and market actors.

Grid Integration projects formed more partnerships on average, nearly two partnerships per project. By contrast, Cross-Cutting and Innovative Business Models projects produced closer to one partnership per every two projects. Across the data streams, we saw no indication that enduring partnerships formed out of the Solar Technologies project funding area. The greater number of partnerships per project for Grid Integration may be in part due the larger average team size; it may also be due in part to the newness or acuteness of the issue during the program implementation period.

Most enduring partnerships formed by Grid Integration projects were with stakeholders, including utilities, continuing and extending work similar to that of the specific projects. Partnerships also formed between research organizations within the teams—for instance, national labs and the Electric Power Research Institute (EPRI)—and other technical team members. Enduring Grid Integration partnerships tended to focus on demonstration or application as opposed to continued research and development.

Enduring partnerships stemming from the Cross-Cutting project funding area took three general forms:

- Partnerships with project stakeholders,
- Partnerships with team members,
- Partnerships with industry partners who have existing supply chain access.

Partnerships between team members tended to be extensions of partnerships that predated the Program.

Team organizations that formed enduring partnerships with other project partners comprised most new partnerships in the Innovative Business Models area. The nature of these partnerships generally centered on research and development, and data sharing. These partnerships tended to be less applied.

Knowledge Dissemination: Assessment of Reach and Effectiveness of Knowledge Exchange Activities

Introduction and Overview

The Program had a sustained focus on knowledge transfer to outside actors, and knowledge exchange among CSI RD&D Program project teams. There are several ways in which program design facilitated knowledge transfer and sharing. First, several knowledge exchange activities were required for all awardees, specifically, interim and final reports, project kickoff and final webinars, and participation in solicitation webinars and CSI RD&D Program forums . Second, the Program Administrator actively promoted projects and facilitated connections with other market actors, reducing the time needed for some projects to identify target audiences. Third, proposals for funds were evaluated in part on a bidding team's intention to educate the market and transfer technology, instilling early on a focus on knowledge exchange.

High buy-in to the Program goals among the projects led to many more knowledge exchange activities beyond what was explicitly required. In addition to knowledge exchange activities, knowledge spillover opportunities developed from demonstration sites and a large number of consumer-ready public resources. The Program's focus on knowledge transfer and exchange resulted in a diverse set of knowledge recipients (discussed in Section 5.1.3), as well as direct outreach to project teams from market actors and stakeholders.

The volume of knowledge transfer opportunities, exchange and spillover was high. Projects still, however, sometimes struggled to connect with the ideal audience. Thus, practices for knowledge transfer varied significantly across the Program, and teams worked closely with the Program Administrator and their professional networks to improve the fit of their knowledge exchange activities with the intended audience.

Data and Analysis

Knowledge Exchange Activities

Teams engaged in a variety of knowledge exchange activities; some activities were required by the CSI program while others were generated by the teams and were not a requirement of the program. We have broken these activities into three categories: stakeholder engagement, reports, and webinars (Table 69). Stakeholder engagement includes sharing data with stakeholders, formal and informal meetings, direct or ongoing outreach to stakeholders, presentations of findings to stakeholders, and project review meetings with stakeholders. The reports and webinars categories include both interim and final reports and webinars.

Table 69: Required Program Activities

Activities	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Stakeholder engagement	3.3	2.7	12.0	7.6	6.4
Reports	1.6	2.7	8.7	5.2	4.5
Webinars	1.2	1.4	4.3	3.4	2.6
Average of funding area	**2.0**	**2.3**	**8.3**	**5.4**	**4.5**

Teams found value in engaging stakeholders for feedback and in disseminating project knowledge into the broader field. Each project team participated in multiple stakeholder engagement activities, but usually produced one report (a final report) and held one webinar.

Interview respondents reported that the Program final reports followed a structured, expansive format, meaning there was little reason to complete additional interim reports. Some grantees felt that the standardized reports were not user friendly enough to capture an audience. Developing the reports was a major time commitment for the teams. A few suggested that they could have done more research or engaged in more effective knowledge transfer with the time it took to produce the required Program reports.

Respondents had similar issues regarding the Program-required webinars. Respondents indicated that the webinars required a huge time commitment; many felt that the return on time spent on producing and delivering the webinar was not high. Although some appreciated the experiences, many felt that the audiences were too small and too poorly matched to their project.

Teams were given license to pursue a variety of other knowledge exchange activities (Table 70). Presenting at conferences was the most common non-required activity, reported by representatives from 89 percent of projects. Innovative Business Models projects were least likely to lead to a conference presentation. About half of the projects published findings in academic peer-reviewed journals or as white papers.

Direct outreach to the intended audience and to stakeholders was reported by about half of the project teams. Grantees described this outreach as "spreading the word," going on "a roadshow," and "web outreach," with one grantee specifying the use of LinkedIn, and "email blasts to registered users." In addition to the required webinars, 14 projects reported conducting additional webinars to share project findings, using webinar distribution channels outside of the Program.

Table 70: Non-Required Knowledge Exchange Activities

Activities	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Presentations or Workshops	8.0	18.0	3.0	3.0	32.0
Collaboration and Direct Outreach	7.0	13.0	3.0	3.0	26.0
Publications	5.0	10.0	4.0	3.0	22.0
Non-Required Webinars	4.0	8.0	2.0	0.0	14.0
Participate in Working Groups	2	4	0	0	6
Commercialization	0.0	4.0	1.0	0.0	5.0

Many projects (74%) created resources that are available to the public as a result of the CSI project research (Table 71). Tools and software included open source algorithms that can be downloaded from websites, formal datasets that can be downloaded, training videos that demonstrate how to use project outputs, and a handbook for distribution engineers working with PV assessment and modeling.

Table 71: Resources Available to Public

Resource	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Tool or Software	5	12	3	1	21
Technical Report	3	7	4	1	15
Dataset	1	4			5
Showcase or Demonstration	3	1			4
Map		2			
Website	2				2

The non-required activities provided a way for the project teams to inform their intended audience of project developments, obtain feedback from stakeholders to guide project research, and to promote the tools and methodologies developed during these projects. Four of the nine project teams in the Cross-Cutting program funding area and eleven of the eighteen project teams in the Grid Integration funding area reported presenting information about their projects at trade conferences specific to their research areas. Examples included the Energy Efficiency Building Coalition conference, Electric Vehicle Association conference (EVA), ACEEE, and IEEE. Four Grid Integration project interviewees reported that a main purpose of talking about their CSI project with outsiders was to get feedback from stakeholders or the broader industry to help inform the project research. As one grantee from the Grid Integration funding area stated,

> *"Getting that feedback from the industry along the way helps steer some things. When the broader industry provides some of that feedback and input, frankly, it helps to strengthen and bolster the research."*

One Cross-Cutting project team used these non-required knowledge dissemination activities to announce when the California version of the BEopt tool was available, and another let the public know when resources became available for download from their individual websites.

A quarter of the projects had a demonstration site (26%). In total, there were 11 reported demonstration sites across all 35 projects (Table 72). The Grid Integration funding area accounted for more than half of these demonstration sites, as five of those projects combined for a total of six sites. Examples of demonstration projects given in interviews include demonstrations of battery packs, a showcase home for Zero Net Energy (ZNE) homes and their integrated technologies, a field demonstration of the Qado tool for modeling PV penetration, and a training facility for people to learn how to use the project outputs.

Table 72: Demonstration Sites

	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Number of Demonstration Sites	2	6	2	1	11
Number of Projects with Demonstration Sites	2	5	1	1	9

Efficacy and Fit of Knowledge Exchange Activities

Project teams did not view the knowledge exchange activities as equally effective. Webinars and conferences targeted at the intended audience were viewed as effective by interviewees from more than half of the projects (57% and 54%, respectively; Table 73). By contrast, approximately one-third of projects (37%) found the final reports to be an effective method of spreading information about their project findings. Interviewees discussed the effectiveness of these activities mostly by describing what they found to be effective, while few commented on what activities were less effective.

Table 73: Most Effective Knowledge Exchange Activities

Knowledge Exchange Activities	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Stakeholder Engagement	4	8	5	5	22
Webinars	4	7	5	4	20
Conferences	2	10	3	4	19
Final Paper or Reports	3	3	4	3	13
Working Groups or Standards Committee	0	1	1	0	2
Field Demonstration	0	0	0	1	1

The two grantees who explicitly mentioned activities they found to be less effective at disseminating project findings focused on Program-required reports and webinars. The grantee who mentioned reports said that “most people don’t sit around and read those.” The other grantee was disappointed with the number of attendees at his webinar.

The presence of stakeholder engagement, webinars (primarily non-Program related), and conferences at the top of the effectiveness scale for respondents across the funding areas reinforces the importance of audience and time spent in preparation. Numerous respondents expressed sensitivity to the time it takes to reach the right audience. One contact pointed out that for topics as technical as what the Program dealt with, teams needed to find key people in organizations (like utilities) that really dealt with the topic, as there was little value to others.

Knowledge Spillover and External Knowledge Interest

The Program generated substantial interest from stakeholders and outside actors. During the interviews, we inquired about occasions when requests for information came directly from stakeholders or market actors. Fifty-six percent of Grid Integration project teams and 44 percent of Cross-Cutting project teams received direct interest in their work from utilities[10] or ISOs, more than the other funding areas (Table 74). These market actor-to-team overtures came in the form of requests for data or explanations of methodologies after research presentations. A few projects noted that they pointed these interested stakeholders to the Go Solar California website (www.gosolarcalifornia.org), where reports and other information were available. Two project teams even noted interest from outside the US: one from Italy and one from the Caribbean.

Table 74: Interest Received from Stakeholders or Others

Stakeholders	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)
Utilities or ISOs	4	10	2	
Other, unspecified	3	9	2	
Solar hardware or installation firms	1	5	1	1
Commercial organizations	3	3		1
CPUC	1	2		1
Non-profit or community-based organization		2		1
Public agencies or municipalities			2	1
National labs or research organizations		3		
CEC	1			
Standards or testing organizations	1			

Innovative Business Models and Solar Technologies projects received interest from public agencies or municipalities, solar hardware or installation firms, and community-based organizations. Examples of solar hardware and installation firms include Solar City and other manufacturers of inverters, batteries and modules. The CEC as well as standards and testing organizations expressed interest in Cross-Cutting projects.

Influential Knowledge Disseminators

[10] Several respondents described "system planners and operators", which we included in the utility category.

Many but not all projects described individuals from team organizations or stakeholders as highly active and effective in disseminating project findings. We use the term 'knowledge disseminators' when referring to these types of actors. We categorized knowledge disseminators according to whether they were outside the team—either Itron or someone else—or whether they were inside the project team as a prime or sub grantee (Table 75).

One grantee described their project's main knowledge disseminator, which was the US Department of Energy, in the following way:

> *"They helped us broadcast the findings and invited us to speak at certain forums to talk about these projects. Just [identifying] opportunities to spread the word and share some of the findings."*

We found that all mentions of Itron as an influential knowledge disseminator were by project teams in Solicitation 1; more than half (4 of 7) of those projects named Itron. Project team members, including both sub grantees and prime grantees conducted more knowledge dissemination in later solicitations.

Table 75: Knowledge Disseminators by Funding Area*

Knoweldge Disseminator	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Sub	1	6	0	0	7
Outside Team	3	2	0	1	6
Prime	1	4	1	0	6
Itron	2	2	0	0	4

*Multiple responses allowed

Project teams reported that the Program facilitated knowledge exchange. In particular, interviewees from five project teams called out the joint DOE/CEC High Penetration PV forum as one of the most valuable aspects of the Program. Project team members also learned and made important contacts during occasions when the Program Administrator arranged for meetings between different active Project teams. In fact, six project teams reported that a key way the program helped with knowledge exchange was facilitating connections to other researchers and organizations within the Program.

> *"The primary stakeholder outreach was the workshop we did, and here I have to give credit to Smita and Itron. They were really supportive in getting the right people there including those from utilities, the people working on building standards, people who are tasked with implementing codes from CEC, and PUC folks."*

Only two project teams identified a way that the Program hindered knowledge exchange activities, both of which were in Solicitation 4 and in the Grid Integration project funding area. Their critiques related to the rules around how the project budget could be spent, which reportedly limited their ability to attend conferences. One interviewee said that he desired greater flexibility with how project dollars can be spent for things other than labor, such as travel to conferences, and thought the documentation requirements were a bit excessive. The other interviewee reported being constrained by the deadline by which he had to use the grant funds. He desired more time after completing the research to disseminate the findings.

Analysis Performed and Knowledge Produced: Assessment of Knowledge Gaps Filled and Follow-on Knowledge Production

Introduction and Overview

At the outset of the Program, team proposals were evaluated in part based on the reasonableness of the case made that the project outputs would address one of the knowledge gaps identified in the resolution. The teams identified specific knowledge gaps that were specific, narrow, and tailored to their skillsets. We reviewed project funding proposals to get a sense of how subjects envisioned critical gaps in the market and how they planned to close them. During interviews, we asked grantees and sub grantees to retrospectively define the knowledge gap they had sought to close, their target audience, and the innovative project outputs that resulted from project activities. We also asked them to explain how they leveraged existing public and proprietary resources to complete their projects. We then explored how program participation directly affected the teams and outside actors in terms of follow-on research and changes in firm, product, or market strategy.

In this section, we discuss how effectively the Program addressed the needs and knowledge gaps that project teams targeted. In order to accelerate the California PV market, Program knowledge needed to do each of the following:

- Produce outputs that closed knowledge gaps;
- Develop outputs into deliverables suitable for the habits and expectations of the intended audience; and
- Identify, reach, and transfer Program knowledge to market actors.

We collected data that made it possible to identify market actors exposed most directly to the projects. These knowledge recipients interacted with the Program in many different ways, but key activities included direct interaction (word of mouth), conferences, webinars, facilitated meetings, the formation of partnerships, and the acquisition of papers and reports.

Program knowledge—and how it is packaged—interacts with the characteristics of knowledge recipients and the means of knowledge transfer, making the dynamics of knowledge diffusion difficult to measure. We avoided over-interpreting observed knowledge transfer by considering the characteristics of Program knowledge and knowledge recipients when analyzing the implication of our observations.

In Section 5.1.1, we discussed the implication of team formations in the Program as an antecedent to knowledge impacts. We expand upon that discussion in this section, as we explore follow-on knowledge production. We sought to understand which projects led to follow-on knowledge production, who produced the knowledge, and who is investing in extending Program knowledge.

We used a number of complementary, cutting-edge network estimation techniques (see Section 3.2.5) across our data collection activities. This helped ensure the data we captured accurately reflected the diverse range of market actors exposed to the Program and their interactions. This section focuses on knowledge recipients who gained direct exposure to the Program. The subsequent section then presents our findings on market actors exposed to the Program indirectly.

Data and Analysis

Knowledge Gaps and Application

Through our analysis of grantee interviews and program documents, we identified 15 distinct categories of knowledge gaps that project teams attempted to address through their research (Table 76). Knowledge gaps related to forecast modeling and design tools were most prevalent. For projects in the Cross-Cutting funding area, gaps related to improved PV technologies were most common. Grid Integration projects largely focused on gaps related to forecast modeling, design tools, Interconnection Rule 21, and solar resource modeling.

Knowledge gaps differed somewhat across the four Program funding areas, though many overlapped. A large number of the knowledge gaps addressed by projects in the Cross-Cutting funding area centered around the intersection of technology integration (e.g., energy storage) and energy analysis and optimization. While there were common strands across several projects within this funding area, they varied in how and where in the value chain their outputs mattered.

Table 76: Knowledge Gaps Addressed by Project Teams, by Funding Area

Knowledge gaps related to…	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Forecast modeling	0	8	2	0	10
Design tools	1	7	1	1	10
Forecast modeling	2	4	1	2	9
Improved PV technology	6	1	1	0	8
Innovative business and financial models	3	2	1	1	7
Interconnection Rule 21	1	5	1	0	7
Personal Electric Vehicles	3	1	2	0	6
Regulatory challenges	0	4	1	0	5
Solar resource modeling	0	5	0	0	5
Storage	0	3	1	0	4
T&D model	1	1	0	0	2
Tariff and incentive design	2	0	0	0	2
Unintentional islanding	0	2	0	0	2
Utility tools	0	1	1	0	2
Zero Net Energy (ZNE) and iDSM	0	1	0	0	1

Knowledge gaps articulated by Innovative Business Models projects were the most eclectic, sharing little in common with other funding areas. Knowledge gaps included advanced solar hardware that needed demonstration and commercialization, procurement challenges at public agencies and inadequate rate and tariff structures. In this area, knowledge gaps tended to focus much more on major market gaps as opposed to the nuanced technical, skill, and process gaps evident in the other funding areas. A statement from a grantee illustrates this market focus:

> *"Part of the need … in California regarded how the different tariffs, time of day tariffs and things like that, could be leveraged or changed to better suit using renewables."*

Generally, projects addressed multiple complementary knowledge gaps, which enabled the project scopes to evolve in tandem with the teams' understanding. Many subjects credited the program managers for working with them to revise the focus of projects in order to emphasize efforts that would be more likely to succeed, would have greater near-term impact, or would lead to more opportunities for follow-on knowledge creation after the Program. While the orientation of knowledge gaps guided Program activities, teams had flexibility during Program implementation to act strategically and pursue high-impact opportunities.

Project Knowledge Creation, Recipients, and Audience

The Program produced a variety of outputs. Most projects pointed to multiple products or outputs, often in a sequence that led to a goal or benchmark. Teams often developed models and unique processes to validate assumptions, and then used their takeaways for further product development, or, in several cases, packaged useful aspects of modeling activities into functionalities in new or existing software programs.

We sought to characterize knowledge outputs across the Program. The characteristics of the spectrum of products or outputs is one determinant of knowledge diffusion. Proprietary, inaccessible, esoteric, or complex knowledge is less readily absorbed in the market. By contrast, easily accessible, user-friendly, and useful knowledge is easier for market actors to absorb and apply. These conditions, however, to some extent depend on the intended audience. A complex model that closes a critical knowledge gap intended for use by ISO system planners may be a perfectly acceptable fit. The same would not be true if it targeted solar installation contractors.

While broadly characterizing the types of knowledge emanating from the Program is a valuable part of tracing knowledge flow, during interviews with Program grantees and sub grantees, we asked respondents to describe the innovative outputs of their RD&D efforts. We qualitatively assessed their responses and categorized outputs using a coding scheme. Because most projects pointed to multiple outputs, we identified either the output category that represented the most outputs or the greatest effort for a single project, resulting in classification of project knowledge outputs limited to one category per project (Table 77).

Table 77: Project Knowledge Outputs, by Funding Area

Funding Area	Business model	Hardware	Methodology of process validatioon	Software, interactive programs	Tools
Cross-cutting	1	1	2	4	1
Grid Integration	1		8	2	7
Innovative Business Models	2	1		2	
Improved Solar Technologies		2	1		

Knowledge outputs fell into five categories:

1. Business models
2. Hardware
3. Methodology of process validation
4. Software/interactive programs, and
5. Tools

These broad categories define the outputs associated with the four Program funding areas. The final forms of knowledge from Grid Integration projects were utility tools and methodologies validating complex or untried processes. Innovative Business Models projects developed software, demonstrated unique business models, and, in one case, improved and demonstrated solar hardware.

Along with knowledge type, ease of codification correlates with how readily new knowledge is absorbed by market actors. We asked respondents about the ease with which they could codify their primary innovative outputs. Respondents from 21 of 35 projects provided answers, but the Solar Technologies funding area was not represented in the responses. Responses by project were consistent; individuals who worked on the same project did not contradict their team members. Roughly 62 percent responded that the knowledge from their project was easily codified, compared with 38 percent who responded that codification was difficult. Responses did not vary meaningfully across funding areas. Methodologies of process validation were the only knowledge type where a majority of respondents indicated that knowledge was hard to codify.

Audience and Knowledge Recipients

Project teams identified a range of potential audiences for their research. They identified utilities and ISOs as the primary audience for most projects, followed by public-facing and commercial organizations (Table 78). Regulators and standards and testing organizations were a primary audience for each funding area, except Cross-Cutting. System planners were a significant focus for Grid Integration projects. Conversely, public organizations (such as academics, community-based organizations, and municipalities) and commercial organizations (especially consultants and program implementers) were a high priority for all funding areas, except for Grid Integration projects.

Table 78: Project Audiences, by Funding Area

Organization Type	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Utilities and ISOs	5	18	2	3	28
Commercial organizations	8	12	1	2	23
Public organizations	5	8	2	2	17
Regulators, standards, testing organizations	3	10	1	2	16
System planners and operators	3	11	1	1	16
Solar hardware and installation firms	3	6	1	0	10
Solar renewables community and experts	3	6	0	1	10
Technology companies and software developers	3	6	0	0	9
National labs and research organizations	2	5	0	0	7

We found that knowledge recipients differed slightly from the intended audience. For example, while utilities and ISOs represented both a target audience and a primary knowledge recipient, national labs and research organizations were more likely to be targeted as knowledge recipients than targeted as an audience. Additionally, we found the volume of knowledge recipients was significantly higher for projects in the Solar Technologies funding area compared to other funding areas. The three projects in this funding area confirmed an average of 13 direct knowledge recipients, compared with averages of nine, ten, and five direct knowledge recipients from the Cross-Cutting, Grid Integration, And Innovative Business Models areas, respectively. Table 79 provides an overview of the proportions of knowledge recipients across the funding areas.

Table 79: Percent Project Knowledge Recipients, by Funding Area

Organization Type	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)
Total Knowledge Recipients	80	186	14	65
Average Per Project	9	10	5	13
Utilities and ISOs	20	22	29	14
Commercial organizations	23	25	14	20
Public organizations	11	21	14	14
Regulators, standards, testing organizations	5	11	14	15
System planners and operators	11	3	7	20
Solar hardware and installation firms	6	5	7	3
Solar renewables community and experts	4	2	7	6
Technology companies and software developers	4	3	7	3
National labs and research organizations	5	3		5

Only minor variations are evident across the funding areas. Reported direct knowledge recipients were more fixed across the funding areas than were the target audiences. Section 5.4 presents the results of our analysis of Program report citation, which illustrates greater variation across knowledge recipients. The fixed nature of the direct knowledge recipients suggests that the Program structure facilitated connections between key actors in the California market.

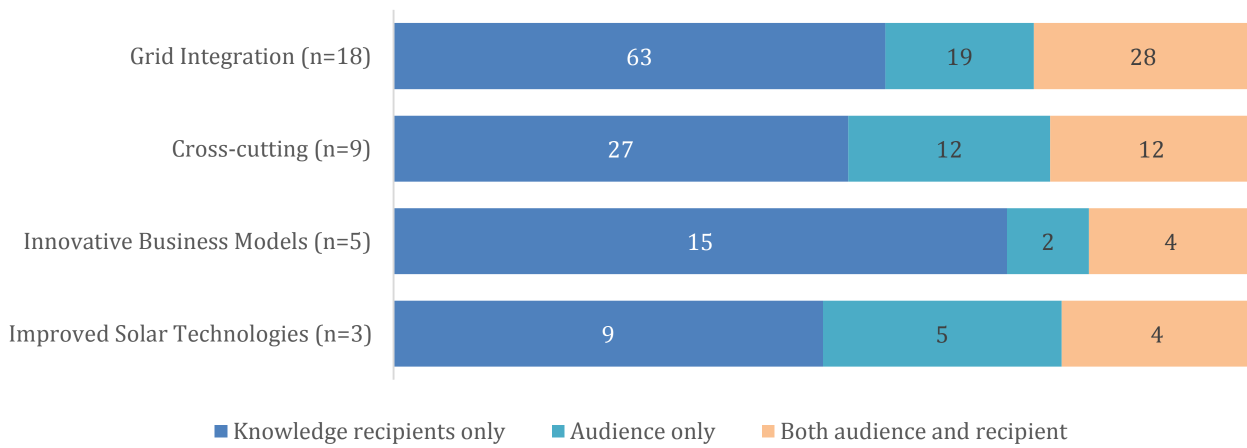
We qualitatively reviewed subject responses for evidence that the Program implementation process affected the proportions of direct knowledge recipients we observed. Several aspects of the Program supported this finding. First, numerous subjects described ongoing efforts by the Program Administrator to make connections and facilitate meetings among project teams and key market actors. Several respondents expressed appreciation for this role, suggesting they would not have been able to obtain such broad audiences were it not for the Program Administrator. Respondents also credited the Program Administrator's staff for having widespread connections through the

California market and federal agencies, due to their significant experience working in state agencies.

Respondents also noted that the Program Administrator helped to facilitate joint workshops with the U.S. Department of Energy, as well as periodic meetings among the project teams. The required knowledge exchange activities also standardized the immediate knowledge recipients. Webinars and Program sources (i.e., reports and papers) were posted on the Go Solar California website, and announcements were made through an opt-in email list. These Program attributes help explain why projects across the funding areas shared many knowledge recipients, even though intended audiences varied.

To assess the extent to which projects successfully reached their intended audiences, we drew upon interview data to compare the target audience for each project with the organizations that ended up receiving knowledge from the project. Figure 3 illustrates the overlap between audience and knowledge recipients for projects across all funding areas.

Figure 3: Comparison of Project Knowledge Audience and Knowledge Recipients, by Project Funding Area

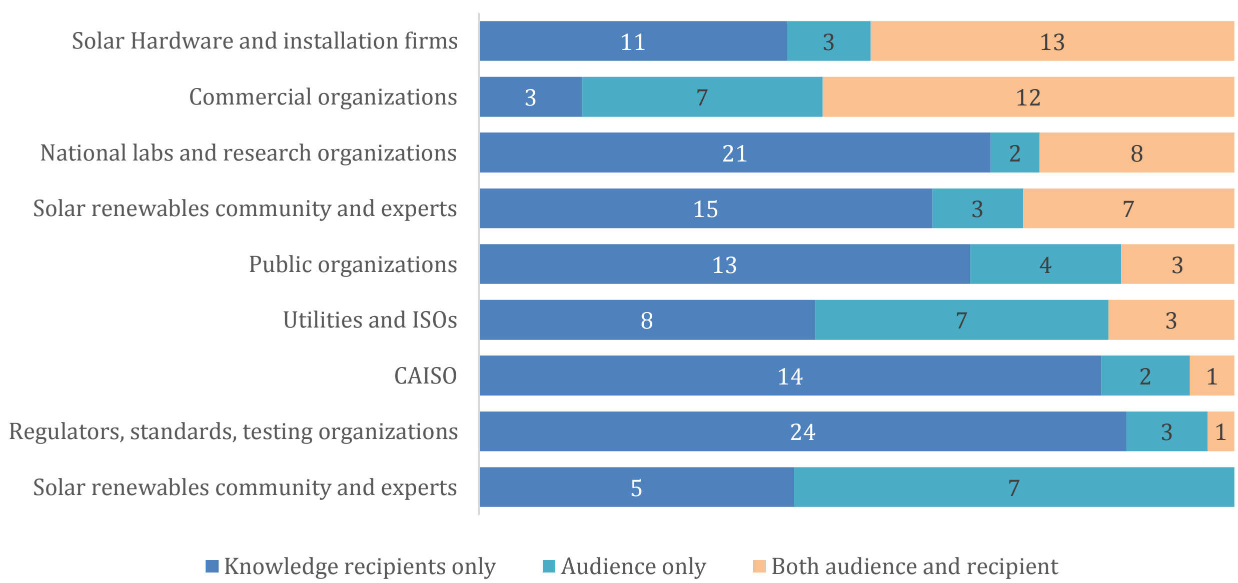


This brief analysis reinforces the role that program design played in determining the composition of Program knowledge recipients. Teams interacted directly with a large number of knowledge recipients who had not been identified as target audiences. This, however, does not necessarily indicate a mismatch between the target audiences and knowledge recipients. Projects were able to make connections with their target audiences in every funding area. The over-representation of knowledge recipients who were not part of the target audiences is likely a consequence of the formalized Program knowledge exchange activities. A second factor we identified that may have contributed to non-targeted knowledge recipients derived from subject responses, suggesting they changed the scope of their research as they learned and gained expertise during Program implementation. Changes in the research scope would reasonably change the intended audiences.

Figure 4 illustrates the challenge that projects had in connecting with certain target audiences. Two audiences in particular proved challenging: solar hardware and installation firms, and commercial organizations (for instance, builders and retail). The difficulty to connect with solar hardware and installation firms, in particular, is surprising, considering that several subcontractors were from this subsector, as were a few of the principal organizations.

Only a handful of projects pointed to CAISO, regulators, and standards bodies as a primary audience for their outputs. Even so, these organizations were well represented among knowledge recipients. We can attribute this to the role of the Program Administrator and the required knowledge exchange activities.

Figure 4: Comparison of Project Knowledge Audience and Knowledge Recipients, by Recipient Organization Type



Follow-on Knowledge Creation and Changes to Strategies

The Program awarded large teams with top-flight experience and broad representation of industry perspectives (See Section 5.1.1). While much of the focus of this analysis rests on the extent and effectiveness of knowledge transfer from the Program to market actors, one of the ways the Program may benefit the California solar sector is through ongoing efforts from the teams and their extended networks. Of course, there are a limited number of team members—a total of XX organizations that were awarded as grantees and sub grantees. Program participants, however, may have developed expertise and capabilities that improve their ability to lead the market.

We considered the production of follow-on knowledge, based on the assumption that knowledge benefits will emanate from the increased knowledge capacity across the organizations directly involved in the Program, as well as their immediate networks. Each of these factors has implications for the near- and long-term benefit of the California solar sector:

- The extent to which projects drew on and leveraged existing resources to the benefit of their research;
- How and with whom projects developed follow-on efforts to extend some or all of their outputs; and
- How the near- and medium-term product, firm, and market strategies of the organizations involved directly in the Program changed as a result of participating.

Intellectual Property and Intention to Use Program Knowledge

We asked interviewees to explain any intellectual property strategy that developed around the Program outputs. Twenty-one respondents from 19 projects provided responses; seven from Cross-Cutting, ten from Grid Integration, two from Solar Technologies, and two from Innovative Business Models.

Overall, six grantees indicated that they did not have an intellectual property strategy at all. An additional 11 grantees reported that all project-related results (i.e., knowledge) was open source. In these cases, subjects explained that the research effort was not developed in a manner that easily lends itself to an intellectual property strategy.

A few projects stand out as exceptions. Five grantees reported that they developed intellectual property strategies to commercialize some of what they learned during the Program. The intellectual property strategies centered on patent application. Four of the five were Grid Integration projects, and the fifth was an Innovative Business Models project.

No respondent mentioned other explicit intellectual property strategies such as trade secrets, copyrights, or joint partnerships. The teams submitted patents around specific components of their outputs. For instance, one indicated they filed patents around software control methodologies; another indicated that the project prime had some intellectual property already in place prior to the project for some of the hardware components developed. One subject indicated there was some resistance from another project team member to give away testing and validation software due to the information being proprietary.

Intention to Use: Team and Non-team

We reviewed program documents and asked interview respondents if they planned to apply the knowledge gained during Program implementation after the end of the project. We collated the data from interviews and program documents and identified four general areas for follow-on use:

- **RD&D**. Many teams applied for and were awarded funds for publicly-funded RD&D.
- **Client services**. Several teams launched follow-on work to apply what they learned during the Program in operational contexts, usually with existing or previous clients, though sometimes through word of mouth.
- **Expansion of products and services**. Several teams indicated they intend to use the knowledge gained during the Program to expand services offered to clients, rethink existing services, or improve, expand, or refine products.
- **Application by outside partners**. Numerous teams indicated they were aware of outside actors (i.e., individuals or organizations not directly involved in the Program) already or who are planning to apply the knowledge or know-how produced by the Program in products, services, or operations.

Grantees from 16 teams reported that they would leverage Program knowledge with follow-on RD&D funding, primarily by the U.S. Department of Energy and the California Energy Commission (CEC). Table 80 provides an overview of follow-on RD&D funding. Four grantees and sub-grantees interviewed provided details on the follow-on research funding amounts they received. Follow-on research funding ranged from $90,000 to $13,000,000.

Although the CEC invested in follow-on projects, several individuals who participated in the Program but whose firms are located outside of California mentioned that the contractual obligations of the Electric Program Investment Charge (EPIC) program—the successor to the CSI RD&D Program—were too onerous, induced greater uncertainty, and ultimately led to decisions not to pursue further RD&D funding from the State.

Table 80: Organizations Funding Follow-on Research

Resource	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Department of Energy (DOE)	2	9	1		10
California Energy Commission (CEC)	2	5	1		8
California Solar Initiative (CSI)	2	1			3
Utilities and ISOs	1	1			2
Department of Defense		1			1
National Science Foundation (NSF)			1		1
Technology companies		1			1
Unknown funder	1	2	1	1	5

[a] We were only able to interview grantees and sub-grantees from 32 of the 35 CSI-funded projects.

The Program has been effective in stimulating other forms of follow-on use, apart from RD&D funding. According to interviews with project grantees, two-thirds (66%) of projects resulted in some type of follow-on research (Table 81). Grid Integration projects were more likely to result in follow-on research compared to projects in the Innovative Business Models and Solar Technologies project funding areas.

Table 81: Project That Conducted Follow-on Research, by Project Funding Area

Project Funding Area	Count	Percent
Grid Integration (n=18)	13	72%
Innovative Business Models (n=4)	2	50%
Solar Technologies (n=2)	1	50%
Cross-cutting (n=8)	5	63%
Total (n=32) [a]	21	66%

[a] We were only able to interview grantee and sub-grantees from 32 of the 35 CSI funded projects.

Utilities and ISOs were the main external organizations that expressed interest in using project knowledge operationally after the Program ended (Table 82). This included utilities within California, and throughout the United States. Innovative Business Models and Solar Technologies projects had a more limited range of organizations that expressed interest in using project knowledge compared to projects in the Cross-Cutting and Grid Integration funding areas. Apart from experiencing more overall outside interest, Grid Integration and Cross-Cutting projects made inroads with regulators and with standards and testing organizations.

Table 82: External Organizations That Expressed Interest in Using Project Knowledge, By Funding Area

Organization Type	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
Utilities and ISOs	2	10	0	1	13
Public organizations	2	3	2	2	9
Commercial organizations	1	3	2	2	8
National labs and research organizations	1	3	0	0	4
Standards and testing organizations	1	3	0	0	4
Technology companies and software developers	1	3	0	0	4
CAISO	0	1	1	0	2

Table 83 illustrates the expression of interest in follow-on use of Program knowledge from within the teams. National laboratories, research organizations (Electric Power Research Institute, for example), and utilities (both grantees and stakeholders) were most likely to have plans to use the knowledge gained after the Program ended. Interestingly, no grantees with Solar Technologies projects reported that team members intended to use project knowledge. Team members from Grid Integration projects were much more likely to indicate an intention to produce follow-on work.

Table 83: Project Team Organizations That Expressed Interest in Using Project Knowledge, By Funding Area

Organization Type	Cross-cutting (n=9)	Grid Integration (n=18)	Innovative Business Models (n=5)	Improved Solar Technologies (n=3)	Total (n=35)
National labs and research organizations	1	13	1	0	15
Utilities and ISOs	2	11	0	0	13
Solar Hardware and installation firms	1	10	1	0	12
Technology companies and software developers	0	3	2	0	5
Standards and testing organizations	0	3	1	0	4
CAISO	0		0	0	1
Commercial organizations	1	0	0	0	1

Overall, both market actors internal and external to the Program expressed a significant degree of interest in leveraging their Program experience to conduct follow-on work. The diverse spectrum of external actors planning to or already using Program knowledge sets in motion several distinct trajectories into the market. For instance, the application of knowledge by technology developers addresses a different market niche than does application by grid management experts or standards and testing organizations. This benefit is especially true for knowledge produced by the Cross-Cutting and Grid Integration funding areas.

Grid Integration team members are currently well positioned to leverage Program knowledge directly. Application of Program knowledge directly by project teams carries with it several implications for knowledge benefits. First, the team members have the benefit of direct experience and "learning by doing", thus improving the ease and cost of leveraging Program knowledge. Second, as evidenced in this Section and Section 5.4.1, the project team members have diverse networks of partners and clients, who become likely beneficiaries and recipients of Program knowledge. Finally, research has begun to show that solar sector knowledge produced in California by firms based in California or working in California localizes the benefits of innovation to the state.[11] It is reasonable to assume that follow-on innovation from the Program by firms based, working, or demonstrating in California will lead to accumulation knowledge benefits over time.

Knowledge Impacts: Awareness, Perceptions, and Early Indicators

Introduction and Overview

The Program produced at least 153 original papers and reports, with more forthcoming from several projects. Teams developed interim and final reports in compliance with Program requirements, and many teams published additional journal articles or technical reports to highlight specific aspects or implications of their findings.

Program knowledge appears already to be influencing the California market. The responses to our market actor survey illustrate the relevance of Program knowledge to various actors across California. The value, application, and intention to use Program knowledge varies across market actors.

In this section, we discuss evidence of knowledge receipt by analyzing citation of program outputs and responses to the market actor survey. We find that Program knowledge is already being applied by the broader community of California market actors, with more interest and perceived value in some pockets.

[11] For more details, see Venugopalan, Subhashini, and Varun Rai. "Topic based classification and pattern identification in patents." *Technological Forecasting and Social Change* 94 (2015): 236-250.

Data and Analysis

Citation Analysis

As one measure of Program knowledge reach, we analyzed the citation of project reports and papers. We collected data and examined the following:

- Number of citations per project report and paper;
- The venue where a Program source was cited;
- The organization type of the citing author's affiliation; and
- The citation pattern over time.

Project knowledge type, the project funding area, and the venue where the Program source was published are factors that appear to affect how swiftly and broadly sources are cited. As shown in Table 84, projects that developed tools or models in the Grid Integration area received the most citations.

We identified three factors that appear to affect the uptake of project knowledge: Program funding area, knowledge type, and citing venue. As shown in projects which developed tools or models in the Grid Integration area received the most citations. The most important citation driver appears to be the venue in which the project outputs were published.

Factors that Drive Citation

Among the 153 papers and reports publicly released by Program teams, 26 have been cited at least one time at the time we collected data in the fall season of 2016. The 26 Program sources have been cited 395 times to date; though a single Solicitation 1 Grid Integration project accounts for 315 citations (80%). This unique project published four of its seven papers in *Solar Energy* (n=3) and *Energy Policy* (n=1). The papers published in these high impact journals reached a combined total of 303 citations. The project's three other papers, two published in less well-known journals and one Program report, reached a combined total of only 13 citations. This strongly suggests that publication in high impact venues increased visibility of findings and drove a signification level of citation. Further supporting this observation, across all cited Program sources, papers that were self-published or published by the Program represented only 11 percent of citations. It is worth noting, however, that team members from universities and national laboratories released a number of reports beyond what the Program required. It may be too soon to determine the long-term impact of these sources. At this stage, it does seem that uptake of self-published and Program-released sources is slower than publication in high-impact journals.

Table 84: Count of CSI Project Output Citations by Year

Funding Area	Knowledge Type	Project Prime	Paper	Citing Venue	2010	2011	2012	2013	2014	2015	2016**	Total
Grid Integration	Tools	Clean Power Research	A	ASES National Solar Conference	0	0	1	1	1	0	0	3
		UCSD	A	UC San Diego*	0	0	0	6	1	1	1	9
			B	EnerNex Corp	0	0	0	0	0	1	1	2
			C	UC San Diego*	0	0	0	0	1	3	2	6
		SMUD	A	European Photovoltaic Solar Energy Conference and Exhibition	0	0	0	0	0	0	2	2
			B	IEEE Power & Energy Society General Meeting	0	0	0	0	4	4	0	8
		Clean Power Research	A	Solar Energy	6	5	19	26	28	30	24	138
			B	Technical Report to the California Solar Initiative	1	1	1	0	0	2	1	6
			C	Solar Today	0	1	1	0	0	1	0	3
			D	Solar Energy	1	2	5	6	6	9	9	38
			E	Energy Policy	0	0	5	8	12	16	7	48
			F	Foundations and Trends in Renewable Energy	0	0	0	0	0	1	3	4
			G	Solar Energy	0	1	8	15	13	25	17	79
		EPRI	A	Sandia National Laboratories	0	0	0	0	0	0	3	3
	Methodology of Process Validation	UCSD	A	Technical Report to the California Solar Initiative	0	0	0	0	0	0	2	2
			B	UC San Diego*	0	0	1	0	0	0	0	1
		NREL & SCE	A	National Renewable Energy Laboratory*	0	0	0	0	0	1	1	2
			B	Photovoltaic Specialists Conference (PVSC)	0	0	0	1	5	2	0	8
			C	National Renewable Energy Laboratory*	0	0	1	1	1	1	2	6
			D	National Renewable Energy Laboratory*	0	0	0	0	0	1	0	1
			E	IEEE Power & Energy Society General Meeting	0	0	0	0	0	2	0	2
			F	National Renewable Energy Laboratory*	0	0	0	0	0	1	3	4
Improved Production Technology		Amonix	A	National Renewable Energy Laboratory	0	0	0	0	0	1	1	2
			B	IEEE Journal of Photovoltaics	0	1	2	3	2	1	1	10
			C	AIP Conference Proceedings	0	0	1	0	2	2	1	6
			D	IEEE International Reliability Physics Symposium	0	0	2	0	0	0	0	2
Total					8	11	47	67	76	105	81	395

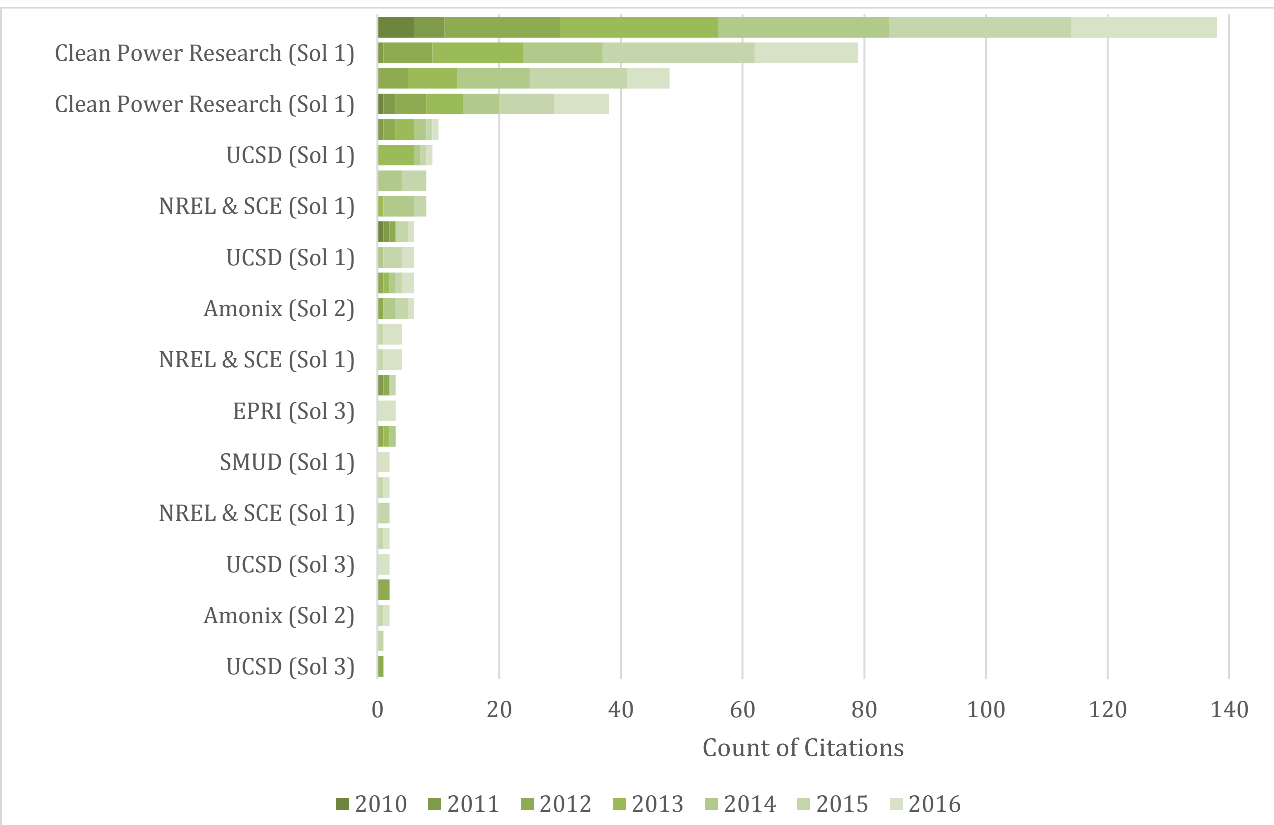
*Indicates self-published papers; **Data collected before end of 2016, does not reflect end of year total.

NOTE: Tabulation of citation across project funding area, knowledge type, project prime organization, paper and citing venue. The "Project Prime" column represents a single project. The "Paper" column represents a unique paper. "Citing Venue" represents the venue where the original project paper was published. Counts in each cell reflect the number of times each paper was cited. Data-bars (including the total column) for years are proportional to the total unique paper citations (read across).

Most of the sources that have been cited were produced by projects in Solicitation 1. A few projects from Solicitation 3 and one project from Solicitation 2 have also been cited. Program sources released in later solicitations likely have not yet had sufficient time to be cited, especially when considering the lag time associated with peer review. Figure 5 illustrates how citation counts have accumulated by year. The citation pattern to date for all but two papers, from 2011 to 2015, follows a positive linear trajectory, suggesting that the net impact of the program by citation will continue to accumulate for many years.

It is notable that only one project outside the Grid Integration funding area has been cited. No projects from the Cross-Cutting or Innovative Business Models areas have been cited. Solicitation 1 and 2 had multiple projects from each funding area. The lack of citation suggests that the knowledge produced by Grid Integration projects is more relevant to market actors who cite research in the course of their work. It is too early to identify an effect for this observation, but this observation appears to reinforce the idea the other evidence highlighted in this report that knowledge-audience fit varies by knowledge type and the means of knowledge exchange.

Figure 5: Count of Citations by Project, by Year



Academic organizations were the most represented citing organizations. Projects with papers published in prestigious journals were heavily cited by academics and also had the most diverse reach. In Figure 6, papers around Clean Power Research's *Advanced Modeling and Verification for High Penetration PV* findings received the most citations and the greatest diversity of citing organizations. Notably, private sector organizations that were cited comported a greater portion of the Program's citation base.

Figure 6: Proportion of Citing Organization Types by Project (counts in bars)

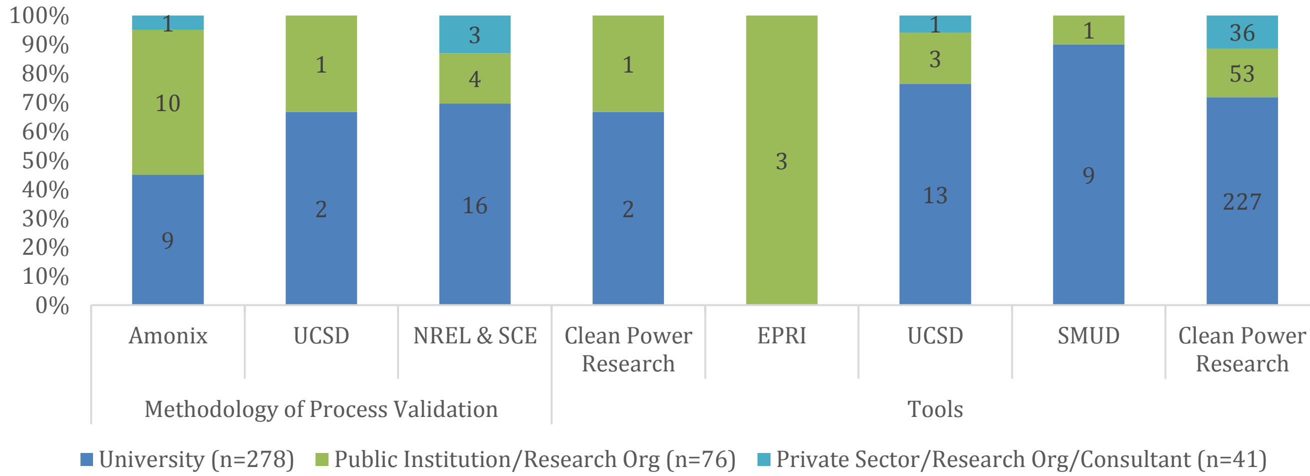


Table 85 illustrates the citation of papers across the project types by different kinds of private sector actors. Most private sector organizations cited papers from only two Grid Integration projects. Citations by academic, public research, and regulatory organizations were distributed more equally across the projects.

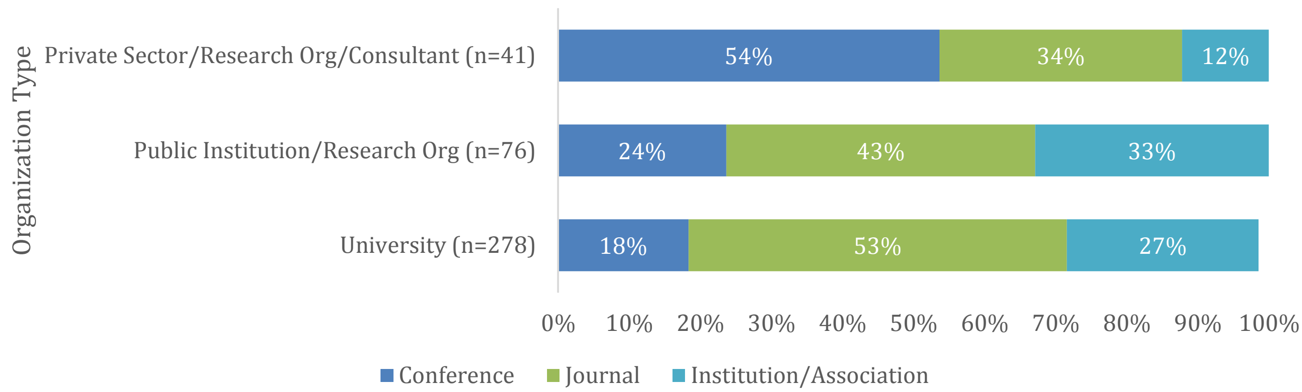
Table 85: Count of Citations by Knowledge Recipient Type

Funding Area	Knowledge Type	Project Prime	Paper	Knowledge Recipients					
				Academia & Universities	Research Orgs (includes NLs)	Consultants, Contractors & Service Providers	Hardware or Software Developers	Regulators, Municipalities, Non-Profits, Utilities	Total
Grid Integration	Tools	Clean Power Research	A	2	0	0	0	1	3
		UCSD	A	9	0	0	0	0	9
			B	1	0	1	0	0	2
			C	3	2	0	0	1	6
		SMUD	A	2	0	0	0	0	2
			B	7	0	0	0	1	8
		Clean Power Research	A	111	12	5	7	3	138
			B	5	0	1	0	0	6
			C	2	0	1	0	0	3
			D	24	5	6	1	2	38
			E	37	6	3	1	1	48
			F	3	1	0	0	0	4
			G	64	8	4	1	2	79
		EPRI	A	0	3	0	0	0	3
	Methodology of Process Validation	UCSD	A	2	0	0	0	0	2
			B	0	0	0	0	1	1
		NREL & SCE	A	0	1	0	1	0	2
			B	6	1	0	1	0	8
			C	5	1	0	0	0	6
			D	0	1	0	0	0	1
			E	1	0	0	1	0	2
			F	4	0	0	0	0	4
Improved Production Technology		Amonix	A	2	0	0	0	0	2
			B	6	3	0	1	0	10
			C	1	5	0	0	0	6
			D	0	2	0	0	0	2
Total				297	51	21	14	12	395

NOTE: Tabulation of citation recipient type by funding area, knowledge type, project prime and paper. The "Project Prime" column represents a single project. The "Paper" column represents a unique paper. Counts in each cell represent the number of times each paper was cited. Data-bars for knowledge recipients are proportional to the total of citations across the rows (read across). Data-bars for the total column are proportional to the total 395 citations (read down).

Private sector organizations also differed in the venues where they cited Program sources. Figure 7 illustrates that public research organizations and academics mirrored each other in citing Program sources roughly half in journals, and roughly one-quarter each in conference proceedings or by self-releasing reports. By contrast, private organizations cited Program sources primarily in conference proceedings. This stands out in part because conferences were noted by project teams as one of the most effective ways to disseminate findings to colleagues. It is possible that citation by private sector organizations has been concentrated in conference proceedings as these organizations benefit from or respond to knowledge produced by the Program.

Figure 7: Distribution of Venue Types by Citing Organization Types



Market Actor Awareness and Perceptions

We developed the market actor survey to address three project outcomes:

- Awareness of program, of project outputs;
- Awareness of new ideas, know-how; and
- Adoption of program knowledge.

Respondents had higher than expected awareness about the Program. Responses regarding the value and need for the Program outputs varied meaningfully across subject organization types. The responses yielded valuable insights about the common and preferred communication channels through which they generally stay up-to-date about solar RD&D efforts. Finally, the responses depict current and intended uses for Program knowledge.

Market Actor Program Awareness

Overall, the majority of the market actors we surveyed (91%) across the variety of the organization types reported they were aware that the state of California has funded RD&D to stimulate the state's solar market. More than half of the market actors (56%) knew about specific projects that were funded by the Program, although there were some organization types that were less aware of specific projects than others, including utilities, manufacturers, and installation contractors (Figure 8).

Figure 8: Awareness of the Program and Projects by Organization Type

Organization types	Aware of CSI RD&D program	Aware of CSI RD&D projects
Government (n=17)	100%	65%
Private research and consulting company (n=16)	94%	63%
University or nonprofit (n=15)	100%	67%
Utility (n=12)	92%	33%
Hardware manufacturer (n=11)	73%	36%
Installation contractor (n=9)	67%	44%
3P program implementer or software developer (n=8)	100%	75%
Total (n=88)	**91%**	**56%**

Perceived Value of Program

To assess how these market actors perceive the value of the Program funded projects, we asked a set of questions about each of four actual projects that had completed their intended activities. Each project was presented with two pieces of information: 1) the particular barrier or challenges the California solar industry faced to which the project attempted to address, and 2) the project's outcome. Two projects fell under the Grid Integration funding area, and the other two projects fell under the Cross-Cutting funding area as follows:

- Project 1: Development of optimal smart inverter setting (Grid Integration)
- Project 2: Software development for custom system design (Cross-Cutting)
- Project 3: Understanding the effects of geographically-dispersed PV system (Grid Integration)
- Project 4: Software development that optimizes energy efficiency, demand response, storage with PV (Cross-Cutting)

We presented one randomly selected set of two projects to each respondent: Project 1 and Project 2, or Project 3 and Project 4. Figure 9 summarizes the responses to each of the four projects.

Figure 9: Perceived Value of Program by Project

	Project 1 (n=46) Grid integration	Project 2 (n=46) Cross cutting	Project 3 (n=42) Grid integration	Project 4 (n=42) Cross cutting
a) Project outcome "very relevant" to your organization's work	59%	30%	67%	60%
b) Project findings "very needed" for the CA solar market	67%	52%	74%	64%
c) "Very effective" in reducing knowledge gaps that exist in the CA solar market	57%	33%	50%	57%
d) "Very effective" in improving understanding and capacity of regulators, grid operators, and standard setters	50%	26%	74%	52%
e) "Very effective" in improving your organization's ability to provide services or develop products	33%	28%	36%	36%
f) "Very effective" in accelerating the integration of distiributed solar power into the CA grid	54%	39%	60%	55%

All of the above items were asked using 5-point scales with similar expression of degrees – for instance a) 'not at all relevant', 'a little relevant', 'somewhat relevant', 'very relevant', and 'extremely relevant'. The percentages show a combination of 'very' and 'extremely'.

Overall, the respondents reacted favorably to the outcomes of Project 1, 3, and 4, while slightly less so to Project 2's outcome. Across Projects 1, 3, and 4, more than half of the market actors thought that the project outcomes were 'very relevant' to their organizations (a) and about a third thought those projects 'very effectively' improved their organization's ability to provide services or develop products (e). Regarding these three projects, more than half of the market actors also thought the outcomes were 'very needed' for California's solar market (b), and 'very effectively' reducing knowledge gaps existing in California's solar market (c). Additionally, more than half of the market actors thought these three projects were 'very effective' in increasing the capacity of regulators, grid operators, and other standard setters (d). As a whole, more than half of the market actors surveyed responded that these projects' contributions to the acceleration of solar power integration into the California grid was 'very effective' (f).

Although the perceived value of the Project 2 outcome was not as great as other projects, more than half of the market actors thought the project outcome was 'very needed' for the California solar market.

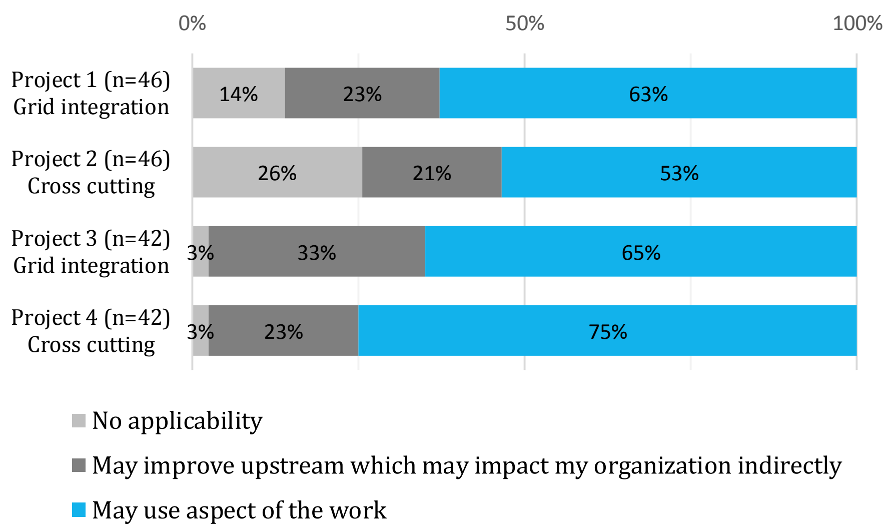
Generally, across the four projects, market actors who are engaged in research and development, grid operation and management, or third party services tended to hold higher opinions of the value of Program outputs. Contacts of hardware manufacturers were the group least impacted by these projects.

Intention and Early Indication of Program Knowledge Use

Using the same four projects as concrete examples, we asked the market actors some questions that assessed the early indications that Program knowledge is being adopted.

Regarding all the four projects, more than half of the market actors reported they are likely using Program outputs, findings, and tools for their organization's future work (Figure 10). The Project 4 outcomes in particular were viewed as directly relevant to their work. Even if they do not see these project outcomes to be directly useful to their work, about a quarter to a third of the market actors thought their work will indirectly benefit as these project outcomes influence the upstream. Overall, market actors thought Projects 3 and 4 produced the outcomes they are likely using.

Figure 10: Intention to Use Program Knowledge by Project



41 percent of the surveyed market actors reported that their work has already used or benefitted from program outputs, clearly indicating early impacts of the Program outside of the project teams (Figure 11). Contacts of government, university/nonprofit, and private research and consulting companies, or those who are engaged in the research and development or policy analysis, are the leading users of the Program outputs so far. Few of the hardware manufacturers have yet found ways to adopt the project knowledge.

Figure 11: Early Indication of Program Knowledge Use by Organization Type

Organization types	Have used or benefitted from CSI RD&D projects outcomes
Government (n=17)	53%
Private research and consulting company (n=16)	44%
University or nonprofit (n=15)	53%
Utility (n=12)	33%
Hardware manufacturer (n=11)	18%
Installation contractor (n=9)	33%
3P program implementer or software developer (n=8)	38%
Total (n=88)	**41%**

We further asked market actors who reported having used or benefited from Program outputs how their organizations have used the information (Figure 12). Most commonly, market actors reported Program outputs are used to educate their clients or audience, for their research and development activities or for improving their projects and services. Another use of the Program outputs reported was to apply for other research funding, for which a few of them have been awarded.

Figure 12: Ways Program Knowledge Used (n=36)

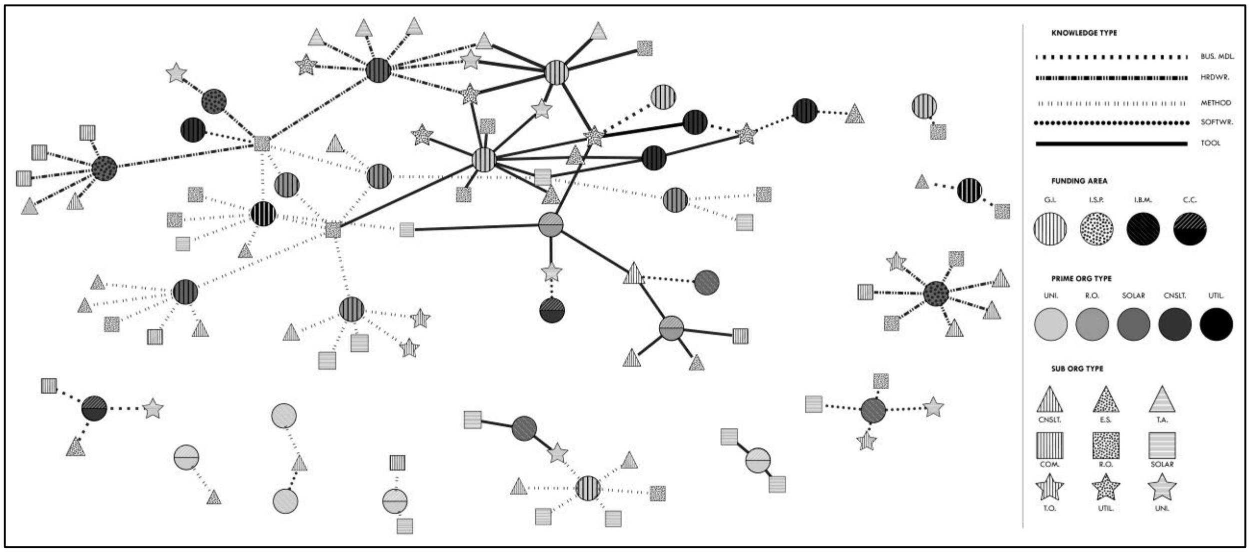
Ways CSI RD&D project information used	
Educating clients and audience	69%
Research and development	69%
Improving products and services	58%
Applying for funding	39%
Increasing sales or market	31%
Other	14%

Program Sociograms

The following Program Sociograms illustrate networks engaged at various levels of the program:

- Program team composition;
- Direct, immediate knowledge recipients; and
- Indirect, distant knowledge recipients.

Figure 13: Program Knowledge Recipient Network Assessment – Team Composition



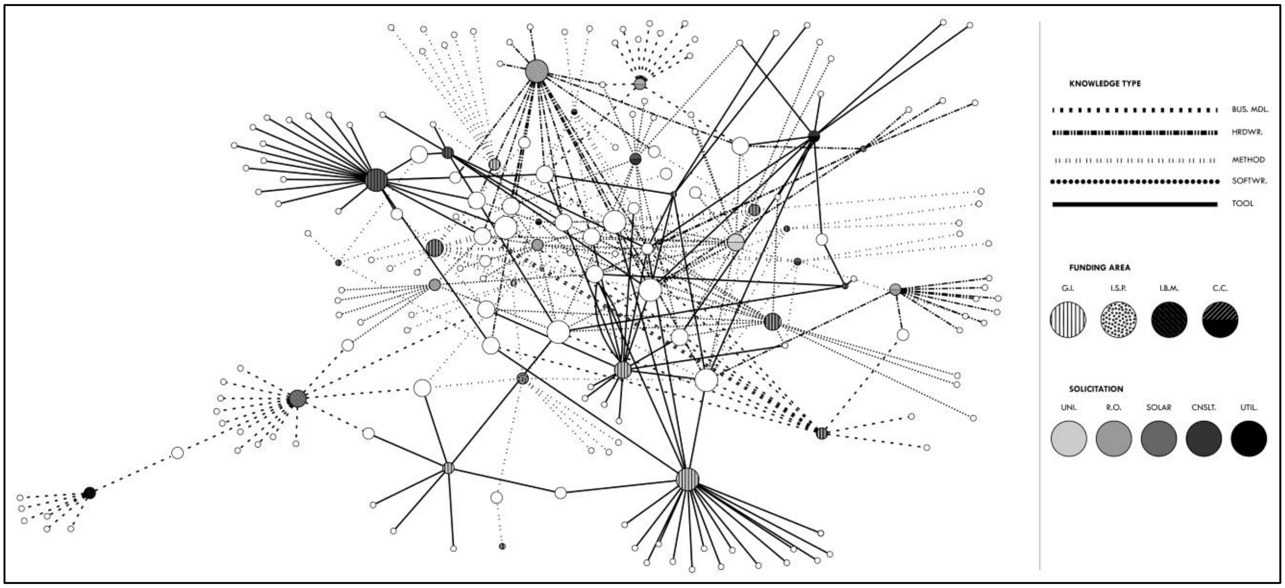
Icon key: G.I = Grid Integration, I.S.P.= Improved Solar Technologies, I.B.M.=Innovative Business Models. C.C.=Cross-Cutting; UNI.=University, R.O.=Research Organization, SOLAR=Solar hardware, installation, or SaaS, CNSLT.=Consultant; UTIL.=Utility; E.S.=Energy services, T.A.=Trade association or agency, COM.=Non-energy commercial, T.O.=Testing organization.

Figure 11 illustrates the network of organizations engaged during Program implementation. Grid Integration teams are clustered together more densely, due to greater overlap between teams. Teams also cluster by knowledge type, indicating that teams with similar interests and competencies tend to work both in similar areas of work (funding areas) and toward similar ends (knowledge types).

Around the exterior of the network, several smaller teams are isolated, sharing no members with other teams. Innovative Business Models projects are overrepresented among the isolated teams. Across the board team makeup is diverse, with most teams involving multiple partners of varying organization types.

Apart from Innovative Business Models teams, this diagram indicates a high degree of reciprocity and transitivity within the Program network. This network context, therefore, as verified by our interviews, has created social capital within the Program, and is well-positioned to facilitate knowledge diffusion and knowledge spillovers.

Figure 14: Program Knowledge Recipient Network Assessment - Direct Knowledge Recipients

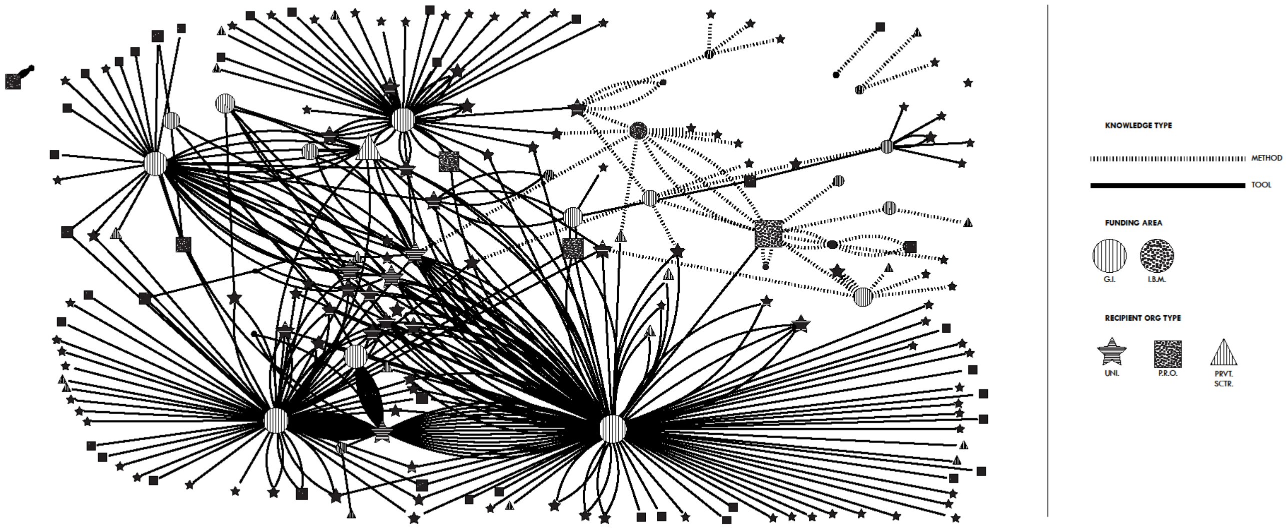


Icon key: G.I = Grid Integration, I.S.P.= Improved Solar Technologies, I.B.M.=Innovative Business Models. C.C.=Cross-Cutting; UNI.=University, R.O.=Research Organization, SOLAR=Solar hardware, installation, or SaaS, CNSLT.=Consultant; UTIL.=Utility;

Figure 12 illustrates the network of direct knowledge recipients engaged during Program implementation by project teams. The network is highly dense, with significant interaction and overlap between knowledge recipients and various project teams. In this diagram, the size of the "head"—the node representing the project team—increases with the number of knowledge recipients, and the centrality of the node is a function of both the number of knowledge recipients reached and the overlap of the knowledge recipients with other teams. Grid Integration and Innovative Business Models projects are the largest, but Grid Integration and Cross-Cutting projects are more central.

The density of the network is remarkable, implying high propensity to create social capital and transfer knowledge. In this case, network density is likely a consequence of the deliberate efforts by the Program to connect teams with key actors in the California market. The network estimate in this diagram indicates that the Program succeeded in creating a dense, valuable network.

Figure 13: Program Knowledge Recipient Network Assessment - Indirect Knowledge Recipients



Icon key: G.I = Grid Integration, I.B.M.=Innovative Business Models; UNI.=University, P.R.O.=Public Research Organization, PRVT. SCTR.=Private Sector Firms.

Figure 13 illustrates the network of organizations that cited Program reports during implementation, up until the end of October, 2016. As discussed previously, only reports released by Grid Integration and Cross-Cutting projects have been cited, largely because more Grid Integration projects were funded during the early solicitations.

The network clusters densely around Grid Integration reports. The density of the network is characterized by recipient organizations citing more than one unique Program report. The densely-clustered portion of the network is also characterized predominantly by a methodology reports, though a few of the recipient organizations cited both methodology and tool-focused reports. Reports from projects that developed tools were less central, positioned in a less dense part of the network, had a lower proportion of private sector knowledge recipients, and interacted with recipient organizations that cited fewer total Program reports.

In this diagram, the size of the recipient organization is proportional to the number of unique Program reports that it cited. The larger recipient organizations overwhelmingly represent private research organizations or universities, with private sector firms more likely to cite a single methodology report. The implications of this diagram generally point to a high degree of transitivity in the network among methodology-oriented reports, which indicates a high degree of perceived value by market actors. The density of the network around methodology reports also suggests that, as Program reports continue to be cited, network effects are more likely to propel methodology innovations.

Knowledge Benefits Conclusions

Team composition was near-optimal for long-term knowledge benefits across the program, highest among Grid Integration projects. Teams leveraged rare skills, strong market position, and operational expertise, and included a mix of private sector firms and public research organizations. The benefits of strong team composition were strengthened by collaborative working relationships.

Collaborative team dynamics were typical, and led to many follow-on collaborations, with more than 40 enduring partnerships stemming from the Program. Partnerships formed among team organizations, between team organizations and stakeholders, and between team members and market actors. Working dynamics and robust team composition set the stage for strong knowledge and absorptive capacity benefits; the high number follow-on RD&D and applied partnerships are early evidence that the benefits will follow.

Many follow-on applications of Program knowledge are already underway, many of which include direct support from grant awardees. The presence of team members in follow-on use of Program knowledge accrues to the benefit of their partners and client networks. Follow-on projects included RD&D, client services, expansion of products and services, and use by outside partners. The high degree of evident follow-on uses of Program knowledge is in part due to the flexibility afforded to teams by the Program Administrator, which worked with teams to revise research emphases as new information came to light. Teams felt this Program aspect was atypical for public RD&D programs, and that it helped match outputs with market needs.

Program design led to selection of teams committed to knowledge transfer. Most teams went beyond Program-required knowledge exchange activities, and many created knowledge spillover opportunities by releasing resources freely to the public and by developing demonstration sites. Teams identified direct stakeholder engagement, non-Program webinars, and conference presentations as the most effective knowledge exchange methods. Many projects relied on non-required knowledge exchange opportunities to reach key audiences.

The Program Administrator worked closely with teams to cultivate audiences for their outputs, but some struggled to make the right connections. The time it took to produce Program-required webinars and reports was viewed to be incommensurate with the effectiveness of knowledge transfer. Thus, teams emphasized one-off and non-required knowledge exchange activities. Some teams noted that restrictions on how the Program could be used for knowledge exchange complicated pursuit of effective knowledge exchange activities.

Teams connected with knowledge recipients throughout the California market; however, many of the knowledge recipients for some projects did not align with the intended audiences the teams set out to reach. Teams praised the Program administrator for facilitating stakeholder and market actor relationships, reducing the time spent for teams to reach key audiences. The mismatch between knowledge recipients and target audiences, however, appears to be due to the formalized Program knowledge exchange activities, which centralized a lot of Program outreach through the Go Solar California website, the opt-in email list, and existing contacts of teams and the Program manager. Teams may have better reached their intended audiences with a more exact and individualized approach for market actor and stakeholder engagement, and for knowledge exchange efforts.

California market actors were familiar both with the Program and with specific projects. Market actors who engaged in research and development, grid operation and management, and third-party electricity market services held the highest opinion of the value of Program outputs. Market actors are currently using Program outputs primarily to educate their clients, for their own research and development, and to improve products and services. Even market actors who do not see an immediate direct use for Program outputs in their own work viewed outputs as needed and likely to benefit them indirectly.

Appendix G: Survey Instruments

In-Depth Interview Guide – Program Administrator

Program Design and Changes

Q1. First, what is your position and role at Itron in relation to the CSI RD&D Program? What are your responsibilities? How long have you been in this position?

Q2. Did the program evolve or change from the original plan over time?

  a. What changed specifically and why did those changes occur? (Probe on changes to specific project categories)

Q3. What aspects of the program design have worked particularly well?

Q4. What aspects of the program design have been challenging?

Project Coordination, Successes, and Challenges

Q5. What process was implemented for the project teams to report their progress to the grant managers?

  a. How well did this process work?

Q6. What activities were project teams required to perform that intended to transfer knowledge from the program?

  a. What were the expectations for the project teams' efforts to reach out to stakeholders?

Q7. To the extent known, what types of working relationships developed within the project teams over the course of the program?

Q8. To the extent known, how did the project teams identify stakeholders (individuals and organizations) that were or should have been the target audience for their results or findings?

Program Coordination

Q9. Which entities did you coordinate with for implementation of the program? (Probe on involvement of CPUC, CEC, IOUs, and ask if any others)How were stakeholders involved in the program?

  a. Do any specific stakeholders stand out?

Q10. How did you work with other entities to develop and implement the project selection process?

Q11. How often were you in communication with stakeholders?

Q12. What worked well in coordinating with stakeholders?

Q13. What were the challenges in working with stakeholders and others?

Early Indicators of Success

Q14. Are there projects that have been particularly successful in achieving their goals? (Probe to get specific project examples)

a. Why do you believe they were successful?

Q15. Are there projects that have struggled to meet their goals or faced more challenges than others? (Probe to get specific project examples)

a. Why do you believe they struggled to meet goals? What challenges did they face? What are the important lessons for the market from these challenges?

Q16. Are there any early indications that knowledge gained from the program is being applied by stakeholders or others outside of the project teams? From which projects? What is the evidences?

Q17. What would you say are the key lessons learned from running the program?

Q18. Looking back on the program over the last eight years, what would you have done differently?

Q19. What recommendations would you give to others running an RD&D program like this?

Website Statistics

Q20. Did you collect or maintain any data reflecting the use of the CSI RD&D website?

a. If yes, what did you collect?

b. If no or don't know, is there a company or service that maintains the website for you? Would you be able to direct us to someone at that organization that might be able to provide some website statistics?

Q21. Do you have any summary reports, such as a web-analytics report, or summaries of historical visitation or download records? (If yes – ask if okay to follow up with them to obtain copies.)

Upcoming Interviews

Q22. What stakeholders and solar industry experts would you suggest that we interview for this evaluation? (get names and contact info)

Q23. Including but not limited to stakeholders, what types of organizations might the project teams have interacted with or transferred knowledge to over the course of the Program?

Q24. We are interested in speaking with solar industry experts and co-funders at CEC, DOE and other relevant organizations. We are also interested in speaking with people at CAISO and the California utilities, and are hoping you could share with us some names and/or other organizations that you believe would be helpful:

<For ORG= CEC, DOE / Sun-Shot, CAISO, PG&E, SCE, SDG&E, SMUD>

Q25. Who did you work most directly with at <ORG>? (collect name/contact)

Q26. Is there anyone else you would suggest we speak with at ORG? (collect name/contact info)

Q27. Would you elaborate a bit on that suggestion, what particular experience or perspective does this person offer for the study?

Q28. Are there any individuals or organizations we haven't talked about yet, that you would suggest we make a higher priority to contact for the evaluation?

   a. What particular experience or perspective does this organization /individual bring?

   b. Collect names and contact info.

In-Depth Interview Guide – Grantees and Sub-Grantees

Introduction

We are conducting the evaluation of the California Solar Initiative Research Development and Deployment Program. The primary objective of this evaluation will be to determine the impact the CSI RD&D Program has had on growing the distributed solar market in California. To evaluate progress towards these goals, we are speaking to project grantees to gather their perspectives of the performance of the Program and unique experiences and outcomes from their specific projects. As we go through the interview when I/we mention "the Program" we are referring to the CSI RD&D Program unless we state otherwise.

Thank you for agreeing to assist our study!

To ensure we capture all the information in this interview, are you okay if we record the interview, the recordings will not be released outside of our study team and are for reference purposes only.

Engagement with CSI RD&D Program and Solicitation Process (ask all)

I would like to start with a few questions about your experience with the solicitation process and engagement with the Program through the lifetime of the project.

Q1. How did you first become aware of the CSI RD&D funding opportunity?

Q2. Overall, how was your experience with the solicitation process, and the project award and contracting? [PROBE: Were the solicitation instructions clear? Was communication clear? Were the processes timely and appropriate? Did you get the information and feedback you needed?]

Q3. What are your overall perceptions of your interactions with the program manager, Itron? [PROBE: What worked well? What needs improvement? How often were you in contact with Itron? How did they feedback or direction from program manager, if at all?]

a. Was there anything that could have been done differently or better?

Project Description

Now I have a few questions about your project.

Q4. Can you briefly describe your grant project?

a. What existing research did your team leverage to implement the project?

b. What specific need or knowledge gap did your project address?

Q5. What where the innovative outputs your project produced?

Knowledge Base Questions (ask all)

Networks and Relationship Building

Now I would like to discuss the people and organizations that you partnered with through the Program, the networks and new relationships you developed and how you communicated throughout the implementation of the project.

Q6. Please describe the collaboration between your organization and project partners. [PROBE: Did any team members form relationships to continue working jointly after completing the project? How many? What nature?]

a. Would you describe the collaborations among the team organizations primarily as closely coordinated – frequently providing feedback and working together – or more independent, completing tasks more or less independently and integrating later with the team?

b. [If not addressed above] What was the role of stakeholders in the project?

c. Over the course of the project, were any working relationships formed with others **outside** of the core project team? [PROBE: How many? With whom? What nature?]

d. Did any project partners bring unique, hard-to-find skills or experiences to the project?

Q7. Has your organization or another team member begun additional RD&D work due in part to their experience with the Program? [**IF YES**: How many? Who are the funders? How much have they been awarded?]

A lot of factors, including scopes of work, affect how the various Program teams went about promoting their findings and outputs and transferring their know-how to stakeholders and market actors. Now I would like to discuss some of the details around how these type of knowledge exchange activities took shape.

Q8. Please provide a description of how you went about disseminating knowledge/know-how about your project. [**PROBE**: What key events or products stand out as more or less effective?]

a. [If not addressed above] Which of the outputs or presentations do you feel were more effective, and which were less effective? Why?

b. How effectively could the knowledge generated in the project be codified into a useful manual or a document?

c. Were any individuals, from your project team or otherwise, especially effective or influential in disseminating information about the project? [PROBE: Who were they? How/why were they effective?]

Q9. To the best of your recollection, what was the average number of attendees at webinars and other presentations? What about stakeholder meetings?

a. Were you able to track the number of downloads of final reports, databases or other tools your project produced? [If YES: ask for estimates, or send to team as follow up]

The Program required that each project release a technical report, a final report, conduct a final webinar, and hold advisory meetings with stakeholders. Some teams elected to produce additional outputs or activities to help transfer knowledge from their project.

Q10. Apart from required program activities, what opportunities for actors apart from the project team and stakeholders were there to learn about your project or its outputs? [PROBE: What type of organizations showed the most interest in learning about your project?]

Q11. What, if any, aspects of the program hindered or facilitated your efforts to disseminate information project?

Knowledge Recipients and Network

Now I would like to discuss your role in the solar sector, and the people and organizations outside your team that you engaged with over the course of your involvement with the Program.

Q12. We'd like to know a bit about your niche in the solar industry. In your opinion, what are the most relevant firms or research groups operating in your area?

Q13. What are the most relevant conferences and working groups?

Q14. Who did you consider to be the primary audience for your project's findings or outputs? [Probe for any not mentioned: Utilities, system operators, project implementers, researchers or analysts, utility planners, standards setters]

Q15. I'm going to list a few types of organizations, to the best of your recollection please indicate whether any organizations from these types received information about your project or its findings:

a. Utilities or ISOs (Yes, No); [PROBE: Please name any specific examples]

i. [If not listed: What about CalISO?]

b. Standards and testing organizations (Yes, No); [PROBE: Please name any specific examples]

i. [If not listed: What about IEEE?]

c. Research Organizations, including National Labs (Yes, No); [PROBE: Please name any specific examples]

i. [If not listed: What about EPRI?]

d. Solar hardware or installation firms (Yes, No); [PROBE: Please name any specific examples]

i. [If not listed: What about SolarCity, SunPower, or Enphase?]

e. Trade associations or non-profits (Yes, No); [PROBE: Please name any specific examples]

i. [If not listed: What about SEPA or SEIA?]

Knowledge Produced

Now I would like to discuss the knowledge and know-how that your project produced.

Q16. Do any of the project team members intend to use the findings or outputs from the project? [PROBE: Who or which organization on the team is planning to use the work? How will they use it?]

Q17. Are you aware of any organizations or individuals, apart from your project team, who are planning to use the findings or outputs from the project? [PROBE: Who or what organizations?]

a. Have any of your project outputs been implemented in an operating environment? Will they be in the future? [PROBE: What aspects? By whom?]

Q18. What, if any, intellectual property strategy has your team put in place to commercialize what you learned while implementing the project? [PROBE: Did you file any patent applications? (If YES: How many?) Are any of your stakeholders involved in the market strategy?]

Research Area Questions

[Note to Interviewer] Ask specific research area battery questions noted for each question. based on project research area from program documentation.

Q19. [ALL] Do you know or can you estimate the cost of implementing the outputs (models, tools, data) of your project in an actual operating environment?

a. [IF NO] Would you characterize implementation as resource intensive or not?

Q20. [GRID INTEGRATION AND/OR SOLAR TECHNOLOGY] Have there been any formal performance tests of your project outputs? Was this in a lab or at a test site under realistic operating conditions? Have the results been documented or distributed? [PROBE: Where documented and distributed? How can we access this?]

Q21. [GRID INTEGRATION AND/OR SOLAR TECHNOLOGY] Did the outputs developed in your project perform as your team expected, in relation to other similar tools and the expectations of the project? In what way?

Q22. [GRID INTEGRATION; SOLAR TECHNOLOGY] Has any output from your project been commercialized?

a. [IF YES] Have there been any sales of your technology, or has there been a transfer of ownership of the technology to another entity? [PROBE: Details on number of units sold or installed, revenue]

b. [IF YES] How is the output made available to the market?

Q23. [GRID INTEGRATION; SOLAR TECHNOLOGY] Have any team partners or other market actors made additional investments in the technology to meet demand or potential demand? How much has been invested? [PROBE: firm's capital, investment capital, venture capital, growth in number of investors, investment in production]

Q24. [ALL] Have any stakeholders or market actors made any investments to adopt or implement output from your project? [PROBE: Capital investment; training; investment in other resources]

Q25. [ALL] Is there evidence of reduced cost of solar projects, reduced risk of solar projects or other indicators of success of the output of your project? Can you please provide the details of these successes?

Q26. [ALL] Is there evidence that the output from your project will help accelerate grid integration of distributed solar?

Impact of CSI RD&D Projects Overall

Now we would like to discuss the potential impact of your project in the solar sector.

Q27. I am going to read a list of declarative statements about potential program impacts on the general solar market. Can you please answer yes or no to each statement if there is evidence your project output has already or will affect the solar market? For statements where you answer yes, can you provide a brief, one to two sentence, explanation of how your project might influence the market.

Outcome	Has Influenced (Y/N)	Will Influence (Y/N)	[If YES] In what way?
Improve overall system reliability such as reduced unintentional islanding, inverter trips etc.			
Improved identification of optimal locations for high penetration levels of PV			
Improved visibility of solar generation for system			

planners	
Made interconnection simpler or more streamlined	
Made solar projects easier and cheaper to implement	
Decreased the overall cost of solar generation and led to improvements in rates and tariffs	
Increased overall penetration of solar generation	
Made the value of solar projects easier to determine and increased the bankability of solar projects	
Made solar projects less risky to customers and stakeholders	
Made the solar market easier for new market actors to enter with innovative solar solutions	

Q28. Are there any other impacts that your project has or might have on the market we haven't discussed? [PROBE: geographic influence, economic influence, improved rates, lowered transaction costs, changes to interconnection standards, increased spending on training]

Q29. Thinking about the overall program and your knowledge of it, what impacts related to improvement and acceleration of grid integration of distributed solar have you observed or do you expect from the outputs of the program?

Conclusion

That's all the questions I have today. Do you have any final comments on the CSI RD&D Program that you would like to provide?

Thanks for your time and good information. Is it OK if we call or email you later if we have any follow up questions?

In-Depth Interview Guide – Stakeholders

Introduction

We are conducting an evaluation of the California Solar Initiative Research Development and Deployment Program. The primary objective of this evaluation will be to determine the impact the CSI RD&D Program has had on growing the distributed solar market in California. To evaluate progress towards these goals, we are speaking with stakeholders in the Program to gather their perspectives of the performance of the Program. As we go through the interview when I/we mention "the Program" we are referring to the CSI RD&D Program unless we state otherwise.

Thank you for agreeing to assist our study!

It's OK if you can't answer all of the following questions. We'll be talking to several people and expect that different people will have different roles and focus areas.

Your answers will be kept confidential and will be grouped with other respondents for reporting in aggregate form only. No findings will be directly linked to your name or job title in any project reports.

Role of Interviewee

Q1. First, what is your position and role at [ORGANIZATION NAME]? How long have you been in this position?

Q2. What does [ORGANIZATION NAME] do? What is the focus of [ORGANIZATION NAME] in the solar industry? (Probe: technology focus, research focus, transmission and distribution system focus, market focus etc.)

Q3. The Program was designed to address four focus areas:

a. Grid integration tools and models
b. Developing grid integration policy, standards and guidelines
c. Developing solar system hardware and software
d. Developing business models, reducing market barriers

Which of these would you say is the closest fit for your organization? (Select all that apply)

Engagement with CSI RD&D Program

Let's talk about your engagement with the Program.

Q4. How did you first become aware of the program, and in what ways did you stay most connected to, or aware of its activities?

Q5. Did you or your organization directly collaborate on any projects?

a. [If NO] Can you describe you involvement with the program?

b. [If YES] Which projects did you collaborate on?

c. [If YES] In what ways did you collaborate with the project team?

Q6. Aside from the projects you collaborated on (if any) did any other Program funded projects address issues relevant to your or your organization's work?

a. [If YES] Which projects?

Q7. What communications and coordination occurred between your organization and other actors in the Program? (Probe on modes of communication such as meetings, calls, webinars, frequency, scheduled or not, and problems in communication)

Q8. Could the communication or coordination activities have been improved in any way?

Q9. Overall, did you find your interactions with the Program to be valuable to you and your organization? In what ways? Is there anything you would suggest doing differently?

Networks and Relationship Building

Now I would like to discuss the people and organizations that you engaged with through the Program. Specifically, I would like to talk about the networks and new relationships developed and how you communicated throughout the implementation of the program.

Q10. Through your knowledge, impressions and interactions with the Program, how have organizations or individuals been affected by the Program? Please explain.

a. Which specific organizations, apart from your own, do you think have been affected?

Q11. Did you develop any new relationships with individuals and organizations involved in the Program? (Which organizations?, Why/how did this unfold?) What about relationships built with non-project partners?

a. [If YES] Have any relationships continued after the Program ended that were formed during your involvement in a project?

Q12. Was there a change in the level of awareness, or visibility, of the progress being made in solar RD&D that you observed either at your organization or other organizations that you would attribute to the Program?

a. [If YES] How have these changes affected solar RD&D?

•

Information Sources and Knowledge Exchange

Now I would like to discuss the information and knowledge generated by the Program projects, how this knowledge was exchanged between stakeholders, and how this knowledge may have filled gaps, or otherwise been of importance.

Q13. How successful were the projects you engaged with in addressing and resolving the knowledge gaps they intended to close? [PROBE: Identify specific projects]

a. How could they have been more successful?

Q14. Did the market relevance of the projects, the extent to which findings might lead to revenue opportunities, impact the degree of interest among stakeholders or market actors? If so, please provide examples.

Q15. Projects were required to complete a number of activities intended to transfer useful knowledge to parties outside of the Program, such as patent applications, webinars, reports, articles, or conference presentations. Did you help create/facilitate these activities? Which do you think were more or less effective?

Q16. Other then the required activities, what activities not specifically intended to transfer knowledge might have provided individuals or organizations outside of the project with opportunities to learn about the ongoing research?

a. [If YES] Did you help create/facilitate these activities?

Q17. Did you participate in any stakeholder advisory group consultations?

a. [If YES] Where the stakeholder advisory groups useful and informative?

b. [If YES] What, if any, improvements would you recommend to make the stakeholder advisory groups more useful and informative?

Q18. How did involvement with the projects enhance knowledge capacity at your organization?

a. That you know of, how did involvement with the project enhance knowledge capacity at other organizations? (utility/ISO staff, public researchers, advocates, heads of business units, program managers, downstream firms, upstream firms, financing entities)

Q19. Has your organization made any changes in your near- or long-term strategy, including products and services, as a result of knowledge gained from Program projects?

a. [If YES] What specific knowledge led to these changes? From which project(s)?

Q20. To what extent do you think Program projects enhance the knowledge capacity among the solar, utility, and research sectors, generally?

Impact of CSI RD&D Projects

Now lets discuss in more detail the impact of the Program on your organization and the solar sector generally.

At the beginning of this interview we talked about four major areas of focus: grid integration tools and models, developing grid integration policy, standards and guidelines, developing solar system hardware and software, and developing business models and reducing market barriers. I would like you to focus on these areas when answering the following questions.

Q21. Thinking back about 10 years , what were the biggest challenges to making progress around <AREAS from Q3>.

-

Q22. Have these challenges been overcome? [PROBE: Impact of Program activities contributing to addressing challenges; which projects and how??

-

Q23. Aside from these critical challenges and developments, were there other aspects of <AREA> that were affected by the activities of the Program?

-

Q24. I am going to read a list of declarative statements about potential program impacts on the general solar market. Can you please answer yes or no to each statement if there is evidence the outputs of projects you were involved with have already or will affect the solar market? For statements where you answer yes, can you provide a brief, one to two sentence, explanation of how they have or will influence the market.

Outcome	Has Influenced (Y/N)	Will Influence (Y/N)	[If YES] In what way?
Improve overall system reliability such as reduced unintentional islanding, inverter trips etc.			
Improved identification of optimal locations for high penetration levels of PV			
Improved visibility of solar generation for system planners			
Made interconnection simpler or more streamlined			
Made solar projects easier and cheaper to implement			
Decreased the overall cost of solar generation and led to improvements in			

rates and tariffs
Increased overall penetration of solar generation
Made the value of solar projects easier to determine and increased the bankability of solar projects
Made solar projects less risky to customers and stakeholders
Made the solar market easier for new market actors to enter with innovative solar solutions

Q25. [IF NOT DISCUSSED IN Q21]Have any of the projects you were involved in led to, or are likely to lead to:

a. Increased investment in integrated solar? (Probe on investment in hardware/software, further research and development, skills and training, etc.)
b. Observable changes in the size of the solar market? (probe on increase in solar penetration, customer engagement, reduced costs, entry or exit of market actors, changes in regulation)
c. Regulatory changes or change in technical guidelines that have impacted penetration of integrated solar, or improved the viability of integrated solar?
d. New technologies, new services or businesses, new methods of manufacturing, marketing or delivering technologies?
e. Reduced cost of overall grid management and operations that positively impact ratepayers?

Q26. Have the projects you have been involved with added value for your organization or your customers? Can you put a dollar value on the benefits?

a. How about over the next 5 years, will the benefits of these projects add value to your organization or your customers?

Q27. Has the Program provided value to the CA economy and ratepayers in general? Please describe the benefits (present or future).

Q28. Are there energy impacts from the Program that increase the generation capacity or deployment of solar in California?

Q29. Has the Program affected the state's energy resource mix? How so? What about over the next 5 years, will outcomes of the program affect the state's energy resource mix?

Q30. How has the Program changed power needs of power generators and utilities in California? Has increased solar generation offset the need for other generation? Has solar generation impacted demand on the grid?

Conclusion

I just have a few more questions and then we'll be done.

Q31. Considering everything we have talked about today, what do you believe are the most important changes that have occurred as a result of the Program?

Q32. Which of these changes do you expect (or have you observed) will carry over after the program has ended? (Why / Why not)

Thanks for your time and good information. Is it OK if we call or email you later if we have any follow up questions?

In-Depth Interview Guide – Industry Experts

Introduction

We are conducting an evaluation of the California Solar Initiative Research Development and Deployment Program. The primary objective of this evaluation will be to determine the impact the CSI RD&D Program has had on growing the distributed solar market in California. To evaluate progress towards these goals, we are speaking with experts in the solar industry to gather their perspectives of the performance of the Program. As we go through the interview when I/we mention "the Program" we are referring to the CSI RD&D Program unless we state otherwise.

Thank you for agreeing to assist our study!

It's OK if you can't answer all of the following questions. We'll be talking to several people and expect that different people will have different roles and focus areas.

Your answers will be kept confidential and will be grouped with other respondents for reporting in aggregate form only. No findings will be directly linked to your name or job title in any project reports.

Organization and Individuals

Q1. What does your organization / institution do?

Q2. What is your role and responsibilities?

a. If needed: What department or division within <organization> do you work in?

Relationship to Solar Industry

Q3. Which of the following areas of the solar industry, and solar RD&D in particular, would you be most comfortable discussing today? (if needed: Which area relates most directly to your expertise?) (Select all that apply)

a. Grid integration tools and models, (provide examples)
b. Developing grid integration policy, standards and guidelines
c. Developing solar system hardware and software (provide examples)
d. Developing business models, reducing market barriers (examples)

Q4. Why do you say that? Could you provide a summary of your interest and expertise in this/these area(s)?

For each AREA indicated above, < grid integration, policy, hardware/software, business/markets>

Q5. Thinking back to 2008 when the CSI program began (or about 10 years ago) what were the biggest challenges to making progress in this <AREA>~~?~~

a. Were there activities, events or other developments that addressed these challenges?

b. In what ways if any did the activities of the CSI RD&D program contribute to addressing these challenges?

Q6. What do you perceive as being the most significant developments in this area over the past 10 years? Please explain.

Q7. Thinking about <AREA>, what do you perceive as being the biggest challenges for this area of the solar industry today, and going forward?

a. In what ways, if any, has the work of the CSI RD&D program contributed to the knowledge base that will be useful in addressing these challenges?

Past California RD&D and CSI RD&D

Q8. How familiar, or how involved have you been in solar RD&D efforts in CA that preceded CSI RD&D?

a. Are you aware of instances in the Program where previous data, findings or lessons learned were successfully leveraged?

b. Do you know of any instances where an opportunity to leverage past experience was overlooked, or otherwise unsuccessful?

CSI RD&D Program Experience

Q9. How did you become aware of the program, and in what ways did you stay informed of, its activities?

~~Q10.~~ Did you follow any particular aspects of the CSI RD&D program, or certain projects more closely as they were being conducted?

a. How did you receive information about this area of the program?

b. How did you use this information?

c. Did you share this information with others? With whom?

Information Sources and Knowledge Exchange

Next I would like to talk with you about whether and how you received information and updates about the Program, and how you may have shared knowledge with others.

Q11. How often over the past eight years have you attend conferences that cover solar-related topics?

   a. Thinking back over the conferences you have attended, how often did those events bring you information related to CSI RD&D?

Q12. Have you attended meetings, webinars, or events hosted by CSI RD&D program or project staff?

   a. [If YES] How often did you attend such events?

   b. [If YES] How did you most often find out about them?

Q13. How often do your work assignments regularly highlight key solar industry or RD&D developments?

   a. How often have they brought CSI RD&D developments to your attention?

   b. Have you leveraged CSI RD&D program as a resource in completing work assignments?

Q14. Do you participate in any working groups, to collaborate on developing solar-related standards, guidelines and/or policy? (record which working groups and url, proceeding number, or other reference to group activities)

   a. Have the findings, data or resources related to the Program been consulted during the activities of (this/these) working group(s)?

   b. Have the findings, data or resources related to CSI RD&D been useful for the activities of (this/these) working group(s)? (probe for details)

Q15. Do you read trade journals or periodicals related to <AREAS>?

   a. Which ones do you read regularly?

   b. Have you run across CSI RD&D related material in these trade journals or periodicals?

Q16. Do you regularly use online databases, or websites that provide resources related to <AREAS>?

   a. Which ones, and for what reasons do you typically visit these sites?

   b. Have you encountered CSI RD&D related information there?

Q17. Are there other publications or activities related to <AREA> that you regularly read or participate in?

   a. Have you encountered CSI RD&D material in these?

Q18. Are there other ways that you regularly share your solar-related knowledge with others?

a. How often /how much has the CSI RD&D-program contributed to the knowledge you share this way(s)?

Q19. Thinking over all of these knowledge-sharing methods, what ways have been effective you for you in receiving solar RD&D knowledge?

a. Are these also the most effective ways you have received Program-specific RD&D information? If not, which?

Q20. What are the most effective ways you share RD&D knowledge with others?

Conclusion

I just have a few more questions and then we'll be done.

Q21. Considering everything we have talked about today, what do you believe are the most important changes that have occurred as a result of the CSI RD&D program?

Q22. Which of these changes do you expect (or have you observed) will carry over after the program has ended? (Why / Why not)

Thanks for your time and good information. Is it OK if we call or email you later if we have any follow up questions?

In-Depth Interview Guide – Market Actors

Introduction

We are conducting an evaluation of the California Solar Initiative Research Development and Deployment Program.

The primary objective of this evaluation is to determine the impact the CSI RD&D Program has had on growing the distributed solar market in California. To evaluate progress towards these goals, we are speaking with market actors who have engaged with or used outputs from the CSI RD&D Program. Our goal is to gather market actor perspectives of the performance of the Program, and the innovative outputs of the program and how they have impacted solar organizations and the market. As we go through the interview when I/we mention "the Program" we are referring to the CSI RD&D Program unless we state otherwise.

It's OK if you can't answer all of the following questions. We'll be talking to several people and expect that different people will have different roles and focus areas.

[If needed: Your answers will be kept confidential and will be grouped with other respondents for reporting in aggregate form only. No findings will be directly linked to your name or job title in any project reports.]

Organization and Individuals

Q1. What does your organization do and what is your role in the organization? [PROBE: if needed department or division]

Q2. Which of the following areas of the solar industry, and solar RD&D in particular, would you be most comfortable discussing today? (Select all that apply)

a. Grid integration tools and models, (such as models estimating solar resources and PV system output, and utility planning, design and operation models)

b. Developing grid integration policy, standards and guidelines

c. Developing solar system hardware and software (hardware such as inverters, storage, and monitoring technology or software such as monitoring and communications software and control software)

d. Developing business models, reducing market barriers (such as cost / benefit models, price sensitivity models, models to determine appropriate tariffs, models that identify market barriers and opportunities)

Q3. Thinking back about 10 years, what were the biggest challenges to making progress around <AREAS from Q3>?

a. Have these challenges been overcome? [PROBE: Impact of Program activities contributing to addressing challenges; which projects and how?]

Q4. Thinking about <AREAS from Q3>, what do you perceive as being the biggest challenges for this area of the solar industry today, and going forward?

a. How will these challenges be overcome do you think? [PROBE: Will any of the activities or projects of the Program contribute to addressing these challenges]

CSI RD&D Program Engagement

As we discussed earlier, we contacted you for an interview partly based on your interaction with the XYZ Project. Now I would like to discuss how you became aware of this project and the Program on general, and how you kept informed about the projects that were of interest to you.

Q5. How did you first become aware of the Program and the projects you were engaged with, and how did you stay informed about them?

Q6. Have you attended meetings, webinars, or events hosted by Program or project staff? [PROBE: How often did you attend such events? How did you find out about them?]

Q7. Aside from XYZ Project how many other CSI RD&D projects did you follow, interact with, or review findings or outputs from? Which ones?

Q8. Did any particular individuals or organizations stand out as good resources for information about projects that were of interest to you?

Q9. Have you developed any ongoing working relationships or collaborations with individuals or organizations that were part of a Program project? [If YES: Who or what organizations / project? What was the nature of those relationships? What insights, tools, or data from the Program are you building on?]

Q10. Do you participate in any working groups, to collaborate on developing solar-related standards, guidelines and/or policy? [If YES: Which working groups, proceeding number?)

a. Have findings, data or tools from the Program been reviewed or used during the activities of (this/these) working group(s)? [If YES: Please provide details.]

CSI RD&D Program Impact on Organization

Now I would like to hear more about your interactions with the Program projects, how you or your organization have used the innovative outputs, and the impact of these outputs on your work.

Q11. Firstly, how you were involved with the Program projects, and give me a brief description of the outcomes of the project that were of interest to you or your organization?

Q12. Why did you view this project as a good opportunity for your organization to be involved with? [PROBE: Did it fill a gap in the market? Opportunity for competitive advantage? Opportunity for improving your business?]

Q13. Has your organization continued to use any of the findings, tools, or outputs from the Program projects, since the end of the project? In what way? [PROBE: Have you cited any project outputs? Have you begun RD&D work that leverages insights, tools or data from the Program?]

Q14. Have you or your organization made any investments in technology or training as a result of a Program project? [PROBE: Which projects? What investments? Why have you made these investments?]

Q15. Has your organization developed any new or improved commercial products, services or business processes as a result of influence by a Program project?

   a. [IF YES] Can you please describe these for me? [PROBE: What stage of manufacturing or development are they in? Commercial viability of products? Impact on the business?]

   b. [IF YES] Do you think your organization would have invested in developing or improving these products, services or processes without the influence of the program? [PROBE: Did the program accelerate development? Did the program improve financial viability or reduce costs to your organization?]

Q16. Have the outputs or influence of the Program projects contributed to growth of your organization? In what ways? [PROBE: Increased sales; increased revenue; added jobs; reduced costs; increased demand or customer awareness of solar; made solar projects faster and easier to implement]

Q17. Have any outputs from the Program projects impacted your organization in ways we haven't discussed?

CSI RD&D Program Impact on Market

Q18. Are you aware of any other organizations or individuals who are planning to use findings or outputs from the Program? [PROBE: Who or what organizations?]

Q19. Are you aware of any other organizations developing new or improved products as a result of the Program? PROBE: What stage of manufacturing or development are they in? Commercial viability of products]

Q20. Are you aware of any Program outcomes that have led to increased installations of distributed solar?

Q21. Are you aware of any industry protocols or guidelines that have or will change as a consequence of the Program? Which ones and how? [PROBE: names of protocols or guidelines; will they become simpler or more complex; impact on cost; impact on penetration of PV solar; impact on grid integration]

Q22. Are you aware of any non-Program RD&D projects that have produced new findings or created new tools or technologies that extend work completed in the Program? [PROBE: types of projects, grid integration, new technology, business models]

Q23. Have the outputs or influence of the Program projects contributed to growth of the solar market in ways we haven't discussed? In what ways? [PROBE: Made solar projects easier to implement; reduced time for project approval; improved economics of solar projects; reduced costs of solar projects including soft costs; increased demand for solar projects]

Conclusion

I just have a few more questions and then we'll be done.

Q24. Considering everything we have talked about today, what do you believe are the most important changes that have occurred as a result of the CSI RD&D program?

Q25. Which of these changes do you expect (or have you observed) will carry over after the program has ended? [PROBE: Why / Why not]

Q26. For which actors in the solar, utility and research sectors do you think the Program data, tools, findings or other outputs will be relevant?

Q27. Are there any other areas where the program has impacted the solar market that we have not talked about?

Thanks for your time and good information. Is it OK if we call or email you later if we have any follow up questions?

Market Actor Survey

The purpose of the Survey of Market Actors is to collect standardized quantitative data to measure the short-term First Order Outcomes of the CSI RDD Program (the "Program) related to increasing the knowledge base of California solar market. As stated in the logic model, the knowledge base First Order Outcomes are defined as (also, see metrics in Table 1):

- Reduced duplication, users needs met, new skills, acceptance, follow-on use
- Knowledge, capacity gaps filled; follow-on funding for similar studies and tools
- Awareness, knowledge of how and why of grid integration in broader solar expert community.

While data collected with in-depth interviews focus on the qualitative investigation (how, what, and who) of the process of knowledge transfer, the survey data will inform numerically the extent to which knowledge transfers have occurred among the broader groups of market actors in the California solar market, and what value these actors perceive the program to have had. Specifically, the key questions the survey data attempt to answer are:

- To what extent has formal and informal knowledge exchange activities taken place?
- To what extent has the knowledge produced by projects diffused beyond the project teams in terms of awareness, know-how, acceptance, and follow-on knowledge production?
- To what extent do different groups of California solar market actors perceive the knowledge produced by projects to be valuable?
- To what extent do different groups of California solar market actors find project findings to be relevant to their work?
- To what extent do different groups of California solar market actors intend to use the knowledge produced by projects in their work?
- To what extent do different groups of California solar market actors perceive that projects closed knowledge gaps or increased knowledge capacity of the solar market in California?
- Which California solar market actor groups benefited most/least from the projects?

Sampling Frame

The population of the market actors survey is deliberately more constrained than the broad community of the California solar market who, we expect, will be potentially affected by the Program efforts in the fullness of time; such as technology experts, installers, manufacturers, system companies, builders, contractors, grid planners and operation staff, and utility program managers. The survey is not a random or general population survey, which, at this point so recently following the close of the Program, would not yield meaningful results. The survey is designed to target a few segments of the solar market whom we expect, based on evidence in the program documents, have had early exposure to the Program or its outputs. We have identified four market actor segments to represent the broader sampling frame, they are:

- Individuals who registered to be part of the CalSolar list serve
- Individuals from teams that submitted losing proposals to the Program
- Individuals who attended the DOE-CSI RDD joint workshops
- Individuals cited in patent applications or references in technical reports submitted by the project teams

We have developed an extensive list of emails for these segments. After piloting, we will invite people from these segments to participate.

Survey Logic

At the beginning of the survey, in the Participant Profile and Awareness sections, respondents who indicate both that they are not aware that the state of California funds RD&D project and that their work/organization does not have a stake in the advancement of the California solar market will be skipped to a control group. Respondents in the control group will take a pared down version of the survey, focusing on questions related to their perceptions of the projects. If sufficient respondents complete surveys in the control group, we will compare their responses to analogous respondents (based on Participant Profile responses) to determine there appears to be any reputational benefit or drawbacks owing to awareness of California's RD&D efforts (a "program effect").

Instrument Information

Table 86: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	Web survey
Estimated Time to Complete	No longer than 15 minutes
Population Description	Market actors described in the “Sampling Frame” discussion above
Sampling Strata Definitions	Randomly assigned respondents corresponding to the two pairs of project descriptions; control group of respondents screened out due to lack of RD&D awareness and stake in the solar market
Population Size	NA
Contact List Size	Approximately 2,000
Completion Goal(s)	80 responses per project description pair, total of 160; no completion goal for control group
Contact List Source and Date	List sources described in “Sampling Frame” discussion above
Type of Sampling	Purposive (Criteria described in “Sampling Frame” discussion above)
Contact Sought	NA
Fielding Firm	Research Into Action

Table 87: Research Objectives and Associated Questions

Research Objective	Research Issue	Associated Questions
Awareness of CSI RDD funding opportunities, projects, and outcomes	Have they heard about CSI RDD funding program? Have they heard about any projects funded by CSI RDD? Have they heard about project status or outcomes of the funded projects?	Q7-10,
Perceived value (lessened knowledge gaps and increased capacity) and relevance of CSI RDD projects and outcomes	How relevant are the CSI RDD projects to their work? Perceived value of the CSI RDD project and outcomes in terms of reduced duplication, user needs, new skills and knowledge in their work. Perceived value of the CSI RDD project and outcomes in terms of reduced knowledge gaps and increased capacity in their work. Perceived valued of the project in terms of contributing to greater or accelerated integration of distributed solar power.	Q13-28
Intention of use and plan for follow-on research of CSI RDD projects' outcomes	Intending to use the knowledge acquired by the CSI RDD projects? To what end? Plan for follow-on research of the CSI RDD projects? Applied or received for follow-on funding for similar studies and tools?	Q30-38
Formal and information knowledge exchange activities specific to CSI RDD projects	How did they hear about the Program or projects? Have they discussed CSI RDD projects or outcomes with their immediate colleagues, distant colleagues, or in any conferences? What information sources do they typically use to learn about RD&D research?	Q11, Q12, Q29
About the respondents, and measures for the network estimation	Level and role in their organization. Role and area in the California solar community (research, installation/contractor, 3P provider, utility, community organization, manufacturer, etc.). Tenure in their organization and the California solar community. Location. Their interests in the California solar market.	Q1-6

RECRUITMENT E-MAIL

Introduction

Email Invitation Content

Subject line: The California Solar Initiative Research, Development, Demonstration, and Deployment Program Needs Your Help

Body: I am writing to ask for your help as a member of the solar community in California. The California Public Utilities Commission (CPUC) established the California Solar Initiative (CSI) Research, Development, and Deployment Program (RD&D), to distribute funds to organizations to explore advancing solar technologies and other distributed generation technologies. The ultimate goal of the program was to build a sustainable and self-supporting industry for customer-sited solar in California.

On behalf of the CPUC, Evergreen Economics has partnered with Research Into Action, Inc. to assess and understand how this program has been doing in its efforts to increase the knowledge capacity among the solar community in California.

Your responses to our short 5-10 minute survey will be very helpful to CPUC as it continues to support members of the solar community in the state like you. Even if you have not heard of the program, your responses will be of great value. It is only by hearing from members of the solar community that CPUC can make meaningful improvements. To thank those who help us with our study, we will send an advance summary report describing our findings (before publication).

Please click here to start taking the survey, or copy and paste the link below into the address space in your web browser.

Survey Link:

We assure you that your responses will remain confidential and will be used only for our research purposes. If you have any questions about this study, please contact XXXX at xxxx@xxxx.com or xxx.xxx.xxxx.

We thank you in advance for your valuable help!

INSTRUMENT

Respondent Profile

To get started, we have a few questions about your organization and your role there.

[ASK ALL]

Q1. Which of the following categories <u>best</u> describes your organization? (Please select only one.)

[SINGLE RESPONSE]

1. Installation contractor
2. Utility
3. Third-party program implementer
4. Hardware manufacturer
5. Software or controls developer
6. Non-profit
7. Government
8. University or college
9. Private research company

96. Something Else - Please tell us: [OPEN-ENDED RESPONSE]
98. Don't know

[ASK ALL]

Q2. In which of the following geographic areas does your organization work? (Select all that apply.)

[MULTIPLE RESPONSE]

1. Primarily California
2. Other specific state or region, please specify: [OPEN-ENDED RESPONSE]
3. Throughout the US
4. International
5. My work is not geography specific [EXCLUSIVE]

96. Something Else - Please tell us: [OPEN-ENDED RESPONSE]
98. Don't know [EXCLUSIVE]

[ASK ALL]

Q3. Which of the following categories <u>best</u> describes your role in your organization? (Please select only one.)

[SINGLE RESPONSE]

1. Executive
2. Administration
3. Research and development
4. Policy analysis

5. Sales and advertisement
6. Communication
96. Something Else - Please tell us: [OPEN-ENDED RESPONSE]
98. Don't know

[ASK ALL]

Q4. Which, if any, of the following areas describes the work your organization does? (Select all that apply.)

[MULTIPLE RESPONSE]

1. Distributed Energy Resource (DER) site assessment
2. Grid operations and management
3. Solar or utility research or consulting
4. Third-party products (non-utility)
5. Third-party services (non-utility)
6. Finance or investment services
96. Something Else - Please tell us: [OPEN-ENDED RESPONSE]
98. Don't know [EXCLUSIVE]

[ASK ALL]

Q5. Approximately, how many years have you, personally, worked in this area?

[SINGLE RESPONSE]

1. Less than 5 years
2. 5 to 9 years
3. 10 years or more
98. Don't know

[ASK ALL]

Q6. Does your organization have a stake or a potential stake in the advancement of the California solar market?

[SINGLE RESPONSE]

1. Yes
2. No
98. Don't know

Awareness

Next, we have a few questions about your understanding of or interest in solar research, development, and demonstration (RD&D).

[ASK ALL]

Q7. Before today, were you aware that the state of California has funded Research, Development, and Demonstration (RD&D) programs to improve the California solar market?

1. Yes
2. No
98. Don't know

[IF 0=2 (No) AND Q7=2 (No), SKIP TO CONTROL GROUP]

[ASK IF Q7 =1 (YES)]
Q8. The CSI RD&D program started in 2008 and has provided over $35 million dollars in funding for 34 solar RD&D projects. Before today, had you ever heard specifically of the CSI Research, Development, Demonstration, and Deployment Program (CSI RD&D)?

[SINGLE RESPONSE]

1. Yes
2. No
98. Don't know

[DISPLAY IF Q8=1 (YES)]
Q9. Are you aware of any projects funded by the CSI RD&D program?

[SINGLE RESPONSE]

1. Yes
2. No
98. Don't know

[DISPLAY IF Q8=1 (YES)]
Q10. How did you hear about the project(s)? (Select all that apply.)

[MULTIPLE RESPONSE]

1. Email from a state agency
2. Webinar
3. Public announcement
4. Conference
5. Word of mouth
6. Other, please specify: [OPEN-ENDED RESPONSE]
98. Don't know [EXCLUSIVE]

[If Q6=2 (NO) and Q7=2 (NO), skip to control group]

Knowledge and value

For the next questions, we will describe two CSI RD&D projects. We will describe the industry barrier or challenge and how a CSI RD&D project addressed this barrier or challenge, followed by a few questions about your opinions.

[EACH RESPONDENT IS SHOWN TWO PROJECTS, EITHER PROJECTS 1 AND 2, OR 3 AND 4]

Industry barrier: As the concentration of distributed solar increases, grid impacts (e.g., costly analysis, system upgrades) have also increased. Smart inverters hold the potential to mitigate voltage and system stability impacts, but utilities have not been equipped to confidently identify optimal smart inverter settings. Compounding the problem, there is no one-size-fits-all arrangement of settings, and utilities lack a methodology that could be easily applied in diverse feeder and PV scenarios. **CSI RD&D Project**: A team of CSI RD&D recipients worked with utility stakeholders to develop a methodology to help utilities identify appropriate smart inverter settings and offset some of the potential adverse impacts from PV. The team produced a replicable methodology that simplifies the analytics required to determine when, where, and how to utilize smart inverters, in a manner consistent with the tools utilities already use.

Project 1:

[ASK ALL]

Q11. Based on the description, how relevant are the outcomes of this project to your organization's work?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant
98. Don't know

[ASK ALL]

Q12. Thinking about the solar industry at the outset of the Program, how much do you think the project's findings were needed for the California solar and utility sectors?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant
98. Don't know

[ASK ALL]

Q13. Using a scale of 1 to 5 with 1 meaning "extremely effective" and 5 meaning "not at all effective," please indicate your level of agreement or disagreement.

[MATRIX QUESTION]

How effective do you think this project would be at . . .	1 Extremely Effective	2 Very Effective	3 Somewhat Effective	4 A little effective	5 Not at all effective	98 DK
Reducing knowledge gaps that exist in the CA solar market						
Improving the understanding and capacity of regulators, grid operators, and standards setters						
Improving your organization's ability to provide services or develop products						
Accelerating the integration of distributed solar power into the CA grid						

[ASK ALL]

Q14. Which of the following statements <u>best</u> describe how your organization might use the project's findings, tools, or outputs? (Please select only one.)

[SINGLE RESPONSE]

1. There would be no applicability to our organization's work or others that impact our work
2. Our organization wouldn't use the findings directly, but it may improve conditions upstream (for instance, ISO, utility, regulatory) that would make our work more efficient or profitable
3. Our organization might use aspects of the findings, tools, or outputs in our work
98. Don't know

Industry barrier: For commercial PV installers, custom system design is a major cost driver. Custom systems tend to be over-designed, leading to unnecessary system weight, anchoring, and cost. Wiring harnesses often have to be crafted on-site, adding significant costs to projects. Because of unique aspects of PV arrays, the California Building Code does not contain specific provisions that allow for optimized structural design of PV arrays.

CSI RD&D Project: A team of CSI RD&D recipients developed software that automatically produces initial layout, ballast configurations, check forces, and displacements, allowing final component manufacturing schedules to be updated automatically. Seismic testing was conducted and results shared with building code officials to improve permitting for lighter and less costly system designs. Finally, the team created a web-accessible database for installers with contact information for permitting and engineering contacts and building departments in all California counties. The completed project created a set of calibrated and validated software tools that do the following:

- Ensure design consistency,
- Decrease engineering time,
- Enable cost-effective design iterations,
- Extend full-optimization capability to a wider market of potential customers, and
- Help guide code refinements.

Project 2:

[ASK ALL]

Q15. Based on the description, how relevant are the outcomes of this project to your organization's work?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant

98. Don't know

[ASK ALL]

Q16. Thinking about the solar industry at the outset of the Program, how much do you think the findings were needed for the California solar and utility sectors?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant

4. 4 = Very relevant
5. 5 = Extremely relevant
98. Don't know

[ASK ALL]
Q17. Using a scale of 1 to 5 with 1 meaning "extremely effective" and 5 meaning "not at all effective," please indicate your level of agreement or disagreement.

[MATRIX QUESTION]

How effective do you think this project would be at . . .	1 Extremely Effective	2 Very Effective	3 Somewhat Effective	4 A little effective	5 Not at all effective	98 DK
Reducing knowledge gaps that exist in the CA solar market						
Improving the understanding and capacity of regulators, grid operators, and standards setters						
Improving your organization's ability to provide services or develop products						
Accelerating the integration of distributed solar power into the CA grid						

[ASK ALL]
Q18. Which of the following statement best describes how your organization might use the project's findings, tools, or outputs? (Please select only one.)

[SINGLE RESPONSE]

1. There would be no applicability to our organization's work or others that impact our work
2. Our organization wouldn't use the findings directly, but it may improve conditions upstream (for instance, ISO, utility, regulatory) that would make our work more efficient or profitable
3. Our organization might use aspects of the findings, tools, or outputs in our work
98. Don't know

Industry barrier: As penetration of solar PV in California increases, concern has grown about potential impacts of power supply variability caused by transient clouds. Planning, scheduling, and operating strategies need to adapt to variability while remaining reliable; however, utilities and grid operators lack a clear understanding of PV output variability and how to quantify it. Utilities also lack the tools needed to quantify the value of distributed solar based on when, where, what type, and how much PV is installed. These problems accrued to undervalue distributed solar, undermining benefits to the grid.

CSI RD&D Project: A team of CSI RD&D recipients studied the effects of geographically dispersed PV systems on variability and the power output of PV fleets. The team produced a tool to assist in the economic evaluation of distributed solar systems. In the process of accomplishing these tasks, the team also developed, validated, and publicly released a novel methodology for simulating PV fleets at high speed time intervals, and developed and released a public online database of satellite-based irradiance data for the state of California, with half-hour temporal resolution.

Project 3:

[ASK ALL]

Q19. Based on the description, how relevant are the outcomes of this project to your organization's work?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant

98. Don't know

[ASK ALL]

Q20. Thinking about the solar industry at the outset of the Program, how much do you think the findings were needed for the California solar and utility sectors?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant

98. Don't know

[ASK ALL]

Q21. Using a scale of 1 to 5 with 1 meaning "extremely effective" and 5 meaning "not at all effective," please indicate your level of agreement or disagreement.

[MATRIX QUESTION]

How effective do you think this project would be at . . .	1 Extremely Effective	2 Very Effective	3 Somewhat Effective	4 A little effective	5 Not at all effective	98 DK
Reducing knowledge gaps that exist in the CA solar market						
Improving the understanding and capacity of regulators, grid operators, and standards setters						
Improving your organization's ability to provide services or develop products						
Accelerating the integration of distributed solar power into the CA grid						

[ASK ALL]

Q22. Which of the following statement best describes how your organization might use the project's findings, tools, or outputs? (Please select only one.)

[SINGLE RESPONSE]

1. There would be no applicability to our organization's work or others that impact our work
2. Our organization wouldn't use the findings directly, but it may improve conditions upstream (for instance, ISO, utility, regulatory) that would make our work more efficient or profitable
3. Our organization might use aspects of the findings, tools, or outputs in our work

98. Don't know

Industry barrier: As distributed solar proliferates, opportunities for combining energy efficiency, demand response, and energy storage with PV are often missed, because the required knowledge and expertise for these different technologies exist in separate organizations or individuals. Lack of affordable quantitative tools to optimize energy efficiency, demand response and energy storage with PV is another barrier.

CSI RD&D Project: A team of CSI RD&D recipients released a free-to-the-public software package that identifies and analyzes approaches for balanced, optimal, and cost-effective integration of energy efficiency, demand response and energy storage with solar PV. Focusing on building retrofits, and hoping to assist utility program managers as well as contractors, the team released the product to the public that can be used for:

- Conducting existing home retrofit analyses
- Accessing retrofit measures and cost data
- Calculating utility tariffs
- Performing utility cost-effectiveness tests
- Identifying incentives for PV and whole-house efficiency
- Demand response

Project 4:

[ASK ALL]

Q23. Based on the description, how relevant are the outcomes of this project to your organization's work?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant
98. Don't know

[ASK ALL]

Q24. Thinking about the solar industry at the outset of the Program, how much do you think the findings were needed for the California solar and utility sectors?

[SINGLE RESPONSE]

1. 1 = Not at all relevant
2. 2 = A little relevant
3. 3 = Somewhat relevant
4. 4 = Very relevant
5. 5 = Extremely relevant

98. Don't know

[ASK ALL]
Q25. Using a scale of 1 to 5 with 1 meaning "extremely effective" and 5 meaning "not at all effective," please indicate your level of agreement or disagreement.

[MATRIX QUESTION]

How effective do you think this project would be at . . .	1 Extremely Effective	2 Very Effective	3 Somewhat Effective	4 A little effective	5 Not at all effective	98 DK
Reducing knowledge gaps that exist in the CA solar market						
Improving the understanding and capacity of regulators, grid operators, and standards setters						
Improving your organization's ability to provide services or develop products						
Accelerating the integration of distributed solar power into the CA grid						

[ASK ALL]
Q26. Which of the following statement best describes how your organization might use the project's findings, tools, or outputs? (Please select only one.)

[SINGLE RESPONSE]

1. There would be no applicability to our organization's work or others that impact our work
2. Our organization wouldn't use the findings directly, but it may improve conditions upstream (for instance, ISO, utility, regulatory) that would make our work more efficient or profitable
3. Our organization might use aspects of the findings, tools, or outputs in our work

98. Don't know

Formal and informal knowledge exchange activities

In this section we would like to learn more about where you get information.

[ASK ALL]
Q27. Below is a list of sources. Please tell us, from what sources do you typically get information about emerging research, products, or market developments relevant to your work?

[MATRIX QUESTION]

Do you get information from…	1 Yes	2 No	97 NA	98 DK
Trade or academic journals				
Industry newsletters				
Government agencies				
Books or other periodicals				

Websites				
Conferences or proceedings				
Word of mouth (friends, colleagues, etc.)				
Somewhere Else - Please tell us: [OPEN-ENDED RESPONSE]				

[DISPLAY IF Q8=1 (YES)]

Q28. Have you or your organization used or otherwise benefitted from information from any CSI RD&D funded projects?

[SINGLE RESPONSE]

1. Yes
2. No
98. Don't know

[DISPLAY IF Q28=1 (YES)]

Q29. How did you or your organization find the project information that you used?

[MATRIX QUESTION]

Did you get information from…	1 Yes	2 No	97 NA	98 DK
Trade or academic journals				
Industry newsletters				
Government agencies				
Books or other periodicals				
Websites				
Conferences or proceedings				
Word of mouth (friends, colleagues, etc.)				
Somewhere Else - Please tell us: [OPEN-ENDED RESPONSE]				

[DISPLAY IF Q28=1 (YES)]

Q30. Below is a list of ways your company may have used the information from a CSI RD&D Funded Project. For each, please tell us; did you use the project for….?

[MATRIX QUESTION]

Did you use the project for…	1 Yes	2 No	97 NA	98 DK
Improving or expanding a product or service				
Increasing sales or otherwise expanding market				
Educating clients or other audiences				
Research and development				
Applying for research funding				
Some other way? - Please tell us: [OPEN-ENDED RESPONSE]				

[DISPLAY IF Q30=5 (APPLYING FOR RESEARCH FUNDING)]

Q31. What funding opportunity did you or your organization apply for?

1. __________
98. Don't know

[DISPLAY IF Q30=5 (APPLYING FOR RESEARCH FUNDING)]

Q32. Were you or your organization awarded the funding?

[SINGLE RESPONSE]

1. Yes
2. No
98. Don't know

[DISPLAY IF Q32=1 (YES)]

Q33. What was the approximate amount of funding you or your organization were awarded?

1. $__________
98. Don't know

[DISPLAY IF Q28=1 (YES)]

Q34. Are you aware of any other organizations that have used content from any CSI RD&D funded projects, including findings, tools, datasets, or other outputs, in their work?

[SINGLE RESPONSE]

1. Yes
2. No
98. Don't know

[DISPLAY IF Q34=1 (YES)]

Q35. What organization(s) are you aware of that have used content from CSI RD&D funded project(s)?

[MULTIPLE RESPONSE]

1. _____________
2. _____________
3. _____________
98. Don't know [EXCLUSIVE]

[DISPLAY IF Q34=1 (YES)]

Q36. How did the organization(s) use the project content? (Select all that apply.)

[MATRIX QUESTION]

Did they use the project for…	1 Yes	2 No	97 NA	98 DK
Improving or expanding a product or service				
Increasing sales or otherwise expanding market				
Educating clients or other audiences				
Research and development				
Applying for research funding				
Some other way? - Please tell us: [OPEN-ENDED RESPONSE]				

[DISPLAY IF Q8=1 (YES)]

Q37. Who, if anyone, provided you with information about CSI RD&D projects? Please provide their name and organization below.

[MULTIPLE RESPONSE]

1. __________
2. __________
3. __________
4. __________
5. I don't remember what individuals or organizations were involved [EXCLUSIVE]

[DISPLAY IF Q8=1 (YES)]

Q38. What organizations were involved in the projects?

[MULTIPLE RESPONSE]

1. __________
2. __________
3. __________
4. __________
5. I don't remember what organizations were involved [EXCLUSIVE]

Appendix H: Database Statistics and Analysis Review

The Evergreen team compiled a comprehensive database of program documents, interview results, survey data, and other secondary data sources collected throughout the CSI RD&D Program evaluation. The Evergreen team used two qualitative analysis software tools, Dedoose and Nvivo, to compile, store, and analyze these data. These qualitative analysis software tools provide a platform for robust qualitative analysis, providing several benefits for researchers to ensure consistent, accurate, and informative analysis. Firstly, Dedoose and Nvivo provide a central repository for storage of primary and secondary data sources including program documents, interview transcripts, and survey results. Maintaining a central repository ensures all researchers are using a consistent set of data. Secondly, Dedoose and Nvivo, include a suite of data coding and analysis tools that give researchers the ability to develop a systematic analysis approach that is consistent across all researchers. The central element of these qualitative software tools is assignment of codes to data segments to identify key themes and topics. In the case of the CSI RD&D Program evaluation, this also allowed the Evergreen team to code references to specific metrics developed through the theory based evaluation approach utilizing the program logic model. Lastly, both software tools provide a variety of analysis tools and the ability to export to other analysis software which give the researchers the ability to identify patterns and develop exhibits to communicate the results of the research.

The Evergreen team conducted extensive research within Dedoose and Nvivo. Given the large volume of data collected through document analysis and in-depth interviews, these software tools were invaluable to ensure that the research leveraged the data collected to provide thorough and consistent insights in the CSI RD&D Program. The following tables provide statistics on the data collected to illustrate the volume of data collected and level of detail of the analysis, beginning with a count of data sources compiled in the analysis database (Table 88).

Table 88: Count of Data Sources

Data Source	Number of Items
Project Reports	35
Project Webinars	36
Project Proposals	35
Program Progress Reports	64
Grantee and Sub-grantee Interviews	59
Other Interviews	17
Total	**246**

The Evergreen team planned and compiled coding schema for each data source that included a combination of codes unique to each data source as well as common codes applied across data sources to identify themes, topics, and metrics.

Table 89: Number of Codes Developed for Each Data Source

Data Source	Number of Codes
Project Reports	191
Project Webinars	191
Project Proposals	53
Program Progress Reports	35
Grantee Interviews	96
Other Interviews	96

For each specific data element (i.e.: interview, program report, etc.), analysts reviewed the source in its entirety and applied codes according to a predetermined and agreed upon protocol. At regular intervals the evaluation team compared coding samples to ensure consistency across researchers. Table 90 below provides a summary of code application across data sources.

Table 90: Code Application Statistics

Data Source	Number of Items	Total Code Applications	Average Code Application Per Source
Project Reports	35	**4,376**	**125**
Project Webinars	36	**1,216**	**34**
Project Proposals	35	**4,524**	**129**
Program Progress Reports	64	**1,922**	**30**
Grantee Interviews	59	**5,439**	**92**
Other Interviews1	17	**1,224**	**72**
Total	**246**	**18,701**	**76**

Appendix I: Delphi Materials

The final task completed by the evaluation team was to convene a Delphi panel to review the research findings and conclusions regarding the effects of the Program. The Delphi panel consisted of four experts with experience in either RD&D program evaluation or the solar industry itself. The Delphi panel was sent a summary of the research findings in the areas of Grid Integration, Solar Technologies and Innovative Business Models. Based on the summary findings in each of these areas, the Delphi panelists were asked to provide an assessment via numerical rating as to the likelihood that the projects in these areas would help meet the original CPUC goals established for the CSI RD&D program. Following the initial assessment, the Delphi panel met via conference call to discuss the individual ratings. The panel members were then given an opportunity to revise their initial ratings based on the results of the conference call.

The evaluation team provided the Delphi panelists with the following review packet.

Peer Reviewer Instructions

Your willingness to serve as a Peer Reviewer for the California Solar Initiative (CSI) RD&D program evaluation is greatly appreciated by both Evergreen Economics and the California Public Utilities Commission. This document provides instructions and context for Peer Reviewers. Please follow the steps below when completing your assessment.

1. Please review this Peer Reviewer Instructions document completely. It provides important contextual information and definitions regarding specific criteria that should be used when assessing accomplishments associated with the CSI RD&D grantee projects.
2. Please familiarize yourself with the Peer Reviewer Assessment Form, which is included separately for each group of CSI grantee projects. This form is where you will record your 0 to 4 ratings on each assessment item. In addition, below each review section is a space for you to note any comments or rationale for your rating. Note that you are not being asked to rate each project individually, but rather provide one overall rating for each criterion based on the project information provided.
   In certain circumstance, accomplishments within a particular section might not be identified or appropriate given the stage or focus of the RD&D effort. In such cases, please note N/A in the comment section rather than providing a rating of "0" for that item. Reasons for the N/A should also be recorded.
3. Please review the project-specific background/accomplishments information included in the Excel file *"Delphi CSI RD&D Project Summaries.xlsx"* provided as part of the review packet. This Project Summary file provides details the grantee projects you are reviewing, including grantee and project information, co-funding, project descriptions and significant project outputs.
4. Please complete each Peer Reviewer Assessment Form and email them back to Steve Grover at grover@evergreenecon.com. If you have any questions, please feel free to contact Steve Grover via email or by phone at (503) 894-8676.

Overview and Context

When making your ratings, we ask you to consider several different types of projects. As a consequence, project activities will vary depending on maturity of the technology, barriers to adoption, degree of risk, timing of benefits, degree of stakeholder participation, etc.

The three basic types of R&D projects included in this review are as follows:

1. **Grid Integration:** The Grid Integration projects are primarily aimed at supporting efforts to enhance the integration of distributed solar into the grid and to maximize the value of distributed solar power for California ratepayers. The outputs of these

projects include such things as demonstration sites, modeling tools/algorithms and improved interconnection methodologies.

2. **Solar Technologies:** With the Solar Technology project group, the CSI RD&D program looks to improve and support commercialization of technologies that are at a near commercial stage, rather than prototype technology. Examples of outputs for these projects include demonstration sites, as well as a variety of hardware and software advances relating directly to improving specific solar technologies.
3. **Innovative Business Models:** These projects are designed to enhance the competitiveness of new technologies, or help reach a 'tipping point' into widespread commercialization. This can include projects that involve testing of technologies or measures that enable streamlining of regulatory processes or standards in ways that allow new products to come to market more quickly and at lower costs.

Please note that some projects produced outputs of more than one type. In these cases the project will appear in more than one CSI group. In addition, scores should be based on each rater's overarching knowledge of the subject area.

Review Criteria

There are five criteria being used to rate project accomplishments:

1. **Addressing Research Needs.** For each project category discussed above, the CPUC identified specific research needs and knowledge gaps that were to be addressed by the CSI RD&D project (these needs are summarized in the Peer Review Assessment Forms). Based on the topic areas and outputs of the reviewed projects, you will be asked to assess how well these projects addressed these research needs.
2. **Ratepayer Benefits.** An important goal for the CSI RD&D projects is to provide benefits to the California ratepayers. Given the long time horizons for RD&D projects, however, identifying specific ratepayer benefits can be difficult, particularly if not enough time has elapsed. For the reviewed projects, you will be asked to assess the *potential* for providing ratepayer benefits based on the observed project outcomes to date.
3. **Economic Value to the Grid.** Similar to ratepayer benefits, the CPUC is also interested in knowing if the CSI RD&D projects provide significant economic benefits to the grid. These benefits can include effects that may only indirectly affect ratepayers, such as including grid reliability and streamlining permitting and approval processes for solar projects. Again, given the long timeline for RD&D projects, you will be asked to assess the *potential* for these projects to provide economic value to the grid.
4. **Expanding Market Opportunities/Reducing Market Barriers.** An ultimate long-term goal for all the CSI RD&D projects is to help develop the market for solar

technologies, either by expanding market opportunities or by reducing market barriers. Accomplishments addressing markets include improving/streamlining policies and regulations for getting solar projects installed, reducing risks associated with technologies, developing databases and analysis tools that help facilitate the adoption of solar technologies.

5. **Institutional and Regulatory Acceptance.** An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. Having the results of a project be used to change or update solar policies and/or processes used for solar installations would also be examples of regulatory or institutional acceptance.

Supporting Comments

For each rating element, space has been provided in the in the assessment form for you to provide the reasons for the ratings, including additional information about the project or assumptions used in responding to the question.

Thanks again for your assistance with this important California CSI

RD&D program evaluation effort!

Summary and Assessment Form - Grid Integration Projects

Introduction and Instructions

A primary focus of the CSI RD&D Program is facilitating grid integration of solar coming from distributed consumer-based sources. Grid integration is primarily aimed at supporting efforts to enhance the integration of distributed solar into the grid and to maximize the value of distributed solar power for California ratepayers. Grid integration efforts are distinct from more traditional R&D efforts focused on progress of distributed energy technologies and controls systems, and instead are focused on ensuring that these resources can be safely and efficiently tied into the existing, or future electricity grids, as well as integrating solar with other resources such as energy efficiency and demand response.

At the outset of the CSI Program in 2008, the California energy grid was looking at a future with high penetration levels of PV due to aggressive goals for renewable energy resource integration including solar PV. A major challenge facing these efforts was that the industry and utilities in particular lacked understanding and familiarity with how PV systems might impact grid operations at high penetration levels. The likelihood of sustaining high PV growth rates in some part relied on the ability, and willingness, of utilities to integrate PV systems into the electricity system, and in a way that provided benefits to both utilities and utility customers. The CPUC identified grid integration as a key focus area for the CSI RD&D program that was not being served by other R&D efforts, and where the CSI RD&D program could provide high value for grant funds.

In total there were 20 Grid Technology projects funded through the CSI RD&D program. The following tables summarize these Grid Integration project characteristics and accomplishments.

Following these tables, each peer reviewer is given a series of statements where the reviewer is asked to assess how well these 20 Grid Integration projects contributed toward accomplishing the overall program goals.

Grid Integration Project Descriptions and Accomplishments

The Grid Integration projects are summarized in Table 91, along with the funding sources. These projects are referred to by number in some of the following tables. Note that some projects also produced business models or grid integration outputs and therefore some projects in this table appear in one of the other two project groups.

Note also that the Grid Integration accomplishments were too detailed to fit concisely into a Word document. **<u>For more information on these projects, please refer to the Excel file</u>**

***"Delphi CSI RD&D Project Summaries.xlsx"* that is included as part of the Delphi review packet.**

Table 91: Grid Integration Project Summary

Project ID	Project Name	Grantee	CSI Funding	Match Funding
1	Advanced Modeling and Verification for High Penetration PV	CPR	$976,392	$543,000
2	Development and Analysis of a Progressively Smarter Distribution System	UC Irvine	$300,000	$100,000
4	Improving Economics of Solar Power Through Resource Analysis, Forecasting and Dynamic System Modeling	UCSD	$548,148	$137,037
5	High Penetration PV Initiative	SMUD	$2,073,232	$1,623,859
6	Analysis of High-Penetration PV Into the Distribution Grid in California	NREL	$1,600,000	$1,400,000
7	Beopt-CA (EX): A Tool for Optimal Integration of EE/DR/ES+PV for California Homes	NREL	$985,000	$329,000
8	Integrated Energy Project Model	KW	$942,500	$250,000
18	Quantification of Risk of Unintended Islanding and Re-assessment of Interconnection Requirements in High-Penetration of Customer-Sited Distributed PV Generation	GE	$629,100	$632,700
19	Screening Distribution Feeders: Alternatives to the 15% Rule	EPRI	$1,978,239	$1,978,239
20	Tools Development for Grid Integration of High PV Penetration	DNV GL	$964,500	$1,077,100
21	Integrating PV into Utility Planning and Operation Tools	CPR	$852,260	$875,000
22	High-Fidelity Solar Forecasting Demonstration for Grid Integration	UCSD	$1,548,148	$1,548,148
25	Standard Communication Interface and Certification Test Program	EPRI	$885,675	$1,016,693
26	PV Integrated Storage - Demonstrating Mutually Beneficial Utility-Customer Business Partnerships	E3	$815,500	$1,072,980
27	Demonstration of Locally Balanced ZNE Communities Using DR and Storage and Evaluation of Distribution Impacts	EPRI	$1,485,476	$2,155,000
28	Analysis to Inform California Grid Integration Rules for PV	EPRI	$399,494	$399,494
29	Advanced Distribution Analytic Services Enabling High Penetration Solar PV	SCE	$934,000	$934,000
30	Comprehensive Grid Integration of Solar Power for SDG&E	UCSD	$1,057,050	$1,057,050
33	Mitigation of Fast Solar Ramps Through Sky Imager Solar Forecasting and Energy Storage Control	UCSD	$100,000	$35,000
34	Supervisory Controller for PV and Storage Microgrids	Tri-Technic	$100,000	$60,000

Prior to soliciting bids for grid integration projects, the CPUC identified key areas of grid integration needs and knowledge gaps, which are summarized in Table 92.

Table 92: Grid Integration Needs and Knowledge Gaps

Area of Need	Description
Planning and modeling for high-penetration PV	Utility grid operation models and planning tools lacked the capability of identifying and optimally siting and incorporating distributed generation technologies and resources. In addition methods for estimating solar resources and forecasting PV system output at high penetration levels were limited and relied on low-resolution insolation data.
Testing and development of hardware and software for high-penetration PV	Existing distribution circuits are generally capable of tolerating some variability in load, however high penetration PV introduces significantly greater variability due to geographic dispersion, impact of variable environmental factors such as intermittent cloud cover, and the fact that behind the meter generation is often invisible to behind-the-meter generation resources. These factors introduce significant challenges to grid integration and overall grid reliability. This situation requires enhanced data, improved analytical capabilities, and development of robust hardware and software resources, including protocols and formal standards, capable of dynamic interaction and communication with the grid to control, and mitigate against issues arising from, varying frequency and voltage conditions on the grid.
Addressing integration of energy efficiency, demand response and energy storage with PV	Significant opportunities exist for integration of distributed PV resources, energy storage, demand response and energy efficiency measures. Improved energy storage and controls could potentially transform distributed generation resources into reserve resources, and allow customers to avoid energy price volatility and respond to demand response events. Energy efficiency measures help reduce the energy footprint of a site and when installed with PV systems can help reduce the size and capital costs for PV systems. Lack of integration means these opportunities are often missed. This presents a need to integrate energy efficiency, demand response, energy storage and PV systems through improved efforts like guidelines on appropriate energy efficiency measures to with PV system integration, combined audits, and improved battery storage and control systems.
Demonstration Projects for Utility Interconnection and Grid Operations Tools, Technology, and Methods	Solicitations three, four and five identified the need to move toward demonstration and operationalization of outputs. The specific areas of need included demonstrations of: PV project screening methods for interconnection, development of technology and protocols for advanced inverter technology, processes for streamlining interconnection and offsetting system upgrade costs, investigations of common challenges to interconnection and mitigation strategies to support standards and rulemaking working groups, methods for optimal siting of PV to enhance value to the grid, methods for risk quantification, enhanced distribution system modeling with capabilities for identifying risks such as islanding, methods to identify distribution line loading and congestion, interconnection of inverters with smart meters, tools with capability for utility system control and inverter dispatch, field tests of high penetration PV, and energy storage systems with capability to provide response to dynamic loads at distribution feeders.
Demonstration of Enhanced Solar Modeling	Solar resource models with higher spatial and temporal resolution to enable better forecasting and planning by grid operators and the CAISO. Validation of estimated PV production at high temporal resolution (less than one- minute intervals) using metered PV data. Of particular interest are demonstrations where PV performance data is collected from Smart Meter/inverter applications that can be used to validate high temporal resolution PV output estimates for anticipated high PV penetration

situations.

A mapping of how the 12 funded Grid Integration projects relate to the knowledge gaps and needs areas is provided in Table 93.

Table 93: Knowledge Gaps and Areas of Need Addressed by Projects

Area of Need	Project ID	Key Project Activity Examples
Planning and modeling for high-penetration PV	1, 2, 4, 5, 6, 18, 19, 21, 22, 26	• Enhancement of insolation data • Enhancement of PV system modeling methodologies and tools • Verification of modeling methods and tools against field data • Development of screening methodology to evaluate new interconnection requests • Methods to estimate impacts from high penetration PV • Modeling impact of ZNE homes • Analysis methods to inform grid integration rules and standards
Testing and development of hardware and software for high-penetration PV	1, 5, 6, 18, 20, 25, 26, 28, 29, 33, 24	• Development of software visualization tools • Enhancement of utility software tools to incorporate enhanced simulation and forecasting methodologies • Lab and field testing of advanced PV inverter technology • Testing ability of inverters to detect and react to islanding conditions • Assessing potential for open standard communication interfaces for smart inverter technology • Developing standards and protocols for hardware
Addressing integration of energy efficiency, demand response and energy storage with PV	7, 8, 27	• Enhancement of existing building modeling software to incorporate identification and implementation of balanced, optimal, and cost-effective integration of EE, DR and PV • Development of data transfer formats for information exchange between software platforms for integrated energy projects • Demonstration of cost effective strategies for ZNE homes incorporating PV
Demonstration projects for utility interconnection and grid operations tools, technology, and methods	5, 18, 19, 20, 25, 26, 27, 28, 29, 33, 34	• Deployment and testing of solar irradiance and cloud speed sensors • Demonstration and quantification of value of PV integrated storage • Demonstration of system control software for micro-grids
Demonstration of enhanced solar modeling tools	5, 21, 22, 26, 27, 29	• Field validation of PV simulation and forecasting model methods and software • Integration of PV fleet simulation methodologies into utility software tools • Development of end-to-end modeling software integrating building modeling and energy storage into distribution modeling.

The logic model created for the CSI RD&D Program identified some key program outputs that are positive indicators that the Grid Integration activities are on a path to achieving the program goals. Specific areas of accomplishments are discussed by output topic below.

The discussions below were informed through several data collection activities, primarily:

- Program documentation review - including: program design documents, project proposals, progress reports, final project reports, publications, and project data.
- In-depth Interviews w/ grantees and program managers – including primary grantees and sub-grantees. At least one project team member for each project was interviewed, except for Project 17.
- In-depth Interviews w/ industry experts and stakeholders – stakeholder group included representatives from organizations related to but not always directly involved in Program projects including utilities staff, solar program managers, industry organizations such as CalSEIA, regulatory agencies, and the CAISO. The expert group was comprised of industry experts from academia, public laboratory researchers, state employees and private sector researchers. These individuals were selected from the following sources:
    - Individuals named as stakeholders on specific projects
    - Individuals who took part in stakeholder advisory groups
    - Attendees of joint DOE-CPUC High Penetration Solar Forums in 2011 and 2013
    - Authors of literature cited in project reports
- In-depth Interviews and a survey with market actors – individuals from market facing organizations such as manufacturers, software developers, standard setting organizations and others, involved with or knowledgeable of program projects

Our expectation was that grantees and would have strong project-level knowledge and some program-level knowledge from the other projects they were exposed to. Similarly, stakeholders would have some specific project knowledge while others would have broader program level knowledge. Solar industry experts would have broader opinions of the effects of project outputs on the wider solar market, and solar research. This turned out to typically be the case, however there were some members of the solar expert group that had limited exposure to the program. All respondents were provided with website details for the CSI RD&D Program where they could access project documentation prior to the interview. However, they were not explicitly instructed to review these materials. Each respondent group was asked questions batteries across the following topics, but each battery was tailored specifically to the respondent group:

- Their level of engagement with the CSI RD&D Program

- How the Program facilitated, and the effect of, networks and relationship building
- The market relevance of projects and where project teams gathered information and how they exchanged knowledge and know-how
- The effect or influence of projects and outputs across the research areas, and how projects filled gaps and addressed challenges faced by the solar market

Standards and/or rules influenced

Common standards and rules provide broad benefits to any industry, ensuring the safety and quality of products and services, making product development and production more streamlined, making it easier for businesses to develop new products and access new markets, improving efficiency and reducing costs for manufacturers, and providing assurance for consumers that products and systems safe and reliable. Targeting the development or improvement of standards is one way to have a high effect on a market, however, requires identifying and engaging specific individuals or organizations with appropriate expertise and influence.

Eight CSI RD&D projects conducted work explicitly designed to influence standards or rules in the solar industry. Key project outcomes that relate to standards and rules include the following:

- **Revision and development of new standards for solar inverters and interconnection.** Specific projects have resulted in revisions or information for multiple standards, and testing certifications including:
  - UL1741 SA - tests and certifies inverters and other utility interconnected distributed generation (DG) equipment for grid support functions enabling smarter, safer, reactive grid interconnection (Project 25).
  - IEEE 1547a Amendment establishing updates to voltage regulation, response to area electric power systems abnormal conditions of voltage and frequency, and considering if other changes to IEEE Standard 1547 were necessary (Project 25).
  - IEEE 1547 Full Revision providing a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). The standard provides requirements relevant to the interconnection and interoperability performance, operation and testing, and, to safety, maintenance and security considerations (Project 25).
  - IEC 61850-7-420 and IEC 61850-7-520 revisions in TC57 WG17 establish communication and information exchange protocols for interconnected DER technology (Project 25).

- IEC 62108 standard for concentrated photovoltaic (CPV) module qualification testing defines testing protocols for CPV technology designed to detect CPV module failures associated with field exposure related to thermal fatigue-related failure mechanisms for the assemblies (Project 10).

- **Improvement to the existing CPUC Rule 21 (CA Rule 21).** CA Rule 21 describes the interconnection, operating and metering requirements for generating facilities connected to the distribution system over which the CPUC has jurisdiction. The rule includes a requirement for additional screening studies to be performed on circuits where penetration of solar PV exceeds 15% of peak load. The additional screening studies requirements were often unclear and the rule did not include considerations for smart inverters or battery storage. As of June 2016, the rule has been updated to include considerations of smart inverters and storage, and includes fast tracking of new solar projects meeting specific requirements. Many of the improvements were derived from CSI RD&D project research including specific improvements related to PV interconnection limits (Projects 19, 25, 28), project screening (Projects 18, 19, 25), and costs and processes for energy storage systems (Project 26). These changes helped streamline the review process for interconnection and storage projects, and played a direct role in the improvement to the existing CA Rule 21.
- **Changes to the PG&E interconnection process.** CSI projects have resulted in enabling the quick interconnection of certified inverters rated less than 1MW potentially streamlining and reducing the cost of applicable projects (Project 18)

Stakeholders and experts interviewed highlighted the influence of the program projects as of high importance suggesting that these efforts have provided critically essential information and guidelines to help accelerate integration of solar PV and help California meet its renewable energy goals. Regarding new and improved protocols and standards interview subjects suggested that these industry led processes helped advance knowledge of advanced smart inverters among key industry personnel.

Comments from stakeholders include:

> *"They (protocols and standards) will certainly impact inverter manufacturers and communications companies, and should help other balance-of-systems and component manufacturers develop products in the future having standard communication language and testing protocols".* In addition, these advances *"should lead to a safer, more reliable, modernized grid and make it easier for smart inverter manufacturers … all this should reduce costs of DER".*

Concerning efforts to improve CA Rule 21, regulatory stakeholders noted that in 2008, at the start of the CSI RD&D process:

> *"With regard to Rule 21 and the 15% peak load threshold, we didn't know … what the limits would be on the existing grid. So with aggressive mandates for increased solar on the grid there needed to be research into how much solar the grid could handle. A number of the projects were relevant to our work Rule 21 and overall we found a high value in terms of pushing ahead with grid integration and becoming comfortable with pushing limits on the grid."*

Another stakeholder noted:

> *"You can tell that the program had an impact because if there wasn't positive progress with these programs then we wouldn't go from a 33 % to 50% penetration goal. The regulators exposure to the outputs of CSI and other research doing this has helped the regulators, grid operators, and utilities be more sure about the impact of distributed energy resources on the grid, and I think that they feel comfortable now and this definitely has helped advance the opportunity for higher penetration."*

Impact of recommendations on inverter system communication protocols

Advanced smart inverters are communication enabled inverters that can improve communication between distributed solar resources and the grid, helping to manage distribution of generation to the grid, cope with distribution-level voltage deviations, and providing additional protection and resiliency to the electric power system. These capabilities can be provided at potentially low cost but can greatly increase the penetration of photovoltaic and other renewable energy on the grid. Harnessing these capabilities required better understanding of the capabilities of smart inverters, how to calibrate inverters to take optimal advantage of these functions, and how smart inverter functionality can interact with distribution-level interconnection rules and regulations for electric generators and electric storage resources. Beyond the influence on specific inverter standards mentioned above, several projects provided important guidelines and recommendations for inverter systems settings and protocols to advance the integration of advanced smart inverters and help increase interconnection limits thereby increasing the penetration potential of solar PV.

Key outcomes in this area include:

- **Demonstration projects of advanced smart inverters**. These demonstration projects provided real world evidence of how advanced communication-connected inverters and communication protocols can help progressively increase PV limits on distribution circuits, pushing limits beyond 15 percent and potentially as high as 100 percent. In some cases, they also provide ongoing test beds for future studies (Projects 27, 29).

- **Technical reports providing guidelines and inverter settings**. Several projects developed technical reports designed to instruct utilities on how optimally calibrate both existing inverter technology and smart inverters to integrate high levels of distributed PV (Projects 2, 6, 18, 28).
- **Studies and analysis to develop optimal control methods**. Multiple projects conducted studies to test the application of settings of smart inverters and develop specific control methods. These control methods help mitigate against voltage variability inherent with high penetration levels of PV (Projects 2, 6, 29).

Again stakeholders and experts agreed that inverter system communication protocols and control methods are key to incorporating high penetration PV, and the project outputs have provided valuable data on the ability of advanced inverters and communication protocols to improve system reliability. In addition to comments already mentioned in the standards section above, with regards to inverter standards, communication and control strategies and protocols were also seen as critical advancements of the program.

One stakeholder explained:

> *"The reason this was critically important unlike other equipment in the utility industry where the utility is the buyer and owner of all equip. So there is no standard, which is ok because they simply pick one vendor and only use that one. In the case of solar or distributed resources of all types … they are owned by the customer and the customer picks. New companies are appearing and old companies are disappearing. So to be able to create a network that connects millions of these together that can monitor them cohesively and manage them consistently requires a standard communication interface."*

One solar expert, independent of the program, stated that the industry:

> *"… have been looking at the communication standards in EV and inverters with building loads and with storage, indicating this is an area of importance, and the CSI projects gave us a look in to some of the challenges that we need to overcome when we start implementing these requirements for communications with smart inverters, so it has provided very valuable information for us and I think for the everyone involved".*

Improvement in system reliability brought by new models, tools, and software

Across the 20 projects with grid integration components, there were over 30 outputs including commercialized software packages, modeling methodologies, open source modeling tools, data collection tools, and databases. These outputs have led to improvements in grid reliability in situations with high penetration PV. Examples of outputs and their effect on grid reliability include:

- **New or enhanced software products for grid planners and operators.** Several software products were developed that improve resource visibility, provide more accurate prediction of generation, and allow grid planners to model economic value of planned solar generation resources. Improvements in these areas add to overall system reliability. Some examples in this area are:

- CPR's PVSimulator™, FleetView™ and WattPlan® tools are commercial products developed based on research from the CSI RD&D projects. According to project partners, the CSI RD&D projects "set the stage, which helped us develop a project to get to a saleable technology". Numerous utility and other stakeholders including CAISO utilize these products for grid planning and operations. Together these tools provide single system, and fleet level modeling services that use hourly resource data and defined physical system attributes in order to simulate configuration- specific PV system and fleet outputs to support utility and ISO planning and load-balancing requirements. In addition they incorporate value analysis tools that allow users to evaluate the economic value of PV system scenarios at very low cost. A project stakeholder explained that the most important thing that this led to was "a system to help do behind the meter PV forecasting, which addresses some of the uncertainty that the ISOs feel." (Projects 1, 21, 37)
- The Sacramento Municipal Utility District (SMUD) and Hawaii Energy Commission (HECO) with a team of industry partners developed high resolution data monitoring and evaluation efforts leading to the development of data visualization software that are being utilized and updated in Hawaii. These tools continued to be refined and commercialized through efforts by the U.S. DOE Sunshot program and the industry partners who have implemented some aspects into energy management systems used by a number of western utilities including California IOUs and the CAISO, as well as utilities in Hawaii. Project partners and stakeholders believe that these products had a highly positive impact on grid planning and grid reliability and some of these outputs have provided significant net benefits to their organizations (Project 5).
- Southern California Edison and their industry partners developed a process for a stochastic distribution planning process that models distribution circuits in GridLAB-D, an open source software platform, forecasting PV adoption, determining native limits, and providing mitigation strategy analysis for interconnection of new PV generation systems. These tools have been integrated into the Qado Systems software platform GridUnity that provides a user friendly graphical interface and visualization tools. Utility stakeholders using these platforms explained this software tool was something that didn't exist prior to the project and is proving very useful in its ability to demonstrate mitigation processes, model native distribution

circuit limits, and expedite the screening process for new projects, which all contribute to grid reliability. (Project 29)

- **Enhanced data products providing critical solar irradiance and other data** that can be integrated into existing modeling tools or software to improve generation visibility, predictive capabilities, and economic assessments, including:
    - SolarAnywhere, a solar resource database containing over 14 years of time- and location-specific, hourly insolation data throughout the continental U.S. and Hawaii. Through a series of CSI Projects these data were enhanced to provide the highest known resolution of any satellite-based irradiance data set in the world, with a 1 km x 1 km, 1- minute resolution. These data were publicly available to users and are used by a broad array of stakeholders around the world (Project 1).
    - SMUD installed a irradiance sensor network within their territory and integrated the resulting data into their existing planning system to enhance planner visibility of solar generation capacity. Utility staff stated that the sensor network and data have been very important for increasing PV penetration in their service territory and to show utility leadership "that this could be future for us". (Project 5)
- **Improved modeling tools and methodologies.** Aside from specific software applications, several projects developed modeling tools in open source modeling tool and modeling methodologies that can be adopted or integrated into existing utility planning and operations tools. These included tools and methodologies for solar irradiance forecasting, generation forecasting for individual systems and fleet systems, distribution system models, and economic value modeling tools. Each of these types directly or indirectly lead to benefits in system reliability through, for example, more accurate predicting of solar generation, and optimal siting of generation resources. Some specific examples of outputs include:
    - A PV performance model that can be applied to satellite solar irradiance data to simulate PV power output taking into account local weather conditions. The model uses SolarAnywhere data and is shown to accurately predict power output to within 3 percent of actual output. The model is provided in MATLAB and can facilitate power conversion modeling for large datasets for variability or forecasting applications. (Project 4)
    - Cloud speed algorithms to help forecast transient cloud cover which is an important variable in estimating PV power output. Two different methods to determine cloud speed were developed by a series of projects as well as innovative cloud speed sensor hardware (Projects 4, 22, 30, 33)
    - A novel PV adoption methodology was developed that estimated the probability of adoption of distributed solar attached behind the meter in residential and commercial applications. The method was developed to simulate allocation of new solar PV installations as penetration levels

increased, in order to inform forecasts of future states of distribution systems. The method was shown to provide more accurate PV adoption in terms of installed size and location than has been modeled before at scale. (Project 29)

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Discussion with stakeholders, experts and market actors indicate that these program outputs have led to greater system reliability, or a better understanding of actual system reliability that has led to a higher degree of confidence in the ability of the CA grid to integrate higher penetrations of distributed PV.

One stakeholder noted that:

> *"Projects I was involved in had a major impact with understanding risks, lots of grants did work with simulating higher penetrations than what is currently being absorbed and allowed utilities and stakeholders to understand the grid impacts as solar penetrations continue to increase."*

Another stakeholder stated:

> *"The generation mix has potentially changed as a direct result of projects increasing the reliability of the grid".*

Reduced cost, saved time and lowered risk of new projects and system operations

Up-front costs are the single largest barrier to widespread adoption of solar DG technologies. A major component of up-front solar costs are soft costs, which the DOE estimate at 64 percent of total solar costs[12]. Three areas of potential soft cost reduction from the customer side are optimized solar project design and integration with energy efficiency or demand response measures, faster approval and interconnection of new solar projects, and reduced costs of interconnection studies. From the utility side, soft costs can be reduced through improved system operations to incorporate new solar PV, as well as potential maintenance and repair costs that can be avoided through mitigating the risk of new solar projects.

A goal of the CSI RD&D program was to identify projects that would lead to reduced up-front costs to increase penetration of solar PV. Several of the outputs already mentioned have made significant advancement toward these goals either directly, or indirectly, in conjunction with meeting other goals. There are also outputs directed specifically at

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[12] U.S. DOE. 2016. Soft Costs 101: The Key to Achieving Cheaper Solar Energy. https://energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy

reducing the cost and time taken for new projects and lowering the risk of project to system operations. Examples of important outputs meeting these goals include:

- **Software products promoting optimal building design and integrated projects.** In theory, optimal building design and integrated projects should help reduce the installation costs of solar PV, through ensuring buildings are energy efficient and solar PV is optimally sized. The program funded a project to enhance the NREL BeOpt building design and simulation software application to facilitate the identification and implementation of balanced, optimal, and cost- effective integrations of EE, DR and PV in the residential retrofit and new construction market, including multi-family housing. An important functionality of the program is appropriate sizing of solar PV systems based on cost effective energy efficiency measures installed in the home. The program also funded the Integrated Energy Project XML Schema project that developed a common data collection and communication protocol for common communication across software platforms. Both projects have the potential to significantly reduce costs and save time related to solar PV installation. (Project 7, 8)
- **Recommendations for Interconnection Regulations and Rules**. Four projects developed recommendations updating either utility level interconnection processes, or recommended modifications for CA Rule 21 based on the technical analysis conducted as part of the projects' scopes. The recommendations from two of these projects (18 and 19) are known to have played a direct role in the improvements to the existing CA Rule 21. Other projects are likely to have influenced these changes. (Projects 6, 18, 19, 20)
- **Mitigation strategies to avoid or control faults related to new solar PV installations.** Interconnected solar PV projects come with risks to grid, including voltage variation causing circuit overload or voltage drops that can negatively impact grid operations. Several projects developed mitigation strategies at system and grid levels to avoid these risks. Implementing mitigation strategies can reduce operations costs, as well as offset future maintenance or repair costs. (Projects 5, 6, 20, 29)

We asked stakeholders and experts outside the projects to discuss the value of efforts to reduce costs and risks of new projects and save time through accelerated project approval. Interviewees noted cost of solar projects as one of the primary barriers to adoption of solar PV, and soft costs of solar as one of the main potential areas of cost reduction. These interview subjects stated that the CSI project outputs have made inroads into reducing costs, saving time and lowering risk of new projects and system operations, with one stakeholder noting that:

"We are seeing significantly lower prices and higher performance and better configuration and training and everything to make things cheaper which wouldn't have happened without structured multi year programs like CSI".

Lower transaction costs for implementing solar projects

One specific area of soft costs that has a high impact on overall solar system costs is transaction costs related to new solar projects. Transaction costs include costs of permitting, costs for interconnection studies or other reporting requirements, among others. Again, many of the outputs mentioned in previous sections have had or could have an impact on transaction costs through improved siting of projects, improvements to standards and rules, and developing a better understanding of the impact of solar PV on the grid. Many project outputs including forecasting models, improved smart inverter protocols, and screening methodologies have already or have the potential to lead to reduced transaction costs for interconnected solar projects. Some examples include:

- **Analysis conducted to inform California grid integration rules** that evaluated a set of advanced inverter methods and settings and developed a complete set of guidelines and recommendations provides a mechanism to improve the distribution system performance (as it relates to voltage) when accommodating higher levels of PV. These methods can help fast track application and therefore reduce costs and achieve higher penetrations of solar PV.
- **Improved project interconnection screening and methods for high penetration PV studies**. Projects developed detailed methodologies for performing high penetration PV studies. Utilities use these types of studies to determine interconnection approval status of new projects. (Projects 2, 5, 6, 19, 29)

We asked stakeholders and experts to discuss the value of project outputs designed to help improve costs of implementing new solar projects. These interview subjects stated that CSI projects provided needed and valuable information to help streamline approval of new solar projects, which leads to lower costs.

One stakeholder noted that the projects have made interconnection:

"much more simple and gave utilities tools to solve problems, allowed more interconnections without expensive upgrades".

Another explained that:

"The tools provided by projects are really pretty good at expediting (the approval) process and improving the time of the screening process".

Peer Review Questions

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Grid Integration project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Grid Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				**Significant Increase in Likelihood**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments:

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Grid Integration projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				**Significant Increase in Expanded Market Opportunities and Reduced Barriers**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments:

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. Having the results of a project be used to change or update solar policies and/or processes used for solar installations would also be examples of regulatory or institutional acceptance. On a scale of 0 to 4, please assess the progress the Grid Integration projects have made with gaining acceptance with related institutions and regulators. A “0” indicates “No Significant Acceptance” and a “4” indicates “Very Significant Acceptance.”

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don’t Know
0	1	2	3	4	98	99

Supporting Comments:

Summary and Assessment Form – Innovative Business Model Projects

Introduction and Instructions

The adopted CSI RD&D Plan describes Business Development and Deployment (aka Innovative Business Models) projects as those "supporting the market and end-users." Within this category, the Plan also focuses on "activities that enhance the competitiveness of new technologies, or help reach a 'tipping point' into widespread commercialization." This can include projects that involve testing of technologies or measures that enable streamlining of regulatory processes or standards in ways that allow new products to come to market more quickly and at lower costs.

Specific categories of business model activities identified in the Plan for possible grant funding include:

- Projects where "potential roles for utilities in solar PV, including attractive business models, are identified and vetted with utility companies"
- Projects involving "lower cost, utility grade PV system control, metering, and monitoring capacity developed consistent with *(*the*)* 1% cost parameter established by the California Public Utilities Commission (Commission) for CSI"
- Projects that "perform field tests to quantify operational risks and benefits of PV" and
- Projects that "demonstrate improved PV economics using advanced metering, price responsive tariffs (e.g., Time of Use—TOU, Feed in Tariff) and storage."

In total there were 10 Innovative Business Model projects funded through the CSI RD&D program. The following tables summarize these project characteristics and accomplishments.

Following these tables, there is a series of statements where the reviewer is asked to assess how well these 10 Innovative Business Model projects contributed toward accomplishing the overall program goals.

Innovative Business Models Project Descriptions and Accomplishments

The 10 Innovative Business Model projects are summarized in Table 91, along with the funding sources. These projects are referred to by number in some of the following tables.

Table 94: Innovative Business Models Project Summary

Project ID	Project Name	Grantee	CSI Funding	Match Funding
12	Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer Sited Distributed Energy Resources	Viridity Energy	$1,660,000	$840,000
13	Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results	Bira Energy	$1,000,000	$932,500
14	West Village Energy Initiative: CSI RD&D Project	UC Davis	$2,500,000	$1,245,000
15	Advanced Grid-Interactive Distributed PV and Storage	Solar City	$1,774,657	$931,187
16	Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery	Sunlink	$996,269	$927,031
17	Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology	Cogenra	$1,467,125	$2,773,304
23	Solar Energy & Economic Development Fund (SEED Fund)	SEI	$300,000	$341,150
26	PV Integrated Storage - Demonstrating Mutually Beneficial Utility-Customer Business Partnerships	E3	$815,500	$1,072,980
31	Sustainable Energy & Economic Development Fund (SEED Fund)	SEI	$100,000	$60,000
37	Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition	CPR	$99,660	$99,660

Prior to soliciting bids for solar technology projects, the CPUC identified key areas of business model needs and knowledge gaps, which are summarized in Table 92.

Table 95: Innovative Business Models Needs and Knowledge Gaps

Area of Need	Description
Demonstrations of innovative ways to lower installation or operations and maintenance costs	Standardization of installation techniques or new approaches for warehousing of parts. Testing and demonstration of low-cost maintenance approaches and trade-offs between automated and manual approaches
Testing and demonstration of virtual net metering approaches	Projects that cut across different geographical/socio-economic strata in such a way that benefits and costs are demonstrated to be shared appropriately among users; and pinpoint significant issues necessary to expand the approach more broadly including but not limited to residential housing developments and the commercial arena and (by testing) help determine appropriate tariffs
Testing and assessment of economic aspects of PV using price responsive tariffs and storage	Projects that meter the energy use and delivery aspects of energy storage used in conjunction with solar systems; and test price responsive tariffs that provide appropriate pricing to higher value energy and can potentially be expanded to the commercial market place rapidly
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems and that allow the end user or utility to capture higher value from the energy produced (e.g., provide energy during peak).	Testing and evaluation of the economics associated with "unloading" of distribution feeders across more than just a peak hour of a peak day and taking into account capacity values used by utilities in determining feeder upgrades or expansion. Testing that quantifies the extent to which increasing the number of solar systems leads to "flow back"13 on distribution feeders and the capital and operations and maintenance (O&M) costs incurred by utilities to prevent "flow back". Testing of solar system technologies developed to prevent "flow back" and how their costs compare to utility-based solutions.

[13] "Flow back" refers to the movement of electricity from the end user to the utility, which is different from the historically typical flow of electricity from the utility to the end user.

A mapping of how the 10 funded Innovative Business Models projects relate to the knowledge gaps and needs areas is provided in Table 93.

Table 96: Knowledge Gaps and Areas of Need Addressed by Projects

Area of Need	Project ID	Project Activity Examples
Demonstrations of innovative ways to lower installation or operations and maintenance costs	13, 16, 17, 23, 31. 37	• Business models and research for new products to lower installation costs and increase PV penetration. • Demonstrations and tools to lower installation and O&M costs of existing products. • Shared, collaborative, funding and procurement mechanism to lower installation costs.
Testing and demonstration of virtual net metering approaches	14	• Demonstration and recommendations for virtual net metering approaches
Testing and assessment of economic aspects of PV and storage using price responsive tariffs including with storage	12, 14, 15, 26	• Case studies of business strategies for optimal tariff decision making (e.g. peak load shifting, PV firming) • Analysis of pricing mechanisms to improve the cost and quality of frequency regulation • Business model development for construction, ownership and operation of community energy systems.
Testing and demonstration of energy storage technologies that allow capture of higher value from the energy produced	15, 26	• Testing and demonstration of financing mechanisms for PV and storage • Testing control strategies for energy storage to absorb renewable production variability

During the evaluation, several key outputs from the logic model were identified, and progress in these areas can be taken as a positive sign that the program is on track to achieve its goals. Specific output areas included here as part of the peer review are:

- Documented performance of business model in an operating environment
- Evidence of models with documented adoption or likely to be adopted; # of stakeholders adopting models outside project
- Documented evidence that business models will support expansion of cost-effective solar
- Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk
- Increased customer awareness of solar projects; increase in sales growth

The discussions below were informed through several data collection activities, primarily:

- Program documentation review - including: program design documents, project proposals, progress reports, final project reports, publications, and project data.
- In-depth Interviews w/ grantees and program managers – including primary grantees and sub-grantees. At least one project team member for each project was interviewed, except for Project 17.
- In-depth Interviews w/ industry experts and stakeholders – stakeholder group included representatives from organizations related to but not always directly involved in Program projects including utilities staff, solar program managers, industry organizations such as CalSEIA, regulatory agencies, and the CAISO. The expert group was comprised of industry experts from academia, public laboratory researchers, state employees and private sector researchers. These individuals were selected from the following sources:
    - Individuals named as stakeholders on specific projects
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    - Attendees of joint DOE-CPUC High Penetration Solar Forums in 2011 and 2013
    - Authors of literature cited in project reports
- In-depth Interviews and a survey with market actors – individuals from market facing organizations such as manufacturers, software developers, standard setting organizations and others, involved with or knowledgeable of program projects

Our expectation was that grantees and would have strong project-level knowledge and some program-level knowledge from the other projects they were exposed to. Similarly, stakeholders would have some specific project knowledge while others would have broader program level knowledge. Solar industry experts would have broader opinions of the effects of project outputs on the wider solar market, and solar research. This turned out to typically be the case, however there were some members of the solar expert group that had limited exposure to the program. All respondents were provided with website details for the CSI RD&D Program where they could access project documentation prior to the interview. However, they were not explicitly instructed to review these materials. Each respondent group was asked questions batteries across the following topics, but each battery was tailored specifically to the respondent group:

- Their level of engagement with the CSI RD&D Program
- How the Program facilitated, and the effect of, networks and relationship building
- The market relevance of projects and where project teams gathered information and how they exchanged knowledge and know-how
- The effect or influence of projects and outputs across the research areas, and how projects filled gaps and addressed challenges faced by the solar market

Specific project-level accomplishments in several key areas from the logic model are summarized below.

Performance of business model in operating environment documented

Six projects included business development and deployment outputs that were designed, tested and then validated in an operational environment either during or shortly after the end of the project. The definition of an operating environment in these cases is somewhat harder to determine than for solar technologies, but we classified outputs as operational if any organizations have formally adopted them in their business strategy or practices.

Across the 10 projects, there were six that ended in operationalized business models, with the remainder either being tested on a small scale or being contained in program documentation as model designs or recommendations. There were some projects that appear to have been very successful or have potential for future success, in particular Projects 15, 16 and 37. However, while these projects and their outputs have positively impacted the project partners, and potentially the broader market, there is little evidence (with the exception of Projects 16 and 37) that there has been widespread awareness or adoption of these outputs beyond the project partners.

The following points describe how each project was operationalized and their performance in these operating environments.

- **Project 15: Advanced Grid-Interactive Distributed PV and Storage.** The primary goal of this project was to test a new energy storage technology, demonstrate strategies to integrate these technologies with existing solar assets and into the solar market, analyze the value streams that these systems could provide, and identify market mechanisms by which this value can be accessed. Key achievements included demonstration of net benefits to the grid and customers of the technology, technology developments and best practices that lowered the cost of installation, and development of important insights into product specification, code requirements and other aspects of the technology. Since the end of the project the project partners have leveraged the findings of this grant to develop fully commercial products with hundreds of residential and commercial installations in California. One project partner stated that the project "*very clearly defined for us what is necessary for a battery system to be designed, owned and operated*" and ultimately was highly influential in the development of widely used commercial technology including software control platforms and storage technology.

- **Project 16: Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery.** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. The outputs of the project have been implemented by the project partners in their business operations in product development and design that has helped reduce balance of systems costs for the project partner. Findings from the project have also been operationalized in that they have been used to inform building code for unattached solar arrays, and helped other market actors develop and refine products to reduce overall cost of solar installation.
- **Project 17: Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology.** This project validated energy models and developed a return-on-investment tool that uses the energy models to provide detailed and comprehensive project financials internally and to customers. These outputs were used by Cogenra to demonstrate the financial viability of their products. The company has since been acquired by SunPower and the products have been discontinued.
- **Project 23 / Project 31: Solar Energy & Economic Development Fund (SEED Fund).** This project developed and implemented an innovative financing mechanism and collaborative project identification and procurement model for regional sustainability projects for municipalities, schools and public agencies. The goal of this project is to help reduce costs through seed funding, resources and training, no-cost solar assessments, and collaborative procurement. Two rounds of funding have occurred across two grants. The project was moderately successful and achieved the performance goals set forth in the grant proposal. A second round of funding began in 2016.
- **Project 37: Innovative Business Models, Rates and Incentives that Promote Integration of High Penetration PV with Real-Time Management of Customer**

Sited Distributed Energy Resources. This project modified and enhanced Clean Power Research's existing solar sustained vehicle (SSV) web service and developed an intuitive user interface to integrate driving and charging habits, financing methods, and smart meter data. The end product, WattPlan, was operationalized and California ratepayers can access the PV+EV calculator and enter specific information about themselves and get information that can help them make decisions about purchasing and installing PV systems and purchasing electric vehicles. The PV+EV calculator developed for CSI was launched on September 23, 2015 and was freely available to ratepayers for one year. It is included as part of WattPlan which is used by several CA utilities. Clean Power Research continues to expand and enhance their software offerings, and the knowledge and insights gained from this project have influenced their software offerings.

Evidence of models with documented adoption or likely to be adopted and # stakeholders adopting models outside project

As noted above, aside from Projects 16 and 37, there is little evidence of adoption or awareness of project outputs beyond the project partners. Stakeholders we interviewed for the evaluation did not raise business model projects as projects they were aware of.

Below is a description of the documented adoptions for Projects 16 and 37.

- **Project 16: Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery.** Outputs of this project have been adopted outside the project in two areas. First**,** the outputs have providing basic data and analysis essential for improvements in building codes that has led to improvements made by the ASCE 7 committee on seismic testing of building components in building codes. Second, roadmaps provided by the project can help facilitate the process for other solar companies in the state. One project partner noted that while he could not provide explicit information on other companies using the outputs, he was aware that other manufacturers were using their work to improve their systems resulting in cheaper and easier installation.
- **Project 37: Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition.** Outputs of this project have been widely adopted by CPR utility customers, as well as ratepayers. The software was available to California IOU customers for one year ending in September 2016 and has seen very widespread use with over 10,000 customers using the tool within the first three

months of it being available.[14] All three IOUs as well as SMUD and other utilities in California and nationwide are continuing to offer Wattplan to their customers.

Documented evidence that business models will support expansion of cost-effective solar

Across the 10 Innovative Business Models projects, there is a varying degree of evidence that the outputs will support the expansion of cost-effective solar. Projects that have shown some results in this area include the following:

- **Project 13:** Market research conducted as part of the project indicated that the plug and play PV kits can provide a valuable addition to the PV market, based on their performance and relatively low cost, estimated to be $3.99/W installed. In addition, the AC-module design provides the opportunity to open a new sales channel in the retrofit market via roofing contractors. Because the specific product has been discontinued there is little ongoing work on this technology, with one stakeholder saying that they *"are not aware of any significant development of AC systems but the market seems to be going in the other direction if anything, which is driving everyone to DC but I think I still stand by my statement that there is a lot of benefit from an AC PV system in the retrofit market".*
- **Project 14:** The project evaluated various business models to determine an "optimal" model that would allow for the deployment of community scale solar. While the evaluations were not achieved in an operational setting, there was some evidence that innovative business models could help achieve ZNE homes with community scale solar for close to the cost of traditional housing. A stakeholder in the project explained that although the project did not complete all its objectives, it *"laid all that groundwork and did a deep dive when we did the grant, it will make it much more likely that we will be able to achieve it as we actually build the single family development going forward."*
- **Project 15:** As part of the project the project team conducted consumer research and investigated finance options for combined PV and battery storage systems. The project found that a combination of PV and grid interactive storage can achieve substantial cost savings for utilities and end customers and a key to unlocking the benefits is overcoming the barriers to adoption including upfront costs. The project suggests that similar innovative finance mechanisms that have enabled recent growth in the distributed solar PV industry may help growth in deployments of distributed energy storage systems. Since the project completion, the project

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[14] WattPlan Revealing Savings of Electric Vehicles and Solar in California, New York, Arizona. http://www.cleanpower.com/resources/pr-wattplan-reveals-electric-vehicles-and-solar-savings/

partners have experienced high uptake of their products, indicating that their business models can help support expansion of cost-effective solar solutions.

- **Project 16:** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. A major component of up-front solar costs are these balance-of-system (BOS) costs, which the DOE estimate at 64 percent of total solar costs[15]. The design automation tools and research contributing to building codes in this project have already or will lead to decreased installation costs, which reduces the upfront cost of solar systems and supports the expansion of cost effective solar.
- **Project 17:** This project demonstrated a business model and emerging technology that presents a financially viable cogeneration solar system. These findings are specific to this technology. Cogenra was acquired by SunPower and the product has been discontinued. However, some research from this technology is being applied as part of a new lower cost product from SunPower. Because the business model was developed specifically for this technology and the technology is now discontinued we cannot say there is strong evidence that the business model related outputs of this project will have significant impact on the solar market.
- **Project 23 / Project 31:** These projects have supported the installation and expansion of cost-effective solar through collaborative project identification and procurement and financing. Two rounds of funding have occurred across two grants. The project engaged 37 Marin, Napa and Sonoma County public agencies in the collaborative procurement process that included 143 high-level site assessments and 41 full feasibility studies. The site-screening process identified potential for over 130 MW of solar power installation, including several sites with the potential for utility-scale PV installations. Twenty-five sites across 12 public agencies have entered, or are planning to enter into purchase or PPA contracts with the selected vendor with a combined total of approximately 5MW capacity. The fund is being replenished and a second round of projects was initiated in 2015, and according to a project partner SEI and Optony are engaging jurisdictions for a third round of projects which will result in at least 12MW of installed solar.
- **Project 37:** This project's output has seen high adoption by utility customers seeking to purchase PV systems or electric vehicles, with between ten and twelve utilities using the product nationwide including SMUD, PG&E, SCE, and SDG&E in California. This has led to further investment of the software of approximately one million dollars by CPR, according to one stakeholder. While this product is relatively new, the project partners and stakeholders suggest that there is some

[15] U.S. DOE. 2016. Soft Costs 101: The Key to Achieving Cheaper Solar Energy. https://energy.gov/eere/articles/soft-costs-101-key-achieving-cheaper-solar-energy

evidence of increased adoption of solar. First, there have been in excess of 10,000 users of the product in California. Secondly, one key finding from this project was that 75 percent of surveyed customers indicated that they would rather get information about solar equipment or electric vehicles from the utility and would trust them more than contractors. Because the software is offered to customers from the utility, one stakeholder explained that it is more likely that these customers would adopt solar technology based on information directly from their utility rather than a contractor.

Reduced cost of solar projects; value of reduced stakeholder acquisition costs and/or reduced business risk

Similar to previous metric, there is limited evidence that the Innovative Business Models projects have led to reduced costs of solar projects or reduced risk and it is difficult to quantify the value of any reduced costs that have been realized. As noted previously, there are six projects that did have some results that may have an impact in this area, and are summarized below.

- **Project 15:** This project suggested similar business models and financing that enabled adoption and deployment of PV be applied to solar storage. Specifically, SolarCity adopted a zero-down, cash-flow positive finance mechanism as the business model for PV product installation, directing private sector tax equity investments toward financing PV system installations, that allow customers to benefit from PV for no upfront cost, with an accompanying monthly finance payment that may be lower than their offset utility bill. This helps negate what is regularly seen as the key barrier to deployment of solar PV – a high upfront cost. In addition, third party ownership models, such as solar leases and power purchase agreements (PPAs) allow households who cannot afford to own a PV system to go solar. SolarCity adopted a similar model for combined PV and storage using Tesla's Powerwall product, and with the merger of Tesla and SolarCity, these products are now combined. This structure reduces the upfront cost of these technologies to customers. Battery storage integration provides risk mitigation for homeowners. There is also strong evidence, based on the use case studies in this project, that the combination of PV and grid interactive storage can achieve substantial cost savings for utilities by decreasing reliance on other energy sources, and provision of backup power for an energy user with the potential to shift time of use energy and demand charges.
- **Project 16:** This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. While we cannot assess the actual impact on array costs of this

specific project, one stakeholder noted that the work from this project was *"available to any manufacturer to use so systems in California became cheaper and easier to install based on their work".*

- **Project 17:** This project demonstrated a business model and emerging technology that presents a financially viable cogeneration solar system. According to project documentation the project led to a 50 percent reduction in materials, installation, and operational cost of the Cogenra product. The product was installed at 20 other sites after this project. As noted above, Cogenra was acquired by SunPower and the product has since been discontinued. However, some research from this technology is being applied as part of a new lower cost product from SunPower. Because the business model was developed specifically for this technology and the technology is now discontinued we cannot say there is strong evidence that the business model related outputs of this project will have significant impact on the solar market.
- **Project 23 / Project 31:** As noted previously, these projects have supported the installation and expansion of cost-effective solar through collaborative project identification and procurement and financing. According to project partners the project has documented evidence that the SEED fund and assistance can reduce administration costs for jurisdictions by up to 75 percent and reduce procurement costs of solar technology by 10-12 percent due to reaching economies of scale through collaborative procurement. In total the project team estimate a total installed cost reduction of 10% for jurisdictions. These savings, as well as ongoing savings or payment for generation accrue to the jurisdiction general funds, improving their overall bottom line which has broad benefits for jurisdictions and their residents.
- **Project 37:** Because this project was completed in mid-2016 we have very limited concrete evidence that business models will support reduced cost of solar projects and increase value of solar PV for customers and utilities. While there is not concrete evidence that this project and the resulting software would reduce costs of solar or EVs for customers, the goal of the project is to improve the value of solar and EVs for customers by providing customers with accurate data and recommendations. As noted previously, this project has had significant levels of usage and the grantee has continued to invest in developing the technology, indicating that there is a perception that the product has value, and therefore may lead to reduced cost and/or increased value of solar PV for customers and utilities.

Increased customer awareness of solar projects; increase in sales growth

Of the six projects discussed above that appear to have been adopted in some form, two are likely to have increased customer awareness and increased sales growth, and one is likely to have contributed to increased sales growth. These include the following:

- **Project 2–15:** Evidence of product specific sales growth and customer awareness although uncertain if this has or will lead to broader industry sales growth or customer awareness of solar PV and storage. The product developed in this project has gone on to have strong, self-sustained, penetration in the solar market. SolarCity and Tesla have adopted the business models developed as part of this project, which took the lessons from PV financing and applied them to create a finance program for distributed storage installations. The success of the product, and increased sales growth indicate suggest that the business models developed in this project may have contributed to this success, but to what extent is not possible to determine. In addition, based on our research and interviews with stakeholders and project partners, it is not possible to determine if there is spillover from this research to the broader market that has increased sales or customer awareness for other similar products.
- **Project 5–37:** Evidence of product specific sales growth and customer awareness although uncertain if this has or will lead to broader industry sales growth or customer awareness of solar PV and storage. Research from this project helped develop the WattPlan software platform that allows utility customers to analyze potential savings from electric vehicles, rooftop solar systems, or both, to assist with purchase decisions. Furthermore, the research indicated that provision of this software through utility platforms and branding increases customer confidence in results and likelihood of adoption. There has been a high level of utility customer use of the platform in California, which likely has led to increased sales of EVs and solar systems, as well as raised awareness of these products among utility customers.
- **Project 2–16:** Limited evidence that business models will support sales growth cost of solar projects. This project aimed to reduce costs of PV array installation by reducing design time through automation, reducing permitting time of projects, enabling optimized designs for smaller commercial rooftop systems, and decreasing on-roof time through factory manufacture of array wiring harnesses and matching combiner boxes. Upfront cost of solar projects is regularly cited as the primary barrier to adoption. As costs reduce due to the influence of this project, there is likely to be associated sales growth, but the magnitude of this growth is not possible to determine.

Peer Reviewer Assessment Form

Based on the information provided above, each peer reviewer is asked to assess the Business Models project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Business Models projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies or business models that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Innovative Business Models projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Innovative Business Models projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

Summary and Assessment Form – Solar Technology Projects

Introduction and Instructions

The success of the overall CSI program depends on increasing performance and efficiency of solar technologies in the market. The CPUC CSI RD&D strategy adhered to seven key principles, which included improving the economics of solar technologies by reducing technology costs and/or increasing system performance, focusing on issues that directly benefit California that may not be funded by others, and overcoming significant barriers to technology adoption. Barriers include high up-front cost, which remains the single largest barrier to widespread adoption of solar technologies, as well as other barriers such as unproven technological performance, and proof of economic value. By targeting RD&D activities at those barriers or opportunities that promise high impact but are currently under-funded, distributed solar applications could become more widespread.

To address these market challenges, the CSI RD&D program looked to improve and support commercialization of technologies that were at a near commercial stage, rather than prototype technology. The CPUC identified solar production technology development as a key focus area for the CSI RD&D program, where the CSI RD&D program could provide high value for grant funds. By supporting these technologies the overall goal to increase performance and efficiency of solar technologies in the market to improve the economic value of solar technologies and reduce barriers to market adoption of promising technologies should be met.

In total there were 12 Solar Technology projects funded through the CSI RD&D program. The following tables summarize these Solar Technology project characteristics and accomplishments. Note that some projects also produced business models or grid integration outputs and therefore some projects in this table appear in one of the other two project groups.

Following these tables, each peer reviewer is given a series of statements where the reviewer is asked to assess how well these 12 Solar Technologies contributed toward accomplishing the overall program goals.

Solar Technology Project Descriptions and Accomplishments

The 12 Solar Technology projects are summarized in Table 91, along with the funding sources. These projects are referred to by number in some of the following tables.

<u>Additional information on each of these projects is included in the Excel file "*Delphi CSI RD&D Project Summaries.xlsx*" that is included as part of the Delphi review packet.</u>

Table 97: Solar Technology Project Summary

Project #	Project Name	Grantee	CSI Funding	Match Funding
9	PV and Advanced Energy Storage for Demand Reduction	SunPower	$1,475,000	$937,990
10	Improved Cost, Reliability and Grid Integration of High Concentration PV Systems	Amonix	$2,139,384	$3,157,000
11	Solaria: Proving Performance of the Lowest Cost PV System	Solaria	$1,217,500	$1,217,500
13	Low-Cost, Smart-Grid Ready Solar Re-Roof Product Enables Residential Solar Energy Efficiency Results	BIRAenergy	$1,000,000	$932,500
14	West Village Energy Initiative: CSI RD&D Project	UC Davis	$2,500,000	$1,245,000
15	Advanced Grid-Interactive Distributed PV and Storage	Solar City	$1,774,657	$931,187
16	Reducing California PV Balance of System Costs by Automating Array Design, Engineering and Component Delivery	SunLink	$996,269	$927,031
17	Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating PV/Thermal Tri-Generation (CPV/T-3G) Technology	Cogenra	$1,467,125	$2,773,304
25	Standard Communication Interface and Certification Test Program	EPRI	$885,675	$1,016,693
27	Demonstration of Locally Balanced ZNE Communities Using DR and Storage and Evaluation of Distribution Impacts	EPRI	$1,485,476	$2,155,000
36	Comprehensive System Assessment of the Smart Grid-tied Energy Storage System Using Second-Life Lithium Batteries	UC Davis	$100,000	$36,917
37	Distributed Solar and Plug-In Electric Vehicles (PEV): Development and Delivery of an Interactive Software Platform that Provides Actionable Insights Regarding Solar Acquisition	CPR	$99,660	$99,660

Prior to soliciting bids for solar technology projects, the CPUC identified key areas of solar technology needs and knowledge gaps, which are summarized in Table 92.

Table 98: Solar Technology Needs and Knowledge Gaps

Area of Need	Description
Projects demonstrating "economic viability of distributed concentrating PV systems"	The CSI RD&D strategy identified CPV systems as an important technology for the success of the CSI program that depended on increasing performance and efficiency of solar technologies in the market. Distributed solar is currently constrained by the size of a roof or available land to site the system. More efficient solar cells, inverters, and wiring solutions will decrease the overall size of the system thus allowing greater potential for more generation.
Projects that help "building integral PV products (BIPV) become competitive with rooftop PV" and which address "key technical integration issues"	Developing innovative PV materials or methods of integrating PV into buildings are also highly promising methods of reducing the cost of PV systems and/or expanding the market for them, by, among other things, reducing material and production costs and allowing more of a building's surface to be used.
Testing and demonstrating inverter technologies that improve reliability or performance of solar systems and help lower costs	Inverter technology has the potential to address barriers to adoption of solar technology in terms of mitigating the impact of solar penetration on the grid, and increasing control over power flow from solar PV to provide value to utilities and ratepayer. In particular the CSI RD&D Program focused on advancing inverters that demonstrate longer periods between failures, that demonstrate lifetimes approaching the expected twenty-year lifetimes for modules, that have lower capital costs and lower operating and maintenance costs, and have the potential for better integration with smart meters
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems and that allow the end user or utility to capture higher value from the energy produced (e.g., provide energy during peak).	Solar storage technology has the potential to convert solar PV resources into reserve resources. To support progress to this goal, and to improve value of solar to utilities and ratepayers the CSI RD&D Program encouraged near-term testing and demonstration of innovative energy storage technologies, storage technologies suitable for community or multi-user applications, and solar thermal/electricity storage systems recently developed under DOE funding
Field-testing and demonstration of innovative hybrid-solar technologies. Possible examples include:	Solar thermal/solar electric technologies that can increase the economic or greenhouse gas benefits being provided by current solar technologies Concentrating solar systems that can increase production for larger commercial applications. Solar/non-solar combinations (e.g., fuel cells/solar applications) that may help extend the energy benefits provided to the end user in a cost-competitive manner

A mapping of how the 12 funded Solar Technology projects relate to the knowledge gaps and needs areas is provided in Table 93.

Table 99: Knowledge Gaps and Areas of Need Addressed by Projects

Area of Need	Project ID	Key Project Activity Examples
Projects demonstrating "economic viability of distributed concentrating PV systems"	10, 17	• Manufacture and installation of concentrating PV systems, • Modeling and analysis tools developed for concentrating PV • International standard developed • Installation and demonstration of innovative concentrating photovoltaic / thermal co-generation (CPV/T-2G) technology,
Projects that help "building integral PV products (BIPV) become competitive with rooftop PV" and which address "key technical integration issues"	27, 35	• Enhancement of existing building modeling software • Construction of demonstration sites of 20 ZNE homes •
Testing and demonstrating inverter technologies that improve reliability or performance of solar systems and help lower costs	25	• Development of smart inverters and accompanying communication protocol
Testing and demonstration of existing energy storage technologies capable of working with smaller solar systems	9, 14, 15, 26, 36	• Development and demonstration of new energy storage technology • Development and deployment of control software
Field-testing and demonstration of innovative hybrid-solar technologies	9, 11, 14, 37	• Development and demonstration of hybrid solar technologies Installed and monitored a 110 kWp photovoltaic tracking system • Field testing performance of hybrid solar technology
Other	13, 16	• Development and demonstration of other innovative solar technology • Development and deployment of software system that automates the BOS component engineering and documentation for optimized PV array

Specific project accomplishments and outputs are shown in Table 100.

Table 100: Solar Technology Outputs by Project

Project ID	Output Type	Output Description
9	Tech - Hardware	Advanced energy storage system: ice energy (thermal storage).
	Demonstration	Demonstration and field test for Ice Energy thermal storage.
10	Tech - Hardware	Amonix high concentration photovoltaic (HCPV) system
	Demonstration	Amonix manufactured and installed 2 CPV units rated at 113 kw as demonstration sites at UC Irvine
	Modeling Tool	UCI's APEP developed a central power plant and CPV dynamic models for system operation.
	Standard	International standard defines a test sequence to detect CPV module failures associated with field exposure to thermal cycling
11	Tech - Hardware	Solaria modules: single axis, dual axis and polar axis
	Demonstration	Two demonstration sites with solaria modules, a 110 kWp system at the solaria manufacturing facility in Fremont, CA and a 240 kWp system installed at alameda county Santa Rita jail in Dublin ca.
13	Tech - Hardware	Low-cost P&P PV Kit - "plug & play" AC micro-inverter PV system.
	Demonstration	Installation in six test homes. Updates to installation protocol and P&P PV kit after prototype install. Installation, monitoring and performance evaluation of the installations
14	Tech - Hardware	Battery buffered electric vehicle charging station
	Tech - Hardware	Second-life batteries for application in single family homes
	Tech - Hardware	Innovative hybrid photovoltaic/thermal (PVT) technologies and designs for solar hot water in multifamily and single family applications
	Demonstration	Demonstration site with installations of three technologies
15	Tech - Hardware	Develop advanced stationary battery product combining tesla motors' vehicle battery with Solarcity's SolarGuard dispatch and monitoring platform, to create a firm, dispatchable, grid-interactive,
	Tech - Software	Advance communication and control technology platform.
	Demonstration	Demonstration of communication and control technology platform and

		advanced lithium-ion battery storage technology at six sites
16	Tech - Software	Automated array design and engineering software for rooftop solar installations - Sunlink Design Studio (SLDS)
	Study	Seismic testing and analysis of rooftop solar arrays
17	Tech - Hardware	Hybrid concentrating PV/thermal tri-gen (CPV/T-3G) technology
	Demonstration	Demonstration system installed at Sonoma Wine Company in Graton, CA rated at 272kw.
25	Tech - Software	Inverter communication driver software that bridges the field bus protocol used by the inverters (Modbus) to the wide area network protocols used by the utility network (IEEE 2030.5 and OpenADR).
	Technology - Software	Test framework software, including test scripts and test lab automation technology, to test inverters complying with CA Rule 21
	Tech Hardware	Prototype advanced smart inverter
27	Demonstration	Demonstration of cost effective technology pathways for ZNE communities
36	Tech - Hardware	Comprehensive system assessment of the smart grid-tied energy storage system using second-life lithium batteries
37	Tech - Software	Development and delivery of an interactive software platform that provides actionable insights regarding plug-in electric vehicles

During the evaluation, several key outputs from the logic model were identified, and progress in these areas can be taken as a positive sign that the program is on track to achieve its goals.

The discussions on program accomplishments below were informed through several data collection activities, primarily:

- Program documentation review - including: program design documents, project proposals, progress reports, final project reports, publications, and project data.
- In-depth Interviews w/ grantees and program managers – including primary grantees and sub-grantees. At least one project team member for each project was interviewed, except for Project 17.
- In-depth Interviews w/ industry experts and stakeholders – stakeholder group included representatives from organizations related to but not always directly involved in Program projects including utilities staff, solar program managers,

industry organizations such as CalSEIA, regulatory agencies, and the CAISO. The expert group was comprised of industry experts from academia, public laboratory researchers, state employees and private sector researchers. These individuals were selected from the following sources:

    - Individuals named as stakeholders on specific projects
    - Individuals who took part in stakeholder advisory groups
    - Attendees of joint DOE-CPUC High Penetration Solar Forums in 2011 and 2013
    - Authors of literature cited in project reports

- In-depth Interviews and a survey with market actors – individuals from market facing organizations such as manufacturers, software developers, standard setting organizations and others, involved with or knowledgeable of program projects

Our expectation was that grantees and would have strong project-level knowledge and some program-level knowledge from the other projects they were exposed to. Similarly, stakeholders would have some specific project knowledge while others would have broader program level knowledge. Solar industry experts would have broader opinions of the effects of project outputs on the wider solar market, and solar research. This turned out to typically be the case, however there were some members of the solar expert group that had limited exposure to the program. All respondents were provided with website details for the CSI RD&D Program where they could access project documentation prior to the interview. However, they were not explicitly instructed to review these materials. Each respondent group was asked questions batteries across the following topics, but each battery was tailored specifically to the respondent group:

- Their level of engagement with the CSI RD&D Program
- How the Program facilitated, and the effect of, networks and relationship building
- The market relevance of projects and where project teams gathered information and how they exchanged knowledge and know-how
- The effect or influence of projects and outputs across the research areas, and how projects filled gaps and addressed challenges faced by the solar market.

Where possible, the evaluation team asked stakeholders and experts for their assessment of the technologies, and whether they perceived the technology as reliable or not, and whether they accepted the results of the studies as reliable, based on the project outputs. It was not always possible to identify a specific stakeholder for each technology, in which case we relied on the combined perception of the grantees and the program manager Itron.

Stakeholders and experts were provided with website details for the CSI RD&D Program where they could access project documentation prior to the interview. They were not explicitly instructed to review these materials, however. Stakeholders were asked to answer the following questions:

> *How successful were the projects in addressing and resolving the knowledge gaps they intended to close?*
>
> *Have any of the projects you were involved in led to, or are likely to lead to - new technologies, new services or businesses, new methods of manufacturing, marketing or delivering technologies?*

Interviewers probed further with stakeholders who mentioned technology projects to ascertain their perception of the technology reliability and potential.

Table 101 below presents an assessment of stakeholder, grantee or program manager acceptance or perception of reliability. Each project receives a score of 1 to 3, where a score of 1 represents low acceptance or perception of reliability and a score of 3 represents high acceptance or perception of reliability. The score assigned to stakeholders and grantees is a score assigned by our team based on the qualitative response from the interview subject. The score provided by Itron staff is an actual numeric score provided by the project manager.

Table 101: Stakeholder Acceptance or Perception of Reliability Score

Project ID	Stakeholder Score	Grantee Score	Itron Score	Average Score
9		2	1	1.5
10	2		1	1.5
11		3	2	2.5
13		3	3	3
14	3		2	2.5
15	3	3	3	3
16	3	3	3	3
17			3	3
25	3	3	3	3
27	3	3	3	3
36		2	2	2
37		3	3	3
Score	**2.83**	**2.77**	**2.42**	**2.58**

Finally, Table 102 summarizes how the project achievements in terms of commercialization, including which had demonstration sites and which resulted in commercial sales and/or increases in production.

As noted in the proposed CSI RD&D Plan, "success of the CSI program depends on increasing performance and efficiency of solar technologies in the market." In the adopted CSI RD&D Plan, production technologies are those "supporting commercialization of new PV technologies." An indicator of success of production technologies is whether they progress to being commercialized technologies, and experience some sales volume or licensing. The following metrics (derived from the program logic model) all address the level of commercialization of products from initial sales and/or transfer of ownership of products, to increased technology production, and on to full-scale production.

An important metric is to determine if there have been any initial sales of the technology, use of software, or transfers of ownership or licenses with a wider range of users who can then further develop the technology into commercialized products. Table 102 indicates if any projects have either had initial sales of products or have engaged in any form of licensing or knowledge transfer leading to development of products by other parties.

The next stage of assessment is whether a technology has moved beyond initial commercial sales and experienced increased investment in production, increased sales, or increased revenues. We reviewed the project final documentation, spoke with stakeholders and market actors, and conducted Internet research to determine if technology experienced increased sales or production beyond initial commercial sales.

Table 102 presents an assessment of increases in sales after the program participation ended. Of the projects that had a solar technology component, four saw increased production and sales after the project with products related to project research. Two of these companies were acquired by other solar companies who discontinued their products but used the technology in other commercially available products. Two solar technology projects, Project 15 and Project 16, saw significant sales increases and commercially viable products. Project 15 in particular, was a successful partnership between SolarCity and Tesla that saw continued commercialization effects. This project developed technology that led directly to Tesla's PowerWall product (their flagship residential storage product) and SolarCity's GridLogic platform and storage control software, both of which are widely used.

In summary, key commercialization results from Table 102 include:

- 7 of 12 projects were tested in an operating environment
- 8 of 12 projects have commercial sales
- 4 of 12 projects have licensing or transfer of knowledge leading to other productive development
- 5 of 12 projects have resulted in increased production or sales since the project ended. Note that the 2 additional projects labeled 'Partial' initially had increased sales, but the company subsequently went out of business.

Table 102: Solar Technologies Demonstration and Commercialization Activities

Project ID	Validation in Operating Environment, Demonstration Site, or Laboratory Testing	Product has Commercial Sales	Project Output has Licensing or Transfer Of Knowledge Leading to Other Product Development	Increased Production or Sales Since Project Ended
9	Operating Environment	Yes	No	No
10	Operating Environment	Yes	Yes	Partial
11	Operating Environment	Yes	Unknown	Yes
13	Demonstration Site	Yes	Yes	No
14	Demonstration Site	No	No	No
15	Operating Environment	Yes	Unknown	Yes
16	Operating Environment	Yes	Yes	Yes
17	Operating Environment	Yes	Unknown	Yes
25	Lab Testing	No	Yes	No
27	Demonstration Site	N/A	N/A	Partial
36	Demonstration Site	No	No	Yes
37	Operating Environment	Yes	Unknown	No

Peer Reviewer Assessment Form

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Solar Technologies project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather on aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Solar Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				**Very Significant**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments:

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				**Significant Increase in Likelihood**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments:

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Solar Technologies projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Solar Technologies projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

Delphi Panel Results – Grid Integration Projects

Reviewer 1:

Peer Review Questions

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Grid Integration project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Grid Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 3. Tables 2 and 3 make a pretty convincing case that the program funded projects consistent with the priorities identified by the CPUC.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 4. Taken together, the materials in this packet tell a persuasive story of: (1) a plausible initial program theory; (2) project funding decisions consistent with the program theory; (3) leading indicators changing in a manner consistent with the program theory; and (4) widespread beliefs among stakeholders and experts that significant long-term ratepayer benefits have already materialized, and are likely to continue materializing.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 4, for the reasons stated above in response to question #2.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Grid Integration projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 4, for the reasons I discuss above in question #2. In particular, there seems to be a compelling case that challenges surrounding Grid posed a significant market barrier and that this program has made a significant contribution to ameliorating that barrier.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. Having the results of a project be used to change or update solar policies and/or processes used for solar installations would also be examples of regulatory or institutional acceptance. On a scale of 0 to 4, please assess the progress the Grid Integration projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 3. It is evident that there is no shortage of interviewees who believe the projects funded through this program have yielded benefits, and the interviewee sample appears to include institutions and regulators. The only reason I am not rating this a 4 is that I do not have the full interview results, nor much detail on the make-up of the sample, and thus cannot assess the representativeness of the interview results that have been highlighted in the packet.

Reviewer 2:

Peer Review Questions

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Grid Integration project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Grid Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

My rating is 4. I think the Grid Technology projects have successfully targeted the needs of the CDI RD&D Program. There are many project addressing each of the needs. And several of them have been "successful" – in developing new technologies, modeling, and designing new and improved regulations and rules.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. For two reasons. First, we are focused on "potential benefits" – not real/actual benefits. So there is more leeway on the eventual impact. And second, the definition of benefits includes improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. I don't see much of an impact on rates or tariffs – they will be determined by other factors. But costs may decrease (or not increase) if some of these projects lead to less expensive offerings, as well as reductions in operations and maintenance. The revision and development of rules, standards and protocols should help reduce overall costs over time – a benefit to ratepayers. And the modeling and planning tools will also help reduce overall costs and contribute to grid reliability. And several of the projects have led to reducing costs, saving time and lowering risk of new projects and system operations.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. For the two reasons mentioned above. While those benefits focused on ratepayers, the grid would also benefit. Of course, there is a big assumption: the technologies and research products from these projects would be available to all customers over the grid. But if these projects are successful in the long run, then there will be a reduced cost of energy supply (i.e., less central power stations need to be built, or less power needs to be imported from power stations outside of California), and grid upgrades or repairs (costly) would be needed – again assuming LOTS of customers are using these technologies.

The projects should also lead to reduced cost of energy supply and offset costs of grid upgrades or repairs through: revisions or information for multiple standards, and testing certifications; changes to interconnection, operating and metering requirements for generating facilities connected to the distribution system; the development and improvement of advanced smart inverters that can improve communication between distributed solar resources and the grid, helping to manage distribution of generation to the grid, cope with distribution-level voltage deviations, and providing additional protection and resiliency to the electric power system; software products that improve resource visibility, provide more accurate prediction of generation, and allow grid planners to model economic value of planned solar generation resources; and transaction costs through improved siting of projects, improvements to standards and rules, and developing a better understanding of the impact of solar PV on the grid.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Grid Integration projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. Based on my limited knowledge, it appears that the PV technology is here and it is reliable and ready to be installed. But one of the biggest obstacles (if not the biggest) is cost. As noted in this writeup: "Up-front costs are the single largest barrier to widespread adoption of solar DG technologies. A major component of up-front solar costs are soft costs, which the DOE estimate at 64 percent of total solar costs." Some of these projects will lead to a decrease in costs – particularly, system cost, as well as reductions in operations and maintenance costs. If these costs go down, then PV opportunities will expand. The total cost may still be high for many people, and some of the opportunities for reducing the total cost (or at least initial cost) may come to fruition. Of course, this will occur in the long run; in the short run, these projects will not lead to these benefits.

In particular, many projects focused on the development and improvement of standards and rules which provide broad benefits to any industry, ensuring the safety and quality of products and services, making product development and production more streamlined, making it easier for businesses to develop new products and access new markets, improving efficiency and reducing costs for manufacturers, and providing assurance for consumers that products and systems safe and reliable. So, this program focused on the right types of projects. And reducing software costs and transaction costs should also be beneficial.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. Having the results of a project be used to change or update solar policies and/or processes used for solar installations would also be examples of regulatory or institutional acceptance. On a scale of 0 to 4, please assess the progress the Grid Integration projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4 because the program specifically targeted institutional and regulatory acceptance. In particular, many projects focused on the development and improvement of standards and rules which provide broad benefits to any industry, ensuring the safety and quality of products and services, making product development and production more streamlined, making it easier for businesses to develop new products and access new markets, improving efficiency and reducing costs for manufacturers, and providing assurance for consumers that products and systems safe and reliable. So, this program focused on the right types of projects.

Reviewer 3:

Peer Review Questions

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Grid Integration project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Grid Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				**Significant Increase in Likelihood**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments:

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				**Significant Increase in Likelihood**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments:

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Grid Integration projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. Having the results of a project be used to change or update solar policies and/or processes used for solar installations would also be examples of regulatory or institutional acceptance. On a scale of 0 to 4, please assess the progress the Grid Integration projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

Reviewer 4:

Peer Review Questions

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Grid Integration project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Grid Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	X	98	99

Supporting Comments:

Area needs are reasonably well addressed.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	X 3.5	4	98	99

Supporting Comments:

For any of the ratepayer benefits of the solar technologies projects and the innovative business models projects to be enjoyed by the ratepayers, grid integration is essential. Grid integration in particular will improve grid reliability and reduce the generation, transmission and distribution costs that should affect customer rates. The documentation review, the in-depth Interviews w/ grantees and program managers – including primary grantees and sub-grantees, the in-depth Interviews w/ industry experts and stakeholders suggest that these grid integration projects will increase the likelihood of providing these potential benefits to California Ratepayers.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Grid Integration projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	X	98	99

Supporting Comments:

The documentation review, the in-depth Interviews w/ grantees and program managers – including primary grantees and sub-grantees, the in-depth Interviews w/ industry experts and stakeholders suggest that these grid integration projects will increase the likelihood of providing economic value to California Ratepayers.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Grid Integration projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	X 3.5	4	98	99

Supporting Comments:

The documentation review, the in-depth Interviews w/ grantees and program managers – including primary grantees and sub-grantees, the in-depth Interviews w/ industry experts and stakeholders suggest that these grid integration projects will increase the likelihood of providing the necessary conditions to integrating distributed solar installation into the grid. This should lead to an increase in the technical and market potential for solar.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. Having the results of a project be used to change or update solar policies and/or processes used for solar installations would also be examples of regulatory or institutional acceptance. On a scale of 0 to 4, please assess the progress the Grid Integration projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	X	98	99

Supporting Comments:

While it isn’t always clear how the results of these projects were disseminated to the relevant audiences (regulators, grid operators, and utilities), they were nevertheless informed. Of the 20 projects, 16 report follow-on use or research. Documenting how these projects disseminated the results of their studies would be useful for others. Perhaps more effective knowledge dissemination plans should be required. For example, CEC EPIC requires that a Technology/Knowledge Dissemination

Delphi Panel Results – Solar Technology Projects

Reviewer 1:

Peer Reviewer Assessment Form

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Solar Technologies project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Solar Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating here is 3. There is enough information presented in this packet to establish at a reasonable level of confidence that the projects funded by the program were generally consistent with the priorities established by the CPUC.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				**Significant Increase in Likelihood**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments: My rating here is a 2. The results presented in this packet establish that the projects funded by the program were associated with concrete outputs for the technologies being promoted. However, little evidence is presented that these outputs will ultimately produce ratepayer benefits. While the depth interviews done as part of the project appear to have addressed interviewees' beliefs regarding the potential benefits of the supported projects, the findings regarding that issue do not appear to be presented; rather, we have only a table showing interviewees' ratings regarding the reliability of the supported technologies. Nor does the packet seem to include material intended to assess the accuracy of the initial program theory – that is, that the priorities initially identified by the CPUC would, if pursued effectively, have an appreciable effect on the speed with which the targeted technologies are commercialized. Finally, we are not presented with any evidence that the targeted technologies faced significant barriers to being fully funded privately. All this adds up to a weak case, as presented, for potential ratepayer benefits.

To be clear, I am not asserting that the program will not produce ratepayer benefits. I am only assessing the strength of the evidence to that effect that is provided in this packet.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				**Significant Increase in Likelihood**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments: My rating here is a 2, for all of the same reasons as my previous response.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Solar Technologies projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				**Significant Increase in Expanded Market Opportunities and Reduced Barriers**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments: My rating here is a 2, for all the same reasons discussed in #2.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Solar Technologies projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				**Very Significant Acceptance**	**Not Applicable**	**Don't Know**
0	1	2	3	4	98	99

Supporting Comments: My rating here is a 3. While the specific interviewees are not identified, the packet presents evidence that interviewees generally view the projects supported as having been successful, and it is a reasonable working assumption that the interviewees include representatives of relevant institutions and regulatory agencies.

Reviewer 2:

Peer Reviewer Assessment Form

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Solar Technologies project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Solar Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

My rating is 4. I think the Solar Technology projects have successfully targeted the needs of the CDI RD&D Program. There are many project addressing each of the needs. And several of them have been "successful" – in developing new technologies and software, modeling, and designing a new international standard.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. For two reasons. First, we are focused on "potential benefits" – not real/actual benefits. So there is more leeway on the eventual impact. And second, the definition of benefits includes improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. I don't see much of an impact on rates or tariffs – they will be determined by other factors. But costs may decrease (or not increase) if some of these projects lead to less expensive offerings, as well as reductions in operations and maintenance. The development of a new international standard should help reduce overall costs over time – a benefit to ratepayers. The modeling and software tools will also help reduce overall costs and contribute to grid reliability. And several of the projects have led to reducing costs, saving time and lowering risk of new projects and system operations.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. For the two reasons mentioned above. While those benefits focused on ratepayers, the grid would also benefit. Of course, there is a big assumption: the technologies and research products from these projects would be available to all customers over the grid. But if these projects are successful in the long run, then there will be a reduced cost of energy supply (i.e., less central power stations need to be built, or less power needs to be imported from power stations outside of California), and grid upgrades or repairs (costly) would be needed – again assuming LOTS of customers are using these technologies.

The projects should also lead to reduced cost of energy supply and offset costs of grid upgrades or repairs through: manufacture and installation of concentrating PV systems and technologies, modeling and analysis tools developed for concentrating PV, development of an international standard, enhancement of existing building modeling software, and development and demonstration of technologies and software systems in homes.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Solar Technologies projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. Based on my limited knowledge, it appears that the PV technology is here and it is reliable and ready to be installed. But one of the biggest obstacles (if not the biggest) is cost. As noted in the Grid Technology writeup: "Up-front costs are the single largest barrier to widespread adoption of solar DG technologies. A major component of up-front solar costs are soft costs, which the DOE estimate at 64 percent of total solar costs." While there was not much discussion on reduction in costs (aside from smart inverters and "plug and play" options), the projects did lead to increases in sales after the program participation ended. Of the projects that had a solar technology component, four saw increased production and sales after the project with products related to project research. Two of these companies were acquired by other solar companies who discontinued their products but used the technology in other commercially available products. Two solar technology projects, Project 15 and Project 16, saw significant sales increases and commercially viable products. Project 15 in particular, was a successful partnership between SolarCity and Tesla that saw continued commercialization effects.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Solar Technologies projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 2 – assuming "institutional" excludes businesses. This group of technologies, unlike the other groups, did not specifically target institutional and regulatory acceptance. One exception: the development of an international standard. Most of the other projects focused on technology and software development. And it is still too early to tell whether institutions or regulators have accepted the project findings or outcomes from these individual technologies and demonstrations. I think this will take time.

If businesses are included in the "institutional" category, then I would have given a rating of 4: there was an increase in sales after the program participation ended. Of the projects that had a solar technology component, four saw increased production and sales after the project with products related to project research. Two of these companies were acquired by other solar companies who discontinued their products but used the technology in other commercially available products. Two solar technology projects, Project 15 and Project 16, saw significant sales increases and commercially viable products. Project 15 in particular, was a successful partnership between SolarCity and Tesla that saw continued commercialization effects.

Reviewer 3:

Peer Reviewer Assessment Form

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Solar Technologies project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Solar Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Solar Technologies projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Solar Technologies projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

Reviewer 4:

Peer Reviewer Assessment Form

Based on the information provided in the preceding tables, each peer reviewing is asked to assess the Solar Technologies project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Solar Technology projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	X	4	98	99

Supporting Comments:

Area needs are reasonable well addressed.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, lower upfront cost of solar technology, more reliable energy services and a more reliable grid. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	X	98	99

Supporting Comments:

All solar projects have the potential to reduce the generation, transmission and distribution costs that should affect customer rates. The results of the survey presented in Tables 5 indicate a high acceptance or perception of reliability (mean of 2.58). There also appear to be a high inter-rater reliability between the grantee Itron and the stakeholder score (when a score is available). In their view, these projects in general have done an excellent job of addressing and resolving knowledge gaps that they intended to close and led to, or were likely to lead to new technologies, new services or businesses, new methods of manufacturing, marketing or delivering technologies.

One might argue that the grantee and even Itron have a vested interest in the outcome and their assessment given less weight. If that were the case, one might have expected that there would have been a tendency for the stakeholder score to be lower than the other two since the stakeholder might be less conflicted. However, for the six projects for which there is a stakeholder score, the score is the same as the grantee and Itron. For the one project where there is a difference, the stakeholder score is higher.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Solar Technologies projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	X	98	99

Supporting Comments:

See comment Item 2 above.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Solar Technologies projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	X 3.5	4	98	99

Supporting Comments:

Table 6 and the associated narrative provided the basis for my score.

All of the technologies were validated. Of the 12 projects, 7 were tested in an operating environment, 4 were tested at a demonstration site, and one was tested in a laboratory.

Of the 12 projects, 8 already had commercial sales (It would have been to have the rough estimate of the percent increase in sales for these 8). Of these 8, 4 experienced an increase in production or sales since the project ended. Of the 3 that did not have commercial sales, 1 had commercial sales since the project ended.

Of the 12 projects, 4 have licensing or transfer of knowledge leading to other productive development.

Not every applied R&D project is expected to be successful. Given that, the performance of these 12 projects seems to be quite good. A mapping of the projects in the areas of need (Table 3) to the projects in Table 6 reveals that there were some successful projects in most of the areas of need. This also seems quite good.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Solar Technologies projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	X 3.5	4	98	99

Supporting Comments:

My responses to items 2 through 4 formed the basis of my score. In the view of the stakeholders, the grantee and Itron, these projects in general have done a very good job of addressing and resolving knowledge gaps that they intended to close and led to, or were likely to lead to new technologies, new services or businesses, new methods of manufacturing, marketing or delivering technologies. Table 6 and the accompanying discussion indicate that, while not every applied R&D project is expected to be successful, the performance of these 12 projects seems to be quite good.

Delphi Panel Results – Innovative Business Model Projects

Reviewer 1:

Peer Reviewer Assessment Form

Based on the information provided above, each peer reviewer is asked to assess the Business Models project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Business Models projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 3, because the packet presents evidence that the projects funded were generally consistent with the priorities established by the CPUC.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies or business models that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 2. Evidence is presented that the funded entities generally developed or continued to develop business models consistent with the contents of their proposals, and that in a few cases the changes in their business models were associated with increases in their business. However, little or no evidence is presented regarding the potential ratepayer benefits associated with these business models. There appears to have been little documented adoption thus far of the business models outside of the funded entities, which would seem to be a necessary prerequisite for major ratepayer benefits. To the extent that only the entities receiving funding adopt the new business models, one must ask the question of whether the public funding was needed in order for them to do this. A business has every incentive to pursue the most successful business model it can find, and for a public program to have a beneficial effect on this it would seem to be necessary that the business have been lacking either the funds or the expertise to pursue the business model it ultimately did. Little if any evidence to this effect seems to be presented.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 2, for all the same reasons discussed above.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Innovative Business Models projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is a 1. No evidence appears to be presented that the entities receiving the funding were unable to pursue the business models they did without funding; it therefore follows that no evidence of reduced market barriers is presented. The best available measure of expanded market opportunities would seem to be adoption of the supported business models outside of the funded entities. It appears that such adoption has been minimal thus far.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Innovative Business Models projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments: My rating is "don't know" because this issue doesn't seem to be explicitly addressed in the packet, but there are indications that it may have been studied via the depth interviews.

Reviewer 2:

Peer Reviewer Assessment Form

Based on the information provided above, each peer reviewer is asked to assess the Business Models project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Business Models projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. From a research perspective, one does not expect every project to achieve what is intended. There are numerous obstacles in completing a project, let alone successfully addressing the needs of the CSI RD&D Program. At the research stage, all of the projects were designed to meet these needs. As of today, a few appear to be quite successful. On the other hand, the "needs" are not trivial – it will take many research projects over time to demonstrate innovative ways to lower installation or operations and maintenance costs, test and demonstrate virtual net metering approaches, test and assess the economic aspects of PV using price responsive tariffs and storage, and test and demonstrate existing energy storage technologies capable of working with smaller solar systems. Obviously, a larger research budget would help, but given the amount of funding that is available, and as an incrementalist, it appears that this is a good first step.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies or business models that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. For two reasons. First, we are focused on "potential benefits" – not real/actual benefits. So there is more leeway on the eventual impact. And second, the definition of benefits includes improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. I don't see much of an impact on rates or tariffs – they will be determined by other factors. But costs may decrease (or not increase) if some of these projects lead to less expensive offerings, as well as reductions in operations and maintenance. I particularly liked the focus on the nexus of production and storage – this could be a game changer if residences and small commercial enterprises are able to be "energy independent" of the grid. This will help reliability and will make them less vulnerable to impacts of grid outages. Again, these are "potential benefits."

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. For the two reasons mentioned above. While those benefits focused on ratepayers, the grid would also benefit. Of course, there is a big assumption: the technologies and research products from these projects would be available to all customers over the grid. But if these projects are successful in the long run, then there will be a reduced cost of energy supply (i.e., less central power stations need to be built, or less power needs to be imported from power stations outside of California), and grid upgrades or repairs (costly) would not be needed as often relative to the counterfactual (none of these projects were funded) – again assuming LOTS of customers are using these technologies.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Innovative Business Models projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 4. Based on my limited knowledge, it appears that the PV technology is here and it is reliable and ready to be installed. But one of the biggest obstacles (if not the biggest) is cost. As noted in the Grid Integration writeup: "Up-front costs are the single largest barrier to widespread adoption of solar DG technologies. A major component of up-front solar costs are soft costs, which the DOE estimate at 64 percent of total solar costs." Some of these projects will lead to a decrease in costs – particularly, system cost, as well as reductions in operations and maintenance costs. If these costs go down, then PV opportunities will expand. And if the building code is a market barrier, then it appears that barrier will be reduced, if not eliminated, due to the projects in this program. The total cost may still be high for many people, and some of the opportunities for reducing the total cost (or at least initial cost) may come to fruition. Of course, this will occur in the long run; in the short run, these projects will not lead to these benefits.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Innovative Business Models projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

I gave a rating of 2 because the market uptake/acceptance is low overall. While two projects have shown some positive news, it is still too early to tell whether institutions or regulators have accepted the project findings or outcomes. I think this will take time.

Reviewer 3:

Peer Reviewer Assessment Form

Based on the information provided above, each peer reviewer is asked to assess the Business Models project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Business Models projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies or business models that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Innovative Business Models projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Innovative Business Models projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	3	4	98	99

Supporting Comments:

Reviewer 4:

Peer Reviewer Assessment Form

Based on the information provided above, each peer reviewer is asked to assess the Business Models project accomplishments in terms of helping achieve some of the overarching goals for the CSI RD&D Program. Please provide a numeric rating for each of the topics below and expand upon your rating as needed in the comments section.

Note that for each topic, you are not being asked to provide a rating for each individual project, but rather an aggregate rating based on your review of the project information.

1. Addressing Needs

It is important that the grantee projects ultimately address the needs originally addressed by the CPUC for the CSI RD&D Program (see Table 92 and Table 93). On a scale of 0 to 4, please assess the degree to which the Business Models projects addressed these needs. "0" indicates "Not At All Significant" effect in addressing these needs and a "4" indicates "Very Significant" effect in addressing these needs.

Not At All Significant				Very Significant	Not Applicable	Don't Know
0	1	2	X	4	98	99

Supporting Comments:

Appears to be good coverage of needs. While there is only Project #14 addresses the testing and demonstration of virtual net metering, it is well funded and comprehensive.

2. Ratepayer Benefits

As the CSI RD&D projects are funded by ratepayer dollars, an important outcome for these projects is to achieve benefits that ultimately will accrue to California ratepayers, for example improved rates or tariffs, more reliable energy services and a more reliable grid, and reduced impact of grid outages. Given the RD&D nature of these projects, however, the timeline for achieving these benefits is longer than with technologies or business models that are closer to wide-scale commercialization. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* benefits to California Ratepayers. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	X	4	98	99

Supporting Comments:

All solar projects have the potential to reduce the generation, transmission and distribution costs that should affect customer rates. Tariffs designed to incent solar installations combined with innovative financing options should make solar more attractive. Improved methods for designing solar installations and assessing the economics of the consumer's decision to install solar are also important. These projects appear to be well designed to address these issues.

3. Economic Value to the Grid

A related goal is providing economic value to the California Grid through effects like reduced cost of energy supply and offset costs of grid upgrades or repairs. On a scale of 0 to 4, please assess whether the Innovative Business Models projects increase the likelihood of providing *potential* economic value to the California grid. A "0" indicates "No Increase in Likelihood" and a "4" indicates "Significant Increase in Likelihood."

No Increase in Likelihood				Significant Increase in Likelihood	Not Applicable	Don't Know
0	1	2	X	4	98	99

Supporting Comments:

All solar projects have the potential to reduce the generation, transmission and distribution costs and increase reliability.   If innovative business models can increase the adoption of solar in individual homes and communities, then the grid will benefit. Of the 10 projects, 6 appear to be successful as indicated by follow-on use or research.

4. Expanding Market Opportunities/Reduced Market Barriers

An additional goal of these projects is to expand PV market opportunities or reduce known market barriers. On a scale of 0 to 4, please assess the degree to which the Innovative Business Models projects are likely to expand PV opportunities or reduce market barriers. A "0" indicates "No Expanded Market Opportunities or Reduced

Barriers" and a "4" indicates "Significant Increase in Market Opportunities and Reduced Barriers."

No Expanded Market Opportunities or Reduced Barriers				Significant Increase in Expanded Market Opportunities and Reduced Barriers	Not Applicable	Don't Know
0	1	X	3	4	98	99

Supporting Comments:

Many of the projects (e.g., Project 31) resulted in cost reductions and financing options both of which address the first-cost issue. With respect to awareness, the interviewees noted that while these projects and their outputs have positively impacted the project partners, and potentially the broader market, there is little evidence (with the exception of Projects 16 and 37) that there has been widespread awareness or adoption of these outputs beyond the project partners. More effective knowledge dissemination plans should be required. For example, CEC EPIC requires that a Technology/Knowledge Dissemination plan be developed by the grantee.

5. Institutional and Regulatory Acceptance

An important step in wider spread adoption of research and technologies is to gain institutional and regulatory acceptance of the project findings or outcomes, which can be demonstrated through technology transfer, knowledge dissemination, or follow on use or research. On a scale of 0 to 4, please assess the progress the Innovative Business Models projects have made with gaining acceptance with related institutions and regulators. A "0" indicates "No Significant Acceptance" and a "4" indicates "Very Significant Acceptance."

No Significant Acceptance				Very Significant Acceptance	Not Applicable	Don't Know
0	1	2	X	4	98	99

Supporting Comments:

Over the 10 projects, there are 29 patents pending, an indicator of innovation, information flow, and value creation. However, as noted in #4 above, there is little evidence (with the exception of Projects 16 and 37) that there has been widespread awareness or adoption of these outputs beyond the project partners, which suggests problems in both the design of the message and its dissemination. More effective knowledge dissemination plans should be required. For example, CEC EPIC requires that a Technology/Knowledge Dissemination plan be developed by the grantee.

However, of the 10 projects, 6 appear to have been successful as indicated by follow-on use or research.