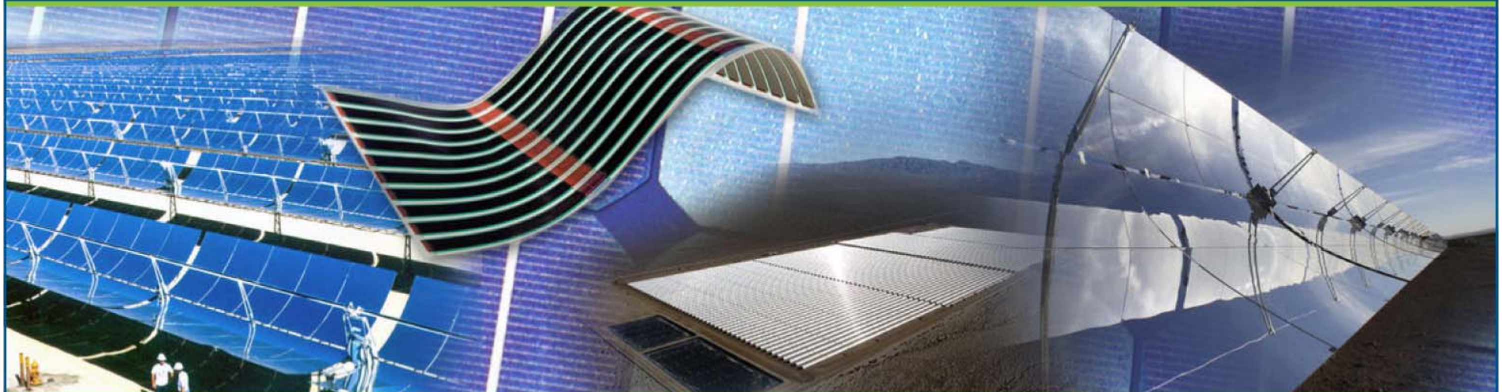
U.S. Department of Energy • Solar Energy Technologies Program



SOLAR ENERGY TECHNOLOGIES PROGRAM

Multi Year Program Plan

2008-2012

April 15, 2008

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

A Letter from the Program Manager

April 2008
Washington, D.C.

Welcome to the 2008-2012 Multi-Year Program Plan for the U.S. Department of Energy's Solar Energy Technologies Program (Solar Program). The Solar Program is responsible for carrying out the Federal role in researching, developing, demonstrating and deploying solar energy technologies. This document presents a look inside the Solar Program's plans for the next five years, as well as the areas of work that we intend to emphasize.

The Solar Program is driven by the Solar America Initiative (SAI), a Presidential initiative launched in 2007 with the goal of achieving grid-parity for solar electricity produced by photovoltaic (PV) systems across the nation by 2015 - making the SAI a nine-year effort. This plan covers years two through six of the SAI, which can be considered the core of the initiative.

The activities covered within this plan highlight what efforts the Solar Program will undertake to reach the SAI goal. We will not, however, reach the SAI goal alone. During the first year of the SAI, the Solar Program was able to lay the initial foundation for success through aggressive research and development (R&D) efforts in collaboration with private industry and national laboratories, and expanded that effort to universities in early 2008. Simultaneously, the program launched a groundbreaking market transformation effort to help commercialize solar technologies by targeting and eliminating market barriers to solar energy, as well as promoting deployment opportunities, through partnerships with cities, companies, non-profits, and universities. The 2008-2012 activities detailed herein build off of these early successes of the SAI.

Several areas of emphasis characterize the 2008-2012 timeframe:

1. Fully incorporating concentrating solar power (CSP) efforts into the SAI.
2. Improving storage technologies for both CSP and PV technologies.
3. Better integrating solar technologies into the electric grid, in both distributed and centralized generation applications.
4. Eliminating city and state level technical and regulatory barriers to solar technology deployment.
5. Improving the ability of DOE and its laboratories and partners to quickly and effectively transfer R&D concepts from basic to applied science and then to the marketplace.
6. Exploring and developing the next generation of PV technologies that will reach consumers beyond the SAI timeframe (post-2015).
7. Assisting U.S. industry in regaining its leadership role in the global solar marketplace.
8. Promoting increased understanding of environmental and organizational safety across all Solar Program activities by all participants.

We appreciate the many years of support from our partners across the solar field and look forward to continued and improved collaboration. We remain your publicly-funded Federal solar program and strive to conduct the most relevant, highly-valued activities to our stakeholders. Your input is always welcomed.

Thomas P. Kimbis
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Solar Energy Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Table of Contents

1.0 Solar Energy Program Overview

Record sales, increased consumer and utility demand, enhanced federal and state incentives, new product development as support by the President's Solar America Initiative (SAI[1]), massive manufacturing growth, and large numbers of new jobs make this an exciting and challenging time for solar energy. Solar energy is a clean, abundant renewable energy source that is vital to our energy security and independence. Targeting improved performance and reliability with reduced cost, the U.S. Department of Energy's Solar Energy Technologies Program (Solar Program or SETP) focuses research, development, and deployment projects[2] and activities in two technology areas[3]: Photovoltaics (PV) and Concentrating Solar Power (CSP), as shown in Figure 1-1. The Solar Program is focused on achieving price-parity with electricity prices and scale for solar electricity generation from both PV and CSP.

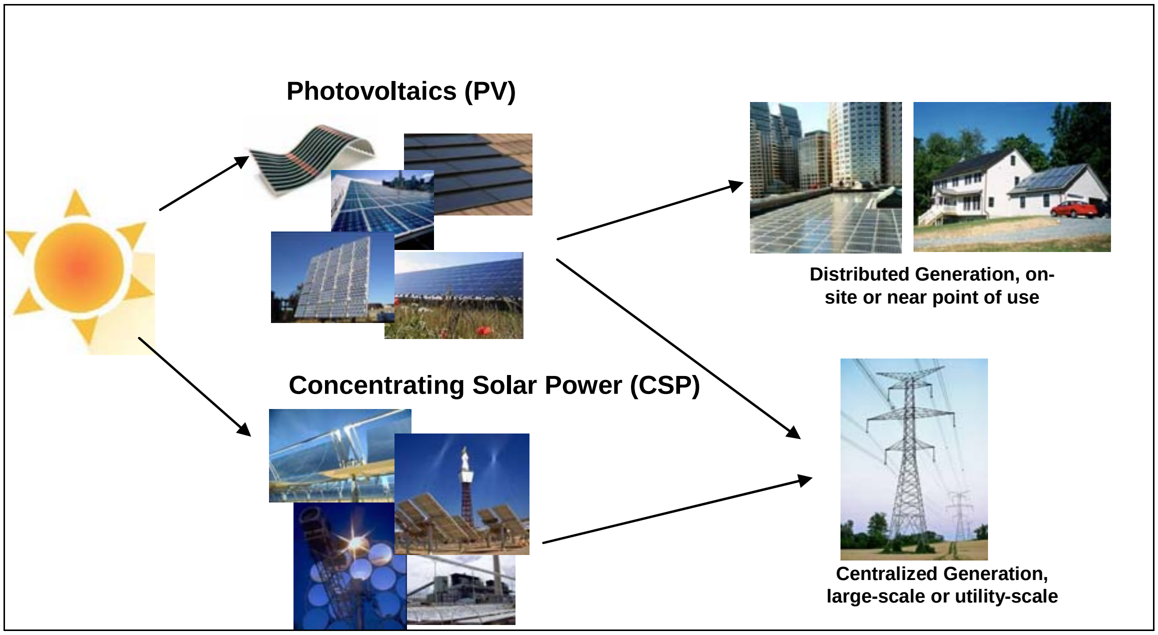

Figure 1-1. Solar Technologies for Electricity Generation

1.1 Market Overview and Role of the Federal Program

Displacing a significant amount of conventional energy production and consumption with new energy technologies is a major challenge. The U.S. electric generation system is enormous, with roughly 1,000 gigawatts (GW) of generating capacity currently in place.[4] However, the solar energy available in the United States is also enormous. For example, the solar electric footprint, defined as the land area required to supply all end-use electricity from solar photovoltaics, is about 0.6% of the total land area of the United States (181 m^2 per person), or about 22% of the

[1] A complete list of acronyms found in this report is provided in Appendix A.
[2] Details on Solar Program projects, such as summaries and milestones, are provided in Appendix B.
[3] A brief explanation of the solar technologies is provided in Appendix C.
[4] Annual Energy Review 2005. DOE/EIA-0384(2005). Washington, DC: Energy Information Administration.

"urban area" footprint.[5] To tap into this vast, indigenous resource, the Solar Program must facilitate the development of cost-effective, reliable solar energy systems that harness the sun's energy and turn that energy into electricity.

1.1.1 Solar Electric Power Markets Using PV Technologies

1.1.1.1 Global PV Market Development

PV is beginning to play a role as a significant source of new generation capacity in certain countries; this role is further differentiated in the varying regional markets of the United States. Markets in Germany, Spain, and Japan have exploded over the past several years, and consultancies and public equity analysts believe this trend will continue and expand. The most optimistic of these forecasts calls for a 51% compound annual growth rate in worldwide solar installations through 2011. This evidence points to the emergence of a worldwide industry at a 'jumping off' point. The International Energy Agency estimates that worldwide investments in energy supply will total approximately $22 trillion dollars by 2030. PV markets will be the recipients of a growing proportion (estimated at 10-20%) of this investment in the years to come.

Figure 1-2 shows various market projections out to 2011. These projections are based on manufacturing capacity expansions, especially in the production of silicon, which has to this point been a bottleneck for the PV industry.

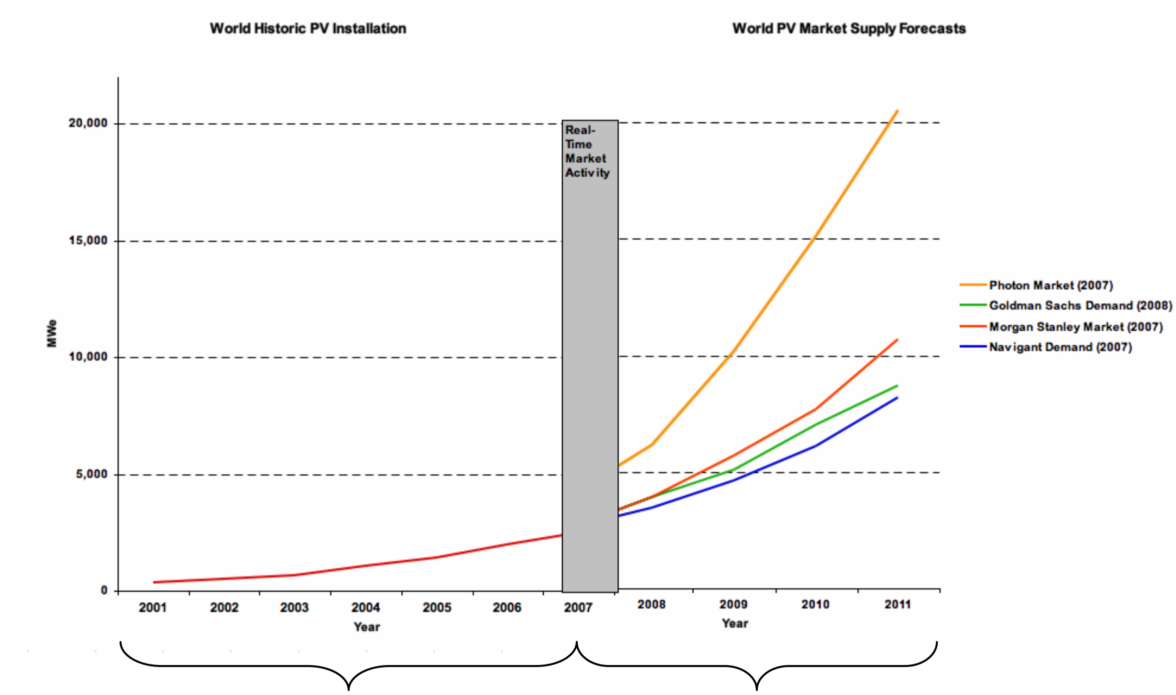

Figure 1-2. Global PV Installations[6] and Global PV Market Forecasts[7,8,9,10]

[5] Denholm, P. and R. Margolis, 2007, The Regional Per-Capita Solar Electric Footprint for the United States, NREL Technical Report, NREL/TP-670-42463, December 2007.

As shown in Figure 1-2, the global PV market is expected to increase its growth rate over the next five years, reaching 8-20 GW by 2011. Supply-Demand-Price forecasts are exhibiting significant variations based on key assumptions, including: polysilicon supply (a key input for the crystalline silicon (c-Si) cells that dominate today's PV marketplace); growth of emerging PV technologies (e.g., cadmium telluride (CdTe), amorphous silicon (a Si), and copper indium gallium diselenide (CIGS)); rising grid electricity prices; and changing rate structures. Other factors impacting the market include expanding PV distribution channels, emerging financing mechanisms, and declining costs across the PV supply chain.

1.1.1.2 U.S. PV Market Development

National, state, and local policies related to subsidies and interconnection rules generally drive demand for PV; these policies are steered by concerns about climate change, environmental impacts, and energy security concerns. Grid-tied markets, primarily systems installed on residential and commercial buildings, have been growing rapidly during the past five years and are expected to be the primary drivers of growth in the U.S. PV market. Legislation to create incentives or renewable portfolio standards (RPS) has passed or is pending in the majority of states (see Figure 1-6 for details on state RPSs). Annual grid-connected PV installations have increased from 10 MW per year in 2001 to about 180 MW per year in 2006, resulting in a cumulative installed base of about 480 MW of grid-connected PV in the U.S. at the end of 2006.

While incentives are important to establishing markets for solar, the Japanese market provides a case study of how markets continue to grow, even as incentives have declined. Note, however, that retail rates for electricity are higher in Japan than in the U.S., and further cost reduction for solar systems is needed to make electricity from solar competitive with the price of electricity from conventional sources in the U.S.

Policy developments at the federal and state level have the capability to increase demand substantially, creating a much more receptive U.S. market. In 2007, the DOE commissioned the Renewable Systems Interconnection (RSI) reports that analyzed the three main policies that would have the largest positive impact on solar demand in the U.S.:

1. Lifting net metering caps and establishing net metering in areas currently lacking these policies led the projected cumulative installed PV in 2015 to increase by about 4 GW;

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[6] Navigant: Navigant Consulting (2007) Photovoltaic Manufacturer Shipments & Competitive Analysis 2006/2007. Palo Alto, CA: Navigant Consulting PV Service. Report NPS-Supply2 (April 2007)
[7] Photon: Rogol, M.; Flynn, H.; Porter, C.; Rogol, J.; Song, J. (2006). Solar Annual 2007: "Big Things in a Small Package". Aachen, Germany: Solar Verlag GmbH/PHOTON Consulting.
[8] Goldman: The Goldman Sachs Group, Inc. (2008). "Positive tailwinds for alternative energy in 2008; we prefer solar" Global Investment Research. New York: (January 10).
[9] Morgan Stanley: Morgan Stanley & Co., Inc. (2007). "Clean Energy, Sustainable Opportunities" Morgan Stanley Research. North America (October 16)
[10] Navigant: Navigant Consulting (2007) Photovoltaic Manufacturer Shipments & Competitive Analysis 2006/2007. Palo Alto, CA: Navigant Consulting PV Service. Report NPS-Supply2 (April 2007)

2. Extension of the federal investment tax credit (ITC) led projected cumulative installed PV in 2015 to increase from 12 GW under a partial extension of the ITC to 17 GW under a full extension of the ITC; and
3. Improved interconnection standards had a significant effect on PV market development, leading to a projected cumulative demand increase of another 7 GW.

As shown in Figure 1-3, combining all three policies is projected to result in a cumulative installed base of about 24 GW of PV in the U.S. by 2015.

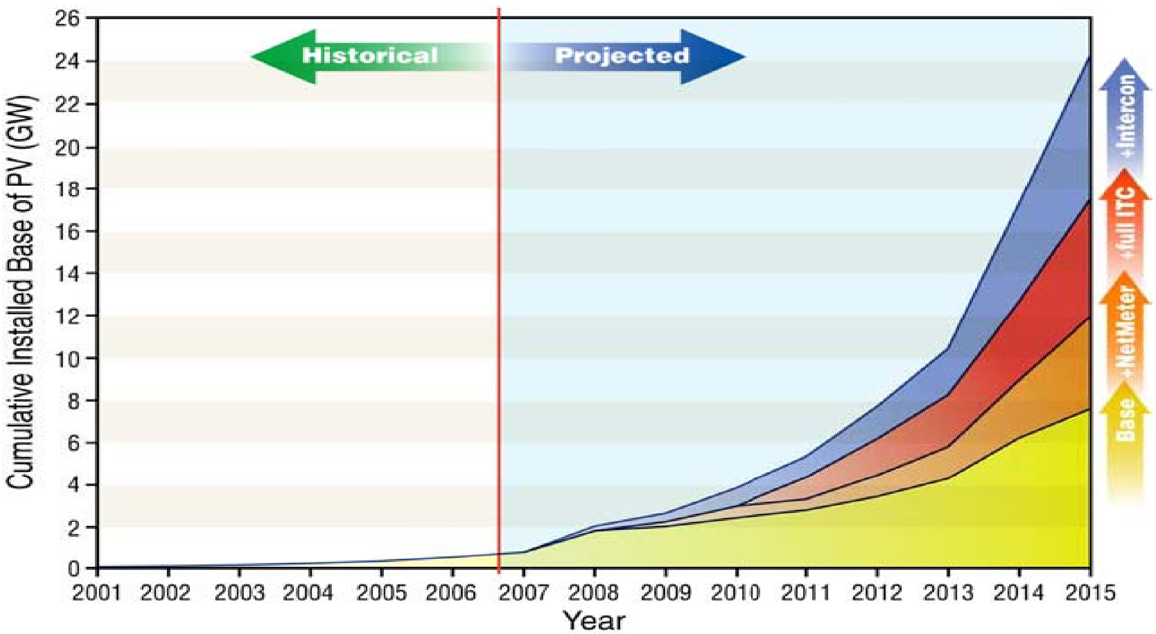


Figure 1-3. U.S. PV Installations and Policy Projections

1.1.2 Solar Electric Power Markets Using CSP Technologies

Concentrating solar power technologies are most often applied in centralized power production. In some regions, such as the Southwest, U.S, the widespread availability of sunshine provides flexibility in locating CSP power plants near existing or planned transmission lines. The principal CSP technologies (e.g., parabolic trough, dish/Stirling, power tower, and linear Fresnel power systems) are described in Appendix C. With each of these technologies, CSP power production aligns closely with periods of peak demand, and the problems of solar intermittency can be overcome with thermal storage or hybridization with natural gas, allowing plants to dispatch power to the line when it is needed.

In the late 1980s and early 1990s, nine trough plants were built in California. Fifteen years of relative inactivity in new construction followed the construction of these plants. The operation of these plants has proven this technology and provided excellent insight into operations and maintenance (O&M) issues. A comeback is now underway for utility-scale solar power plant development. It was recently reported[11] that 2007 has been a pivotal year for solar CSP development with 65 MW of parabolic trough systems having been brought on line in the U.S. (see Table 1-1) and 11 MW of central receiver technologies in Spain. The most recent plant in the U.S., Nevada Solar One, is located near Boulder City (see Figure 1-4). In addition, almost 6 GW were reported[12] as being in the near-term development pipeline over the next 5 years. As shown in Table 1-2, there are up to 3.6 GW of projects being planned in solar-rich areas of the Southwest U.S.

Table 1-1. CSP Current – 418.8 MW Operating in U.S.

Plant Name	Location	First Year of Operation	Net Output (MW_e)	Solar Field Outlet (°C)	Solar Field Area (m2)	Solar Turbine Effic. (%)	Power Cycle	Dispatchability Provided By
Nevada Solar One	Boulder City, NV	2007	64	390	357,200	37.6	100 bar, reheat	None
APS Saguaro	Tucson, AZ	2006	1	300	10,340	20.7	ORC	
SEGS IX	Harper Lake, CA	1991	80	390	483,960	37.6	100 bar, reheat	HTF heater
SEGS VIII		1990	80	390	464,340	37.6		
SEGS VI	Kramer Junction, CA	1989	30	390	188,000	37.5		Gas boiler
SEGS VII		1989	30	390	194,280	37.5		
SEGS V		1988	30	349	250,500	30.6	40 bar, steam	
SEGS III		1987	30	349	230,300	30.6		
SEGS IV		1987	30	349	230,300	30.6		
SEGS II	Daggett, CA	1986	30	316	190,338	29.4		
SEGS I	Daggett, CA	1985	13.8	307	82,960	31.5		

Since the late 1970s, dish/Stirling systems have seen several demonstrations and pre-commercial deployments. A prototype six-dish, 150 kW power plant built with private funds is now operating at the National Solar Thermal Test Facility at Sandia National Laboratories (SNL). The experience gained from the prototype plant has been helpful in reducing the capital cost of these systems, and the operational experience will improve reliability and reduce O&M costs. Recent market activity, as indicated in the power purchase agreements identified in Table 1-2, suggests that large deployments of dish/Stirling systems could become a reality in the U.S. In addition to the power tower that has been built in Spain, three more are under development there (one of

Newest U.S. Concentrating Solar Power Plant—64 MW

Nevada Solar One is the largest CSP facility to be built in the world since 1991. The plant consists of 350 acres of parabolic mirrors and will produce enough power to supply 15,000 average U.S. homes.

Figure 1-4.Nevada Solar One

[11] "Global Concentrated Solar Power Markets and Strategies, 2007-2020," Emerging Energy Research, November 2007.

[12] "CSP Project Developments in Spain," SolarPaces.org, http://www.solarpaces.org/News/Projects/Spain.htm.

these is slated to have sixteen-hours of molten salt storage)[13] and another tower system is under development in South Africa. In the U.S., a 500 MW tower project is being planned.

Table 1-2 CSP Near-Term - Up to 3,353 MW Currently Planned in U.S.			
Utility/State	**Capacity (MW)**	**Company**	**Technology -Status**
Southern Cal Edison	500-850	SES	Dish – signed power purchase agreement
San Diego Gas & Electric	300-900	SES	Dish – signed power purchase agreement
Pacific Gas & Electric	500	Bright Source	Tower – MOU signed
Pacific Gas & Electric	553	Solel	Trough - signed power purchase agreement
Florida Power and Light	300	Ausra	Trough - project announced
Arizona Public Service	280	Abengoa	Trough - signed power purchase agreement
SW Utility Joint Venture (APS)[14]	Est. 250	TBD	TBD – multiple expressions of interest

Markets for CSP are being driven worldwide by new policy incentives and technology improvements, and this is resulting in renewed market interest. Favorable feed-in tariffs have led to commercial projects in Spain, and European suppliers are competing with American suppliers for these markets.[15] The long-term future of the CSP industry in the U.S. also appears robust. As Figure 1-5 shows, projections of future CSP growth show that more than 50 GW of capacity is likely, with the growth rate being significantly dependent upon the duration and parameters of the Investment Tax Credit.

[13] "CSP Project Developments in Spain", SolarPaces.org, http://www.solarpaces.org/News/Projects/Spain.htm

[14] In mid 2007 several Southwestern utilities requested proposals for the development of renewable power plants that will likely result in CSP projects.

[15] Spain introduced a "feed-in-tariff" in September 2002 for CSP-generated electricity and granted a payment of 12 € cents for each kWh output from a CSP plant between 100 kW and 50 MW capacity. In 2004 this was increased under Spanish Royal Decree 436, in which CSP generators receive a tariff of 21 € cents for the first 25 years, and 17 € cents thereafter. Source: IEA Global Renewable Energy Policies and Measures Database: http://www.iea.org/textbase/pamsdb/detail.aspx?mode=gr&id=2034
Actual text of Royal Decree (in Spanish): http://noticias.juridicas.com/base_datos/Admin/rd436-2004.html

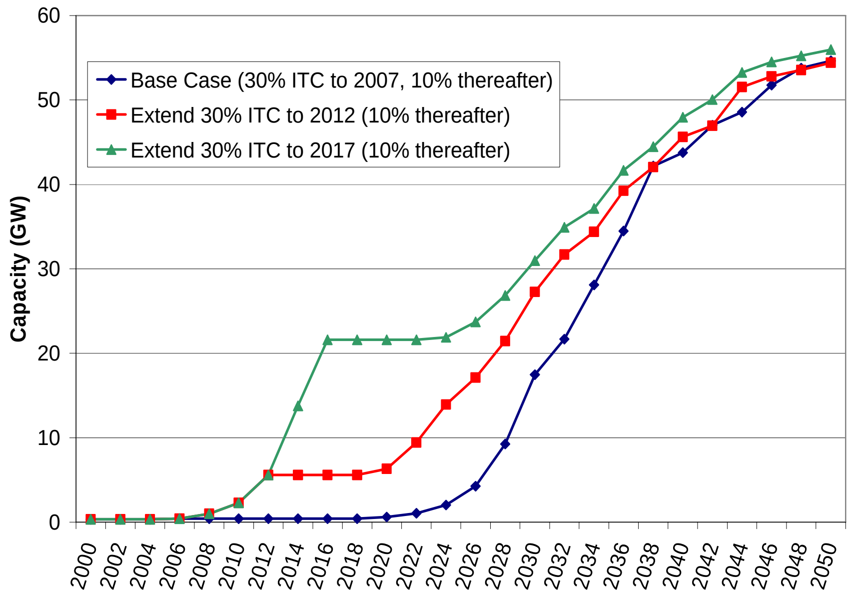


Figure 1-5. Investment Tax Credit Impact on CSP Capacity

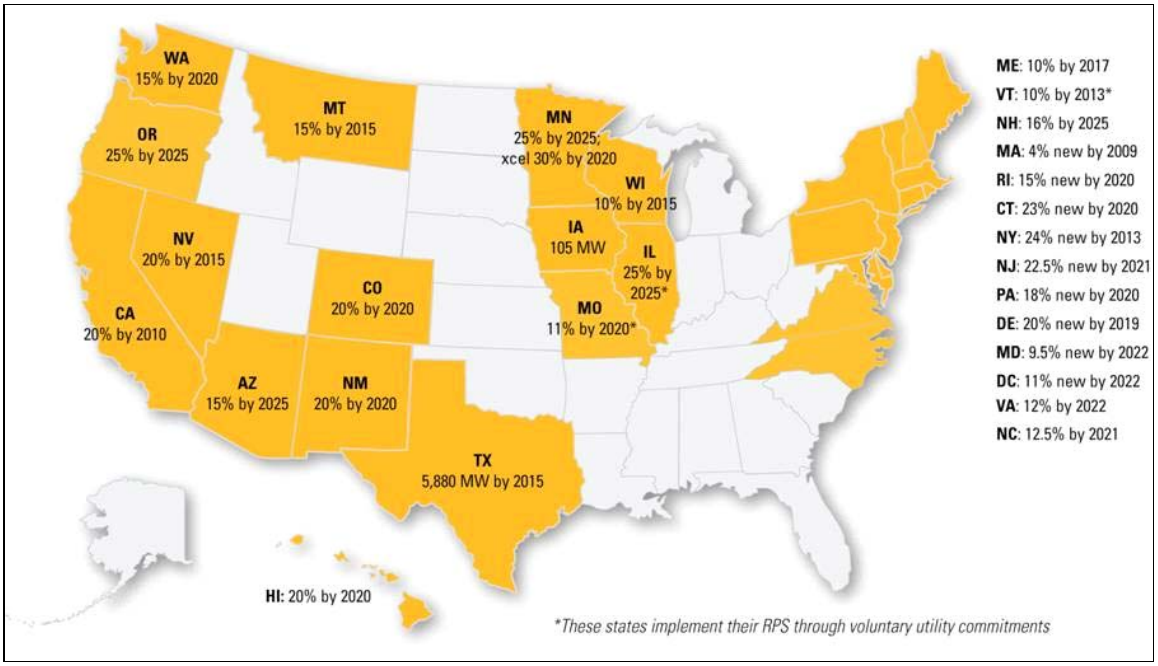
Federal and State Market Incentives

The federal government provides several incentives for the installation of solar energy systems:

- **Residential Solar and Fuel Cell Tax Credit:** Energy Policy Act of 2005 (EPAct 2005) establishes a 30% tax credit, capped at $2,000, for the purchase and installation of residential solar property, now set to expire at the end of 2008.
- **Commercial Solar and Fuel Cell Tax Credit:** EPAct 2005 also establishes a 30% tax credit for the purchase and installation of solar energy systems on commercial property (no cap), through 2008. After its expiration, the tax credit reverts to a permanent 10% level. Accelerated 5-year depreciation is also allowed.

An extension of both investment tax credits is seen by some to be indispensable towards reducing overall project costs. As Figure 1-5 shows, a ten-year extension of the 30% ITC is projected to result in over 20 GW of CSP capacity by 2017, a full 15 years sooner than that level is projected to be reached with no extension.

States that have enacted RPSs are listed in Figure 1-6. These standards are stimulating a market for both PV and CSP solar energy. In addition, several states have solar incentives in place.



Note: "New" means renewable generation sources that were not operating at the time the state RPS was enacted.

Figure 1-6. State Renewable Portfolio Standard Requirements[16]

Federal Role

While rapid growth in deployment is now occurring in the PV sector, U.S. deployment of these technologies lags far behind countries that are aggressively developing and implementing solar technologies. This provides an opportunity for the Federal government to focus its activities to further reduce barriers to accelerated implementation of solar energy technologies.

In his 2006 State of the Union speech, President Bush announced the Advanced Energy Initiative, which states, "Diversification of our electric power sector will ensure the availability of affordable electricity and ample natural gas supplies. At the same time, increased efficiency will help reduce demand for natural gas. By easing the demand pressure on natural gas, prices will drop and U.S. firms will be more competitive in the global market, keeping jobs here at home."[17] One element of the Advanced Energy Initiative is the SAI. For the 2007 and 2008 budgets, additional funding has been provided to help accelerate the development and commercialization of solar energy systems. The Solar Program is executing the Solar America Initiative by working with industry, national laboratories, universities, and other members of the solar energy community. The goals of the Solar Program are directly market-oriented in terms of cost, so all R&D activities initiated under the Solar Program are guided by a systems-based approach that seeks improvements in the primary metrics used to gauge progress.

[16] Office of Energy Efficiency and Renewable Energy. "States with Renewable Portfolio Standards." June 2007. http://www.eere.energy.gov/states/maps/renewable_portfolio_states.cfm#chart
[17] "Advanced Energy Initiative." The White House National Economic Council, Washington, DC, February 2006.

1.2 Solar Program Mission

The mission of the Solar Energy Technologies Program is to conduct aggressive research, development, and deployment of solar energy technologies and systems. As part of the President's Advanced Energy Initiative, which seeks to change the ways we power our homes, business, and automobiles, the Solar Program is working to develop cost-competitive, unsubsidized photovoltaics across the Nation by 2015. Through the President's SAI, announced in the 2006 State of the Union, the Solar Program will accelerate the market competitiveness of solar electricity as industry-led teams compete to deliver solar systems that are less expensive, more efficient and highly reliable. By focusing on manufacturing and systems integration issues, the SAI will support the deployment of 5 GW of new grid-connected solar electricity generating capacity by 2015.

1.3 Solar Program Vision

The vision of the Solar Energy Technologies Program is that:

- Inexpensive solar energy will become available for all Americans,
- Millions of homes and commercial buildings across the nation will use solar technology to provide all or much of their energy needs, and
- Solar energy will constitute a significant portion of our Nation's energy production.

This vision directly supports the goal of the President's Advanced Energy Initiative: "Changing the way we power our homes and businesses." [18]

1.4 Solar Program Design

1.4.1 Program Structure

The major solar energy program activities include:

- **Photovoltaics Research and Development (R&D)** to achieve impactful improvements in the cost, reliability, and performance of devices, components, and systems.
- **Concentrating Solar Power R&D** to develop and improve utility-scale power systems and to create and demonstrate effective storage technologies.
- **Market Transformation** to reduce market barriers through non-R&D activities, including infrastructure development and deployment assistance.
- **Partnerships with Other Programs** to effectively accelerate the commercialization of solar energy systems and to integrate results of basic research results from other government programs into solar program R&D activities.

[18] "Advanced Energy Initiative." The White House National Economic Council. Washington, DC. February 2006.

1.4.2 Program Logic

The basic program structure is designed to assure that: 1) the technology development pipeline, as shown in Figure 1-7, is filled with well-defined, focused projects that address the near-, mid-, and long-term technological and scientific advances for improved performance, lower cost, and improved reliability of solar materials, components, and installed systems; and 2) market transformation efforts are focused to comprehensively identify and overcome the largest remaining obstacles to widespread solar technology adoption and use, while maximizing highly cost-shared commercialization efforts.

In this past year, DOE has invested broadly in U.S. R&D and market/regulatory efforts (see Figures 1-7 and 1-8). Multiple technologies that are at varying stages of technical maturity are included in the portfolio of activities in the Solar Program. The longest-term element in the pipeline represents basic research that typically occurs within university and laboratory programs as a result of proposals funded by DOE's Basic Energy Sciences program. Concepts developed as part of those research activities feed the applied research of the Solar Program. Concepts are evaluated by SETP for both technical merit and the potential for successful commercial application, relative to system requirements identified in the marketplace and as feedback from each successive development step. As technological innovations reach the manufacturing stage, market transformation activities are initiated to clear the pathway for success of the technology in the marketplace.

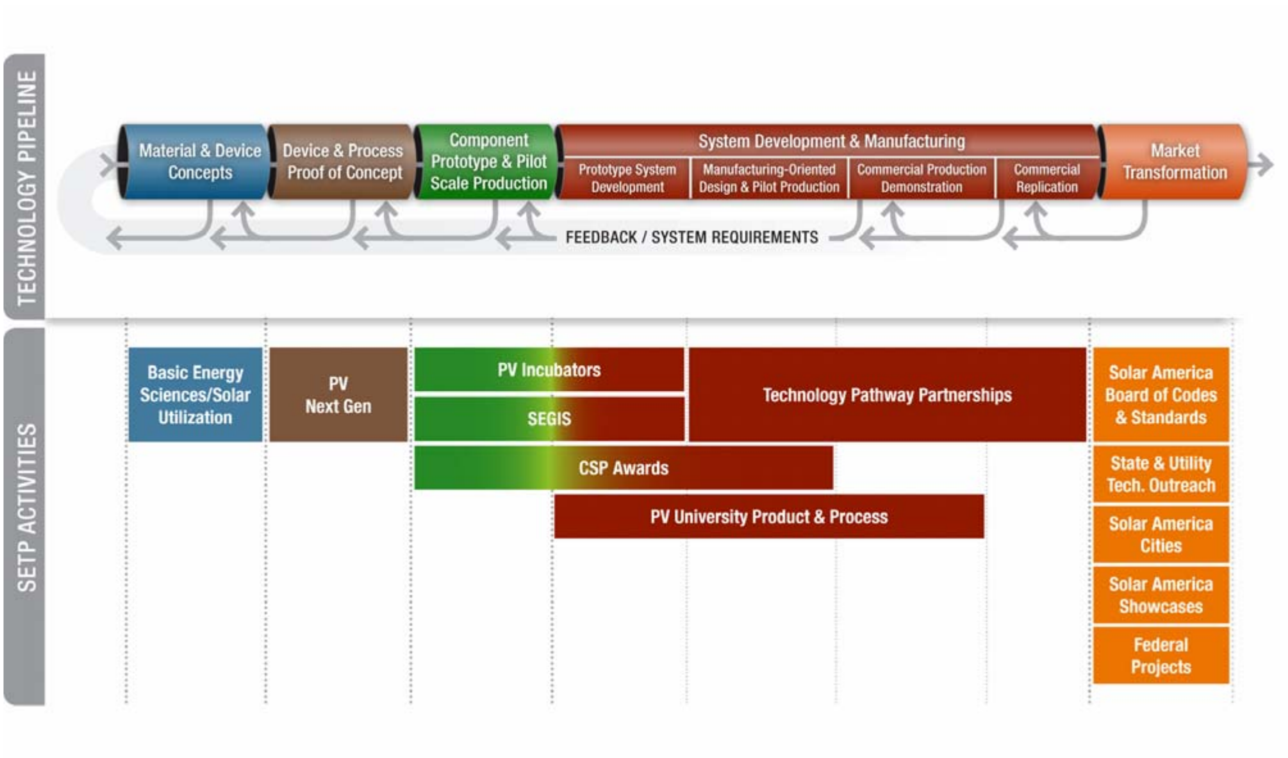


Figure 1-7. Solar Energy Technology Project/Development Pipeline Diagram

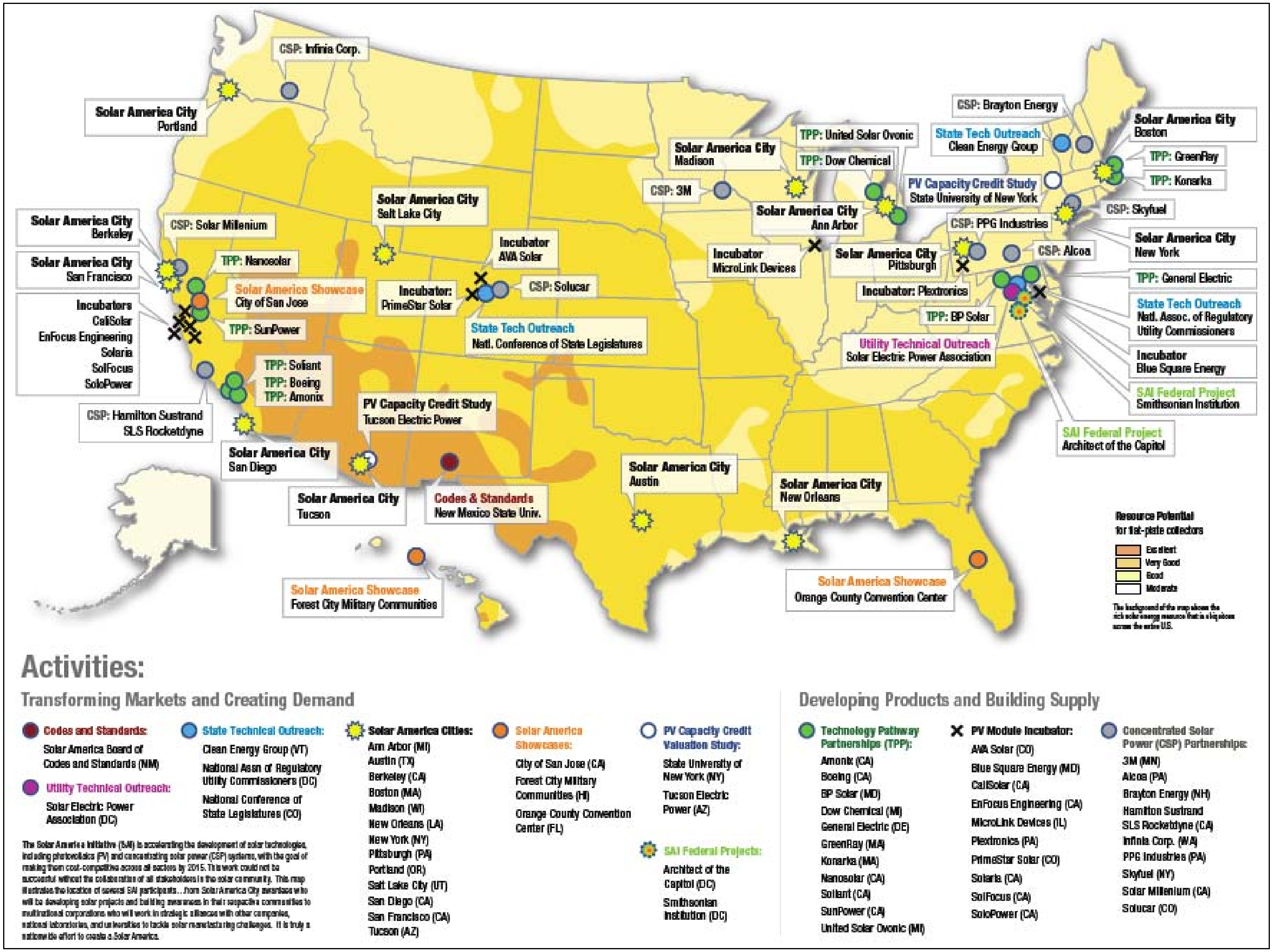


Figure 1-8. Map of Recent Solar Energy Technology Program Activities Initiated in 2007

The program combines the talents of the solar energy industry, the DOE national laboratories, and the nation's leading universities. The DOE aggressively engages industry and its expertise to drive near-term technology development, commercialization and to bring new products to the marketplace. Similarly, university researchers are most heavily involved in revolutionary developments in new materials and technologies that will impact the next generation of solar energy systems. The scientific, engineering and technical facilities of our national laboratories are extensively utilized in leading the applied research that provides proof of concept demonstrations for new devices, helps develop new prototype products and manufacturing processes, and measures the performance of devices, components, and systems. In fact, national laboratories, such as the National Renewable Energy Laboratory (NREL), are making great strides in encouraging U.S. industry to use their facilities for the advancement of solar technologies. Additional stakeholders in the solar community and beyond assist with the market transformation required to accomplish wide-scale commercialization of the technologies. In this way, the solar technology development pipeline can be filled with numerous products and processes in stages of development that range from new material concepts to commercial replication of energy systems. The net result is a very healthy, growing U.S. solar energy industry that is supported in critical areas by a dynamic federal program.

1.5 Solar Program Goals and Multiyear Targets

The Solar Program goals support the DOE 2006 Strategic Plan[19], which identifies five themes and associated goals. The strategic theme of *energy security* is a key driver of the Solar Program activities supported by DOE. The Solar Program also supports the research and development provisions and broad energy goals outlined in the National Energy Policy, EPAct 2005, and the Energy Independence and Security Act (EISA). In both acts, Congress expressed strong support for decreasing dependence on foreign energy sources and decreasing the cost of renewable energy generation and delivery. Support from Congress and state governments and the availability of financial incentives are important to achieving Solar Program goals.

DOE 2006 Strategic Plan Guidance

Energy Security Theme: Promoting America's energy security through reliable, clean, and affordable energy.

Goal 1.1 Energy Diversity- Increase our energy options and reduce dependence on oil, thereby reducing vulnerability to disruption and increasing the flexibility of the market to meet U.S. needs.

Goal 1.2 Environmental Impacts of Energy- Improve the quality of the environment by reducing greenhouse gas emissions and environmental impacts to land, water, and air from energy production and use.

Goal 1.3 Energy Infrastructure- Create a more flexible, more reliable, and higher capacity U.S. energy infrastructure.

1.5.1 GPRA and Solar Program Strategic Goals

The primary goal of the Solar Program is consistent with a solar goal of the Government Performance and Results Act (GPRA). This goal, GPRA Unit Program Goal 1.1.03.00 is:

> To improve the performance and reduce the cost of solar energy systems to make solar power cost-competitive with conventional electricity sources by 2015, thereby accelerating large-scale usage

[19] U.S. DOE Strategic Plan, 2006 , http://www.energy.gov/about/strategicplan.htm

across the Nation and making a significant contribution to a clean, reliable and flexible U.S. energy supply.

The Solar Program's market analysis has identified the following markets as key to achieving a significant solar contribution to U.S. energy supply:

- Electricity for residential and commercial applications (point of use on the customer side of the meter), and
- Utility-scale electricity (tied to the electrical transmission and distribution system on the utility side of the meter).

The primary metric used by the program is the cost of producing or saving energy using a solar energy system, expressed in terms of levelized cost of energy (LCOE). There are multiple ways to reduce LCOE. Some of the critical methods targeted by the program to reduce LCOE are by lowering manufacturing cost, improving performance, and increasing the reliability of technologies. Another important pathway to reduce costs is learning and innovation through increased manufacturing capacity. Thus, generating market opportunities is also a pathway to lowering LCOE.

The Solar Program's economic targets, as shown in Table 1-3, were determined by an analysis of key markets and were set based on assessments of the LCOE for solar technologies to be competitive in these markets. The EIA projects that the cost of new combined cycle gas turbines (CCGTs) will remain fairly constant (in real terms) through 2025, and that this technology will be built to meet new baseload and peaking demand.[20] Therefore, the Southwest market, for example, with its exceptional solar resources, combined with solar's time-production profile, is a reasonable target market (i.e., to meet intermediate and peaking capacity/generation needs in the utility sector). Additionally, incorporating at least a few hours of storage into solar technology will enable centralized solar to meet the requirements of intermediate and peaking power markets.

The target residential and commercial price targets are based on current retail electricity prices and take into consideration EIA's projection that electricity prices will remain fairly constant (in real terms) through 2025. Numerous other factors (e.g., carbon tax legislation, international fuel prices, policies on liquid natural gas (LNG) importation/facility construction, labor costs, exchange rates, inflation, etc.) could combine to help solar energy achieve parity with electricity prices even faster than currently projected.

[20] Energy Information Administration, Assumptions to the Annual Energy Outlook 2007, Report #:DOE/EIA-0554(2007).

Table 1-3. Solar Program Cost Targets by Market Sector					
	Current U.S. Market Price Range for Conventional Electricity (¢/kWh)		Levelized Cost of Energy (¢/kWh)		
			Benchmark	Target	
Market Sector		Technology	2005	2010	2015
Utility	4-0-7.6	CSP[a]	12-14	10-12	8-10[b]
		PV	13-22	13-18	5-7
Commercial[c]	5.4-15.0	PV	16-22	9-12	6-8
Residential	5.8-16.7	PV	23-32	13-18	8-10

a) Utility CSP includes up to 12 hours of thermal storage in 2020, thereby competing effectively as base load power.
b) CSP target for 2020 is 5-7 ¢/kWh; more aggressive funding will shorten that timeframe.
c) In many commercial applications, utility costs are tax deductible. In these cases, the cost of solar energy should be compared to the effective market price, considering tax effects.

Meeting the solar market cost goals will result in 5-10 GW of PV installed by 2015 in the U.S. and 70-100 GW by 2030. For CSP, satisfaction of these cost targets is expected to lead to installation of between 16 and 35 GW of new generating capacity by 2030. Technology specific goals, such as efficiency and manufactured cost, have also been identified. These metrics are reported in the relevant technology sections of this document.

2.0 Solar Technology Research, Development, Deployment and Demonstration Plan

2.1 Photovoltaics

The Solar Program has initiated a number of activities to engage industry. These activities, including the Technology Pathway Partnerships (TPPs), the PV Technology Incubator programs, and the PV Next Generation programs, are focused on achieving cost parity and domestic production levels necessary for market penetration of advanced PV technologies. The TPPs aim to develop scaleable manufacturing processes for commercial (or very near commercial) technologies to be able to meet projected ramped-up production in the 2010-2015 timeframe. The PV Technology Incubators explore the commercial potential of new manufacturing processes and products in order to move from pilot or pre-commercial to commercial applications and to meet the 2015 SAI goal. The PV Next Generation program represents an important early stage investment in exploratory research and development of innovative, revolutionary, and highly disruptive PV technologies, which are expected to produce prototype PV cells and/or processes by 2015, with full commercialization by 2020-2030. To provide maximum value to this rapidly expanding industry, DOE has increased the focus of its R&D on validating the new technologies/products, cost reduction and production scale-up challenges, and creating/preparing markets for PV products. These program activities are further described in Section 2.1.4, and specific projects are detailed in Appendix B. The flow diagram in Figure 2.1-1 shows the advancement of PV technologies from component-level R&D to system integration and through the R&D pipeline to commercial application.

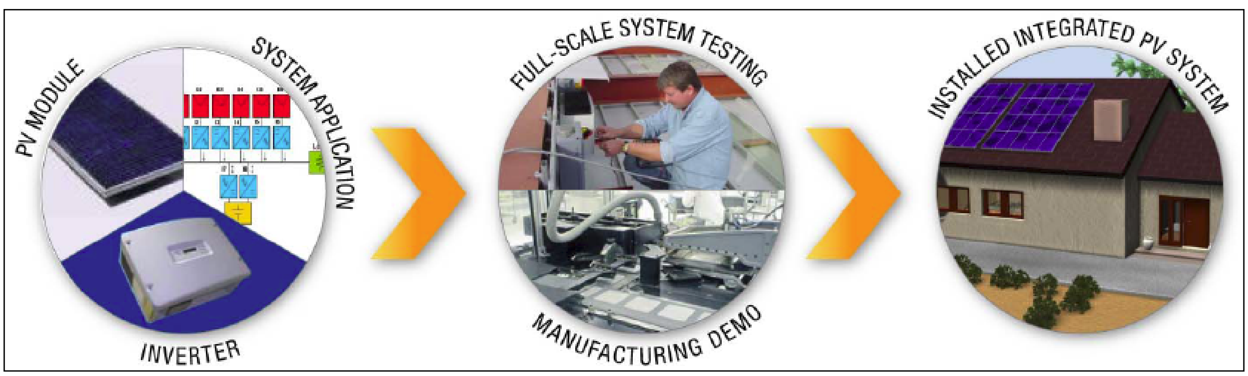


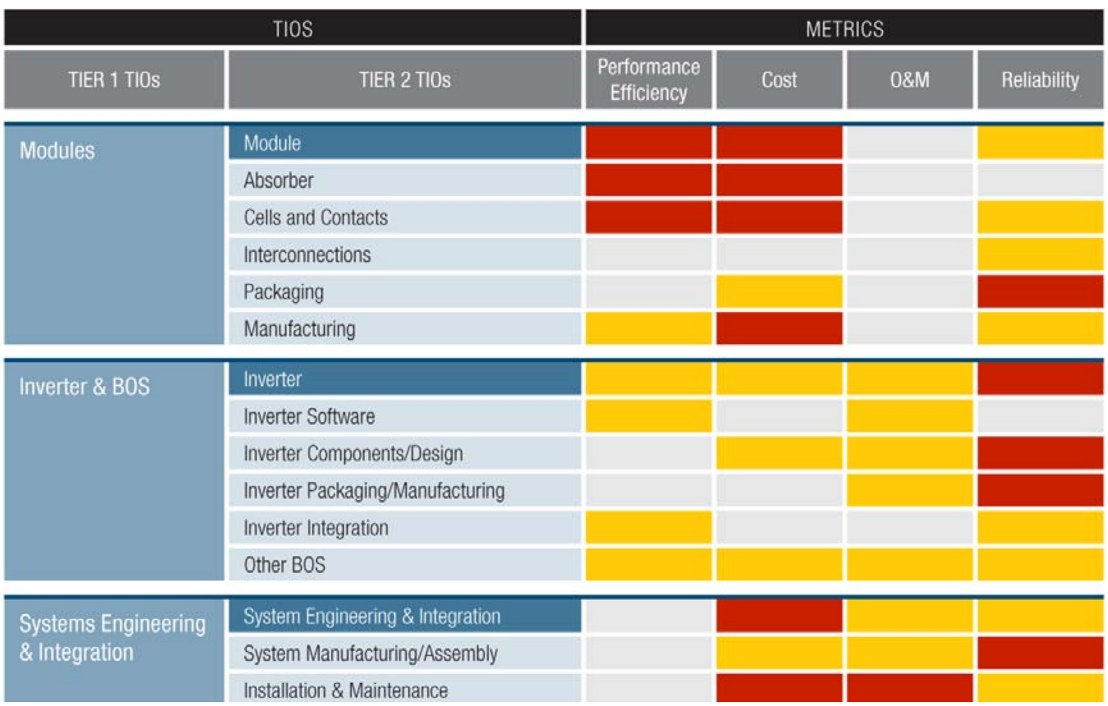
Figure 2.1-1. PV Technology Advance from Component R&D to Commercial Application.

Numerous factors have helped to establish a variety of markets for PV, including the following:

1. Long-term government investment in PV R&D has dramatically decreased cost and increased efficiency of solar energy systems.
2. Incentives have driven steep growth in installations.
3. Cost reductions and incentives have made PV a profitable market, driving investments in manufacturing expansion.

Residential grid-tied, commercial grid-tied, and central power generation are the target markets considered in Solar Program planning for PV. To provide a baseline for analysis, planning, and program prioritization, representative system designs have been identified for each of the target markets. These designs, which have been labeled reference systems, are baseline system designs containing representative components and system sizes that address each of the target markets. These reference systems are used by the Solar Program, national laboratories and industry partners to identify specific areas of R&D that could lead to improved overall system performance. This framework allows for quantifiable objectives to be set (milestones) for each project, with performance evaluated throughout the project lifetime and go/no-go decisions made (i.e., Stage Gate review).

Technology Improvement Opportunities (TIOs) are specific changes that can be made to improve performance, increase reliability, or reduce cost of components and other elements of installed system cost. As shown in Figure 2.1-2, TIOs are first identified at Tier 1 (e.g., Modules), the highest level, and are then broken out into detailed sub-components at the Tier 2 level (e.g., absorbers, cells and contacts, interconnects, packaging, and manufacturing).



Note: Red Box = High Impact, Yellow Box = Moderate Impact and Grey Box = Little or No Impact

Figure 2.1-2. Technology Improvement Opportunities for PV.

For each program activity, participants can identify specific TIOs and the corresponding metrics that will be improved relative to baseline cost and performance characteristics. The Solar Program uses the planned R&D activities along with the new targets established for planning / prioritization activities that quantify the potential impact of R&D efforts.

2.1.1 Photovoltaics Support of Program Strategic Goals

A key element of the Solar Program's PV activities is to support research that keeps the innovation pipeline full in order to achieve the progress needed to accomplish the 2015 SAI cost parity and manufacturing capability goals, as well as to facilitate post-2015 global competitiveness for U.S. PV technologies. In the near- and mid-term, the national laboratories and universities will support the TPPs with their specific research tasks, and will provide extensive progress measurements. In addition, the Solar Program will conduct cross-cutting research that will benefit several companies and technologies by working on fundamental materials, device, and processing issues.

2.1.2 Photovoltaics Support of Program Performance Goals

The principal metrics for PV R&D that directly impact LCOE are performance (efficiency), cost, O&M, and reliability. Improvements in each of these areas will accelerate the development of U.S.-produced PV systems, enabling the Program to meet its 2015 goals of cost parity for PV-produced electricity and domestic installed PV generation capacity of 5-10 GW (see Figure 2.1-3).

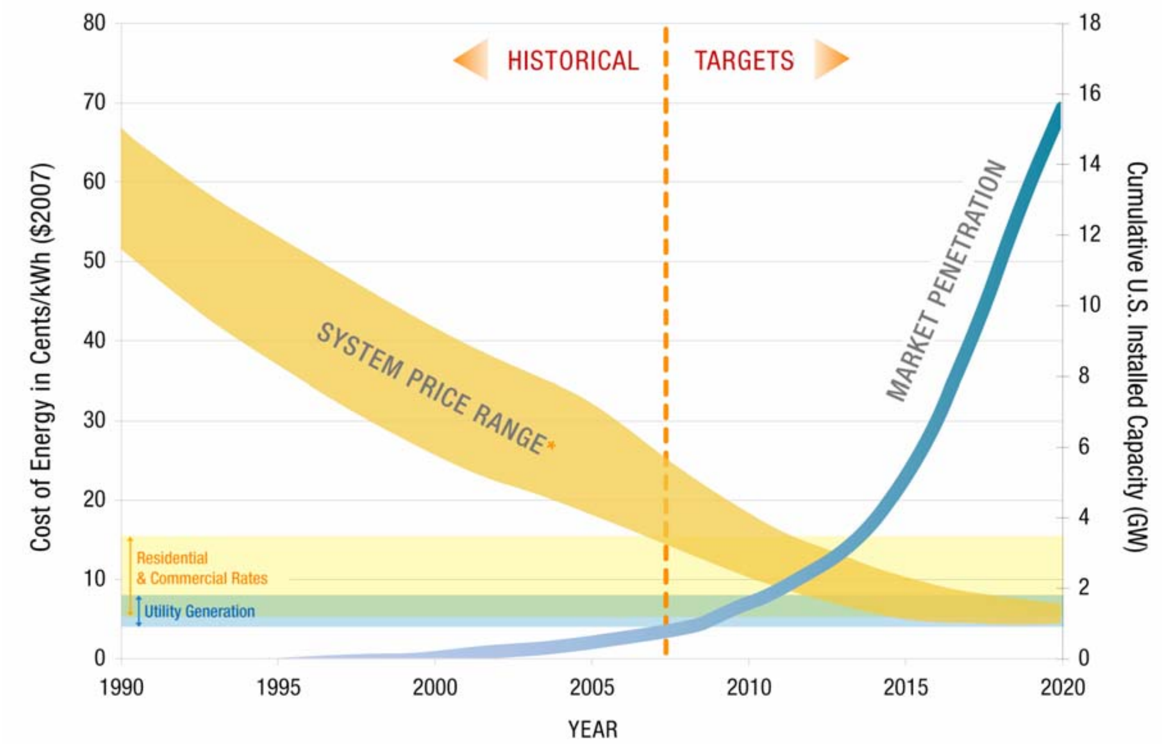


Figure 2.1-3. Projected LCOE and Market Penetration due to SETP Activities.

Although advances in different PV R&D metrics will affect LCOE differently, Program funding opportunities, like the TPP awards, are designed to allow U.S. industry the flexibility to achieve the greatest cost reductions in one or multiple LCOE metrics at their discretion.

In 2006, installed costs for residential PV systems were baselined (see Figure 2.1-4) at $7.97/W, resulting in an LCOE of ~30¢/kWh over the 30-year life of the system. Similar evaluations of commercial systems peg installed costs at about $7.23/W corresponding to an LCOE of 18.6¢/kWh. While this figure shows only one of many possible design solutions (i.e. projections of costs for 2010 and 2015), the associated system analyses show that reaching the SAI cost targets requires a 2- to 3-fold improvement in cost/kWh for modules/inverters. Installation and O&M require even more aggressive improvements through design/reliability enhancements and simplification. As indicated in the systems analysis efforts that evaluated the TIOs, increasing module efficiency, lowering module manufacturing costs and increasing inverter lifetime are high impact activities.

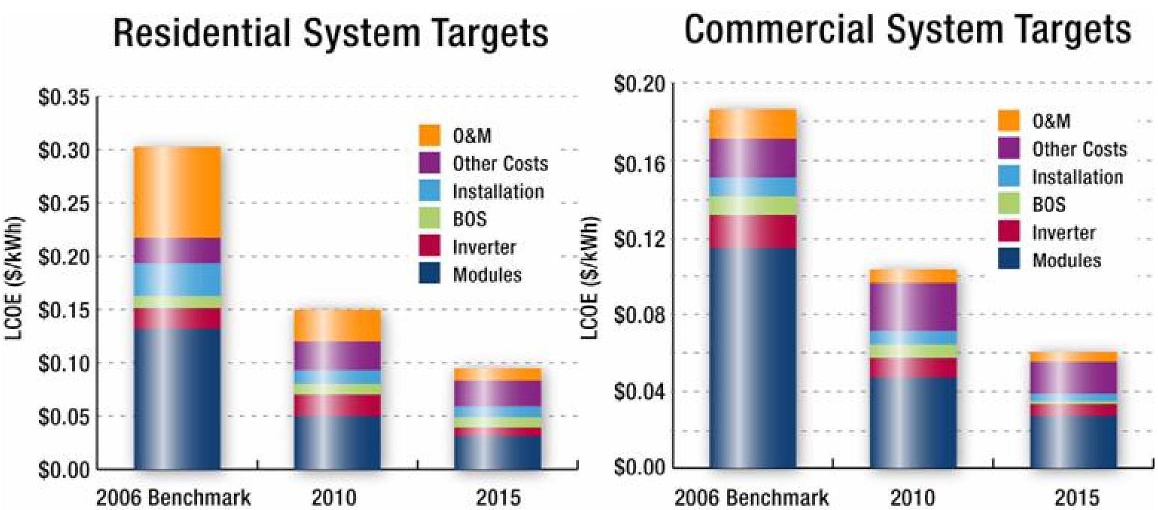


Figure 2.1-4. Benchmark data for reference system with 2010 and 2015 projections.

PV markets in the U.S. are opening up in several states as a result of the convergence of PV cost reductions, rising electricity prices, and attractive subsidies. The three residential sector breakeven maps shown in Figures 2.1-5 through 2.1-7, illustrate the relative competitiveness of a well-configured solar PV system in various regions of the U.S. They compare the effective cost of electricity produced by PV to the retail residential cost of electricity in current and future scenarios. In each map, the performance of PV was evaluated in each of the 1,000 largest U.S. electricity service territories. These utilities provide about 95% of the total residential electricity in the U.S. Within each utility territory, the performance of a residential PV system was simulated and the associated levelized cost of electricity was calculated[21], and then compared to the average price of electricity for three distinct cases.

[21] For the price of electricity, the average electricity price for the 1000 largest utilities in the U.S. based on EIA data for 2006 (except CA, where existing tiered rates structures were used). A 6% price derate factor was assumed to remove fixed billing charges. TOU rates included (+20% price adjustment) for select states in 2007, and all states in 2015. Electricity price escalated at 1.5% per year in moderate case and at 2.5% per year in more aggressive case. The solar performance is based on NSRDB weather station closest to the

The first case, shown in Figure 2.1-5, is based on residential electricity prices in 2006 (the most recent year available), state and federal incentives for solar as they existed in December 2007, and an assumed installed system price of $8500/kW (typical for systems in 2007 albeit higher than the baselined, near-best practices case show in Figure 2.1-4). Thus the first figure provides a reasonable representation of the residential sector breakeven for PV in 2007 including existing incentives. While electricity prices did change significantly in some states between 2006 and 2007 (e.g., Maryland), due to data limitations we did not include these changes in this analysis.

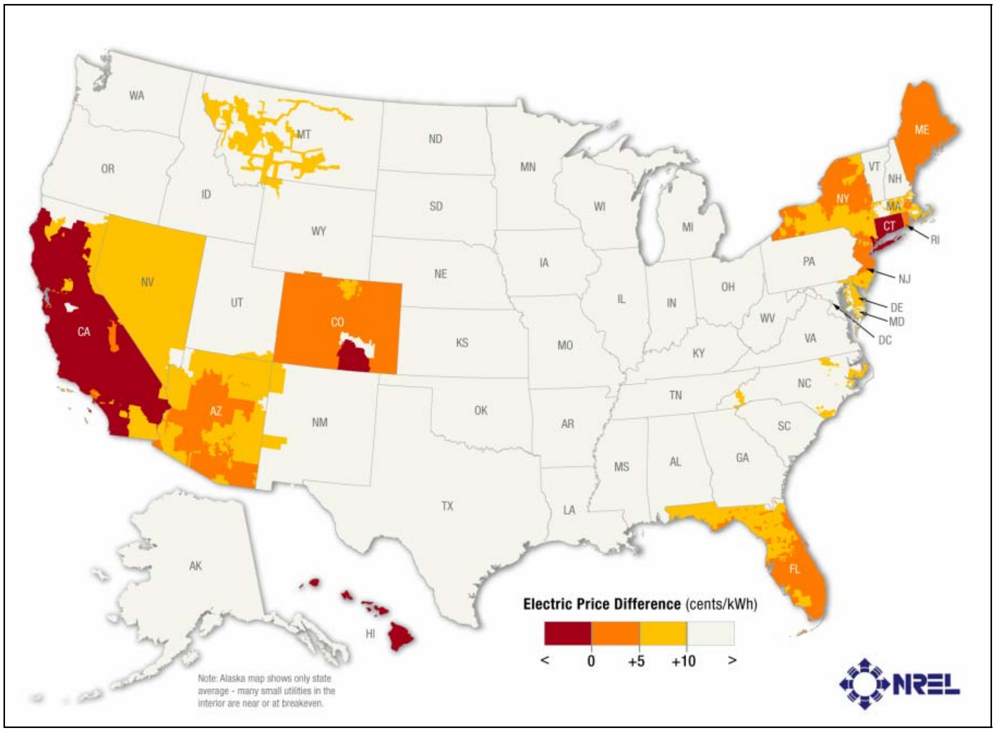


Figure 2.1-5. 2007 PV and Electricity Price Differences for Residential Systems with Incentives.

The second and third maps illustrate two alternative cases for 2015. Both of these cases assume that the SAI targets for PV system cost reductions are met - i.e., the typical installed price of a PV system declines to $3,300/kW, and that time of use (TOU) rates become widely available resulting in a 20% increase in the value of electricity from PV based on previous estimates of the “average” increase in PV value when shifting from flat

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center of the utility service territory, assuming a south facing array, at 25 deg tilt. An 82% derate factor is used to account for inverter and other PV system loses, but no performance degradation over life of the PV system is assumed. For the financial analysis, the installed system price is set at $8.5/Wp in the current case and $3.3/Wp in 2015. The system is assumed to be financed with a home equity loan or through mortgage (i.e., interest is tax deductible), with a 10% down payment, 6% interest rate, with the owner in the 28% tax bracket, and a 30 year loan/30 year evaluation period. Incentives included are the Federal ITC worth $500/kW due to $2000 cap and individual state incentives as of December 2007 in the current case and no Federal ITC or state incentives in 2015.

to TOU rates.[22] For the purpose of this analysis we also removed the impact of potential future federal and state incentives. In other words the 2015 cases provide two potential views of the breakeven for PV *without* incentives in 2015. The difference between the two 2015 cases is driven by different assumptions about the projected increase in electricity rates.

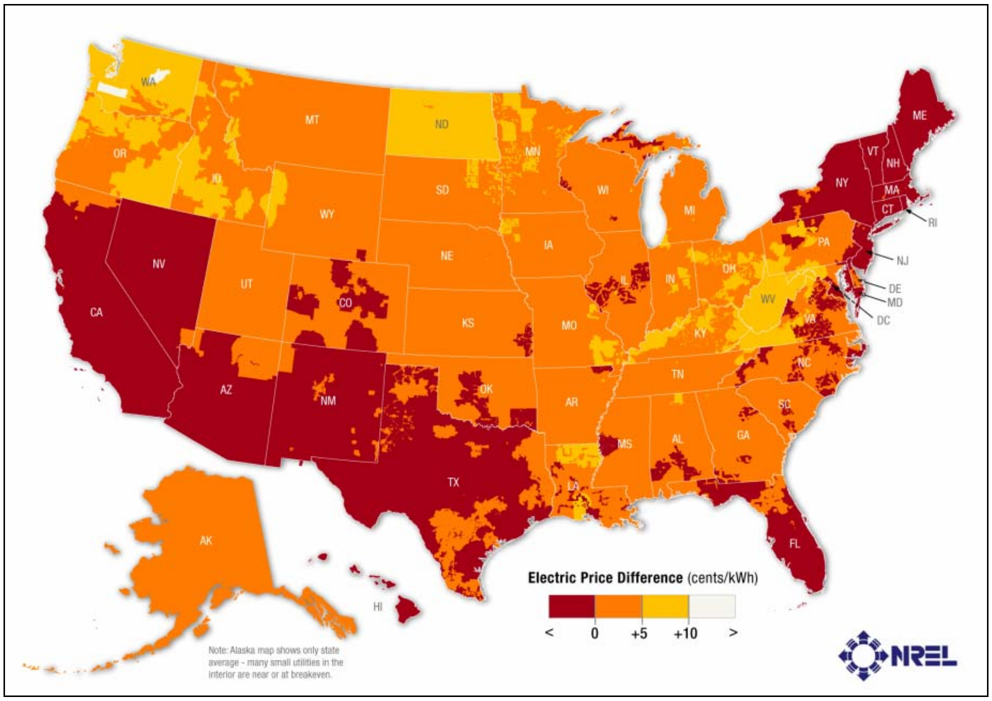


Figure 2.1-6. 2015 PV and Electricity Price Differences for Residential Systems without Incentives and Moderate Increase in Electricity Prices.

In the first case, shown in Figure 2.1-6, the real price of electricity is assumed to increase 1.5% per year. Given existing trends this is a moderate rate of price escalation. The result is only a 13% overall increase in the average price of electricity by 2015. In this case, solar PV is very attractive in states in the Southwest, largely due to good solar resource and high electricity prices, especially in California. PV is also very attractive in the Northeast, due to high electricity prices. Overall, the cost of electricity from PV is less than the price of residential retail electricity for a total of about 250 of the 1,000 evaluated utilities, which provide about 37% of U.S. residential electricity sales. An additional 620 utilities, representing 49% of residential sales have a price difference of less than 5 ¢/kWh. As a result, about 85% of residential sales are projected to occur in locations where the cost of PV electricity is less than 5 cents/kWh higher than the prevailing rate in this case.

[22] Hoff, Thomas and Robert M. Margolis. 2004. "Are Photovoltaic Systems Worth More to Residential Consumers on Net Metered Time-of-Use Rates?" Paper presented at the ASES2004 Conference in Portland, Oregon, July 11–14.

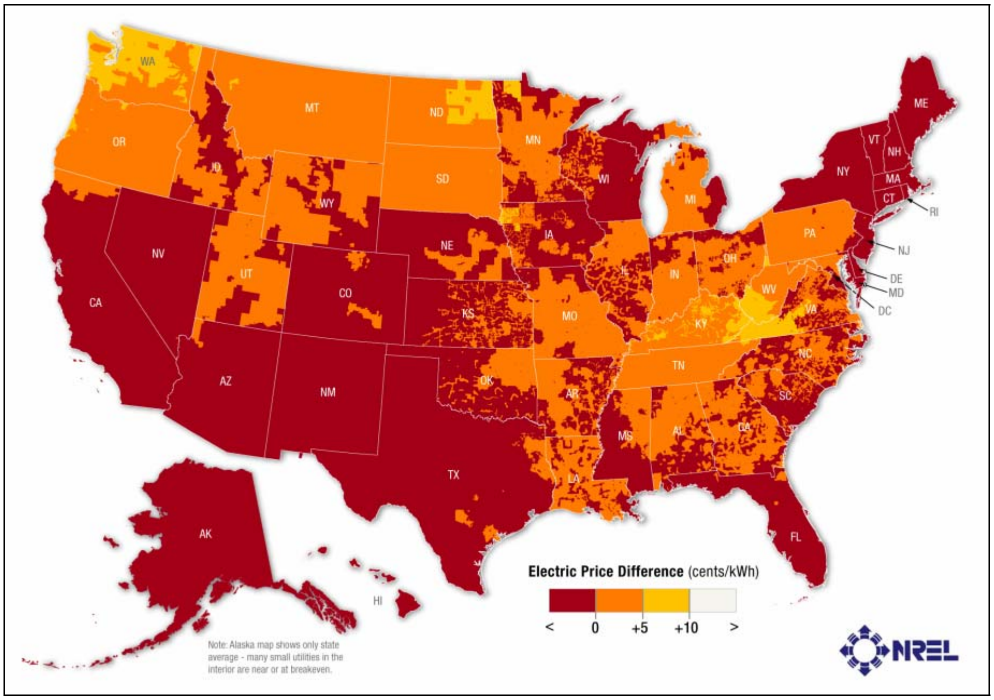


Figure 2.1-7. 2015 PV and Electricity Price Differences for Residential Systems without Incentives and Aggressive Increase in Electricity Prices.

In Figure 2.1-7, the real price of electricity is assumed to increase 2.5% per year. This more aggressive price escalation rate is intended to capture the potential for a number of factors to influence future electricity prices: emerging climate regulations, other environmental issues, transmission constraints, the rising cost of key commodities used in the construction of traditional power plants, and rising fossil fuel prices. In this case, PV is at "breakeven" in a much larger area of the country, including much of the Central, Midwest, and Southeast U.S. Overall PV electricity is less than the retail electric price for about 450 utilities that currently provide nearly 50% of residential demand. The price difference is less than 5 cents/kWh for a total of nearly 950 utilities, representing about 91% of residential demand.

Both future cases project that by 2015, if the SAI cost reduction targets are met, PV will be competitive with retail electricity prices *without incentives* for a very significant fraction of residential electricity consumption in the U.S. While PV is not projected to be cost-competitive in every single utility territory, it will be able to make major in-roads in a self sustaining manner across much of the U.S. The plausibility of exceeding parity in much of the nation is further enhanced if either engineering (manufacturing improvements, volume production, installation simplification, etc.) improvements or scientific (cell efficiency, inverter efficiency / lifetime, etc.) advancements exceed those projected by the SAI participants.

2.1.3 Photovoltaics Technical and Market Challenges and Barriers

Technical challenges and barriers to achievement of PV system and component goals and objectives have been identified. These barriers (shown in Table 2.1-3) will be further examined as we continue our systems evaluation activities that will identify even more definitively the key cost and performance drivers. Individual technologies will have specific barriers that are unique to the technology or its application; overcoming these barriers may be very important to the successful introduction of the technology.

Market challenges and barriers to photovoltaic energy systems are identified and discussed fully in Section 2.3 Market Transformation. Many of the technical evaluations and measurements that support elimination of those barriers are discussed below in the PV technical activity descriptions.

Table 2.1–3 Technical Barriers in Photovoltaics

Photovoltaic Technical Barriers
Modules
A. **Material Utilization & Cost**
B. **Design & Packaging**
C. **Manufacturing Processes**
D. **Efficiency**
Inverters & Other BOS
E. **Inverter Reliability & Grid Integration**
F. **Energy Management Systems**
G. **BOS Cost & Installation Efficiency**
Systems Engineering & Integration
H. **Systems Engineering**
I. **Modularity & Standardization**
J. **Building-integrated products**

2.1.4 Photovoltaics Approach/Strategies for Overcoming Challenges and Barriers

The strategy for overcoming the challenges and barriers to massive manufacturing, sales, and installation of PV technology relies on achieving difficult targets throughout the development pipeline. Multiple technologies are being pursued that are at differing stages of maturity. By effectively combining the talents of industry, university, and national laboratory engineers and scientists, the needed cost, performance and reliability goals can be achieved. Specific PV R&D efforts toward achieving these goals are described in Sections 2.1.4.1-2.1.4.4 below and include:

1. PV Systems & Module Development;
2. PV Materials & Cell Technologies;
3. Testing & Evaluation; and
4. Grid / Building Integration.

2.1.4.1 PV Systems & Module Development

Historically, Solar Program funding has focused on cost reductions at the PV module level. However, module costs have fallen significantly and today account for only half the cost of an installed PV system. The Solar Program's new focus on achieving PV grid parity as measured by LCOE has led to a corresponding shift in program funding structure and the metrics used to assess project performance. New Solar Program activities have been structured to be responsive to the current and future needs of the PV industry.

The Program's R&D on PV Systems and Module Development is carried out through three of these new activities: TPPs, PV Technology Incubators, and University Product and Process Development Support (University P&P), along with substantial support to the National Laboratories. Within these, the Solar Program funds projects related to three general types of module technologies – crystalline silicon, thin films, and concentrating PV – each of which is considered to have a viable path to grid parity by 2015 (see Figure 2.1-8).

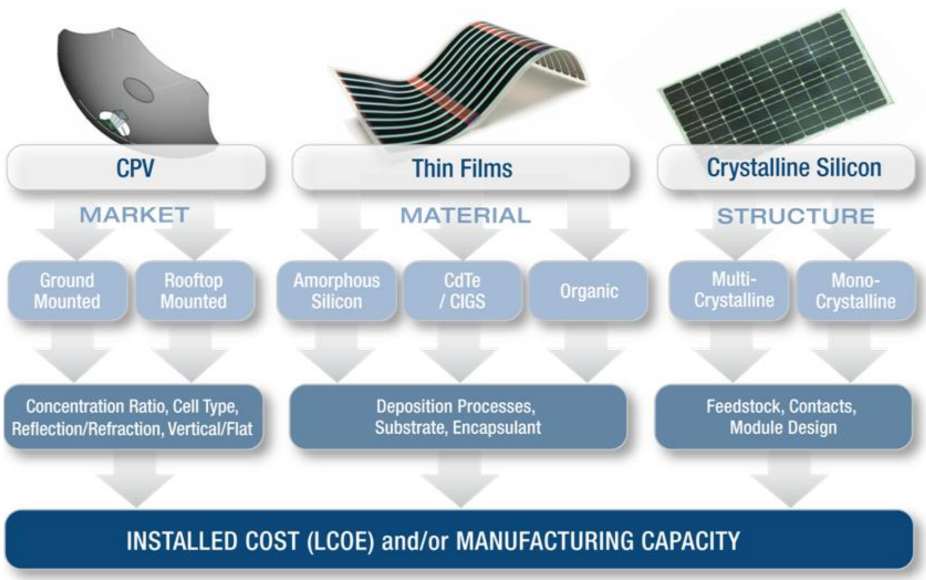


Figure 2.1-8. Organization of R&D activities for the three main PV module types supported by the SETP.

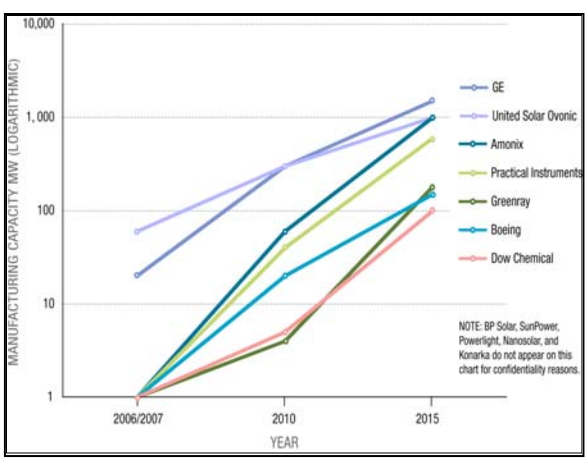
Technology Pathway Partnerships

As mentioned previously, the TPPs target reductions in LCOE (¢/kWh). TPPs require participants from various projects to work as teams, ideally integrated vertically across the entire PV value chain (as an example, see Figure 2.1-9 for a diagram of the polysilicon-to-module Crystalline Silicon PV Value Chain). Project performance is gauged in terms of LCOE and scale-up of production capacity, shown in Figure 2.1-10 (as projected by each TPP partner). This approach marks a shift from the traditional Program approach of targeting lower level metrics such as module costs ($/W). TPP projects are conducted in three 3-year phases. The first 3-year phase began in FY2007 and focuses on development, testing, demonstration, validation, and interconnection of new PV components, systems, and manufacturing equipment.

Figure 2.1-9. Flow Diagram of the Crystalline Silicon PV Value Chain.

PV Technology Incubators

Another Systems & Module Development activity is the PV Technology Incubator. The goal of this activity is to ramp up small companies' device technologies into pilot line or commercial module production over an 18-month period and thus increase the diversity of PV technology that will be available for commercial production in the second 3-year phase of the TPP solicitation, shown in Figure 2.1-11 (as projected by the incubator companies). Risk associated with funding these aggressive projects is mitigated by splitting each 18-month period with a 9-month Stage Gate and also by providing project funding only after quantifiable, hardware-based milestones are achieved (i.e., fixed firm pricing). This solicitation will re-open every 9-12 months to allow new entrants access to funding and details from projects already underway. A detailed list of the TPP and PV Technology Incubator projects, including participants, project titles, project summaries and milestones, is available in Appendix B.



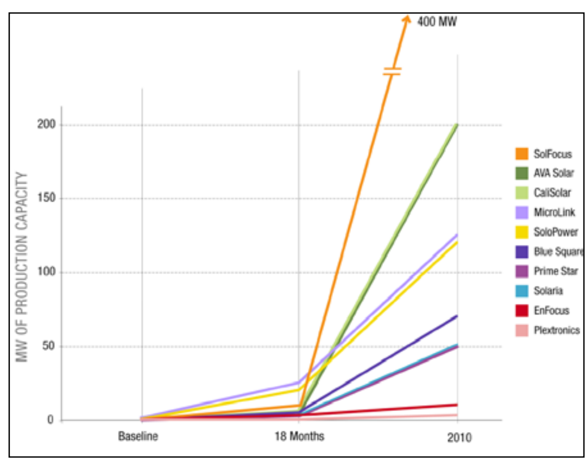


Figure 2.1-10. TPP Manufacturing Capacity Ramp-up. Figure 2.1-11. Incubator Manufacturing Capacity Ramp-up.

University Product and Process Development Support

A third program within Systems & Module Development is the University Product and Process Development Support, which is focused on funding U.S. universities to support the cost reductions/scale-up goals of the Solar Program. Universities will leverage their knowledge in assisting the transition of PV technology from laboratory to marketplace and offer guidance to industry on how to move forward efficiently. Universities may choose to develop a project through a partnership with a U.S. industrial partner currently positioned to achieve the 2015 SAI goals. These applications must clearly state how the university work will assist the industry partner in reducing LCOE and/or increasing manufacturing capacity and clearly indicate how academia is uniquely suited to perform this work. These projects will be funded at a maximum of $1.5M over 3 years.

PV Supply Chain Development

A potential upcoming Systems & Module Development funding opportunity slated to be released in 2008 will be called PV Supply Chain Development, which targets cross-cutting technologies (as opposed to the product-focused funding the Solar Program has already undertaken). Examples of these technologies include optimized optical films, thermal substrates, transparent conducting oxide layers, and flexible encapsulates which provide high moisture barriers, etc. Additionally, a second portion of this solicitation will promote the development of manufacturing equipment tailored specifically towards PV. The impetus for this program is that the PV industry has grown enough, both in terms of maturity and scale, to justify an investment in these broadly applicable yet perhaps higher hanging fruit.

2.1.4.2 PV Materials & Cell Technologies

The Solar Program has a number of applied research projects being carried out at both university and national laboratories (e.g., NREL and SNL, and in conjunction with industry partners). Specific PV research areas include wafer silicon, film silicon (both amorphous and crystalline thin films), concentrating photovoltaics, CdTe thin films, CIGS, organic thin films, and sensitized solar cells. Additionally, the Solar Program funds the Process Development and Integration Laboratory (PDIL), which has been specifically designed to accommodate a new class of thin film PV deposition, processing and characterization tools. In PDIL, these tools can be integrated to prototype processes in a flexible manner. PDIL will allow researchers to pass samples between equipment in a controlled way, avoiding contamination from the air. PDIL will also integrate control systems and databases in such a way that a researcher growing a sample can see results of a measurement and vice versa. Details on the specific PV Materials & Cell Technologies R&D projects can be found in Appendix B.

PV Technology Roadmaps

In order to effectively plan and manage these R&D activities, the Solar Program, with input from researchers at NREL, Sandia, industry and university participants, recently completed 10 PV Technology Roadmaps. The Roadmaps were established as a means by which DOE, with industry input, can assess, guide, and fund PV materials R&D. The Program plans to update them every two years with formal input from relevant industry players. Key gains, in the form of LCOE reductions, are the end goal of the PV Technology Roadmaps. The Roadmaps cover the following seven PV R&D technologies:

Table 2.1-4. PV Technology Roadmaps Technology.

1. Wafer-Silicon	5. Copper Indium Gallium Diselenide (CIGS)
2. Film-Silicon	6. Organic Photovoltaics
3. Concentrating Photovoltaics (CPV)	7. Sensitized Solar Cells
4. Cadmium Telluride (CdTe)	

Each Roadmap defines metrics for measuring the technology's current status and estimating its future potential, and characterizes the R&D needed to reach that potential. Details of the Roadmaps, including summaries of the identified R&D areas and technology goals are provided in Appendix D.

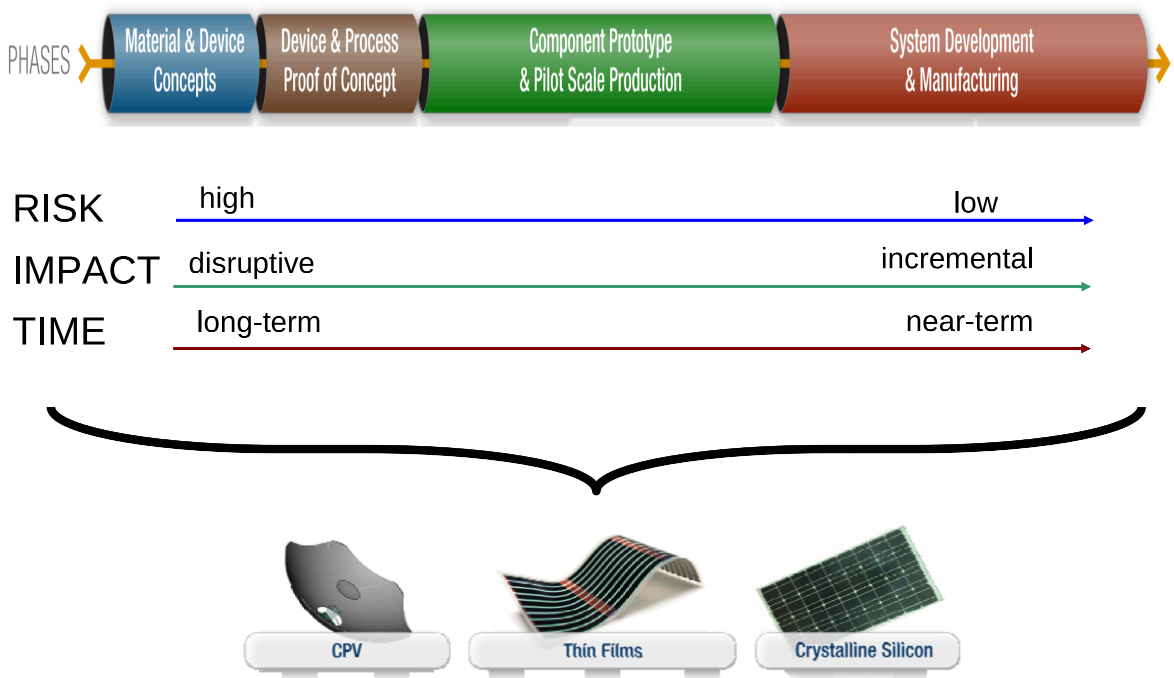


Figure 2.1-12. Risk, Impact and Timing of PV Technology R&D Pipeline.

As can be seen in Figure 2.1-12, The Solar Program's PV R&D activities have different characteristics for risk, impact and timing, depending on where in the pipeline the research falls. Using the Roadmaps, researchers at businesses, universities, and government labs can identify where along the technology pipeline these materials are and what work needs to be completed to move these materials from proof of concept models to pilot and commercial scale production.

Next Generation Photovoltaic Devices and Processes

The SETP recently announced the selection of 25 exploratory research projects that will be funded under the solicitation called "Next Generation Photovoltaic Devices and Processes". This solicitation rounds out the high-risk/high-payoff end of the Solar Program's R&D portfolio. These projects seed the beginning of the technology pipeline with high potential payoff areas of research that could drastically change the solar market's paradigm if successful. While they are generally more risky and long term in nature, as can be seen in Figure 2.1-13 there is a greater potential for impact on the technology, leading to significantly lower costs and higher efficiencies. These innovative, revolutionary, and highly disruptive PV approaches are targeted to produce prototype cells and/or processes by 2015, with full commercialization coming to fruition in the 2020-2030 timeframe.

Another benefit to this program is the application of funding within the gap between basic and applied solar research. This effort will help to develop solar energy science into new PV technologies. Where basic solar research is exploratory in nature with publications as the primary deliverable, the management style of these awards uses milestones with a focus on delivery of devices and processes with confirmed performance (i.e., confirmed efficiencies in NREL's cell characterization labs). Stage Gate decision points are included with appropriate timing within each project, usually at the year 1 or 2 mark, which helps mitigate risk in these inherently risky projects. The technology areas covered within these awards are marked by technological diversity (see Appendix B).

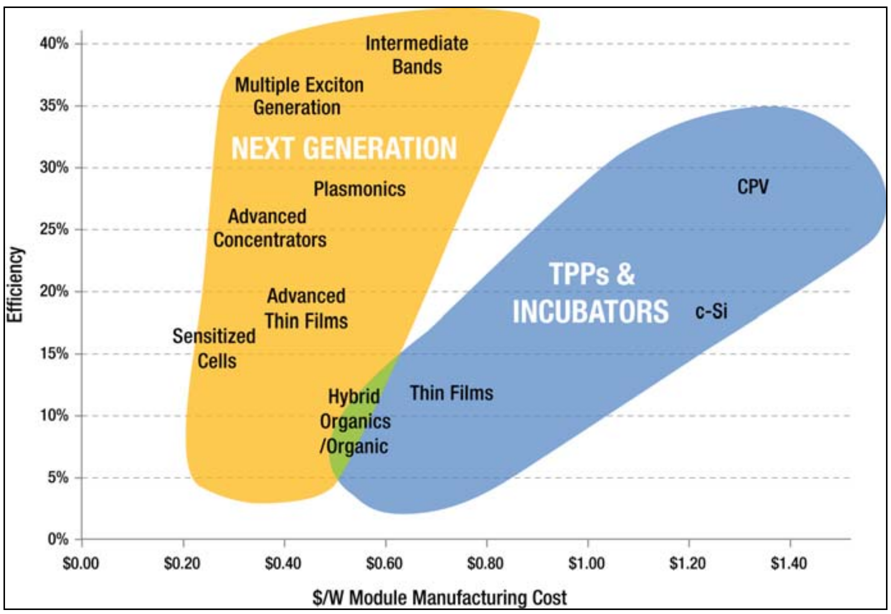


Figure 2.1-13. Cost and Efficiency Potential for PV Next Generation, TPPs and Incubator Projects.

2.1.4.3 PV Technology Testing & Evaluation

The PV Technology Testing & Evaluation (T&E) efforts are focused on the following three integrated areas: Systems Analysis (a crosscutting activity that provides analyses of all solar technologies and their impacts), Systems and Component Testing & Evaluation (performance and cost evaluations that can validate improvements), and Applied Reliability R&D (modeling and testing to evaluate and improve PV product service lifetimes and reliability).

Systems Analysis

The purpose of Systems Analysis is to complete the development and consistent application of a suite of analysis, modeling, and benchmarking tools needed for planning, technology evaluation, and decision-making (e.g., Stage Gate review) throughout the Solar Program. In executing this, the Solar Program partners with industry to improve and advance systems design tools development, component and systems performance database development, systems performance prediction tools, and market penetration models. Systems Analysis takes full advantage of relationships and access to information afforded through the Technology Pathway Partnerships.

As shown in Figure 2.1-14, Systems Analysis has three major activities. These activities are critical to tracking Program progress towards strategic goals, especially the 2015 LCOE targets. *Systems Performance Modeling and Algorithm Development* is used to translate system and component parameters into key program metrics, such as LCOE, to predict system performance and costs based on component and subsystem data, and to conduct parametric analysis of research and design options. Modeling also enables parametric analysis to identify key needs for technology improvement. *Benchmarking and Database Development* assesses the current state of the technology and characterizes systems and components in terms of parameters such as cost, reliability, and efficiency. *Market, Value, and Policy Analysis* provides the basis for setting Program targets, including the Program's strategic goals. This activity also monitors and models technology and market trends. .

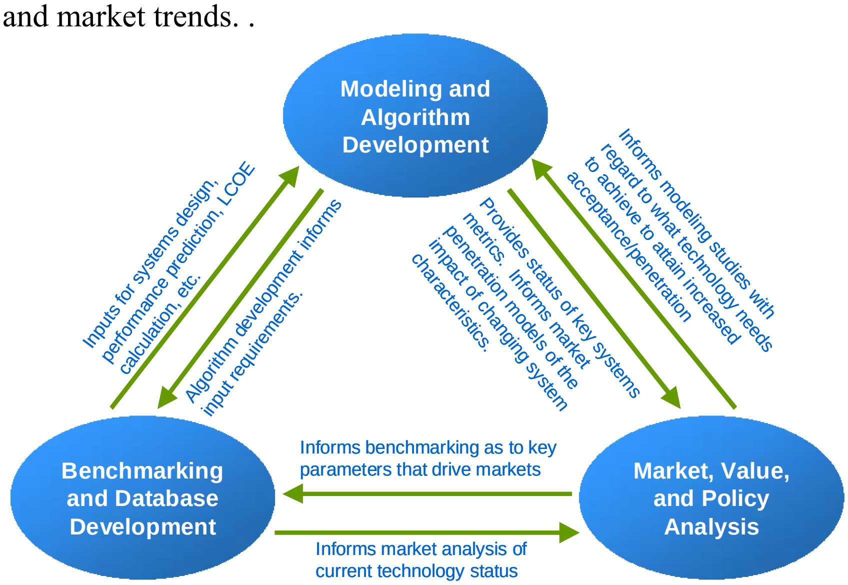


Figure 2.1-14. Flowchart of Systems Analysis project activities.

The systems analysis project's capabilities are key to tracking program progress towards strategic goals, especially the 2015 LCOE targets. The Solar Advisor Model (SAM) provides the primary method of evaluating the effect on strategic goals, expressed in ¢/kWh, of the Solar Program's progress against performance goals. Benchmarking component and system cost, performance, reliability and inputting this data in models is necessary to verify progress. This project is a joint NREL/SNL/Regional Experimentation Station (RES) effort that fully and synergistically utilizes the expertise, capabilities, and experience of each participant. The three Systems Analysis Project activities are discussed below.

1. The **Systems Performance Modeling & Algorithm Development** activity will focus on integrating program modeling efforts to support program planning while making available the latest and most accurate performance prediction component and systems algorithms to the industry for incorporation into systems design tools. To provide the Solar Program support, NREL and Sandia will continue PV performance, cost, and financial modeling and algorithm development that will allow for extensive capabilities in conducting sensitivity studies for PV components and systems. Included in this effort is integration in planning and development of existing modeling efforts in the Program such as the Solar Advisor Model, PVWatts, the Sandia Photovoltaic Array Performance Model and other systems performance models. Enhanced algorithms will be developed for simulating electricity storage, hourly valuation of power produced, greater modeling of inverters and balance of system components, expansion of concentrating solar power performance modeling, and better graphical display of results. The modeling group also applies these models within Solar Program to assess program progress. For example, data provided by the TPPs will be processed to determine if TPPs are on-track to meet stage gates.
2. **The Benchmarking and Database Development** activity will accelerate and expand benchmarking and component/systems parameter database development in a manner that will support algorithm utilization and program progress assessment. The TPPs and the Nevada Solar One CSP project are likely to become key elements of the effort to benchmark program progress. The program will work with the national modeling and database working group to identify sources of validated data that should be included in the database. Ongoing measurements at the laboratories already provide databases of parameters used in system design tools by the industry. Other organizations, such as the California Energy Commission (CEC), are also involved in establishing and populating databases.
3. **The Market, Value, and Policy Analysis** activity will provide an array of support to the Solar Program that integrates the modeling and benchmarking activities into analysis of technology advancement's impact on market penetration and quantifying the benefits of increased solar energy use. The types of analysis carried out under this project include: (a) market penetration analysis: developing a PV market penetration model – the Solar Deployment Systems (SolarDS) model, which is being designed to complement EIA's National Energy Modeling System (NEMS) model; (b) benefits analysis: providing inputs to, support for and review of the annual GPRA benefits analysis process, and developing methods and tools for improving the quantification of the benefits and cost of distributed PV; and (c) policy analysis: defining and carrying out analysis that meets the needs of the Solar Program in a timely fashion, for example related to issues such as the reliability, security and time-of-use value of PV, as well as the potential role of solar in the energy economy in the long-term.

Systems and Component Testing & Evaluation
The System and Component Testing & Evaluation activities of the Solar Program focus on collaboration and cooperation with industry to:

1. Develop and evaluate new and improved PV products, materials, or processes;
2. Provide the technical basis for barrier removal; and
3. Obtain data that quantify performance improvements and cost reductions within the industry and the Solar Program.

Testing and Evaluation activities provide solar industry stakeholders (e.g., manufacturers, materials suppliers, system integrators, investors, researchers, government officials, and system installers) with high quality data that can be used for critical decision-making. In FY 2007, more than 55 PV companies were directly aided by the testing of materials, components, and systems by DOE.

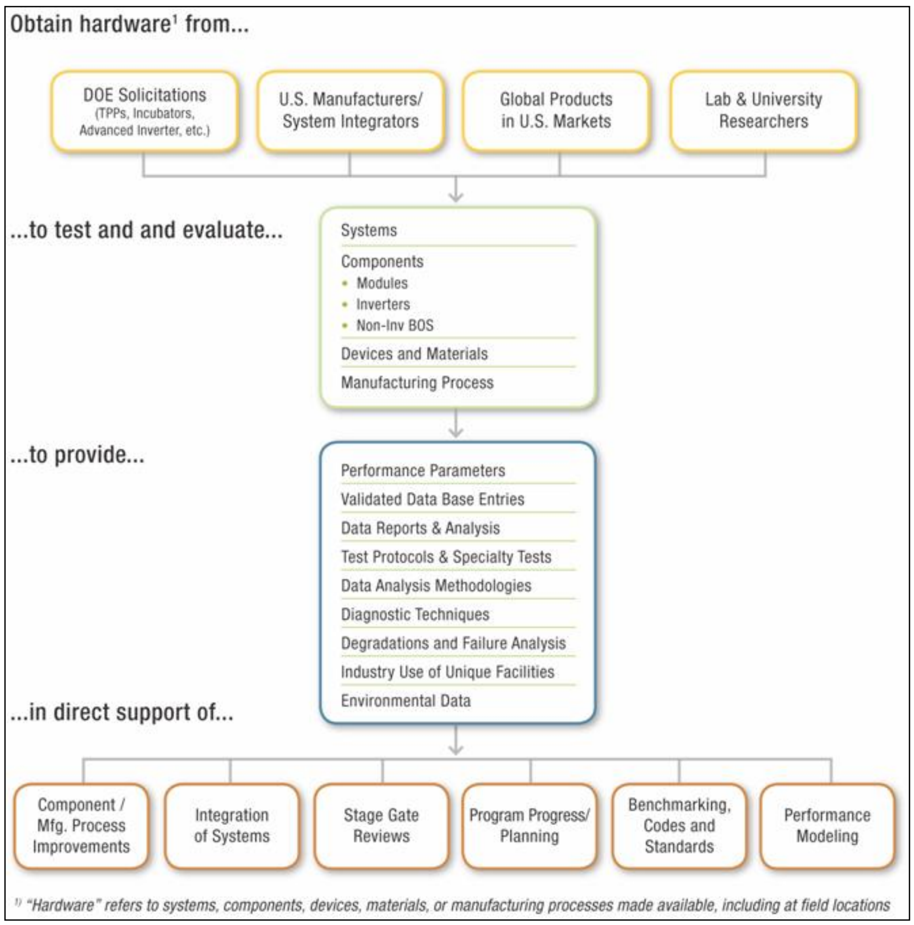


Figure 2.1-15. Testing and Evaluation Flow Diagram.

Currently, the PV T&E activity (see Figure 2.1-15) evaluates hardware obtained from a variety of sources including DOE-funded solicitations (e.g., TPPs, PV Technology Incubators, Solar Energy Grid Integration Systems (SEGIS), etc.) and directly from other industry stakeholders (e.g., U.S. and global manufacturers, system integrators, and university/internal researchers). "Hardware" includes systems, components, devices, and materials. Several different types of tests are performed on systems, subsystems, or devices. These tests produce performance parameters, validated database entries, data reports and analyses, test protocols, and data analysis methodologies. In addition, in-line diagnostics for use in product improvement or process understanding are developed. Similarly, specialty measurements can be performed to support evaluation of new system or component concepts; insights gained in these evaluations often lead to improvements in test protocols. Environmental impacts of materials used in the manufacturing processes can be quantified. Finally, access is provided for direct TPP and industry use of "one of a kind" test facilities, such as the new Science and Technology facility at NREL and the PV Systems Optimization Lab at SNL.

T&E results are used in direct support of subsystem and manufacturing process improvement, integration of systems, benchmarking, codes and standards development, and performance modeling, often for direct input into energy cost evaluations. Results are also valuable in planning and evaluating technical activities in the Solar Program. In addition, DOE will utilize the results in Stage Gate accountability evaluations to ensure that the progress of the funding recipients from the major solicitations is independently and effectively validated. Figure 2.1-16 shows an example of the Stage Gate/Milestones review process for TPPs, with each TPP having reviews at least yearly while the other solicitations will establish the schedules for their reviews.

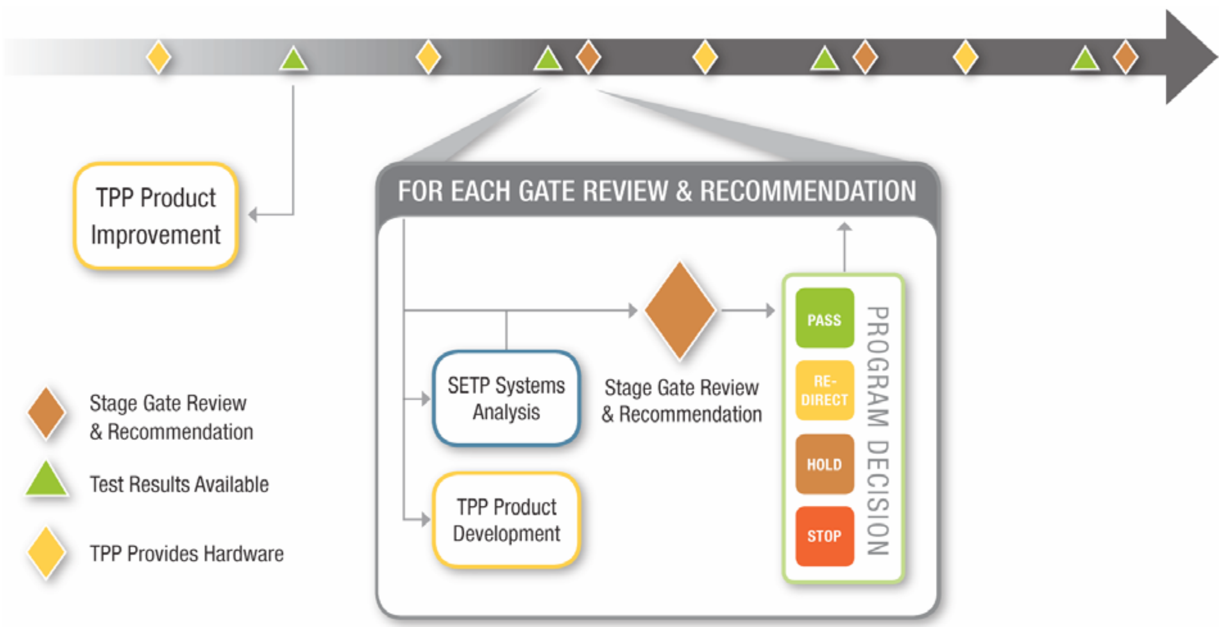


Figure 2.1-16 Technology Evaluation with Stage Gates, Systems Analysis, and TPP Product development.

Much of the enhanced activity within both system and component testing is in direct support of the TPPs engaged in the SAI. While some of the test results will be used for gate review evaluations, most will be in direct support of product development and improvement. Specific test programs have been identified in partnership with individual TPPs that directly support their product development efforts by providing some of the specialty testing needed by the industry partners that complements the testing being done by the TPPs (e.g., component performance, certification tests, manufacturing process sampling, etc.). FY08 activities are often focused on laboratory testing of cell configurations, specialty materials, and evaluations of preliminary products under development by the TPPs. Subsequent years will see more performance and reliability testing of near-commercial products and will include qualification testing in challenging temperature and humidity environments as well as outdoor exposure testing. Monitoring and evaluation of full system configurations will follow as the components are integrated into full systems and installed at customer sites.

PV Applied Reliability R&D

System integrators, project planners, and the financial community are demanding more rigorous performance and reliability data – up to and including service life prediction – as decision-making input. Manufacturers are also seeking techniques for quantifying the performance and reliability of their products. Additionally, reliability is a high priority activity for national laboratory research. As a result, a robust program has been developed that fast-tracks accelerated testing protocol development, leverages the reliability skill set already developed in other areas at our national laboratories, and seeks to develop and validate service lifetime predictions for PV systems and components.

This activity leverages DOE's investments in PV test equipment, facilities, and research staff at NREL and SNL, and draws from other federal investments in reliability engineering methodology, to identify and define reliability issues and apply numerical methods that combine all material and component interactions in defined environments to accurately depict system reliability. Methodology and analysis processes that have been successfully applied in weapons, satellite, and nuclear reactor systems' predictive modeling are being applied.

The objective of this effort is to develop and apply a process (data, methodology, and model) that industry and other stakeholders can use to **predict**, **detect**, and **mitigate** reliability issues in PV components and systems, as shown in Figure 2.1-17

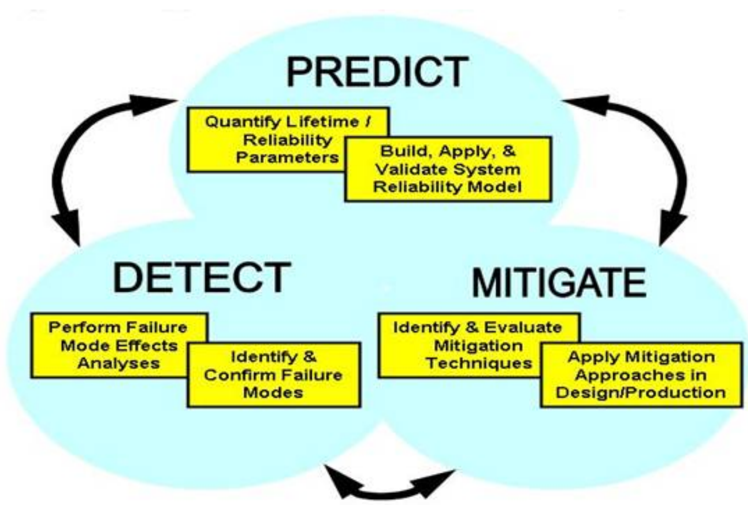


Figure 2.1-17. PV Reliability Program Flow Chart

Prediction of PV system or component reliability requires both an analytic model of the system or component reliability as well as data that quantifies parameters associated with reliability or lifetime predictions. Since reliability evaluations seek to determine if a PV system or component will perform its intended function for the required duration within a given environment, an important first step is to define failure or service life for both systems and components. Building, applying and validating system/component reliability models is one of the major tasks within the PV reliability activities. The goal is to obtain a life distribution that describes the time-to-failure or service life of PV systems and components.

Detection of reliability issues, especially early detection of active failure modes and mechanisms, is critical to risk minimization for PV manufacturers, system integrators, and system owners. Detection is pursued through multiple approaches: field surveillance, laboratory testing, and analysis. Field surveillance efforts are the most important source of information on failure modes and mechanisms that show up in actual use environments. Surveillance activities include assessing failure modes seen in performance of systems or components in current use, product returns, and in outdoor exposure tests. Outdoor exposure tests, such as the DOE Module Long-Term Exposure Tests, are often conducted in multiple (perhaps extreme) environments. Laboratory tests that seek to identify the physics of expected or observed failure modes can be product development/verification tests, qualification (screening) tests, accelerated life tests (ALT), or highly accelerated life tests (HALT). While all of these tests use harsh environments (elevated stresses) to accelerate the precipitation of dormant defects and potential failures, their objectives are different. It is the “regular” ALTs that provide the needed information on failure physics (modes of failure), parametric degradation rates, and longer-term failure mechanisms needed for predictive models of system reliability. Correlation between the field-observed failure modes and those observed in the lab is required. Analysis approaches, especially Failure Modes and Effects Analyses (FMEA) provide the needed framework for cataloging failure modes, determining their effects on the entire system, and prioritizing test/analysis work on understanding or eliminating the most impactive modes.

Mitigation of the potential effects of identified failure modes is an iterative process that is best started early in the design of components or systems. Approaches to mitigation are identified in the FMEA process and data needs are also identified. For example, some failure modes will be effectively mitigated using improved encapsulants; data to quantify the properties of the encapsulant as applied in the environment experienced by PV systems will be needed. Implementation of the mitigation techniques will be primarily a role of the system or component manufacturers with Solar Program roles being related to confirmation of their effectiveness.

FY 2008 efforts are focused on development of a detailed plan for the interrelated activities, identification of the most impactful failure modes, development of needed test protocols, and the initial application of the reliability processes to PV products. Subsequent year emphases become increasingly more focused on both testing and associated analyses that validate the approaches for predicting PV system and component reliability and service life.

2.1.4.4 Grid and Building Integration

The technology development strategy of the Grid and Building Integration effort aims to achieve the near-, mid-, and long-term technological and market advances necessary to achieve the SAI goal. In terms of technology advancement, the Grid and Building Integration will award funds for the performance of R&D targeting dramatic improvements in inverter reliability and increasing the value of PV inverter/controllers while developing interfaces for advanced grid integration. SEGIS will increase the value of solar energy systems in today's "one-way" distribution infrastructure and/or increase the value of systems in tomorrow's "two-way" grid or micro-grid.

In the area of market advances, the Grid and Building Integration effort is developing tools to estimate PV penetration scenarios and model the market and regulatory frameworks necessary for advancing grid penetration to significantly higher levels than those previously anticipated by market analysts. The Grid and Building Integration effort is interfacing with the Solar Program's market transformation effort and the Building Technologies Program within EERE to assure a smooth interaction in areas of common concern.

Barriers to High-Penetration Grid Integration Scenarios
Barriers to a high–penetration scenario take the form of technical, market, and regulatory concerns. First, from a technical standpoint, electric utilities are concerned about the ability of the utility grid to operate within design tolerance when faced with an increasing percentage of the generation mix being supplied by intermittent sources. Specific technical concerns related to intermittency involve grid stability, voltage regulation, and power quality (voltage rises, sags, flickers, and frequency fluctuations). The second major technical concern involves protection and coordination. Operationally, the current utility grid was designed to accommodate power flowing from the central generation source outward to the transmission system and eventually to the distribution feeders. Grid protection systems were not designed to coordinate with small generators upstream from the central generation source that produce so-called "back feeding". Inverters must be designed to communicate with utility systems and energy management systems to lessen these technical concerns.

Market concerns include the future of incentives, such as renewable energy credits, renewable portfolio standards, and production tax credits, which promote the use of PV technology and increase its market penetration. One potential barrier is the reduction of such incentives, slowing the market uptake of PV systems. The Solar Program has made these market barriers their focus through such market transformation efforts as the Solar America Cities and the Solar America Showcases (see Section 2.3).

Program Development Process--Renewable Systems Integration Study
In order to determine the research priorities which would most significantly advance the deployment of grid-integrated PV systems, the Grid and Building Integration Program launched the RSI study in 2007. The completed RSI study consists of fourteen individual reports that address issues related to distributed systems technology development,

advanced distribution systems integration, system level tests and demonstrations, technical and market analysis, and resource assessment. Given the fact that integration-related issues are likely to emerge early in the market penetration of PV, the RSI study focused primarily on distributed PV technology. The results of these studies are being used to guide research programs in the area of advanced inverter development, grid integration, energy storage, market transformation, demonstration projects and testing.

Solar Energy Grid Integration System Development

In attaining SAI goals, the PV market is estimated to grow to 5-10 GW of new installations. Central to this growth is the development of SEGIS, for integrating and managing distributed photovoltaic generation, as shown in Figure 2.1-18. SEGIS is a key element of the Solar Program. SEGIS may incorporate energy management functions and communicate with stand-alone energy management systems as well as with utility energy portals, such as smart metering systems. The purpose of the SEGIS program is to enable seamless grid integration of new PV system designs into a more distributed electrical grid. System reliability, costs, and value will all be improved. The SEGIS will enhance the value of PV systems for the customer by increasing the reliability of electrical service and delivering power options when they are most valuable. The ability to manage power flows by communicating actively and passively with the utility, manage storage and load/energy management systems, and anticipate electricity value will be characteristic of the optimized SEGIS.

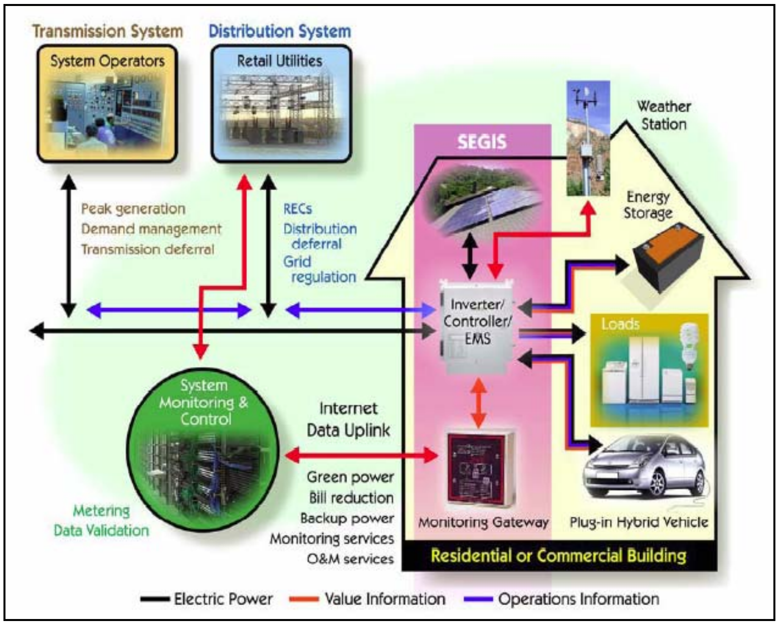


Figure 2.1-18. Flow Diagram of SEGIS Operations.

At the heart of SEGIS is the advanced integrated inverter/controller, which will manage generation and dispatch of solar energy to maximize value, reliability, and safety. Many advances are needed to transform today's inverter designed for a grid dominated by central generation into one suitable for a grid in which distributed generation (DG) sources provide significant energy to the utility. As distributed generation grows, advanced inverter/controllers and utility rate structures or dispatch signals can be used to manage reverse power flow into a distribution system that is not designed for it. The grid will ultimately need to be redesigned and replaced, at least in areas of high DG penetration. It will also be desirable for the inverter/controllers to enable distributed generation systems to continue to supply power during grid disturbances or to disconnect from the grid while continuing to meet customer needs as a stand-alone micro-grid.

Another critical feature of emerging importance for SEGIS is the ability to interface with, and in some cases serve as, the energy management system (EMS) for buildings hosting PV systems. The EMS features differ between residential and commercial applications. For residential systems, the SEGIS must be capable of providing overall energy management, and interfacing with the utility as well as smart appliances. For commercial systems, EMS manages all aspects of the building energy profile, including air handling and lighting, as a standard feature. The next generation of EMS may include the ability to manage the utility interface of the building and eventually even control such things as the building power factor. The SEGIS can be utilized in this regard in supplying volt-ampere reactive (VAR) control of PV or storage to assist in managing a building's overall energy utilization profile.

Energy storage is an important element of advanced power management systems, as adding storage to a PV system has the potential to increase its value. Figure 2.1-19 shows the charge controller supplying energy to the energy storage unit and the inverter converting the output of the energy storage to AC power as part of the PV inverter/controller. However, this is just one of many possible configurations. DC chargers, AC chargers, and dedicated inverters for storage are all available and could be operated in coordination with a PV inverter. While PV can charge storage via a DC charger, an AC charger may be preferred since at least some of the charging will be done when utility-supplied electricity is cheap (e.g., overnight for a summer peaking utility). Another desirable feature for a system with storage is to enable the system to operate independently during a grid outage. Usually, to maximize the period of independent operation, essential and non-essential loads are separated at the load center and/or by the EMS, and only essential loads are supplied with energy from storage.

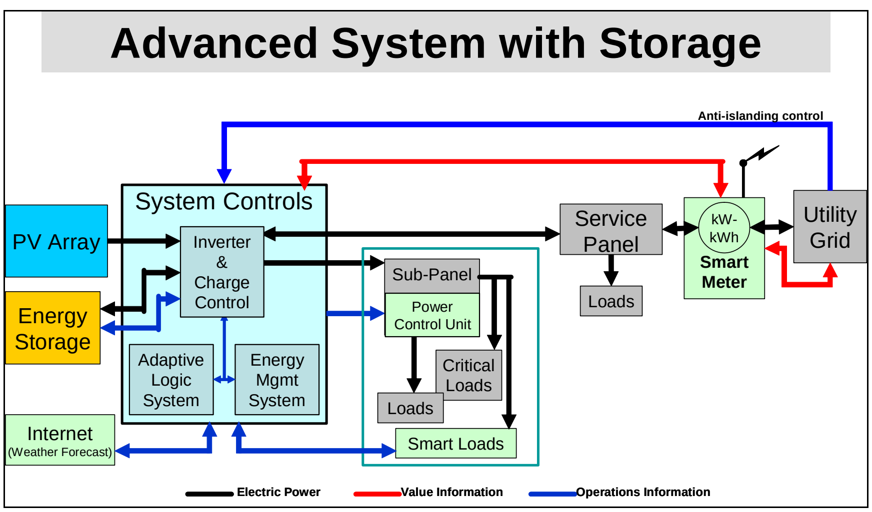


Figure 2.1-19 Flow Diagram of Advanced System with Storage.

As building energy systems and grid operations become increasingly integrated, the need for advanced communications in the inverter/controller becomes paramount. The SEGIS may function in any of several configurations, depending upon whether the application is a commercial or residential application. In order to interact with a building's EMS, the inverter/controller must be capable of using the most common building EMS protocols.

Demonstration and Testing Analysis

A wide range of testing and demonstration is required to understand the effects of a large number of PV systems on the grid. Analysis and modeling will be an integral part of grid impact evaluations. Because grid-level testing is prohibitively expensive, extensive analysis will precede testing with most testing done to verify or evaluate analysis results. These include laboratory testing, and field testing and demonstrations. Laboratory testing is used to develop and validate models for specific PV systems equipment; to model a variety of high PV penetration scenarios under close to real world conditions; to establish and carry out test protocols for communication methods between distributed PV systems, utility grid operations and energy management systems; and to evaluate different control schemes for autonomous VAR compensation under conditions of multiple inverters. Field testing and demonstrations utilize fielded systems to test a variety of non-traditional benefits including voltage and frequency regulation support, spinning reserve, and customer peak load reduction; test the integration of EMS with PV systems and storage to optimally manage power for commercial facilities; evaluate the impact of relatively high PV penetration on existing distribution systems with intermediate voltage and current monitoring; investigate voltage impacts, fault contributions and fuse coordination/desensitization; and investigate PV installed on undersized/overloaded primary or secondary distribution lines where the substation voltage is elevated to deal with the voltage drop.

Utility Integration/Control Systems

In order to plan for a high-penetration PV scenario, integration issues (e.g., voltage regulation, unintentional islanding, and protection coordination) need to be addressed from the distributed PV system side and from the utility side. SEGIS development must produce hardware, including inverters, controllers, EMS hardware, and balance-of-system components, that allows PV to operate safely with the utility and become a resource providing benefits to both the owner and the grid, both in today's unidirectional grid and the smart grid of the future.

2.2 Concentrating Solar Power

Concentrating solar power (CSP) technologies are one of the most attractive renewable energy options for large-scale power generation in the U.S. Southwest, which is home to 15 of the 20 fastest-growing metro areas in the country. CSP plants produce power by first converting the sun's energy into heat, next into mechanical power, and lastly, into electricity using a conventional generator.[23] A description of CSP technologies is given in Appendix C.

The CSP subprogram's focus is on technology development and refinement of parabolic trough and dish/Stirling systems to lower costs, pursuing thermal storage technologies to enhance the dispatchability of power, exploring advanced CSP concepts such as linear Fresnel technology and advanced power towers, and market transformation activities that will reduce barriers and increase market penetration (see Figures 2.2-1 through 2.2-5). In 2007, the Solar Program announced the funding of twelve new industry-based projects that will focus on developing and deploying new technology systems or components that can dramatically lower CSP system costs. The focus of this funding opportunity is discussed in Section 2.2.4, with details of the individual projects provided in Appendix B.

Figure 2.2-1. Trough Plant

Figure 2.2-2. Dish/Stirling System

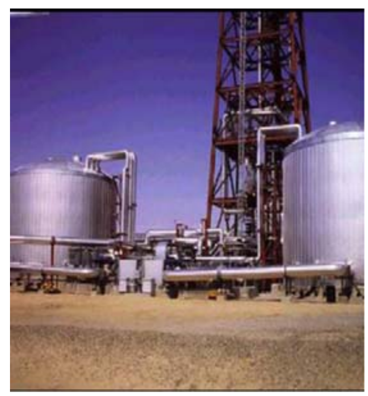


Figure 2.2-3.Thermal Storage

Figure 2.2-4. Linear Fresnel System

Figure 2.2-5. Advanced Power Towers

[23] Furthermore, it is possible to create hydrogen from CSP heat through thermolysis.

2.2.1 Concentrating Solar Power Support of Program Strategic Goals

Three factors contribute to cost reduction of electricity generated by CSP: technology development, volume production, and scale-up in plant or project size. Technology development includes evolution in the performance and reliability of specific technology components (receivers, concentrators, reflectors, and balance of solar field), improvements in construction techniques, and reductions in O&M costs due to learning experience from large projects. It is on the components level that DOE will solicit industry partnerships. Volume production brings significant cost reductions due to decreases in manufacturing cost, material procurement costs, standardized engineering, and project development costs. Large power plant sizes or multiple plants in a single project invoke economies of scale in equipment and systems. Large projects will be encouraged by the Federal government (e.g., ITC) and State policy (e.g., RPSs).

2.2.2 Concentrating Solar Power Support of Program Performance Goals

The program goals for CSP technologies are:

1. 8-10¢/kWh with 6 hours of thermal storage in 2015 (intermediate power).
2. 5-7¢/kWh with 12-17 hours of thermal storage in 2020 (baseload power).

The 2007 parabolic trough technology baseline is a 100-MW trough plant with 6 hours of thermal storage. By 2011, the CSP subprogram will assist technology development for and validate the performance of a 150-MW trough plant, with the cost and performance targets[24] shown in Table 2.2-1.

Table 2.2-1. Parabolic Trough Cost and Performance for Reference and Target Systems.

	2007	**2011**	**2015**
Capital Cost ($/kWe)	4,900	4,100	3,600
O&M Cost ($/kW-yr)	67	62	60
Annual Solar-to-Electric Efficiency	13.1%	15.5%	16.0%

The 2007 dish/Stirling technology baseline is a unique, hand-built prototype 25-kW dish/Stirling system that is part of a 1-MW (40-dish system) power plant. By 2011, the CSP subprogram will assist technology development for and validate the performance of a 25-kW commercial dish/Stirling system that will achieve the cost and performance targets outlined in Table 2.2-2.

[24] Note that these program-generated cost estimates are not the actual costs of projects, which will depend greatly on the actual parameters of each project and the production levels of the components.

Table 2.2-2. Dish/Stirling System Cost and Performance for Reference and Target Systems.

	2007	2011
Capital Cost ($/kWe)	8,600	4,500
O&M Cost (¢/kWh)	10.0	5.0
Annual Solar-to-Electric Efficiency	22%	24%

To achieve the Solar Program goals, storage costs will need to be reduced to $15/kW$_{thermal}$ with round trip efficiencies of at least 93%.

2.2.3 Concentrating Solar Power Technical and Market Challenges and Barriers

CSP technologies face similar hurdles to any new technology trying to penetrate the market. These can include difficulties in financing projects and reducing risk. It is important to identify and understand these types of market-entry barriers so that solutions (technical, policy, or other) can be developed. For example, the hybridization of CSP technologies with fossil fuels may provide a market "on-ramp" wherein cost and/or risk are reduced, thereby easing the transition to larger or solar-only deployments.

CSP technologies have the potential to be a very large supplier of electricity, but face a number of market barriers:

A. **Large-size.** To achieve economies of scale, the market focus for all solar thermal electric technologies is central power generation at utility or independent power purchaser (IPP) sites in units of 100 MW or greater. While dish/Stirling systems are designed in 10 or 25 kW-sized packages and can potentially meet distributed generation applications at smaller scales, plans over the next 5 years focus on deploying larger numbers of systems at central power sites, pending validation and reductions in the O&M costs.

B. **Direct sunlight.** Concentrating solar systems require direct sunlight. The available land and solar resource is sufficient in the Southwest to provide far more generation capacity (6800 GW) than the nation currently has (1000 GW). CSP with thermal energy storage (TES) could potentially provide over 50% of the power in the Southwest, and the potential exists for exporting power to other regions. However, a lack of transmission capacity will limit the amount of power that can be exported.

C. **High tax burdens.** Renewable energy systems have "free fuel", but the cost of equipment to convert the "fuel" to electricity is high. Taxation of solar energy equipment as real property presents a substantial addition to the LCOE from renewable energy systems.

D. **Number of installed systems.** Until 2006, no commercial solar thermal electric systems had been installed in the U.S. since 1991. Two parabolic trough systems were completed in 2006 - 2007. No commercial dish-engine or power tower systems have ever been built in the U.S., although an 11 MW power tower began operation in Spain in 2006 and another 20 MW power tower is under construction.

These technical barriers apply broadly to all CSP systems:

E. **Capital Cost.** The high capital cost of CSP technologies leads to high LCOE and also makes project financing more difficult compared to technologies that are fuel-cost intensive.
F. **Reliability.** Reliability issues vary by technology, but improved reliability is desirable or necessary in all cases.
G. **Performance.** Improved system performance (efficiency) reduces the required quantity of solar hardware to produce a given amount of power.
H. **O&M Cost.** Historically, small plant sizes and low capacity factors have led to O&M costs for troughs and towers that are significantly higher than their competition. O&M costs for developmental dishes have been very high and must be reduced to be competitive in both distributed and, especially, remote markets.
I. **Technology Risk**. New technologies that have never been deployed commercially need to be fully demonstrated to reduce the uncertainty to the industry in cost, performance, and reliability.

Additionally, many non-technical factors can interfere with achieving cost goals, despite achieving technical targets. Such factors include, but are not limited to, the following:

1. Real cost of capital to the developer.
2. Return on investment required by the project equity partners.
3. Time and cost of obtaining approvals for starting or completing construction.
4. Cost of land needed for the project.
5. Federal, state, and local taxes, such as property taxes, that impact solar technologies much more than fossil-energy technologies.
6. Cost of commodity materials such as glass, steel, and concrete.
7. Currency exchange rates.

2.2.4 CSP Approach/Strategies for Overcoming Challenges and Barriers

CSP Industry Partnerships

The CSP awards made by the Solar Program in 2007 were designed to create industry partnerships to develop storage solutions, manufacturing approaches, and new system concepts for large-scale CSP plants (see Table 2.2-3). The collaborative public-private partnerships will work to reduce the LCOE of CSP power plants to meet the Solar Program goals.

Table 2.2-3. CSP Technology R&D Objectives.

Technology	Objective
Thermal Storage	• Low cost • High temperature • Increase dispatchability to meet baseload and intermediate load applications
Trough Component Manufacturing	• Lower cost • Establish manufacturing capability in the U.S.
Advanced System/Component Development	• Identify new CSP concepts that generate low cost power with 12-17 hours of storage by 2020

The projects awarded under this solicitation are divided into three main topic areas: (1) thermal storage; (2) trough component manufacturing, which include the collectors and mirrors projects shown in Figure 2.2-6; and (3) advanced CSP systems and/or components, which include the systems and receivers/engines projects shown in Figure 2.2-6 (see Appendix B for details on the individual projects). The projects will have three phases of effort: concept feasibility, prototype development, and field validation with a "go/no-go" decision at the end of each phase.

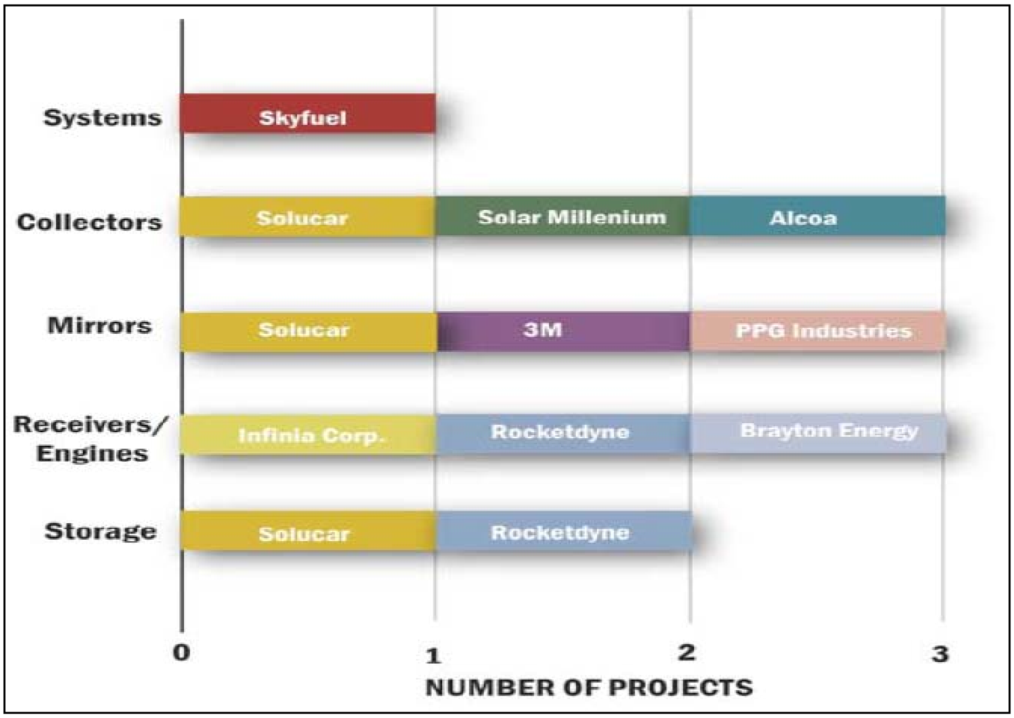


Figure 2.2-6. CSP Projects awarded by the Solar Program.

Parabolic Troughs

The tasks and subtasks in parabolic trough R&D activities are shown in Table 2.2-4, along with the barriers addressed by the respective tasks.

Table 2.2-4. Parabolic Trough R&D Tasks and Subtasks

Task	Title	Barriers
I	**Solar Field Technology**	
1	Improve Near-Term Concentrator Components & System	C,F,H
2	Develop Advanced Concentrator	C,F,H
3	Evaluate and Demonstrate Advanced Receiver Technologies	H,I,G
II	**Thermal Energy Storage Technology**	
4	Demonstrate Improved Near-term Thermal Energy Storage	F,G,H,I
5	Conduct Thermocline Thermal Energy Storage Test	F,G,H
6	Evaluate Molten Salt HTF/TES	G,H
7	Advanced HTF Development	G,H
III	**Power Cycle Development**	
8	Develop Dry and Hybrid Cooling Systems	I
9	Develop and Demonstrate Advanced Power Cycle Integration	H
10	Reduce (and Quantify) Operation & Maintenance Cost	I
IV	**System Integration**	
11	Expand Industry Support	G,H,I
12	Develop Testing Protocols and Industry Standards	H,I
13	Develop and Validate Modeling and Analysis Techniques	H,I
BARRIERS KEY A = Large-Size; B = Direct Sunlight; C = High Tax Burdens; D = Installed Systems; E = Capital Cost; F = Reliability; G = Performance; H = O&M Cost; I = Technology Risk		

Dish-Engine

The tasks and subtasks in dish engine R&D activities are shown in Table 2.2-5 along with the barriers addressed by the respective tasks.

Table 2.2-5. Dish-Engine R&D Tasks and Subtasks

Task	Title	Barriers
I	**Dish Concentrator**	
1	Develop Advanced Dish Structure Design	F,H,
2	Develop Improved Azimuth Drive	F,I
3	Design New Optical Elements	F,H,I,J
	Power Conversion Unit	
4	Develop Next-Generation PCU Design	F,G,H,I,
5	Develop Advanced DIR Receiver	F,G,I,
II	**Systems Engineering and Integration**	
6	System Reliability Improvement	F,G,I,
7	Develop Simulation and Design Tools	H,I
8	Develop Next-Generation Controls	G,H,I
9	Address BOP Issues	F,G,H,I
III	**Deployment Facilitation (All CSP Technologies)**	
10	Perform Market Analysis and Support	F,D,H
11	Support Outreach to State Governments and Stakeholders	F,D,H
BARRIERS KEY A = Large-Size; B = Direct Sunlight; C = High Tax Burdens; D = Installed Systems; E = Capital Cost; F = Reliability; G = Performance; H = O&M Cost; I = Technology Risk		

Thermal Energy Storage and Heat-Transfer

The integration of thermal energy storage (TES) is needed to boost overall plant capacity factors for solar-only operation from about 25% in current plants without thermal storage to greater than 50% in the future. This will enable dispatching electricity without hybridizing the system with natural gas or other fossil fuels, and will thus significantly increase the value of the power (see Figure 2.2-7).

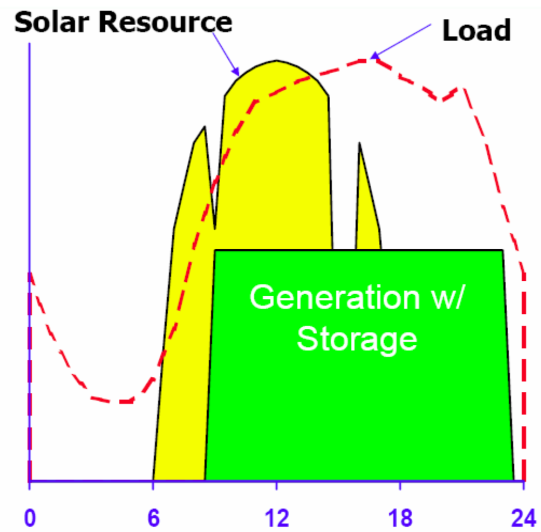


Figure 2.2-7. Increasing Dispatchability of CSP Technology Using Thermal Storage

A near-term high-temperature TES option has been developed for parabolic troughs that uses molten nitrate salt as the storage medium in a two-tank system; it has an oil-to-salt heat exchanger to transfer thermal energy from the solar field to the storage system. The second TES option is to develop an advanced heat transfer fluid (HTF) that is thermally stable at high temperatures, has a high thermal capacity, has a low vapor pressure, and remains a liquid at ambient temperatures. The R&D plan for this advanced HTF will focus on identifying commodity materials that can be modified at low cost to achieve these desired properties.

2.3 Market Transformation

The Solar Program goal of achieving cost-competitiveness of solar energy technologies by 2015 will require both technological improvements and lowering of market barriers to reach full-scale market penetration.

As more than a decade of analyses has shown, the installation of kilowatt-scale PV systems in adjacent city or state jurisdictions can have widely disparate associated costs, despite being interconnected to the same utility grid. This lack of standardization in electric interconnection, net-metering regulations, and other solar-friendly policies can inhibit the growth of PV installations in the U.S., regardless of any technical enhancements achieved by this initiative. It is therefore critical to address market barriers to solar technologies, systems and applications concurrent with science and engineering improvements.

In planning the SAI, the Solar Program consulted with specific industrial, governmental and academic groups to identify the highest impact market segments, communication channels and stakeholder groups to achieve solar commercialization. The Market Transformation effort aims to comprehensively identify and overcome the largest remaining obstacles to widespread solar technology adoption. All activities are designed to maximize short- and mid-term market penetration. Based on input from a wide variety of government, commercial, utility, and institutional representatives, technology improvement opportunities for the market transformation activities were identified.

2.3.1 Market Transformation Goals

In order to facilitate the early market adoption needed to achieve the cost parity and manufacturing capability goals, market transformation activities are explicitly designed to aid in accelerating widespread commercialization of clean solar energy and making it available to all Americans by fostering the following outcomes:

1. Accelerated stakeholder consensus to resolve regulatory, institutional, infrastructure, and education-related barriers to solar technology adoption.
2. Accelerated demonstration and commercialization of new solar energy technologies through collaborative efforts with the private sector and public sector entities.

As such, transformations must be catalyzed by the Solar Program to:

1. Establish the Federal government as the nation's leading buyer of solar energy.
2. Enhance collaborations among states and among utilities in the design of regulations and incentives that promote adoption of solar technologies.
3. Facilitate solar "showcase" projects that will demonstrate novel large-scale solar applications, thereby reducing risk and allowing future private financing of similar projects.
4. Assist city governments in combining regulation, training, and other measures on route to becoming desirable locations for establishing solar businesses and marketing solar products.

5. Assist the solar marketplace by offering solutions to solar workforce development obstacles.

2.3.2 Market Transformation Challenges and Barriers

The principal challenges and barriers addressed by market transformation activities are summarized as:

A. Inconsistent **interconnection**, net metering, and PV-friendly utility rate structure practices;
B. Inconsistent and lack of widespread **incentives** and other drivers (e.g., RPSs);
C. Complex **permitting** procedures and fees;
D. Lack of flexible, sophisticated, proven **financial** approaches; and
E. Limited **education**/experience of key building trades with solar technology.

2.3.3 Strategies for Overcoming Challenges and Barriers

The Market Transformation strategy represents a portfolio approach to addressing the barriers encountered or created by various stakeholders. Activities target specific groups and provide tailored information and assistance to enable them to overcome the solar-related issues they face. Recognizing the Department's limitations in reaching every state, utility, or local jurisdiction directly, we empower third-party organizations where possible. The Solar Program wishes to not only address known issues, but to provide resources for each key stakeholder group to proactively address new issues that arise as solar technology moves toward cost-competitiveness and mainstream adoption. The specific activities and the barriers they address are shown in Table 2.3-1.

Recipients of the Solar Program's Market Transformation funding address each of these activity areas in order to minimize the outlined barriers to solar market penetration. These activities are discussed in more detail below.

Table 2.3-1. Market Transformation Tasks and Subtasks

Task	Title	Barriers
1	**PV Codes & Standards**	
	Solar America Board of Codes & Standards (Solar ABCs)	A, B, C
2	**Workforce Development: Education and Training**	
	Certification, Training and Education	E
2	**Technical Outreach & Communication**	
	State Technical Outreach	A, B, C
	Utility Technical Outreach	A, C
	Installer and Code Official Training & Certification	A, E
3	**Technical Partnerships & Demonstrations**	
	Solar America Cities	A, B, C
	Solar America Showcases	B, C, D
	Government Solar Installation Program	A, D
BARRIERS KEY A = Interconnection; B = Incentives; C = Permitting; D = Financial; E = Education		

2.3.3.1 Market Transformation Activities

PV Codes and Standards

Solar America Board of Codes and Standards (Solar ABCs)
The specifications and regulations governing PV undergo continuous revision to enable the adoption of new technologies, to implement lessons learned from fielded systems, and to facilitate maturation of PV into a major energy source for the U.S. and the rest of the world. Presently, the practice of developing, implementing, and disseminating PV codes and standards has deficiencies:

1. There is no formal coordination in the planning or revision of different, though interrelated, codes and standards.
2. Opportunities and procedures for presenting information from PV stakeholders to standards-making bodies are limited, difficult to find, or absent.
3. No centralized repository exists for collection and dissemination of documents, regulations, and supporting technical materials.
4. No centralized service exists for generating consensus "best practices" materials or providing such materials to utilities, state and other regulating jurisdictions, answering code-related questions (technical or statutory in nature), or providing feedback on important related issues to DOE and government agencies.

To address these deficiencies, the Department is convening and supporting the Solar ABCs. This group will create a major improvement in the responsiveness, effectiveness, and accessibility of codes and standards to U.S. PV stakeholders at all levels. In addition, the Solar ABCs will focus on codes and standards planning as needed to support the new technologies of the Technology Pathway Partnerships.

The Solar ABCs will identify current issues, establish a dialogue among key stakeholders, and catalyze appropriate activities to support the development of codes and standards that facilitate the installation of high quality, safe photovoltaic systems. The group will address specific code development and outreach activities in the areas of Building Electrical Codes, Product Safety, National Standards Coordination, Interconnection and Net Metering, and International Standards Coordination.

Solar ABCs activities will include:

1. Serving as a centralized Federal clearinghouse to assist state regulating and inspection bodies in adopting best practices.
2. Guiding stakeholders in understanding the state of progress on specific objectives.
3. Verifying the adequacy of particular equipment and installation methods.
4. Promoting "Best in Class" standards and code requirements and work with utilities and State and Local jurisdictions to standardize interconnection and installation requirements for the PV system connected to the utility grid.
5. Providing input into the modification of national codes, such as the National Electrical Code.

6. Creating topical studies to be specified by DOE, in response to changing technologies and their relationship to existing standards.
7. Issuing recommendations on key codes and standards issues.

Membership in the Solar ABCs is open to representatives from State and local governments, regional organizations, associations, standard-setting organizations, manufacturers, other laboratory personnel, and other interested stakeholders, including DOE and its national laboratories.

Technical Outreach & Communications

State Technical Outreach
States are critical partners in achieving the success of the SAI. State decision-makers enact policies, programs, and plans that are key drivers for solar technology market transformation within their borders. The Department wishes to strengthen its relationship with the States, but recognizes its limitations in providing one-on-one assistance and developing direct partnerships with each of the fifty States. Consequently, DOE has enlisted the assistance of select State membership organizations to act as a conduit between DOE and key state decision-makers on solar issues. These organizations will represent one or a variety of State entities, such as State legislatures, energy offices, public utility commissions, air quality offices, and others. This activity will complement the core support DOE provides to States' energy efforts through the State Energy Program.

Specific activities include:

- Facilitating the adoption of known best practices in a range of State policy and program areas, including renewable portfolio standards, clean energy funds, market transformation programs, and other state initiatives.
- Identifying and codifying new best practices to accelerate the dissemination of innovative state activities.
- Tracking State progress on solar issues and identifying high-priority opportunities for action.
- Providing model legislation (non-partisan) where appropriate.
- Providing accurate, up-to-date solar technology information to States as needed.
- Identifying new opportunities to leverage resources for solar promotion and adoption at the State level (e.g., increasing the role of solar technologies in air quality State Implementation Plans).

Utility Technical Outreach
Like States, participation by utilities in SAI is absolutely crucial to the success of the initiative. Utilities have the ability to enable sweeping progressive changes across large market areas for solar technologies. DOE sees utilities as essential partners in reaching our 2015 SAI goals; yet, like with States, DOE cannot practically work one-on-one with each utility across the Nation. Therefore, much like the State Technical Outreach activity,

DOE has chosen to enlist the assistance of select utility membership organizations that are well-positioned to deliver key assistance to utilities to enable the success of the SAI.

Specific activities include:

1. Creation and dissemination of utility case studies documenting innovative program design or the use of advanced solar technology.
2. Assisting utilities in making the business case for solar with model approaches and accurate up-to-date technology information.
3. Responding to utility inquiries as to the technical characteristics of solar technologies.
4. Facilitating peer-to-peer communication among utilities to accelerate the spread of best practices.
5. Strengthen outreach to utilities that already maintain advanced Solar Programs and assist such utilities in advancing their acceptance and promotion of solar even further.

Workforce Development: Education and Training

Workforce development is considered a critical need on the path to achieving the SAI goals. It is estimated that more than 5,000 trained installers will be needed to successfully accomplish the SAI mission. In addition, with more than 40,000 jurisdictions across the U.S. approving PV installations, there is a need to train a good portion of the 65,000 existing building inspectors on how to evaluate a PV installation.

With the exception of the North American Board of Certified Energy Practitioners (NABCEP), training and certification in this area has been taking place at the State and local level without national coordination. National consistency on accreditation and certification will avoid duplication of efforts and create a more fluid installer labor force that can cross State boundaries through increased reciprocity provisions.

Planned work under this area includes:

1. The creation of a process and structure to certify the requisite number of solar electric system installers to meet the SAI mission.
2. The development of training curricula for use in universities, community colleges, trade schools, and other institutions.
3. Promoting the education of the various building trades (e.g., roofers).
4. Educating code officials inspecting PV installations to ensure compliance with the National Electrical Code (NEC).

Technical Partnerships & Demonstrations

Solar America Cities

As the load centers of energy use across the nation, cities will play an important strategic role in SAI and present unique challenges and opportunities for solar market transformation. DOE recognizes the important role of cities as champions of progressive energy efficiency and renewable energy efforts, and wishes to support their bold and innovative approaches to accelerate solar technology adoption at the local level.

City councils and associated tax boards, planning commissions, fire marshals and zoning officials can all accelerate or inhibit the adoption of solar energy systems. The Solar America Cities activity will assist cities ready to adopt a comprehensive, systemic, city-wide approach to solar technology that facilitates mainstream adoption and provides a model for other local jurisdictions. Consistent with the mission of Solar Program, DOE looks for cities to commit to achieving a sustainable solar infrastructure, not simply a year or two of experimental solar projects.

Participant cities are receiving assistance to develop city-wide efforts to:

1. Integrate solar technologies into city energy planning, zoning and facilities.
2. Streamline city-level regulations and practices that affect solar adoption by residents and local businesses (e.g., permitting, inspections, local codes).
3. Promote solar technology among residents and local businesses (e.g., outreach, curriculum development and/or implementation, incentive programs, etc.).

Solar America Cities Strategic Partnerships will build on the networks and momentum of former Million Solar Roofs partnerships.

Solar America Showcases

In addition to working with the key state, utility, and city stakeholder groups above, the Department also wishes to push the envelope on specific installations that can showcase state-of-the-art solar technologies and applications.

Under this activity, DOE provides hands-on technical assistance to large-scale, high-impact solar installation projects initiated by businesses, developers, cities, or other entities. DOE defines high-impact in terms of large project size, use of a novel solar technology, and/or use of a novel application for a solar technology (e.g., new methods of building integration). In addition, it is desired that the project be replicable or have replicable components. Showcases may utilize photovoltaic (PV), concentrating solar power (CSP), and solar water/air heating (SWAH) applications. DOE does not purchase hardware or otherwise provide direct funding to organizations under this activity.

Government Solar Installation Program (GSIP)

The U.S. Federal Government is the largest single energy user in the country and thus presents a unique opportunity for deployment of solar technologies. GSIP takes a targeted approach to the specific needs and barriers presented by the Federal sector, and includes innovative financing approaches, third-party Power Purchase Agreements, and streamlined contracting arrangements that accelerate the ability of the growing solar industry to deliver solar-generated electricity at cost-competitive rates. This program will be coordinated with the FEMP to ensure maximum combined impact.

2.4 Partnerships with Other Programs

2.4.1 Basic Research Partnerships

The solar energy utilization research supported by DOE's Office of Science (OS) and its Office of Basic Energy Sciences (BES) is focused on advancing fundamental understanding of atomic/molecular level interactions and reactions associated with the conversion of solar energy into electricity and chemically stored energy. Programs in both OS and EERE support exploratory research in solar energy by the nation's best researchers from national laboratories and universities for the purpose of discovering the next generation of PV technologies. Experience shows that funding this area requires a relatively low budget.

The key linkage between EERE's Solar Program and the BES Program is the transfer of knowledge from the solar scientists to the solar engineers that make devices converting sunlight to electricity, with the goal being that they must perform at costs competitive in future energy markets. The products of these collaborative efforts will provide market impacts beyond 2015, but with the nature of scientific research and development that breakthroughs can happen much sooner.

For solar-to-electric energy conversion, major emphasis will be on the synthesis and discovery of new materials to efficiently absorb sunlight, and new techniques to harness the full spectrum of wavelengths in solar radiation. Recent advances in the design and synthesis of nanostructured architectures offer great promise to revolutionize the technology used to produce solar electricity. Major solar electricity research activities will be aimed at paving the scientific foundation to drive a revolution in the way that the next of generation solar cells are conceived, designed, implemented, and manufactured. These breakthroughs will come from a broad range of research activities in both materials and device topologies. They include 1) single-crystal, polycrystalline, amorphous, and nanostructured inorganic and organic materials; 2) understanding of the electronic structure of these materials; and 3) implementation in single and multiple junction solar cells to take advantage of optical shifting, multiple exciton generation and hot carrier generation. These projects are expected to last 3 years and to overlap with projects funded by EERE's Solar Program.

Another government agency, the Defense Advance Research Projects Agency (DARPA; a central research and development organization for the Department of Defense), is developing high efficiency PV devices based on multijunction cell technology. In February 2005, DARPA's Advanced Technology Office issued a solicitation for up to $53 million for Very High Efficiency Solar Cell (VHESC) program.

In late July 2007, a consortium led by the University of Delaware (UD) announced that it had created a solar cell with a conversion rate of 42.8%. They employed an optical system that splits sunlight into three components while concentrating it by about a factor of 20. Three separate solar cells – made by NREL, UD, and Emcore Corporation - convert each piece of the solar spectrum into electricity to achieve the record conversion efficiency. Unlike the typical concentrating solar cell, the new device features optics that are less than one centimeter thick and that accept sunlight from a wide range of angles, allowing the device to be mounted in a fixed position. Based on the success of this effort, DARPA announced recently the start of a new three-year effort to drive efficiency to more than 50%.

2.4.2 Partnerships with Other Federal Agencies

Collaboration with other government offices and departments extends beyond basic research. With solar cell efficiencies above 40% today, a different Department of Defense group is re-exploring the potential for satellite-based solar power stations to meet future energy needs by beaming power to military locations around the world. To meet today's military needs, the Army's Rapid Equipping Force is bringing energy efficiency as well as solar and wind energy power sources to forward operating bases in the Middle East in order to dramatically reduce the long and vulnerable supply lines of diesel fuel needed for diesel generators. The Federal Energy Management Program (FEMP) has a long history of supporting solar projects at federal installations, especially military bases in the U.S. The U.S. Department of Agriculture is also looking into possible solar projects within its rural utilities service offices. As these and other U.S. government agencies explore the potential to bring solar energy into their activities, DOE's Solar Program expects to serve as a resource, providing information exchange, lessons learned, and interagency collaboration where appropriate.

3.0 Program Management

There are four principal areas of program management that are integral to the Solar Program. These are:

1. Portfolio development and management;
2. Communication of the program;
3. Analysis of the program; and
4. Evaluation of the program.

These management areas combine to assure that industry, the public, and government are effectively served by the Solar Program.

3.1 Program Portfolio Management Process

3.1.1 Solar Program Portfolio Development & Prioritization

The Solar Program follows a multi-step planning process designed to ensure that all funded technical R&D projects are chosen based on a common market perspective and set of national goals. All components and cost elements of solar energy systems are evaluated to assess the relative marketplace impacts of different research and development directions. With this approach, researchers have a common basis to communicate the value of their work and understand how it fits directly into overall program goals. This applies throughout the PV product development pipeline, from fundamental research on materials and devices to improved components and fully-integrated, mass produced PV systems. The key steps in the portfolio decision making process are shown in Figure 3-1.

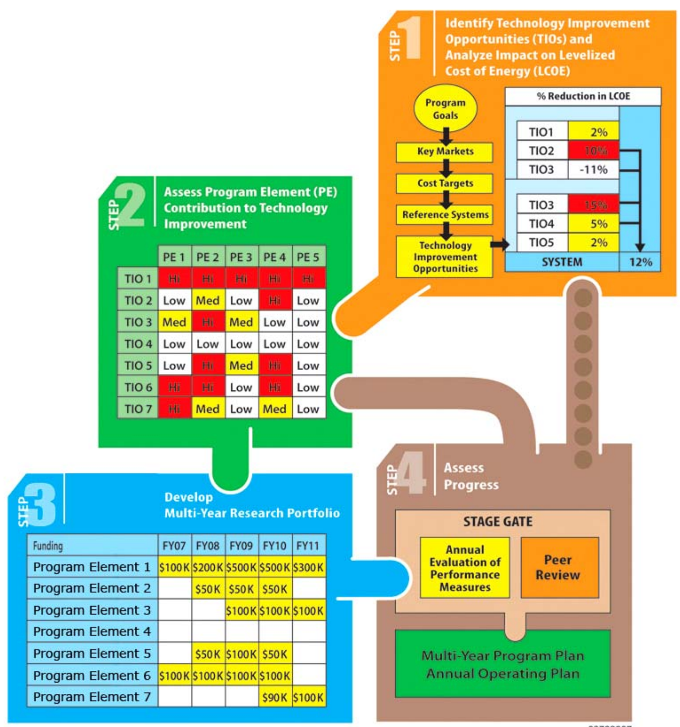


Figure 3.1-1. Flow Diagram of the Portfolio Decision Making Process

Step 1—Identify Technology Improvement Opportunities and Analyze Impact on Levelized Cost of Energy

The Solar Program goals are to improve performance and reduce cost to enable large-scale usage of solar energy technologies. Markets with potential for large-scale commercialization have been identified, and competitive cost targets have been established. Reference systems for each technology area have also been identified. The reference systems provide a basis for analyzing the current state of technology for each application/technology combination and permit the use of Solar Program analytical tools in evaluating TIOs. The reference systems also provide a benchmark against which future progress is measured.

TIOs are identified for each reference system at the system, subsystem, component, and sub-component level. Each TIO is characterized by a set of key metrics, such as performance, cost, O&M, and reliability. For each reference system, a set of benchmark values for the metrics provides a quantitative representation of the current state of the technology. Projected values of the metrics represent potential improvements based on Solar Program R&D efforts. The relative impact of each TIO on the reference system's LCOE is determined by calculating the LCOE using both the benchmark and projected values and comparing each TIO's contribution to changes in the LCOE.

Step 2—Assess Research Activity Contribution to Technology Improvement
Achieving a target for a particular TIO will often require support from a variety of program elements, where the word "element" is intended to include the terms "activity, project, agreement, and contract," as used in EERE's Corporate Planning System (CPS). Solar Program planners use the matrix shown in Figure 3.1 to prioritize program elements in terms of the level of support provided to critical TIOs. Those elements contributing the most are given the highest funding and management priority.

Step 3—Develop Multi-Year Research Portfolio
Having developed a prioritized list of program elements, program planners then formulate the Solar Program's research plan over the planning horizon, as illustrated in step 3 of Figure 3.1. Planners must identify the set(s) of TIOs and associated program elements that will lead to achieving Solar Program goals. These detailed planning and prioritization efforts are aided by the use of technology roadmaps (see Appendix D), as well as technical plans developed for specific program elements (e.g., SEGIS plan and Reliability plan).

Step 4—Assess Progress
The state of the technology is benchmarked, and progress on all Solar Program elements is reviewed periodically, as discussed in Section 3.4. Information from these assessments provides feedback to the Solar Program planning process.

3.1.2 Solar Program Administration

Program Planning & Funding Cycle

Extensive planning is done each year in the Solar Program. Planning activities are timed to provide the level of detailed information needed for the various activities in the budget development and project funding cycle. This budget and planning cycle is depicted schematically in Fig 3.1.2 for Calendar Year 2009. The entire development cycle (over a 4-year period) is depicted in Fig 3.1.3. This extended cycle shows the maturation from roadmap development of program ideas and needs to updating the Multi-Year Program Plans. Next there are planning summits, interactions between DOE, OMB, and Congress, and then guidance is provided for detailed planning of the FY activities. This effort ends with the development, implementation, and completion of the tasks and activities approved in the detailed annual operating plan.

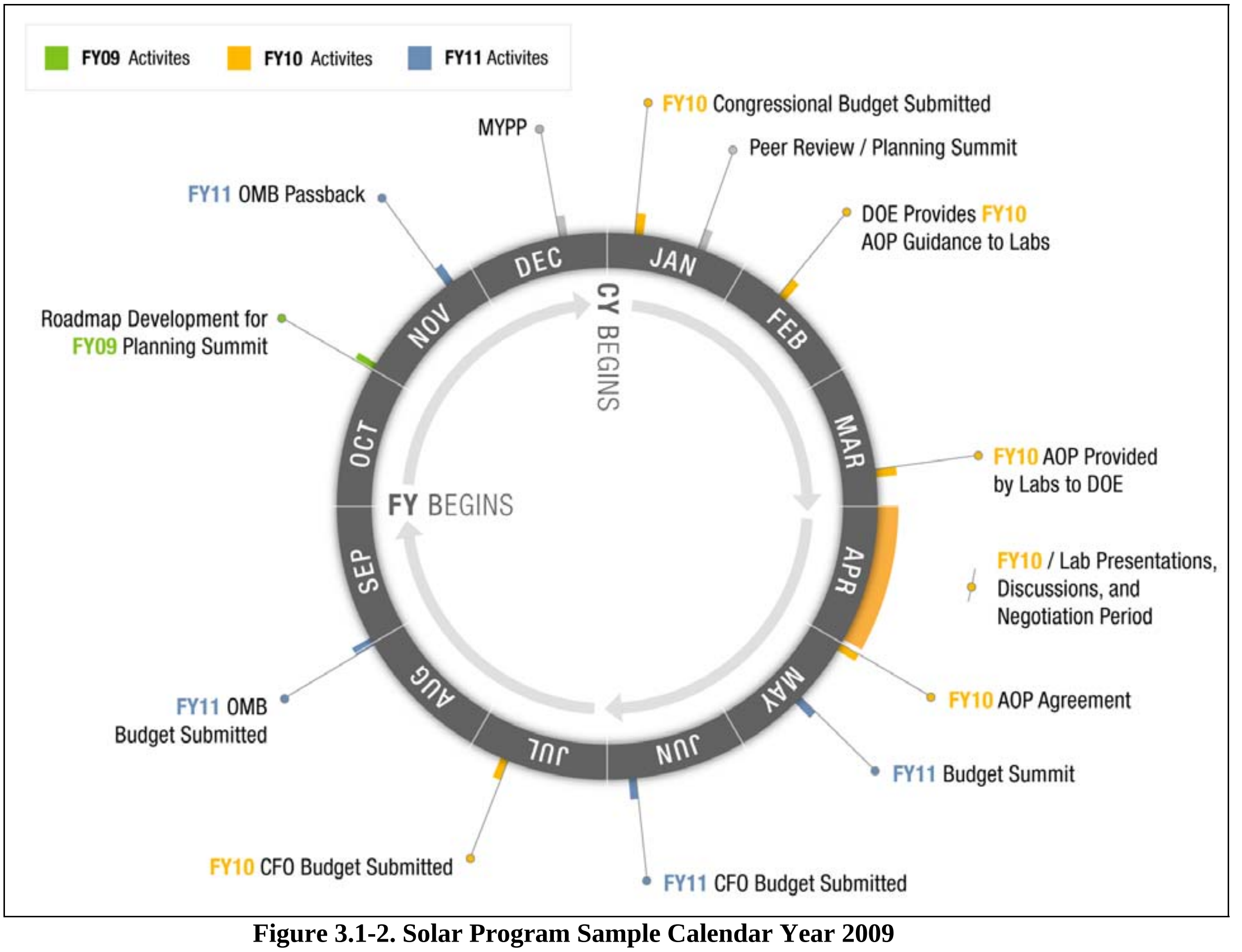


Figure 3.1-2. Solar Program Sample Calendar Year 2009

Annual Operating Plan

Each year, the Solar Program develops an annual operating plan (AOP). The AOP is the agreement between the Solar Program, Golden Field Office, National Energy Technology Laboratory, and the national laboratories on how the money will be spent and what will be accomplished with it. The AOP is developed during the spring and summer and finalized shortly after Congress appropriates a budget for the Solar Program. Projects and their supporting agreements and contracts are established in adherence to the Solar Program's strategy for maintaining a balanced portfolio among industry, universities, and the laboratories. The objective is to combine the best researchers in the country with industrial partners that have the capability of commercializing the technology. The Solar Program now provides well in excess of 50% of its funds to industry and universities. The remainder goes to the national laboratories, principally NREL and SNL, which, over the years, have established staff that are recognized as world leaders in solar R&D. The two laboratories have also developed unique solar testing facilities.

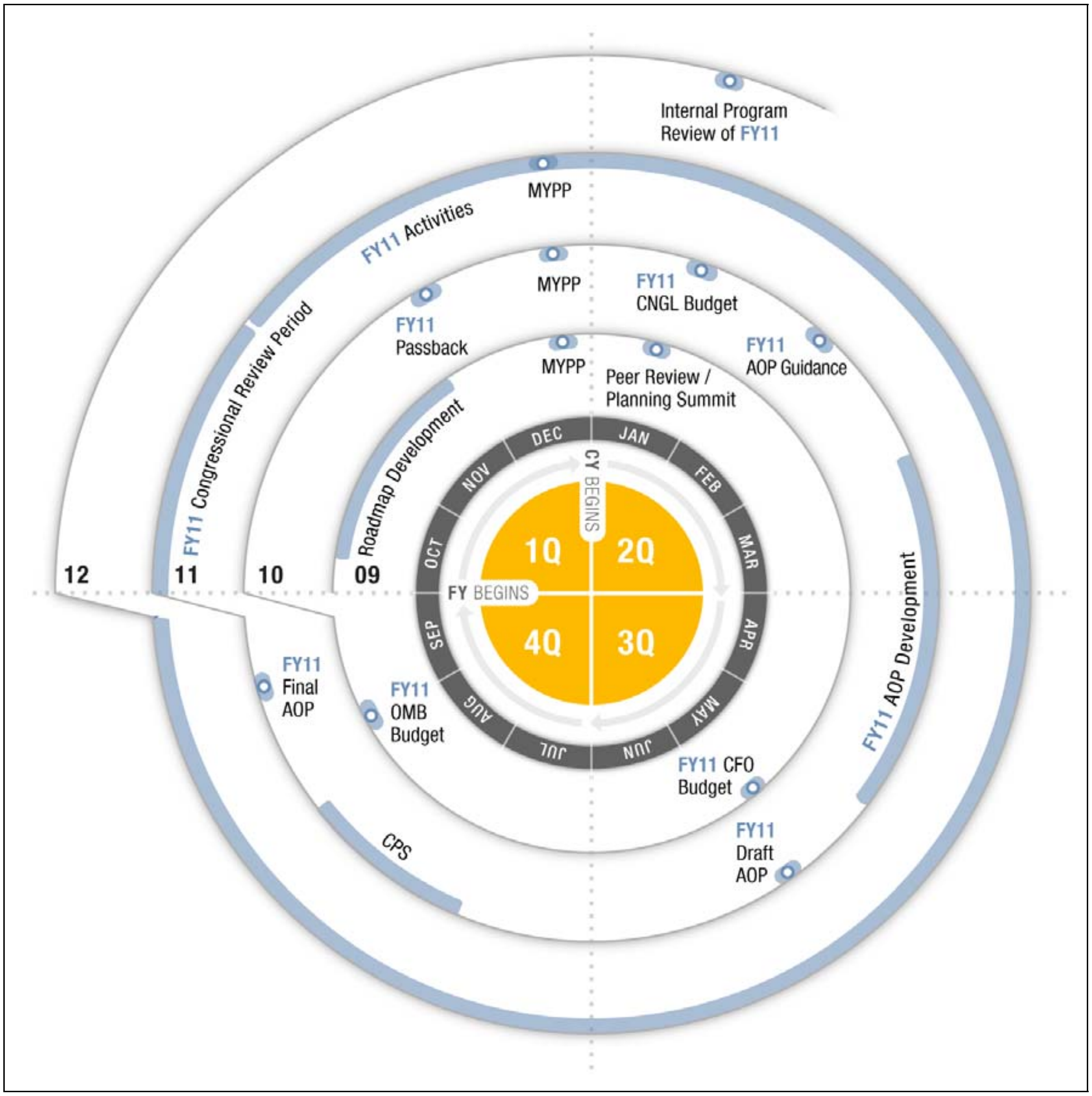


Figure 3.1-3. Sample FY11 Planning & Budget Process (Over a 4-Year Period)

Corporate Planning System

EERE's Corporate Planning System (CPS) helps manage, monitor and develop Congressional Budget Requests, spend plans, budgets, project data, and portfolio performance. It supports multi-year program planning, AOP development, and automated program guidance letter creation in the Solar Program. CPS allows the user to create and manage portfolios in real time, tie projects and milestones to fiscal year budgets, and allows field personnel to review and modify portfolio information. The system stores a range of necessary data, such as DOE investments, carry-over, and cost-share; GPRA energy benefits; total project development time; and technical progress. Other information such as quarterly and final reports can be uploaded and addressed through the system. CPS is a central repository of information that enables the Solar Program and EERE management to track project accomplishments, milestones, and spending. Other methods used by teams to track their projects include communicating with project researchers, attending technical meetings, and giving project reviews.

Risk

The purpose of R&D is to explore new concepts. Inherent in this exploration is the risk that projects will fail to meet their objectives. The project leads manage risk by establishing, when possible, multiple pathways aimed at achieving technical goals. Projects that present significant technical barriers or are particularly important to accomplishing the system goal are likely to have more agreements and contracts than other projects. EERE is exploring a variety of ways to manage risk and develop a more sophisticated risk analysis methodology to assess the risk and uncertainty in estimates of the benefits of its Technology Development programs. These risk assessments require subject matter experts to express their best judgment about the uncertain future cost and performance of a technology due to R&D in the form of estimated probability distributions. This process is currently being conducted on a pilot project level by the Solar Program, using experts in government, industry and academia.

Facilities and Capital Equipment

The DOE national laboratories are government-owned, contractor-operated facilities that rely on government funding for buildings and equipment. The Solar Program uses two existing research facilities at NREL to conduct world-class solar R&D: the Solar Energy Research Facility and the Outdoor Test Facility. A third facility, the Science and Technology Facility, has recently been completed and is currently being fully equipped with the latest equipment for processing and characterizing all PV technologies. In addition, the National Solar Thermal Test Facility for testing CSP technologies is located at SNL, as are the Photovoltaics Systems Optimization Lab (PVSOL) and the Distributed Energy Test Laboratory (DETL). These facilities continually require advanced equipment to conduct research in materials science, electrochemistry, thermal science, and other disciplines.

Contracting

Contracts for R&D projects are funded through the Golden Field Office and the national laboratories. Programmatic activities such as outreach, communications, and conferences are funded, in part, by the Golden Field Office through cooperative grants or contracts. The Solar Program also provides funding to programs established by DOE that sometimes support projects other than solar energy. These programs include the Small Business Innovative Research (SBIR) program, Minority University Research Associates

(MURA) program, and State Energy Program (SEP). In some cases—for example, SBIR and SEP—the projects are managed by other DOE offices with interaction by the Solar Program. Except for unusual situations, all projects are selected through a competitive process. The Solar Program follows DOE guidelines on cost sharing. If the project assists industry in the engineering development of a product, then 50% or greater cost sharing by industry is required. But if the project is research-oriented, then cost sharing may be as little as 10%.

Cost Management and Monitoring
During the year, the Solar Program keeps track of how funds are spent, the rate at which it is spent, and if it is consistent with the AOP. This is done through information obtained from the laboratories and from DOE's Standardized Tracking and Reporting System (STARS). STARS provides information at a relatively high level—for example, the amount of money sent to and spent by NREL for PV each month. The laboratories, on the other hand, provide data for all levels of the Solar Program—projects, agreements, and contracts—and much of this information is included in the CPS system. In addition, EERE has strict guidelines limiting the amount of money a program can carry over from one year to the next.

Environmental Safety and Health
EERE requires the integration of Environmental Safety and Health (ES&H) into planning, execution, and measurement of all work performed at its sites and facilities. The EERE ES&H staff advises the Solar Program on ES&H policy; performance and resources; adherence to statutory, regulatory, and DOE requirements; the National Environmental Policy Act (NEPA); occupational safety and health; and emergency management activities. A number of environmental benefits are associated with solar energy. Because developing an environmentally friendly energy supply is an important aspect of the National Energy Plan, the Solar Program makes every effort—through research and a rigorous industry outreach program—to minimize the environmental impacts of solar technologies, and to address issues of manufacture, installation, and disposal.

3.2 Communications and Outreach

Communications & Outreach Strategy
The Solar Communications staff supports the communications and outreach needs of the Solar Program and the National Center for Photovoltaics (NCPV) by targeting key audiences, with the objectives of helping to raise awareness, inform and educate, and move people to action. The staff also contribute to the program goal of creating a growing market for research results/advances and technologies by addressing barriers to acceptance and presenting examples of successful deployment of solar technologies.

The Solar Program's core programmatic communications, such as the Annual Report, Program Overview, Web site, and program exhibits describe the Solar Program itself and are intended for "general purpose" use, typically for solar energy stakeholders, Solar Program partners, EERE/DOE management, and Congressional staff. These communications products highlight the increased performance, reduced costs, improved reliabilities, and scientific and technical breakthroughs for solar technologies.

Collecting Market Information
Access to the latest information and the ability to spot trends are key to effective communication. Information on key markets is collected and analyzed through a variety of methods. Keeping abreast of market activities requires tracking information in relevant journals, trade magazines, and significant solar Web sites. Information is also obtained from subcontracted sources.

Disseminating Information
Telling the R&D story is just the first small step. Getting that information into the hands of appropriate audiences—ranging from stakeholders who develop and market the products to the consumers who make the ultimate decision with their pocketbooks—is a giant step. Information is distributed through a wide range of channels. If people visit our facilities, whether our national laboratories or headquarters, information products are readily available. Conference and exhibiting opportunities create “touch points” to connect with key stakeholders; distribute and promote information products; and to communicate more about Solar Program activities, capabilities, and successes. Volumes of information are also available via various Web sites as files that can be viewed, downloaded, or printed. Finally, some requests for specific information reach us via our Web sites, and the Webmaster responds to those needs.

Interacting with EERE Communication and Outreach
The Solar Communications staff is part of a larger group responsible for outreach and stakeholder relations that includes the Golden Field Office outreach staff, DOE Headquarters Communications, and Solar Program staff. This group works to help identify key audiences, establish audience and messaging priorities, and assess strategies and proposed communications products within the communications plan.

3.3 Program Analysis

The Solar Program carries out a wide range of analytical activities coordinated through the Systems Driven Approach to program planning. This analysis provides the tools and information for evaluating research activities based on their ability to contribute to Solar Program technical and economic targets. This includes cost and performance analysis to identify and evaluate research activities, and market analysis to set the technical and economic targets and to identify key markets.

Benchmarking of program deliverables as well as commercial components and systems is used to monitor the status of the technology. Benchmark data is inputted into the integrated Solar Advisor Model (SAM model), which has been developed to permit analysis of all Solar Program technologies using a common modeling platform. The model allows analysts to investigate the impact of variations in performance, cost, and financial parameters on key figures of merit. The model, which is currently being refined and updated, is used by DOE, laboratory management, and research staff. The model is also used by members of the solar industry to inform their internal R&D direction and to estimate systems cost and to quantify the impact of performance improvements made in their DOE-funded activities. SAM was a key tool in evaluating applications for TPPs and will be used during Stage Gate and other review activities.

The SAM Model consists of four modules: (1) a user interface module for selecting and providing input data on the system configuration and operating environment, (2) a system performance module that simulates the hour-by-hour output of the selected system for the lifetime of a project, (3) a cost input module for providing simple or detailed cost inputs for system components, and (4) a financial analysis module for calculating system economics. The model integrates data from each module to calculate and display results, including such figures of merit as energy production, cost flows, and LCOE. The Solar Program, along with it National Laboratory partners, is currently updating and refining the SAM model to ensure it represents the most current and up-to-date PV and CSP solar energy technologies.

Market analysis within the Solar Program focuses on three key areas: improving the understanding of long-term market potential for solar technologies, reviewing the Solar Program's technical and economic targets, and carrying out detailed value analysis of solar technologies. In developing long-term market penetration projections for solar technologies, the Solar Program is examining both the system and policy drivers of solar technologies in various markets in both the short- and long-term, as well as improving the analytical basis for projecting the Solar Program's economic and environmental benefits. For this analysis, the Solar Program uses existing models, including the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), MARKAL, and other models. The Solar Program has also developed the new Solar Deployment Systems (SolarDS) model, a PV market penetration model designed to serve as a counterpoint to NEMS.

Together, these tools are used to:

- Determine appropriate LCOE targets that are cost-competitive with electricity from conventional sources;
- Compare and prioritize research options by analyzing their impact of LCOE targets; and
- Evaluate progress towards achieving those targets by benchmarking and modeling program progress as well as commercial products.

As technology evolves, promising new research pathways may be explored, while research pathways that are not yielding sufficient progress may be dropped. These tools are applied from the conceptual stage, when only rough estimates of potential impact are possible, through to evaluation of deployed systems. Systems analysis is a key part of the Stage Gate evaluation process.

3.4 Program Evaluation

Managers take seriously the evaluation function of the Solar Program, as the programmatic portfolio and all activities are critically, regularly, and independently reviewed, as shown in Table 3.4-1. Reports on the following regular activities are provided to Solar Program managers to aid them in decision-making:

- Stage Gate Reviews are done frequently as part of DOE's continuous assessment of its investment in its projects, see Table 3.4-1. At each stage gate, the maturity of the proposed products, the manufacturing process and capacity, and the efficacy of the commercialization plan are assessed. Each partnership defines its stage gates, associated criteria, deliverables, and timing, and states how they it will demonstrate satisfaction of criteria.
- Peer Reviews provide periodic independent review and confirmation of the technical quality and merit (significance) of the entire Program's activities. Each technical research area is reviewed at least biannually. EERE peer review guidelines are followed and peer review panel reports are provided for Solar Program management use.
- Technical / Management Reviews are routinely performed. An Internal Program Review is conducted; all program elements are reviewed in a conference setting, including paper and poster sessions. In addition, DOE and national laboratory executive and program managers perform quarterly program reviews to evaluate the status, progress, budgets and issues for the entire Solar Program, including reviews of milestone requirements for awardees of funds. Review meetings are scheduled as needed for topical areas requiring more intense scrutiny. Findings from these secondary meetings are communicated to program managers for key decision-making. In addition, at least yearly reviews of all major solicitations are held to evaluate and track progress.
- Activity Terminations, or "off ramps", are considered as part of the rigorous decision-making AOP process and as a direct result of Stage Gate, program, or peer reviews. Each year, there are several key decision points that may terminate a specific activity while new research breakthroughs or priorities necessitate new directions.

Table 3.4-1 Performance Assessments in the Solar Program

Solar Program Performance Assessments	2008	2009	2010	2011	2012
Performance Monitoring					
Joule (quarterly)	✓	✓	✓	✓	✓
PART	✓	✓	✓	✓	✓
CPS (quarterly)	✓	✓	✓	✓	✓
Internal Program Monitoring	✓	✓	✓	✓	✓
Stage Gate					
Technology Pathway Partnerships* (each partnership will have at least one Stage Gate Review each year)	✓	✓	✓	✓	✓
Selected Internal R&D Projects	✓	✓	✓	✓	✓
PV Technology Incubator Projects*	✓		✓		✓
SEGIS*		✓		✓	
Advanced CSP Projects*	✓	✓	✓	✓	✓
Peer Review					
Program Level Peer Review (biannually)		✓		✓	
Technical / Management Reviews					
Internal Program Review	✓		✓		✓
Quarterly Program Review (Internal) - 4/year	✓	✓	✓	✓	✓
Reviews of Major Solar Program Solicitations					
• University Product & Process Dev. Support*	✓	✓	✓	✓	✓
• PV Technology Incubator*	✓	✓	✓	✓	✓
• Next Generation PV Devices & Processes*	✓	✓	✓	✓	✓
Reviews of Market Transformation Solicitations					
• Solar Codes & Standards	✓	✓	✓	✓	✓
• State & Utility Solar Technical Outreach	✓	✓	✓	✓	✓
• Solar America Cities	✓	✓	✓	✓	✓
• Solar America Showcases	✓	✓	✓	✓	✓

* The Solar Energy Technology Program Funding Opportunities generally run for one to three years, after which they are open to re-compete and re-award.

Appendix A: Acronyms

AC	alternating current
ALT	accelerated lifetime testing
a-Si	amorphous silicon
a-Si:H	hydrogenated amorphous silicon
BIPV	building-integrated photovoltaics
BOP	balance of plant
BOS	balance of systems
Btu	British thermal unit
c-Si	crystalline silicon
CdTe	cadmium telluride
CIGS	copper indium gallium diselenide
CIS	copper indium diselenide
cm^2	square centimeter
COSE	cost of saved energy
CPV	concentrating photovoltaics
CRADA	cooperative research and development agreement
CSP	concentrating solar power
DC	direct current
DETL	Distributed Energy Test Laboratory
DG	distributed generation
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EERE	DOE Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPAct	Energy Policy Act of 2005
ES&H	environment, safety, and health
FMEA	Failure Modes and Effects Analyses
FY	fiscal year
GaInNAs	gallium indium nitrogen arsenide
GPRA	Government Performance Results Act
GW	gigawatt
GWp	peak gigawatt
HALT	highly accelerated lifetime testing
HTF	heat-transfer fluid
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IPP	independent power producer
ITC	investment tax credit
kW	kilowatt
kg	kilogram
kWe	kilowatt electric
kWh	kilowatt-hour
kWht	kilowatt-hour thermal
LCOE	levelized cost of energy
LEC	levelized energy cost
m^2	square meter
MMBtu	million Btu
MTBF	mean time between failure

MTBI	mean time between incident
MURA	Minority University Research Associates
MYPP	Multi-Year Program Plan
MW	megawatt
MWe	megawatt-electric
NCPV	National Center for Photovoltaics
NEMS	National Energy Modeling System
NREL	National Renewable Energy Laboratory
NSTTF	National Solar Thermal Test Facility
O&M	operations and maintenance
OLED	organic light-emitting diode
PDIL	Process Development and Integration Laboratory
PV	photovoltaics
PVSOL	Photovoltaics Systems Optimization Lab
R&D	research and development
RFP	request for proposal
RPS	renewable portfolio standard
SAM	Solar Advisor Model
SBIR	Small Business Innovative Research
SEGIS	Solar Energy Grid Integration Systems
SEP	State Energy Program
Si	silicon
SNL	Sandia National Laboratories
TBD	to be determined
TES	thermal energy storage
TIO	technology improvement opportunity
UV	ultraviolet
W	watt
Wp	peak watt

Appendix B: SETP Activity Summaries and Milestones

The following milestone appendix provides a prospectus breakdown of the different areas of research, development and demonstration that Solar Energy Technologies Program projects will focus on over the next five years. The appendix is divided into five sections:

1. PV Applied Research
2. PV Systems & Component Development
3. PV Test & Evaluation
4. PV Market Transformation
5. Concentrating Solar Power

1. PV Applied Research

Program Type: PV Next Generation Solicitation
Project Type: Advanced Concentrators
Contractor: University of Illinois/Wakonda Technologies
Project Title and Summary: *Transfer Printed Microcells with Micro-Optic Concentrators for Low Cost, High Performance Photovoltaic Modules*: Transfer printing to distribute large numbers (>250,000) of GaAs microcells with molded, micro-optic concentrators over large area foreign substrates, interconnected with direct ink writing.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Single Junction Cells
Contractor: MIT
Project Title and Summary: *Thin, High Lifetime Silicon Wafers with No Sawing; Recrystallization in a Thin Film Capsule*: To create a silicon wafer-making technology that will set a new standard by combining high electronic quality and low cost.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Single Junction Cells
Contractor: Pennsylvania State University
Project Title and Summary: *High Aspect Ratio Semiconductor Heterojunction Solar Cells*: Photovoltaic devices made from radial single junction a-Si/nc-Si nanowires grown on inexpensive substrates like glass.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Single Junction Cells
Contractor: Stanford University
Project Title and Summary: *Culn (Ga) Se_2 (CIGS) Nanowire Solar Cells*: Production of inorganic nanostructured thin film solar cells made of CIGS nanowires with diameters less than 200 nm.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Single Junction Cells
Contractor: University of South Florida
Project Title and Summary: *Next Generation CdTe Technology Substrate Foil- Based Solar Cells*: To transform the standard process/product design of CdTe cells and modules from a glass-to-glass superstrate configuration, into a metallic foil substrate configuration using close- spaced sublimation, a high throughput process.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Single Junction Cells
Contractor: Soltaix
Project Title and Summary: *Feasibility Demonstration and Performance Optimization of a Disruptive Ultra-High-Efficiency, Thin-Film, Crystalline Silicon Solar Cell for Cost- Effective, Grid-Connected Electricity*: Use of thin film Si absorber layer for high-efficiency cells with efficient light trapping and reduced Si usage. The technical approach removes dependency of cell manufacturing on the traditional Si wafer supply chain.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Tandem Cells
Contractor: Arizona State University
Project Title and Summary: *II-IV-V Based Thin Film Tandem Photovoltaic Cell*: Development of materials for II-IV-V based tandem thin film cells, starting with $ZnSnP_2$ and $ZnGeAs_2$, to push 20% efficiency.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Tandem Cells
Contractor: University of Delaware
Project Title and Summary: *All-Inorganic, Efficient Photovoltaic Solid State Devices Utilizing Semiconducting Colloidal Nanocrystal Quantum Dots*: Tunable bandgap using Cd or Pb quantum dots. Tandem devices are made by putting quantum dots on top of a conventional cell or mechanically stacking quantum dot cells with different bandgaps. Solution processible for low cost photovoltaics.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Advanced Thin Films – Tandem Cells
Contractor: MIT
Project Title and Summary: *Novel Approaches to Wide Bandgap $CuInSe_2$ -Based Solar Cells*: Development of a highly efficient, wide bandgap, $CuInSe_2$ chalcopyrite-based solar cell, which is necessary for polycrystalline tandem devices. Laser processing will be used to control defects, which will improve the performance of the cell.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: High Efficiency Multi-Junction Cells
Contractor: Arizona State University
Project Title and Summary: *Advanced Semiconductor Materials Breakthrough Photovoltaic Applications*: To demonstrate the fundamental viability of new semiconductor materials with a potential for disruptive breakthroughs in photovoltaics.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Hybrid Organic/Inorganic
Contractor: University of Florida
Project Title and Summary: *Very High Efficiency Hybrid Organic-Inorganic Photovoltaic Cells*: Aligned, inorganic ternary alloy nanorods with tuned bandgaps combined with organic polymer hole conduction media arranged in tandem devices. Solution processible for low cost photovoltaics.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Intermediate Bands
Contractor: Rochester Institute of Technology
Project Title and Summary: *High Efficiency Nanostructured III-V Photovoltaics for Solar Concentrators Application*: InAs quantum dots incorporated into the GaAs cell of a multijunction III-V device to enhance IR absorption in the near term and provide initial insight into intermediate band cells in the long term.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Multiple Exciton Generation
Contractor: University of Colorado
Project Title and Summary: *Exciton Fission for an Ultra-High Efficiency, Low Cost Solar Cell*: Graetzel cell that will use dye molecules and nanocrystals of dye to produce multiple electrons from one photon of light.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Multiple Exciton Generation
Contractor: Voxtel
Project Title and Summary: *Optimization of Impact Ionization in Composite Nanocrystal Photovoltaic Devices*: "Janus" nanoparticles incorporated in conducting polymer cells will use multiple exciton generation to go beyond conventional limits in power production.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Multiple Exciton Generation
Contractor: Solexant
Project Title and Summary:
High Efficiency Quantum Dot Solar Cells Based on Multiple Exciton Generation: To demonstrate that the efficient multiple exciton generation observed in quantum dot materials can be harvested in nanostructured solar cells to dramatically improve the maximum power efficiency obtainable in photovoltaic modules.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Organic Photovoltaics
Contractor: University of California, Davis
Project Title and Summary: *Functional Multi-layer Solution Processable Polymer Solar Cells*: Organic photovoltaics made from of multiple polymer films with electron- only, hole-only and interface dipole layers. A gel protection layer allows for spin coating of the multiple polymer films. Solution processible for low cost photovoltaics.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Organic Photovoltaics
Contractor: University of Michigan
Project Title and Summary: *Crystalline Organic Photovoltaic Cells*: Organic, small molecule planar hetero- junction, tandem cells utilizing the crystalline physical form.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Organic Photovoltaics
Contractor: University of Washington
Project Title and Summary: *Interfacial Engineering for Highly Efficient π-Conjugated Polymer-Based Bulk Heterojunction Photovoltaic Devices*: Devices with 10nm interdigitated organic nanostructures, where self assembled electroactive molecules will improve performance by reducing interface recombination. Multilayer, solution processible tandem cells are the ultimate goal.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Plasmonics
Contractor: California Institute of Technology
Project Title and Summary: *Solar Cells from Earth-Abundant Semiconductors with Plasmon-Enhanced Light Absorption*: Plasmonic light absorption in earth-abundant semiconductors (quantum dots, and Zn_3P_2). A top cell with earth abundant absorber will be integrated with a Si bottom cell.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Plasmonics
Contractor: University of California, San Diego
Project Title and Summary: *High-Efficiency Photovoltaics Based on Semiconductor Nanostructures*: Researchers will produce high- efficiency photovoltaics that combine plasmonics and III-V quantum well and nanowire solar cells.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Sensitized Cells
Contractor: Pennsylvania State University
Project Title and Summary: *Improved Electrodes and Electrolytes for Dye-Based Solar Cells*: Graetzel cell with polyphosphazene polymer gel electrolyte, used in lithium ion batteries, intercalated between TiO2 columns.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Other (Si Synthesis)
Contractor: Stanford University
Project Title and Summary: *Nanostructured Materials for High Efficiency Low Cost Solution-Processed Photovoltaics*: Ordered ZnO nanowire networks or Ag nanowire meshes for low cost contacts. Solution processing into ordered networks through bubble expansion of nanowire/polymer suspension.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation
Project Type: Other (Si Synthesis)
Contractor: Mayaterials
Project Title and Summary: *Solar Grade Silicon From Agricultural By-Products*: Polysilicon solar cell feedstock derived from agricultural by-product streams without the Siemens process. With anticipated energy contents and production costs equal to or lower than conventional methods. Target cost: < $25/kg.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: PV Next Generation Solicitation **Project Type:** Other (Si Synthesis) **Contractor:** Solasta **Project Title and Summary:** *High Efficiency Solar Power via Separated Photo and Voltaic Pathways*: Nanostructures of carbon nanotubes, PV absorber material (a-Si), and metal to make nanoengineered solar cells, which separates the path of the photons from the path of the generated charge carriers. Milestone: 25% efficiency by 2010.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Exploratory Research **Project Title:** Organic Photovoltaics (OPV) **Contractor:** NREL **Project Summary:** Excitonic solar cells, which rely on exciton dissociation at a donor-acceptor interface to create carriers, have recently reached certified solar efficiencies of 5%. Improvements in material quality, device design, and understanding of the device physics are necessary to further improve cell efficiencies.

SETP Project Milestones/Decision Points	Due Date
4% OPV device with 1 cm^2 area and 2,000 hour stability[1]	2008
5% OPV device with 1 cm^2 area and 3,000 hour stability[1]	2009
7% OPV mini-module (~200 cm^2) 5,000 hour stability[1]	2010
10% OPV mini-module with 7,000 hour stability[1]	2012

[1]stabilility = less than 10% loss over the specified time period

Program Type: Exploratory Research **Project Title:** Sensitized Solar Cells **Contractor:** NREL **Project Summary:** The original design of sensitized solar cells – the liquid-electrolyte-based dye-sensitized solar cell (DSSC) – has reached certified efficiencies >11% for laboratory cells and 6%–7% for modules. However, certain environmental conditions greatly increase degradation and efficiency in cells. The design and development of more effective materials (sensitizers, nanostructured films, charge-conducting phases, conducting substrates) and cell configurations and the assessment of cell stability at different cell efficiency levels will constitute a significant fraction of the research effort. Both organic/inorganic hybrids and entirely inorganic versions of sensitized solar cells will be developed.

SETP Project Milestones/Decision Points	Due Date
5–8% device with <15% degradation for 1000 h[1]	2008
6–9% device with <15% degradation for 1200 h[1]	2009
8–10% device with <15% degradation for 1400 h[1]	2010
8–10% device with <10% degradation for 2000 h[1]	2012

[1]@80ºC in the dark *or* @60ºC with continuous light soaking

Program Type: Exploratory Research **Project Title:** Film Silicon Photovoltaics **Contractor:** NREL **Project Summary:** Films of crystalline silicon could reach the DOE 2020 goal of 6¢/kWh PV electricity by leveraging the existing crystal silicon infrastructure, but circumventing the need for high-cost wafers. This film silicon project proposal addresses key research problems toward near-term expansion of today's thin-film silicon industry and the mid-term creation of a wafer-replacement crystalline film Si technology.

SETP Project Milestones/Decision Points	Due Date
Demonstrate epitaxy at least 1 μm thick on industrial layer-transfer silicon at above 100 nm/s without melting the glass substrate. (Film Silicon)	6/30/2008
Establish control of both n- and p-type doping levels below 1017 cm-3 in epitaxial film Si	9/30/2008
Fabricate 8.5% a-SiGe:H solar cell at 1.45 eV gap with i-layer grown at >4Å/s	2008
Demonstrate new seed-layer-on-glass fabrication technique with >10 μm grain size and grow 5 nm of epitaxial Si on it	2009
Demonstrate 10 microns of epitaxy on seed layer with minority carrier diffusion length of 20 microns Demonstrate 50% collection at 850 μm wavelength in stable lowgap a-SiGe:H grown at >4Å/s	2010
Demonstrate 10% solar cell on large-grain crystal silicon on glass	2011
Demonstrate light trapping strategy for absorption equivalent to 28 mA/cm^2 in 10-micron thick film Si solar cell on glass	2012

Program Type: Exploratory Research
Project Title: Wafer Silicon Photovoltaics
Contractor: NREL
Project Summary: As the Si-PV industry grows further, it faces challenges to further lower the PV energy cost, increase throughput and conversion efficiencies, and improve reliability (longer life expectancy) of solar modules. This project will target new methods of crystal growth, new cell designs, and Si solar cell process development. These are in the areas of novel device design that are not only capable of higher efficiency but simpler to fabricate, novel processes such as optical processing, device process modeling, characterization, and diagnostic technologies for Si-PV manufacturing.

SETP Project Milestones/Decision Points	Due Date
Demonstrate 13% 1 cm2 solar cell with inexpensive production-worthy black Si anti-reflection	6/2008
• Develop a theory for Si-Ag interactions in a fire-though process • Comparison of surface recombination velocity on multi-crystalline wafer passivated with a-Si:H and a SiNx:H in PDIL cluster tool	7/2008
• Distribute four 15% 1 cm^2 heterojunction solar cells across 6-inch wafer, with a-Si layers made in PDIL Si Cluster Tool • Organize 18th silicon workshop	8/2008
• Grow CZ-crystal from feedstock and make 13% diffused-junction 1 cm^2 cell • Demonstrate 12% manufacturable interdigitated solar cell incorporating heterojunction a-Si:H layer • Demonstrate multilayer contacts with conductivity better than screen print contacts/50 micron lines • Demonstrate >19% efficient HIT cell with new low temperature TCO	9/2008
• Develop 5" solar wafer size heterojunction solar cells using PDIL Si Cluster Tool • Understand black Si anti-reflection	9/2009
• Grow CZ-crystal from various source of Solar Si feedstock and evaluate Si feedstock with chemical analysis, 1 cm^2 solar cell, and electronic properties • Develop 6" mc-Si solar cells using best thin film passivation in PDIL cluster tool • Demonstrate multilayer contacts with conductivity better than screen print contacts/50 micron lines in solar cells • Continue to develop new low temperature TCO with high mobility for HIT solar cell	9/2010
Demonstrate over 20% 5" wafer size heterojunction solar cells in PDIL Si Cluster Tool	9/2011
Develop 25% back interdigitated solar cell incorporating heterojunction a-Si:H layer	9/2012

Program Type: Seed Fund
Project Title:
Contractor: NREL/SNL
Project Summary: The Solar Energy Technologies Program primarily funds research to further develop commercially attractive photovoltaic technologies. In general, these efforts support existing industry partners and/or new companies that are attempting to commercialize a proven photovoltaic concept. These efforts may last for multiple years and can be most successful with stable staffing serving a sustained effort. It is also useful for the SETP to fund temporary projects that explore new ideas. If the new concepts are successful, the efforts may be expanded; if they are unsuccessful, then they should be terminated to free those funds for new projects. The NREL/Sandia Seed Fund is proposed to provide temporary funding for exploration of new ideas. The new ideas funded by the Seed Fund may include new materials, devices, or processes that have not reached the proof-of-concept stage. Ideally, the Seed Fund leverages other investments by the Department of Energy by (1) providing follow-up programmatic support to successful Laboratory-Directed Research and Development projects, or (2) complementing the basic research studies funded by the Office of Science. The activities under the Seed Fund facilitate the Solar Program's mission of transitioning basic research to applied research and development by targeting the earliest stage this transition can occur. This type of activity is intended to be a practical complement to the fundamental, exploratory research funded by the DOE Office of Basic Energy Sciences. NREL's activities under the seed fund include:

- Doped Polymeric Semiconductor p-n Junction
- Carbon Nanotube Architectures for Low Cost and High Efficiency
- Incorporation of 3rd generation mechanisms into OPV devices
- Microfabrication and Design of High Watt/Gram Si and III-V Photovoltaic Cells and Modules
- Novel Nanocrystal-Based Solar Cell to Exploit MEG
- Thin c-Si cells
- Multifunctional TC and Self-Healing Impermeable Barriers
- Si Quantum dot solar cells
- Amorphous oxide semiconductors for ambient temperature deposited PV

SETP Project Milestones/Decision Points	Due Date
Create simulations package to calculate the electronic and optical properties of Si quantum dots embedded in a foreign matrix.	12/30/2008
Select and specify the most promising growth method of quantum dot structures.	12/30/2008
Reproducible 2% efficient MEG devices; quantitative assessment of cell processing parameters; encapsulated air-stable cells.	12/30/2008
Spray deposition of bulk CNT electrode with area > 10 sq cm, T > 80%, and series resistance < 50 ohm/sq.	12/30/2008
Synthesis of gram quantities of n-type and p-type polymers; preparation of first functional solar cells from the new materials.	12/30/2008
Develop methods to release of thin c-Si PV cells that allow reuse of the substrate with progress toward release of III-V PV cells and inexpensive one-sun and concentrator module assembly.	12/30/2008
• Demonstrate release of thin III-V PV cells and reuse of substrate. • Demonstrate parallel self-assembly of sparse (concentrator) and dense (one-sun) PV cell arrays on inexpensive substrates as a precursor to inexpensive modules.	2009
Demonstrate a one-sun module with thin c-Si PV cells utilizing microphotonic structures for optical path extension.	2010
Demonstrate a flat-panel, microsystem based PV micro-concentrator with an integrated micro-tracking approach suitable for flat installation on roof-tops.	2011
Complete stage-gate decision process to select which Seed Fund projects are terminated and which are moved in core program	2009-2012

Program Type: Exploratory Research
Project Title: CdTe Photovoltaics
Contractor: NREL
Project Summary: Near-term improvements in CdTe module efficiency will be achieved primarily by improving light transmission into the active layers through the use of improved glass superstrates and improved transparent conductor layers. Longer-term improvements will be achieved through enhanced understanding of the mechanisms that presently limit V_{oc} and development of solutions to minimize or eliminate these limitations.

SETP Project Milestones/Decision Points	Due Date
Establish infrastructure for expanded capability of device stability testing; Establish technology to produce high-quality TCO/buffer on soda-lime glass	2008
Complete Phase-1 and Phase-2 procurements for CdTe PDIL platform	2009
Demonstrate 15 efficient CdTe device using all-dry contact technology	2010
Provide industry with guidance to scale up CTO and ZTO	2011
Demonstrate ability to produce both high-efficiency p-n or p-i-n CdTe junctions	2012

Program Type: Exploratory Research
Project Title: Minority University Research
Contractor: NREL/Golden Field Office (with various minority university partners)
Project Summary: The focus of the DOE-NREL Minority University Research Associates Program (MURA), formerly the Historically Black College and University (HBCU) PV Research Associates Program, is to encourage undergraduate minority students to pursue careers in science and technology while participating in DOE/NREL-sponsored research projects. Students involved in research excel in the classroom and are committed to contributing to sustainability through the development of renewable energy technologies. The program helps retain minority students in the science and technology areas and enables many students to reach their educational and career goals.

SETP Project Milestones/Decision Points	Due Date
REAP Conference/Review Meeting	10/1/2007
REAP Conference, August 2008.	8/29/2008
Transition Program from NREL to Golden Field Office.	2008

Program Type: Electronic Materials & Devices
Project Title: Cross-Cutting R&D Proposal for Transparent Conductors (TC)
Contractor: NREL
Project Summary: This project will allow an integration of two unique NREL capabilities in theory and experiment to develop new TC materials by design. Toward this end, a significant component of the project will be focused initially on the coupling of our current capabilities to fully realize and integrate both the theory tools and the experimental tools for "Material By Design" and using them to develop new high performance TC materials. Subsequently, there will be a focus on the development of new TC materials for specific PV device technologies as well as the continued development of the tools for implementing this strategy.

SETP Project Milestones/Decision Points	Due Date
• Materials by design demonstrated for TC materials • Leading to thin film TC material with 10,000 S/cm and 90% T across the visible	2008
Demonstration of a new TC material suggested by the design rules and demonstrated by the high-through-put techniques	2009
Enhanced TC performance for CdTe front and back contacts and for CIS to enhance stability	2010
Next generation absorber materials identified	2012

Program Type: Exploratory Research
Project Title: CIGS Photovoltaics
Contractor: NREL
Project Summary: In the CIGS technology, two major needs must be addressed to make it successful and accepted in the marketplace. The first is to close the gap between the high performing laboratory cells and the prototype large area modules. The second is to demonstrate reliable and durable performance. Research activities in the next five years will utilize the PDIL CIGS and characterization platforms. Selected manufacturing processes will be targeted for a comparative study/evaluation of material quality and device performance losses compared to high performing laboratory devices.

SETP Project Milestones/Decision Points	Due Date
• Installation and operation readiness verification of the PDIL CIGS deposition module. First module of the platform. • Demonstrate the deposition of state-of-the-art CIGS film in CIGS Tool • Integrate the central distribution chamber with CIGS deposition module	2008
• Complete stress test infrastructure, database, and Cell Reliability ALT systems • Demonstrate > 10% CIGS device produced by alternative process to evaporation	2009
Demonstrate concrete progress in stability of the CIGS device	2010
Comparative evaluation of production vs. high efficiency devices (methods and metrics) to assess the performance limits-in partnership with industry	2011
Demonstrate concrete progress in closing the gap between laboratory and production cells.	2012

Program Type: Exploratory Research
Project Title: Concentrator Photovoltaics
Contractor: NREL/SNL
Project Summary: This project will build on NREL's leadership in the CPV through work on a broad spectrum of cell development programs ranging from near- and mid-term work on inverted cell structures through work on new materials to ensure longer-term leadership in cell technology development. This project will involve interdisciplinary collaborations between NREL's Concentrating Solar Power (CSP), Reliability, and Thermal Systems programs, and with Sandia National Laboratory's PV program. This project will develop a new capability in advanced 2- and 3-dimensional modeling of the interactions of light, heat, and thermal stress with concentrator cells.

SETP Project Milestones/Decision Points	Due Date
Demonstrate iLMM cells with optimized second- and third-junction band gaps	9/30/2008
Develop capability to model and optimize performance of cells under real-world conditions in a concentrator system, including effects of inhomogeneous non-normal illumination; thermal hotspots; and mechanical stress.	2010
Develop a comprehensive catalog of MJ cell degradation mechanisms; establish the science underpinnings of their root causes; and identify mitigation paths.	2011
Develop next-generation broadband antireflection coating optimized for operation under concentrator optics, and suitable for production cells.	2011
Demonstrate 48%-efficient concentrator cell hardened against degradation	2012

Program Type: Measurements & Characterization
Project Title: Measurements and Characterization (M&C)
Contractor: NREL
Project Summary: The M&C project focuses its efforts in three areas: M&C support, collaborative R&D, and technique development. *M&C support* focuses on providing routine and specialized measurement and characterization support for the PV community through rapid and direct response to requests. M&C support also includes T&E and stage-gate review activities in support of the SAI. *Collaborative R&D* focuses on contributing to and leading collaborative research projects to address critical issues and problems in PV technologies. *Technique development* focuses on developing and implementing new and specialized measurement techniques in response to specific needs in PV R&D and manufacturing.

SETP Project Milestones/Decision Points	Due Date
Complete construction and fit-up of the Outdoor Test Facility expansion project.	3/31/2008
• Design and procure a PECVD tool for the M&C PDIL cluster tool. • Design and procure the integrated plasma etch/sputtering.	5/30/2008
• Procure Multi-source Concentrator Cell Solar Simulator • Stage-gate decision to build custom multi-source 1-sun simulator internally or externally	6/30/2008
Install Auger tool and complete acceptance tests at NREL. Demonstrate Auger tool automation by performing large area compositional mapping	7/31/2008
Install wet chemistry etch tool in PDIL and complete ES&H operational readiness review.	8/29/2008
Electro-Optical Characterization • Design, procure and build the universal chamber and sample translation/mapping stage for all electro-optical-based PDIL tools. • Complete minority carrier lifetime measurement system prototypes. Demonstrate complete functionality over 6”x6” sample. • Complete PL imaging measurement system prototype. Demonstrate complete functionality over 6”x6” sample. • Design, procure, and install the reflectance spectroscopy tool in the PDIL. Demonstrate full tool functionality. • Design, procure, and install the optical thermal annealing tool in the PDIL. • Demonstrate capability for one-sun SPV measurement of diffusion length in wafer silicon. **Surface Analysis** • Successfully complete UHV sample handing robot acceptance test at vendor’s facility. • Install XPS tool at NREL and complete acceptance tests. Demonstrate full flipping station functionality. **Cell & Module Performance** • Maintain full ISO 17025 accreditation for primary reference cell, secondary reference cell, and secondary module calibrations • Support SAI subcontractors (TPP and PV Incubator) at the highest level possible – Evaluate whether support levels are adequate for FY09 and beyond • Procure and install Large Area Module Solar Simulator System. Bring unit to operational status compliant with teams ISO 17025 quality system • Procure multi-source 1-sun simulator	9/30/2008
Complete PDIL Platform #1 and bring all tools to fully operational status	2009
Work with the Reliability and Electronic Materials and Device groups to develop new tools and techniques to define failure modes and mechanisms in PV cells and modules.	2009/2010
• Develop new characterization techniques to probe small dimension defects and grain boundaries • Develop new characterization techniques to probe small dimension defects and grain boundaries.	2009/2012

Program Type: PDIL Hardware Development **Project Title:** Process Development and Integration Laboratory (PDIL) **Contractor:** NREL **Project Summary:** This program seeks to ensure the infrastructure and capital equipment development of the PDIL and related activities support the research plans within the technology roadmaps. PDIL will conduct characterization research on Wafer-Si (e.g., manufacturing diagnostics and process modeling), Film-Si (e.g., develop high-growth-rate methods for nanocrystalline silicon), CdTe (e.g., reduce module and device efficiency gap), CIGS (e.g., enhance module efficiency and lower cost), and OPV (e.g., optimization of complete device architecture).

SETP Project Milestones/Decision Points	Due Date
• Provide project management, software, and engineering support for the PDIL platforms • Manage proposal management and industry liaison support for the PDIL	9/30/2008
• Infrastructure development • External Proposal Management	2009
• Infrastructure development • External Proposal Management	2010
• Infrastructure Maintenance & Improvement • External Proposal Management	2011
• Infrastructure Maintenance & Improvement • External Proposal Management	2012

The following projects are being phased out in FY2008:

Program Type: Exploratory Research **Project Title:** Exploratory Research **Contractor:** NREL **Project Summary:** This project includes funding for minority universities, NREL basic sciences, X-Si university research, polycrystalline thin-film tandems, III-IV concentrators, and next generation research.

SETP Project Milestones/Decision Points	Due Date
Demonstrate lift-off of thin c-Si chips and cells as well as reuse of substrate	9/1/2008
Explore techniques to lift-off III-V PV cells	9/22/2008
• Explore methods to deposit/grow micron-grain and heteroepitaxy c-Si thin films on glass substrates. • Begin phase-out of subcontracted multi-junction cell work through transfer of key technologies and I.P. to industry leaders and SAI TPP teams.	9/30/2008

Program Type: Exploratory Research **Project Title:** Silicon Center of Excellence - University Photovoltaic Research, Education and Collaboration **Contractor:** Georgia Institute of Technology • **Project Summary:** Under the program, Georgia Institute of Technology will fabricate large area (~100 cm2) solar cells on commercial substrates, using commercially compatible high throughout processes, with target efficiencies of 18-19%. The program will emphasize fundamental and applied research appropriate for education and advanced degrees, while performing industry relevant research that would lead to low-cost high-efficiency silicon solar cells.

SETP Project Milestones/Decision Points	Due Date
Demonstrate a screen-printed contact with 6% shading loss.	4/30/2008

Explore methods to deposit/grow micron-grain and heteroepitaxy c-Si thin films on glass substrates.	9/30/2008
• Fabricate 4cm^2 untextured CFP/PL cells on FZ Si with a target efficiency of 19% • Reduce high temperature processing time from more than 6 hours to less than 30 minutes	2008
• Fabricate 4cm^2 CFP/PL cells on CZ silicon with target efficiency of 18% • Develop self doping Ag paste that can give < 40 ohms/Gamma region upon firing	2009
• Fabricate 4cm^2 cells on CZ silicon with target efficiency of 19% • Develop screen printing of IBC structures	2010
• Fabricate 4cm^2 cells on CZ silicon with target efficiency of 20% • Develop porous silicon texturing for light trapping	2011
• Fabricate large area 42cm^2 cells on CZ silicon with target efficiency of 19-20% • Fabricate selective emitter, bifacial and IBC cells on commercial materials with target efficiencies in the range of 17-20%	2012

Program Type: Exploratory Research
Project Title: Thin Film Center of Excellence - University Center of Excellence
Contractor: University of Delaware
Project Summary: The multiyear objectives of these advanced research activities are to perform leading-edge research in thin-film materials and solar cells. The UCE will also provide scientific and applied research support to the new emerging thin-film companies, which do not have the expertise or the resources to do it on their own. The research tasks could be in the area of device fabrication, device analysis, film growth, materials characterizations, and modeling.

SETP Project Milestones/Decision Points	Due Date
Begin phase-out of subcontracted multi-junction cell work through transfer of key technologies and I.P. to industry leaders and SAI TPP teams.	9/30/2008

2. PV Systems & Component Development

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Reaching Grid Parity Using BP Solar Crystalline Silicon Technology
Awardee: BP Solar International
Project Summary: Low-cost approach to grid parity using crystalline silicon. This project will cover all aspects of the PV product chain from raw materials through installation of the systems. Key aspects are development of solar grade silicon feedstock, implementation of Mono2™casting, optimized thin cell processing and modules designed for integration into roofs.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: A Value Chain Partnership to Accelerate U.S. PV Industry Growth
Awardee: GE Global Research
Project Summary: GE will collaborate with a team of industrial partners to develop various solar technologies, simplifying the integration of PV systems into residential and commercial buildings. This program will help foster solar energy industry growth, resulting in reduced greenhouse gas emissions and favorable economics.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Delivering Grid-Parity Solar Electricity on Flat Commercial Rooftops
Awardee: Nanosolar
Project Summary: Grid-parity PV system for large-area, flat commercial rooftops. This project will work on cost-efficient components and system integration for commercial buildings with large-area, flat rooftops based on ultra-low-cost thin-film CIGS PV cells.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Low Cost, Lightweight Solar Modules Based on Organic Photovoltaic Technology
Awardee: Konarka
Project Summary: Building-integrated organic photovoltaics. This project will focus on manufacturing research and product reliability assurance for extremely low-cost photovoltaic cells using organic polymers that convert sunlight to electricity.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Grid-Competitive Residential and Commercial
Fully Automated PV Systems Technology
Awardee: Sunpower
Project Summary: Grid-competitive residential solar power generating systems utilizing industry-leading modules already in production. This project will research lower-cost ingot and wafer fabrication, automated manufacture of back-contact cells, and new module designs, to lower costs while improving the aesthetics of residential PV installation and will provide the marketplace with a more streamlined sales/installation process.

Program Type: Technology Pathways Partnership (TPP)
Project Title: Low Cost High Concentration PV Systems for Utility Power Generation
Awardee: Amonix
Project Summary: A low-cost, high-concentration PV system for utility markets. This project will utilize our real-world, utility field-tested concentrator system and incorporate the most advanced solar cell technology (>40 % efficiency) to produce the lowest cost of PV-generated electricity.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: High Efficiency Concentrating Photovoltaic Power System
Awardee: Boeing
Project Summary: High-efficiency concentrating photovoltaic power system. The Boeing TPP will develop a concentrating PV power system targeted at utility-scale markets drawing on Spectrolab multi-junction solar cell technology and advanced high concentration non-imaging optics.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Fully Integrated Building Science Solutions for Residential & Commercial Photovoltaic Energy Generation
Awardee: Dow Chemical Company
Project Summary: PV-integrated residential and commercial building solutions. This project will employ the team's expertise to explore improvements in PV technology, component design, packaging, integration, and installation to achieve major cost reductions for producing electricity in a building integrated, grid connected system.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Development of an AC Module System
Awardee: GreenRay
Project Summary: Development of an AC module system. This team will design and develop a high-powered, ultra-high-efficiency AC module that contains an inverter, eliminating the need to install a separate inverter and facilitating installation by homeowners. Research will focus on increasing the lifetime of the inverter.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Concentrating Solar Panels: Bringing the Highest Power and Lowest Cost to the Rooftop
Awardee: Soliant Energy
Project Summary: High-concentration CPV systems for commercial rooftop applications. This project will develop a combination of high-concentration optics and a practical approach to rooftop tracking to dramatically increase PV power density. The technology will be paired with high-efficiency multi-junction cells enabling exceptionally high power solar panels. The modules will have a flat panel configuration with fully integrated tracking for a conventional installation process.

Program Type: Technology Pathway Partnerships (TPP)
Project Title: Low Cost Thin Film Building-Integrated PV Systems
Awardee: United Solar Ovonic, LLC
Project Summary: Low-cost thin-film building-integrated PV systems. This project will focus on reducing the delivered cost of electricity by lowering the cost of multi-bandgap, flexible thin film PV modules, and by reducing system cost using innovative installation methods and by lowering the cost of balance-of-system components.

Program Type: SAI Project Monitoring
Project Title: SAI Project Monitoring
Contractor: SNL
Project Summary: This Project Monitoring proposal for the SAI consists of two unique activities: (1) Technical Project Monitoring (provide technical direction and coordinating national lab-based assistance as needed) and (2) Integrated Plan Development (SNL will develop a means of managing, storing, tracking, and assimilating plan data that will be generated through the TPPs – critical database for conducting stage gate reviews).

Program Type: SAI Project Monitoring **Project Title:** Testing and Evaluation (T&E) **Contractor:** NREL/SNL **Project Summary:** A DOE priority for T&E is to include procedures that ensure new system designs satisfy performance and cost specifications as defined by DOE LCOE targets, such as for the 12 Technology Pathway Partnerships (TPPs) recently announced under the President's Solar America Initiative. Supporting the TPPs will require coordination and implementation of T&E activities at SNL, NREL, SERES, SWRES, other qualified facilities, and in the field. The following types of tests will be required to validate stage gates: ***Component Performance***: Cells; CPV Optics; Modules(indoor/outdoor); BOS(materials/devices); Diode function; Inverter ***System Performance***: Tracker characterization; Lab and field systems; Long term perf/degradation; Grid compatibility; Solar resource measurements ***Reliability***: Qualification; Screening; Failure analysis; Safety testing	
SETP Project Milestones/Decision Points	**Due Date**
• Completion of all stage-gate required tests and reports delivered for S-G reviews. Baseline assessments of all TPP technologies completed, and capabilities in place for further assessment of technology developments. Field assessment completed on one large (utility-scale) system. • Methodology in place for entry of new modules into performance database. Report on T&E requirements for all SAI initiatives, such as Advanced Integrated Inverters, Technology Incubator, University solicitation, etc. Two-axis tracking test bed completed at NREL.	2008
• Completion of all stage gate assessments. Module performance database brought fully up to date with all commercial modules included. • Enhancement of PV Systems Optimization Laboratory to assess CPV systems complete. Full procedure implemented for provision of accelerated test data to reliability program. PVWATTS revised for use with 10-km satellite derived solar radiation data. PV module energy rating methodology implemented.	2009
Completion of all stage gate assessments; recommendations report complete for transition into TPP Phase 2. Accelerated tests complete on all TPP technologies, data provided to reliability program team. Module database activities fully transferred out of the national lab environment.	2010
Transition to Phase 2 of TPPs. Documented full integration of T&E capabilities in support of all SAI initiatives.	2011
Completion of all Phase 2 technology baselines and stage-gate assessments.	2012

Program Type: PV Technology Incubator **Project Title:** Low Cost, High-Throughput, Automated Fabrication of Thin Film Cells and Modules **Contractor:** AVA Solar **Project Summary:** AVA Solar has demonstrated fully automated, continuous in-line fabrication of CdS/CdTe PV. This project will enable the demonstration of extremely low manufacturing and equipment costs, improved module efficiencies and the ability for rapid manufacturing capacity expansion.	
SETP Project Milestones/Decision Points	**Due Date**
Approximately 10 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Silicon Solar Cells on Low Cost Substrates
Contractor: Blue Square Energy
Project Summary: This project seeks to develop manufacturing practices for thin crystalline silicon solar cells through growth of a high purity silicon layer onto a low cost metallurgical grade silicon substrate. This approach can produce the high performance and reliability of traditional solar cells with reduced material utilization and manufacturing costs.

SETP Project Milestones/Decision Points	Due Date
Approximately 5 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Manufacturing High Efficiency Cells Using Upgraded Metallurgical Grade Silicon
Contractor: CaliSolar
Project Summary: This project seeks to develop manufacturing procedures for cost-effective solar cells from low-cost, abundant, but impurity-rich Si feedstock materials. The focus will be on a novel and adapted metallization method specifically suitable for the use of metallurgical Si to manufacture solar cells with over 17% efficiency using multicrystalline Si.

SETP Project Milestones/Decision Points	Due Date
Approximately 5 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Pilot Manufacturing of Rooftop-Ready Solar Panels Using High Concentration Photovoltaics
Contractor: EnFocus
Project Summary: This project seeks to develop manufacturing procedures for a lightweight, low profile, high concentration PV module that is fully encapsulated and protected from wind, hail, dust and moisture. This module will utilize high efficiency multi-junction cells to generate higher power outputs in area constrained applications such as rooftops.

SETP Project Milestones/Decision Points	Due Date
Approximately 3 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Development of Lower Cost, High-Efficiency, Solar Cells for Concentrating Applications
Contractor: MicroLink Devices
Project Summary: MicroLink Devices will develop a low-cost, high efficiency dual-junction GaAs-based solar cell for use in 500x concentrator systems. The developed solar cell minimizes GaAs material usage while improving heat dissipation with potential cost reductions near 50%.

SETP Project Milestones/Decision Points	Due Date
Approximately 20 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Economic On-Grid Solar Energy via Organic Thin Film Technology
Contractor: Plextronics
Project Summary: This project seeks to commercialize Thin-Film Organic Photovoltaic (OPV) Technology. Plextronics will develop higher efficiency cells while increasing module lifetime design to enable this ultra low-cost material to compete with traditional PV technology.

SETP Project Milestones/Decision Points	Due Date
Approximately 1 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Production Scale-Up of World Record CdTe/CdS Cell
Contractor: PrimeStar Solar
Project Summary: This project will develop commercial CdTe module production based on the NREL 16.5% world record CdTe laboratory solar cell technology. The increased module energy conversion efficiency will lower installation costs and open new markets for CdTe based thin film modules.

SETP Project Milestones/Decision Points	Due Date
Approximately 5 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Simplified, Low Cost, 2x Concentration Flat Plate Module
Contractor: Solaria
Project Summary: Solaria's reliable PV-multiplying process yields two to three highly efficient cells from one, via solar cell singulation and optical amplification to create cost effective modules. Solaria's DOE project aims to produce a non-tracking standard module form factor with 2-3X concentration manufactured in a reliable high volume automated process.

SETP Project Milestones/Decision Points	Due Date
Approximately 5 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: Reflective Concentrating PV Panels Enabling Large-Scale, Reliable Energy Generation
Contractor: SolFocus
Project Summary: This project will develop 500x concentrating PV module emphasizing high reliability and high efficiency to enable large-scale commercial and utility market penetration. A folded reflective design will allow for a high optical efficiency and acceptance angle in a compact frame.

SETP Project Milestones/Decision Points	Due Date
Approximately 10 MW of production capacity	2009

Program Type: PV Technology Incubator
Project Title: CIGS Technology Based on Electroplating
Contractor: SoloPower
Project Summary: The project will develop an electroplating-based, high-efficiency, low-cost CIGS cell and module manufacturing technology. Advantages of this deposition technique include lower equipment costs, reduced processing times and increased material utilization.

SETP Project Milestones/Decision Points	Due Date
Approximately 20 MW of production capacity	2009

The following projects are being phased out in FY2008:

Program Type: Industry Thin Film Partnerships
Project Title: Industry Thin Film Partnerships
Contractor: NREL
Project Summary: This project supports R&D with the leading thin-film companies in the U.S. toward the SAI 2015 goals. These companies will focus R&D efforts on improving cell and module efficiency, reducing module cost, and creating greater device and module reliability for the following materials: amorphous silicon, cadmium telluride, and copper indium diselenide.

SETP Project Milestones/Decision Points	Due Date
Milestones pending contract negotiations	Pending

Program Type: University Thin Film Research
Project Title: University Thin Film Research
Contractor: NREL
Project Summary: This project addresses mid- and longer-term research goals to fill in the gaps. The project will strengthen the ability of thin films to reach the ambitious SAI cost-parity goals; reduce the risk of failure from subtle issues associated with device stability and processing reproducibility; and provide the innovation and developmental momentum to extend U.S. technological and processing leadership post-2015. The necessary research breaks down into the following topics: (1) science base, (2) cross-cutting advanced research, (3) materials and device innovation, and (4) new thin films without availability issues.

SETP Project Milestones/Decision Points	Due Date
Milestones currently being developed.	Pending

Program Type: PV Manufacturing R&D
Project Title: PV Manufacturing R&D
Contractor: NREL
Project Summary: This project seeks to improve module manufacturing processes to increase module reliability; system and system-component packaging, system integration, manufacturing, and assembly; product manufacturing flexibility; and balance-of-systems (BOS) development and quality control.

SETP Project Milestones/Decision Points	Due Date
Reduction in direct module-manufacturing costs to $1.75	Pending
Achieve module manufacturing processes capable of $1.50/watt direct module manufacturing costs with 500-megawatt production capacity	Pending

3. PV Test & Evaluation

Program Type: Modeling & Analysis
Project Title: Systems Performance Modeling and Database Development
Contractor: NREL/SNL
Project Summary: The combined output of the model and database activities will provide 1) a model that will calculate energy output, energy costs, and cash flows using up-to-date component and system data while enabling parametric analysis; 2) validation of SAM, PVWATTS, and, potentially, other solar models for a variety of technologies, applications, and locations; and 3) the database of information necessary to accurately model solar systems, including an improved understanding of PV system derate, a factor of about 20% which can be highly uncertain. Together, these tools can be used by industry and government to guide R&D prioritization, and to provide credible energy production and cost data using a common platform for project development, evaluation, and due diligence.

SETP Project Milestones/Decision Points	Due Date
• New SAM release includes SNL inverter model with coefficients for all inverters in CEC database. • Release SAM version with major update of user manual with documentation, improved PV performance algorithms, capability of using latest CEC and SNL module and inverter databases, and detailed O&M inputs (annual $, $/MW, $/MWh options).	4/30/2008
Validate SAM vs. measured system data – publish paper.	5/30/2008
• Update GIS-based radiation & meteorological data in SAM performance model, also supporting Industry resource assessment surveys for SAI. • Systems-database with map interface operational • Release SAM version with dish/Stirling models present, enhanced GUI and greater graphical output capability, time-of-use rates	9/30/2008
• Addition of Enhanced Performance Modeling Capabilities to SAM. • Expanded systems database with more reliability/O&M data.	2009
• Enhancement of risk analysis for various planned improvements to SAM. • Addition of diverse technologies to systems database, including Solar America Cities projects.	2010
Providing up-to-date content for most solar systems to modelers. Systems database updated to include TPP systems from Phase 1 contracts; geographic diversity expanded.	2011
• SAM acceptance as standard techno-economic Solar Modeling Tool. • Systems database encompasses publicly-available data and provides comprehensive summary of technologically and geographically diverse systems, with detailed performance and cost data for select, representative systems.	2012

Program Type: Systems Analysis
Project Title: Market, Value, and Policy Analysis
Contractor: NREL
Project Summary: The primary objective of the market, value and policy analysis activity is to provide a broad range of analytical support to the Solar Program. The work carried out under this agreement anticipates and responds to the rapidly evolving analytical needs of the Solar Program.

SETP Project Milestones/Decision Points	Due Date
Publish 1st Annual Solar Market, Cost and Performance Trends report	2008
Publish 2nd Annual Solar Market, Cost and Performance Trends report	2009
Publish 3rd Annual Solar Market, Cost and Performance Trends report	2010

Publish 4th Annual Solar Market, Cost and Performance Trends report	2011
Publish 5th Annual Solar Market, Cost and Performance Trends report	2012

Program Type: PV Grid & Building Integration
Project Title: Grid Integration Studies
Contractor: NREL
Project Summary: The PV Grid Integration activity addresses both the technical and analytical challenges that need to be overcome in order to enable high penetration levels of photovoltaics into the electrical distribution system. This activity will support work initiated in FY07 under the Renewable Systems Interconnection (RSI) effort. The RSI work focuses on the following specific activities related to integrating PV into the electricity distribution system under high penetration: Distributed PV System Technology Development, Advanced Distribution System Integration, System Level Test and Demonstrations, Distributed Renewable Energy System Analysis (Technical and Economic), Solar Resource Assessment, and Standards, Codes, and Regulatory Implementation.

SETP Project Milestones/Decision Points	Due Date
Complete RSI studies and develop a multi-year research plan	2/15/2008
Implement data collection on 2-4 fielded system	06/2008
Annual Report on PV Grid Integration Activities	09/2008
Integrate Solar Resource data and performance models into Distribution Engineering Workstation (DEW) software	09/2008

Program Type: PV Grid & Building Integration
Project Title: Inverter and BOS (Balance of System) Testing and Evaluation
Contractor: SNL
Project Summary: SNL's Distributed Energy Technologies Laboratory (DETL) will lead the reliability testing on inverters and BOS components as the basis of system-level service life determinations. This will be accomplished through maintaining current capabilities and developing new tools to meet upcoming needs and challenges. DETL capabilities will be extended to field evaluations through the acquisition of new equipment and the refinement of existing protocols.

SETP Project Milestones/Decision Points	Due Date
Report demonstrating effectiveness of inverter performance model with measured data, including its use in SAM, and addressing new topologies promised or delivered by TPPs.	3/31/2008
Establishment of "Inverter/Controller/BOS/EMS Industry Advisory Group" for R&D Prioritization for Renewable System Integrations and Energy Management Systems with initial survey released to the membership.	8/31/2008
• Initiate grid integration test and field demonstration program • Establish and implement plan to address key stakeholders including developing briefing package and stakeholder meetings; establish plan for high quality data gathering and analysis of data on fielded systems that represent high penetration of PV on distribution feeders. • Conduct long-term inverter operation detailed laboratory recharacterization and make comparative evaluations to previous evaluations. • Complete all inverter and BOS-related stage-gate evaluation requirements, including feedback to review teams in a timely and complete manner to support the stage gate review process. • Complete performance and operational assessments of at least 3 new inverter and system controller topologies. Examples may include micro-inverters, utility-scale inverters, and new component integrations, such as transformer-less designs. • Publish journal article on linkage between field and lab operational data in	9/30/2008

determining inverter-related aspects of PV systems reliability. • Field Data Collection and Analysis Solar Resource Assessment. Establish plan for high quality data gathering and analysis of data on fielded systems that represent high penetration of PV on distribution feeders. Participants: SunEdison, PowerLight, Solar Integrated Technologies, etc. Potential systems include: Alamosa, Nellis Air Force base, Premier Gardens/SMUD, etc.	
• Complete stage-gate deliverable validations. • Evaluate Advanced Integrated Inverter deliverables. • Acquire field and laboratory data to determine modifications and needs of modeling and analysis tools based on TPP and industry R&D developments. Testbed in place for controlled evaluations of utility-scale inverters and for various micro-grid PV configurations.	2009
Complete Advanced Integrated Inverter deliverable validations. Provide assessment report on state of technology through TPPs and Advanced Integrated Inverter Initiative with recommendations for path forward for DOE leadership.	2010
Attain broad recognition of DETL as testbed for new PV systems configurations under several scenarios, such as high penetration, advanced controls and communications, etc.	2011
Complete all stage gate evaluations and provide data to reviewers. Provide full status report of PV systems technology and recommendations for path forward for DOE program.	2012

Program Type: PV Grid & Building Integration
Project Title: Inverters, BOS and Energy Management R&D
Contractor: SNL
Project Summary: The most critical factor in assuring PV technology progress and for sustainable markets is the development of advanced, integrated, highly reliable and cost effective inverter, controller, BOS and energy management system technologies. In addition to support for conventional PV system inverter developments, this project proposes the establishment of a unique integrated controller/micro grid at SNL to support developments for smart inverters/controllers/BOS and energy management.

SETP Project Milestones/Decision Points	Due Date
• Complete formation of the Industry Advisory group to help guide future R&D related to inverter/controller/BOS and energy management. • Establish baseline integrated controller/micro-grid facility at SNL. • Complete specifications and design of 150-kW PV array simulator.	2008
• Coordinate Industry Advisory group to help guide R&D related to inverter/controller/BOS and energy management with one workshop. • Complete baseline integrated controller/micro-grid facility at SNL. • Complete and install 150-kW PV array simulator	2009
• Coordinate Industry Advisory group to help guide R&D related to inverter/controller/BOS and energy management with one workshop. • Complete validations of integrated controller/micro-grid/utility integrations for system optimizations, utility stabilization and economic benefit analysis	2010
Coordinate Industry Advisory group to help guide R&D related to inverter/controller/BOS and energy management with workshop for links of advanced inverters/energy storage and utility integrations	2011
Demonstrate integrated controller/micro-grid and advanced integrated power electronics	2012

Program Type: PV Grid & Building Integration
Project Title: Inverters, BOS and Energy Management
Contractor: SNL
Project Summary: The activities in this proposal will focus on new advanced integrated inverter, controller, balance-of-system, and energy management hardware and control technologies that target dramatic improvements in reliability, MTBF, costs and system performance as compared to the current state of the art technologies. The hardware and controls must be compatible with residential and commercial applications ranging from 100W through 250kW with the larger applications likely to use modular system configurations. The concept that an inverter is also the controller, or is fully integrated with a controller that provides value-added features including energy management will also be developed.

SETP Project Milestones/Decision Points	Due Date
Review and select applications and proposals for the AII/EMS Program with technical support for Statement of Project Objectives (SOPOs) and/or Statements of Work and early design analysis.	2008
Refine the SNL base-line circuit design tool to model circuit topologies and determine waveforms, critical set point interactions, maximum power point tracking effectiveness, harmonics, and dynamic responses that will be released to industry once validated.	2009
• Conduct "Stage-Gate" reviews and provide technical support such as SNL's Topology Development Model for cooperative agreements and contracts in developments that require support using existing laboratory expertise in activities such as circuit board evaluations, developmental modeling, materials compatibilities, corrosion resistance, integrated circuit developments, etc. • Refine and publish details of the tool to model circuit topologies and determine waveforms, critical set point interactions, maximum power point tracking effectiveness, harmonics, and dynamic responses and then released to industry.	2010
Continue Phase I reviews and technical monitoring while initiating Phase II for the program.	2011
• Review and select applications and proposals for Phase II of the AII/EMS Program with technical support for SOPOs and/or Statements of Work and early design analysis. • Establish a focus on the distributed and digitally controlled future grid.	2012

Program Type: PV Grid & Building Integration
Project Title: SEGIS Solicitation
Contractor: SNL
Project Summary: The SEGIS program is a 3-year, 3-Stage effort (approximately one year per stage) that emphasizes the development of advanced inverters, controllers, and other BOS components for distributed PV power applications. The critical components to be developed in this effort are highly integrated and innovative inverters/controllers and associated BOS elements (including communications technologies, energy storage, energy management, and numerous interface options) for residential and commercial solar energy applications.

SETP Project Milestones/Decision Points	Due Date
SEGIS Proposals Review Completed at SNL	3/21/2008
SEGIS contracts for Stage 1 (Conceptual Designs) to multiple contractors.	6/20/2008
Publish on SEGIS Web Page and Links a list of winning Stage 1 contractors and subject matter.	7/15/2008
SEGIS Stage 1 Quarterly Reports to SNL for contracts under way.	9/30/2008

Program Type: Reliability R&D
Project Title: PV Reliability Program
Contractor: NREL/SNL
Project Summary: This program fast-tracks accelerated testing protocols, leverages the reliability skill set already developed in other areas in SNL (i.e., weapons), and seeks to develop and validate service lifetime predictions for PV systems and components. The objective of this effort is to develop and apply a process (data, methodology, & model) that industry and other stakeholders can use to predict, detect, and mitigate reliability issues in PV components and systems.

SETP Project Milestones/Decision Points	Due Date
• Retrieve inverters for repeat of baseline test and redeploy • Publication of test-to-failure protocol report • Complete fault tree for one c-Si manufacturer's product (Failure Modes) - SNL	3/2008
• Develop reliability program plan that establishes reliability criteria for PV systems • Develop a draft ALT protocol for inverters and a strategy to incorporate ALT into BOS considerations for predictive modeling. • NREL/SNL will jointly develop reliability program plan that establishes reliability criteria for PV systems	4/2008
Complete a materials-based failure mode analysis for one c-Si product with input from NREL and industry (Identify critical manufacturing process/ product variables to be controlled)	5/30/2008
• Report documenting results of the Accelerated Aging and Reliability Workshop • Draft Technical Report outlining critical success factors and approach to building a robust reliability program (SLP) NREL/SNL • Complete a materials-based failure mode analysis for one c-Si product (Failure Mode) - SNL (EC) Albin will coordinate • Build large-sample set ALT system for cell level testing • Experimental design for accelerated aging of a CIS PV technology • Establish experimental designs for accelerated aging of one c-Si module / system	6/2008
• Identify critical c-Si manufacturing process/product variables to be controlled. • Report on module/inverter reliability data based on integrator experience and manufacturer returns • Report documenting results of the Accelerated Aging and Reliability Workshop (NREL/SNL) • Complete fault tree for one c-Si manufacturer's product. Exercise system reliability model for this technology.	7/31/2008
Technical report that details assembled data, defines additional data needs, and details predictive model architecture and initial predictive results for a c-Si technology application (SLP)	8/29/2008
• Complete initial demonstration of reliability modeling process. Use results to define additional information needed for a robust model. • Complete installation and fit-up of four new environmental chambers in the OTF high-bay laboratory (NREL) • Field minimodules/coupons (TPP participants will be given priority) expecting commercialized or near- commercial products in FY08 • Assessment of fielded module reliability in system throughout the U.S. • Complete initial demonstration of reliability modeling process. Use results to define additional information needed for a robust model. • Complete preliminary materials-based failure mode analysis for 1 CIS product	9/2008

• Issue Reliability Program Plan • Complete initial demonstration of modeling process providing data needs & sensitivities • Document initial FMEA/FTA for priority applications (CIS, c-Si) • Identify acceleration factors for adhesion in hot/humid environment to validate adhesion test protocol • Publish screening test protocol for TPP & Incubator reliability evaluation	2008
Achieve first validated module/system lifetime predictive model [f(t) in specified environment for applicable modes]	2010
• Document service life prediction for least LCOE system produced in TPP phase 1 activities • Attain industry adoption of PV reliability methodology	2012

Program Type: Regional Experiment Stations
Project Title: Southeast Regional Experiment Station (SERES)
Contractor: SNL
Project Summary: The SERES at the Florida Solar Energy Center/University of Central Florida provides technical support to DOE's Solar Energy Technology Program by testing and evaluating the performance of PV systems in hot, humid climates. Key activities: 1) PV systems analysis; 2) Benchmarking of PV systems performance/costs/reliability and validation of same; 3) PV systems design assistance and reviews for PV industry; 4) Field and acceptance testing of PV systems; and 5) PV systems performance measurements for safety, reliability, performance and consumer acceptance.

SETP Project Milestones/Decision Points	Due Date
Milestones currently being developed.	Pending

Program Type: Regional Experiment Stations
Project Title: Southwest Regional Experiment Station (SWRES)
Contractor: SNL
Project Summary: This project is focused on increasing the viability and deployment of renewable energy technologies. The scope of SWRES activities includes tasks in the areas of System Benchmarking and Validation, PV System Performance and Standards, PV Technology Adoption, and Inverter Testing and Industry Support.

SETP Project Milestones/Decision Points	Due Date
Milestones currently being developed.	Pending

Program Type: Resource Assessment & Characterization
Project Title: Solar Resource Assessment and Metrology
Contractor: NREL
Project Summary: This proposal addresses solar resource modeling and measurement activities necessary to make available the necessary information to support rapid growth in grid-tied PV and CSP applications, building applications, and the R&D community. Data needs to support this growth include improved data reliability, spatial and temporal resolutions and data sources, and products such as short-term and day-ahead solar resource forecasting.

SETP Project Milestones/Decision Points	Due Date
• Complete a test and validation of a solar resource forecasting application. • Optical Metrology (calibration) support (NREL Pyrheliometer Comparisons, Calibrations, Spectral distributions for SAI sites, instrumentation loans)	9/30/2008

• Optical Metrology calibrations, Reports and instrumentation, NREL pyrheliometer Comparison (NPC) • NSRDB Updates and forecasting feasibility study • Satellite Data 10 km 1983-1998 retrofit • Outreach Improved customer interface	2009
• ISO 17025 Accreditation Optical Metrology (spectral/broadband) • Metrology: Calibrations, Reports, International Pyrheliometer Comparison (IPC), Davos, Switzerland • Data and Model Access; Industry interaction/support report • High time/Space Resolution model/forecasting validation • Revised satellite-based solar resource methodology with improved AOD and terrain algorithms • PVWatts V2 for NSRDB2 and gridded data tool • Operational forecast tool/Report	2010
• Metrology Activities/calibrations/reports, loans, NPC • Data / Model Activities; Industry interaction/support • Report on benchmarking of international data sets • PV Watts update tools • Forecasting methodology	2011
• Metrology Activities • Data / Model Activities; Industry interaction/ support; updates • Release of 1981-2010 NSRDB • Report on recent solar resource trends	2012

Program Type: Environmental Safety & Health/Lifecycle Research
Project Title: Environmental Safety & Health
Contractor: Pending
Project Summary: The major objectives of this project are to assist in preserving the safe and environmentally friendly nature of PV and minimize ES&H risks and associated costs to ensure the public support and economic viability of PV systems; identify potential ES&H barriers of photovoltaic materials, processes or applications and define strategies to overcome such barriers; and, maintain the Center as the world's authority on PV-ES&H, providing accurate information related to ES&H issues and perceptions.

SETP Project Milestones/Decision Points	Due Date
Support SAI TPP's in resolution of life cycle issues resulting from new process/product designs -- conduct critical EIA investigations where appropriate.	9/30/2008

4. PV Market Transformation

Program Type: Codes & Standards
Project Title: Codes & Standards
Contractor: NREL/SNL
Project Summary: This project will overview the various existing PV codes and standards, and will seek to develop draft standards for review by industry.

SETP Project Milestones/Decision Points	Due Date
Update information on IEEE PV standards and projects and consider new or modifications to IEEE PV standards and codes projects (ongoing).	2/28/2008
Summary report on contributions and interactions with existing bodies, including NEC, UL, IEC, IEEE, IBC NAHB, etc., with a discussion of their receptiveness to new SAI directions.	8/15/2008
• Provide periodic reports and annual letter report (September 2008) addressing the status and accomplishments pertaining to critical PV market barriers related to codes, standards, certification, related infrastructure enhancements. • Develop draft standards and issues for industry review and feedback.	9/30/2008

Program Type: Codes & Standards
Project Title: Solar America Board of Codes and Standards (Solar ABCs)
Contractor: New Mexico State University
Project Summary: The Solar Codes and Standards Working Group (SCSWG) will improve responsiveness, effectiveness, and accessibility of codes and standards to U.S. solar stakeholders at all levels. In addition, the SCSWG focus will be on planning, as needed to support the new technologies of the TPP award winners.

SETP Project Milestones/Decision Points	Due Date
The SCSWG web site will be on-line within six months of project start. The web site will remain in use throughout the five year project period, during which time, it will remain the primary source of communication to and from PV stakeholders and members of the *Steering Committee*.	10/2007
Steering Committee will develop a comprehensive Gap Analysis of the current state of the major codes and standards for solar. This will be based on the activities of the working panels and the reports from the one-year study areas.	10/2008
1. Interconnection Standards Study (IREC/BEW) 2. Net Metering Study (IREC/BEW) 3. Local and Building Codes Study (FSEC/IREC) 4. PV/CSP Product Standards Study (FSEC/ASU/UL)	2007-2008

Program Type: Codes & Standards
Project Title: PV Capacity Credit Valuation Study
Contractor: State University of New York (NY)
Project Summary: The objectives of this project are:
To establish a set of consensus-driven standard methodologies to quantify PV capacity credit that are acceptable to all concerned stakeholders: utilities/grid operators, solar industry and advocacy groups; to document and describe the methodologies as a function of the relevant parameters affecting capacity, including PV generation, load demand, and market structure; and to disseminate results via papers, presentations and targeted technical articles.

SETP Project Milestones/Decision Points	Due Date

A face-to-face meeting of all parties involved with the objective of approaching such a consensus (Case studies).	9/2007
A dissemination phase including publications and presentations. (Team & Stakeholders Meeting/Workshop).	12/2007

Program Type: Codes & Standards
Project Title: PV Capacity Credit Valuation Study
Contractor: Tucson Electric Power (AZ)
Project Summary: Tucson Electric Power (TEP) will develop, test and verify a new and appropriate method for accurately evaluating the capacity credit of time variant solar generating sources and to develop new methods to appropriately and fairly evaluate the value of solar generation to electric utilities. The project will also propose general integrated approaches for adequately compensating owners of solar generation for their benefits to utilities.

SETP Project Milestones/Decision Points	Due Date
Develop Analysis Model	7-9/2007
Extract and Process Data from SGSSS	1/2008
Develop Integrated Solar DG Approaches	3/2008
Evaluate Model Analysis Results	4/2008
Develop and Complete Final Project Reporting	6/2008

Program Type: Workforce Development: Education and Training
Project Title: PV Installer Certification – NABCEP
Contractor: NABCEP
Project Summary: The NABCEP Program is a national, program designed to provide voluntary certification for those PV installers who demonstrate the requisite skills, abilities and knowledge typically required to install and maintain PV systems. Certification of PV installers will be achieved through certification examination.

SETP Project Milestones/Decision Points	Due Date
Milestones currently being developed.	Pending

Program Type: Workforce Development: Education and Training
Project Title: PV Installer Training – IREC
Contractor: IREC
Project Summary: This project addresses five different areas, which will allow for more effective assessment of the solar service industry and implementation of project goals:

- RFI to assess local workforce needs
- Curriculum development
- Faculty development
- Facilities development
- Student job placement

SETP Project Milestones/Decision Points	Due Date
Manage the PV Training and Certification Task Force under the Solar America Initiative and prepare a white paper with recommendations of needs nationally in PV education, training and certification.	1/7/2008

Program Type: Technical Partnerships
Project Title: Government Solar Installation Program (GSIP)
Contractor: SNL
Project Summary: This project seeks to lower solar costs by building demand to encourage increased production, and help Federal agencies meet renewable energy requirements.

SETP Project Milestones/Decision Points	Due Date
Train tiger team members on lessons learned from past solar technical assistance projects for Federal Government installations.	3/24/2008
• Merit review • Selection and negotiation of power purchase agreement on Forrestal building • 200 KW installation	4/1/2008
Provide technical assistance for DOE-selected GSIP projects, including Architects-on-the-Capitol, NAVFAC SW, and SNL solar site survey.	9/24/2008

Program Type: State/Utility Technical Outreach
Project Title: Utility Technical Outreach
Contractor: Solar Electric Power Association (DC)
Project Summary: The project seeks to stimulate the increased utility adoption and integration of solar electric technologies (hereafter "solar"), on either side of the meter, by providing a variety of support services and information to electric utilities (hereafter "utilities") throughout the United States. The expected outcomes include the development of new utility solar programs, the expansion of existing utility solar programs, increased utility and customer-owned solar installations, and increased general awareness and understanding of solar technologies and applications by utility employees.

SETP Project Milestones/Decision Points	Due Date
Contracting for three research and analysis projects that will fill gaps to the large-scale adoption of solar directly by utilities.	2007-2008
Developing and disseminating a "Utility Solar Toolkit" to nearly all utilities in the U.S..	2008-2009
Providing direct utility support services to a list of target utilities throughout the U.S.	2009-2010

Program Type: State/Utility Technical Outreach
Project Title: State Technical Outreach
Contractor: Clean Energy Group (VT)
Project Summary: A major project focus will be to identify, track, evaluate, communicate and facilitate state adoption of effective financial, policy and technology activities and best practices that accelerate solar technology use and markets across the country.

SETP Project Milestones/Decision Points	Due Date
Developing a distribution plan to disseminate informational materials to membership groups and other stakeholder groups as designated by DOE.	2007
State Policymaker Education and Outreach	2008
• Coordination of Efforts with Other Groups • Partnership Development • Solar Market Research and Public Education • Renewable Portfolio Standard (RPS) Implementation Collaborative	2007, 2008, 2009

Program Type: State/Utility Technical Outreach **Project Title:** State Technical Outreach **Contractor:** National Association of Regulatory Utility Commissioners (NARUC) (DC) **Project Summary:** This project attempts to foster dialogue among, and educate, State Officials and provide them with the resources and technical basis needed to effect changes to state policy and regulation. In the longer term, the goal is to increase the implementation of policies that foster solar technology deployment.	
SETP Project Milestones/Decision Points	**Due Date**
• Develop a solar technologies and policies primer for state officials. • Host workshops at NARUC's 2007 Annual Convention in Anaheim and 2008 Winter Committee Meetings in Washington • Host a webcast version of the workshop, allowing the information from the primer to be disseminated to a very broad audience of DOE designated stakeholders	2007-2008
Release updated 2009 "Renewable Portfolio Standard: A Practical Guide"	2008-2009
Work with NCSL, CESA, IREC and others to promote the guide's use by policymakers.	2009
Linking Solar technology with Ancillary Services Markets, Peak Demand Management, and Demand Response programs	2009
• Developing a distribution plan to disseminate informational materials to membership groups and other stakeholder groups as designated by DOE. • Presentation of White Paper results at Summer and Winter Meetings	2010

Program Type: State/Utility Technical Outreach **Project Title:** State Technical Outreach **Contractor:** National Conference of State Legislatures (CO) **Project Summary:** The National Conference of State Legislatures' Solar Energy Project will provide outreach to state policymakers on solar technology and policy options that can assist in integrating solar energy into the fuel mix while breaking down market barriers to the adoption of solar energy. The project will communicate the economic, energy security and fuel diversity benefits of solar energy to state policymakers; provide policymakers with options for creating policies that increase the use of solar energy; and create a forum where policymakers can share ideas and learn from their cohorts and other stakeholders.	
SETP Project Milestones/Decision Points	**Due Date**
Developing a distribution plan to disseminate informational materials to membership groups and other stakeholder groups as designated by DOE.	2007-2008
• NCSL will create a LegisBrief on Solar Technology and state policy activities. NCSL LegisBriefs are two-page issue briefs on the important issues of the day for state legislatures. • Solar Energy Institute: This meeting will bring together issue area experts, state legislators and other stakeholders in a seminar targeted toward state legislators and legislative staff, using NCSL's intimate knowledge of state legislatures.	2008-2010

Program Type: Technical Outreach **Project Title:** Solar America Showcases **Contractor:** SNL **Project Summary:** This project provides national lab support for the Solar America Showcases.	
SETP Project Milestones/Decision Points	**Due Date**
• Develop Statements-of-Work and project plans for two selected Solar America Showcase awardees: Forest City Military Communities and City of San Jose. • Assemble teams and provide solar technical assistance for two Solar America Showcases (Forest City Military Communities & City of San Jose) and possibly one additional Solar America Showcase winner in an FY08 selection round.	9/24/2008

Program Type: Solar America Showcases
Project Title: City of San Jose
Contractor: National Renewable Energy Laboratory (NREL)
Project Summary: NREL will provide technical and cost-benefit analysis in evaluating the potential of placing photovoltaic and solar-thermal systems on multiple large buildings and complexes in San Jose, CA.

SETP Project Milestones/Decision Points	Due Date
Initial coordination meeting and preparation of detailed timetable/project tasks and teams (analysis, financial, bid preparation)	1 month after MOA execution
Ongoing coordination – monthly update meetings	Monthly
Analysis of solar potential, technology applications	2-5 months
Identification of financial assistance opportunities, constraints and opportunities	2-4 months (could be concurrent with above task)
Assistance in preparation of bid specifications	2-6 months

Program Type: Solar America Showcases
Project Title: Forrest City Military Community
Contractor: SNL
Project Summary: In 2004, Forrest City Military Communities entered into a joint venture with the Department of the Navy to build or refurbish 6500 homes for military families on U.S. Naval and Marine bases in Hawaii. Members of the technical assistance team will provide them with ideas on how to incorporate solar hot water and photovoltaics into their development.

SETP Project Milestones/Decision Points	Due Date
Technical metering specifications for assessment of existing solar thermal systems	08/31/2007
Analysis and recommendations for use of PV on Forest City warehouses	01/2008

Program Type: Solar America Showcases
Project Title: Orange County Convention Center
Contractor: Florida Solar Energy Center (FSEC)
Project Summary: FSEC will provide technical assistance to the Convention Center for the installation of a 700 kW PV system on their roof. Project has just received funding and will commence soon.

SETP Project Milestones/Decision Points	Due Date
Site survey of the Convention Center roof	01/2008
Assistance in writing technical specification for the PV system	03/2008
Design review and assistance in the selection process	06/2008
Acceptance testing	08/2008
PV System Monitoring	09/2008

Program Type: Technical Outreach
Project Title: Solar America Cities
Contractor: SNL
Project Summary: This project provides national lab support for the Solar America Cities.

SETP Project Milestones/Decision Points	Due Date
Develop Statements-of-Work and project plans for provision of solar technical assistance to five cities: Ann Arbor, Austin, Madison, Pittsburgh, and Salt Lake City.	3/31/2008
Form Tiger Teams and provide solar technical assistance to five Solar America Cities: Ann Arbor, Austin, Madison, Pittsburgh, and Salt Lake City.	9/24/2008

Program Type: Solar America Cities
Project Title: Solar America City - Ann Arbor
Contractor: Ann Arbor, MI
Project Summary: The goal for this program is to utilize a wide range of community partners and resources to remove market barriers to the adoption of solar energy while simultaneously increasing consumer awareness and demand, and helping solar energy manufacturers and contractors to succeed.

SETP Project Milestones/Decision Points	Due Date
• Develop a Solar Plan to Identify and Reduce Barriers to Solar • Expand The Plan To Other Jurisdictions • Propose Commercial and Residential Solar Installations • Implements City Level Solar Incentives • Integration of Energy Efficiency & Renewable Energy Into K-12 Curriculum • Development of Solar Installer Training: Train local solar energy installers trade skills and successful business development practices	2007-2010

Program Type: Solar America Cities
Project Title: Solar America City - Solar San Francisco
Contractor: San Francisco
Project Summary: The City and County of San Francisco's "Solar San Francisco" Initiative will strive to remove barriers to the deployment of solar technologies in San Francisco as part of its effort to reduce its overall greenhouse gas emissions to 20% below 1990 levels by the year 2012.

SETP Project Milestones/Decision Points	Due Date
Develop a program to group commercial and residential customers into one or more large, aggregated purchasing pools to be marketed to two different types of prospective solar installers.	2007
Identify sites for large installations and marketing to those building owners.	2008
Develop a plan to address problems installing solar on multi-tenant buildings.	2009

Program Type: Solar America Cities
Project Title: Solar America City - New York
Contractor: The City of New York
Project Summary: The activities under the Solar America City Partnership will include: the development of a long-term solar energy plan, a feasibility study of real-time pricing for PV net metering, an evaluation of how best to integrate solar energy into emergency planning and demand reduction programs, the creation of new municipal solar energy incentives, and collaborative stakeholder processes focusing on interconnection and code barriers. The Partnership will also seek to advance close to five hundred kilowatts of planned PV capacity, and explore the use of innovative financing and ownership structures to accelerate the pace of in-City solar energy development. The City will work with the New York State Energy Research and Development Authority to expand solar energy training activities at the community college level and work with local schools to integrate clean energy into K-12 curricula. These activities will ensure that short term barriers are addressed, that the solar energy market continues to expand, and that the workforce is equipped to take advantage of solar energy opportunities within the five boroughs.

SETP Project Milestones/Decision Points	Due Date
Lay the foundation to support a growing industry by reducing barriers and educating the labor pool.	2007
Use the City's resources to spur the market and create economies of scale to lower prices.	2008
Create the institutions to plan and monitor future growth.	2009

Program Type: Solar America Cities
Project Title: Solar America City - Midwest Solar America City Model (MadiSUN)
Contractor: City of Madison
Project Summary: Under the MadiSUN program, the City of Madison will coordinate and galvanize substantial local and state resources with a motivated population to showcase how a U.S. Midwest city can dramatically increase the use of solar energy. The City of Madison adopted the objective of: "Making Madison a green capital city, a national leader in energy efficiency and renewable energy that also supports the city's economics vitality."

SETP Project Milestones/Decision Points	Due Date
MadiSUN solar team goal is to have 250 kW of PV and 200 solar hot water systems installed by 2010	2010

Program Type: Solar America Cities
Project Title: Solar America City-Solar Now!
Contractor: City of Portland
Project Summary: City of Portland's Solar Now! program will pursue solar market transformation for Portland residents, businesses, and city operations. The program will work with other City bureaus to ease the regulatory process by streamlining city-level regulations for contractors, homeowners and businesses. The City will use its influence as a regulator, educator and motivator to reach the larger regional community. City of Portland will facilitate market transformation as an end user of solar technology on its own facilities, as well as use proven marketing and outreach strategies to promote solar adoption within the commercial and residential public. Solar Now! will work with other jurisdictions to promote solar as renewable energy option. In collaboration with its partners and in partnership with the Solar America Initiative, by year 2010, the City of Portland will have become a leader in solar energy.

SETP Project Milestones/Decision Points	Due Date
• Increase market demand among local residents and businesses • Provide high level policy support to solar market transformation Provide high level policy support to solar market transformation • Streamline City-level regulations and practices that affect solar adoption	2007-2009

Program Type: Solar America Cities
Project Title: Solar America City - Smart Solar Program: A Partnership to Serve the East Bay
Contractor: City of Berkeley
Project Summary: The goals of this project are to (1) accelerate the adoption of solar technology at the local level by engaging the City, service providers, end users and regulators; (2) provide a model for other cities; and (3) promote solar technology among residents and local businesses. This will be achieved by developing and piloting a turn-key program to install solar photovoltaic (PV) and solar hot water and air heating (SWAH) systems in the residential and small-to-medium commercial/public sectors. This program approach will use a city-sanctioned third party that is independent of installing contractors and/or product manufacturers, to represent owners in specifying, purchasing and managing energy efficiency projects.

SETP Project Milestones/Decision Points	Due Date
Phase I: Program Development. Development of a complete business plan for Smart Solar, a turn-key program to install solar photovoltaic (PV) and solar hot water and air heating (SWAH) systems in the residential and small-to-medium commercial/public sectors.	Pending
Phase II: Pilot Operations. Roll out a pilot program within the City of Berkeley. Install 142 kW of PV installations producing 219,000 kWh annually, and 10 solar SWAH systems producing at least 30 therms per month, at 10 residential and 5 commercial/public sites. Update the business plan for deployment under the East Bay Energy Watch, the utility-administered local government partnership.	Pending

Program Type: Solar America Cities
Project Title: Solar America City - Tucson Solar Initiative
Contractor: City of Tucson
Project Summary: The Tucson Solar Initiative will develop a comprehensive City and regional approach to solar implementation that involves key stakeholders, utilities and private partners. Tucson Solar Initiative partners include the City of Tucson, Tucson Electric Power Company, Greater Tucson Coalition for Solar Energy, Tucson-Pima Metropolitan Energy Commission, the Arizona Department of Commerce Energy Office, and neighboring jurisdictions in southern Arizona.

SETP Project Milestones/Decision Points	Due Date
Expand the Tucson solar market through accelerated investments. Expected outcomes – A City of Tucson Solar Energy Integration Plan, a Greater Tucson Solar Energy Development Plan & two megawatts (MW) of solar capacity installed by 2015.	Pending
Transform financial barriers into opportunities for solar installations. Expected outcome – Financing techniques for large-scale solar energy installations.	Pending
Transform informational barriers into opportunities for solar installations. Expected outcome – Solar energy best practices and outreach to the region.	Pending

Program Type: Solar America Cities
Project Title: Solar America City - Solar Salt Lake Program
Contractor: Salt Lake City
Project Summary: Through the development of the "Solar Salt Lake" program, our goal is to develop a fully-scoped city and county-level implementation plan that will facilitate at least an additional ten megawatts of solar photovoltaic (PV) installations in government, commercial, industrial, and residential sectors by 2015. To achieve this aggressive goal, our program strategy includes a combination of barrier identification, research, and policy analysis that utilizes the input of various stakeholders. The result will be a comprehensive plan for Salt Lake City and Salt Lake County that supports long-term solar deployment, including integration into City/County planning and facilities, the introduction of policies and regulations that support solar adoption, the integration of solar in new housing developments, evaluation of solar bonds and other funding sources, and community-wide solar education and outreach.

SETP Project Milestones/Decision Points	Due Date
Deliverable 1: Identify barriers to solar deployment in Salt Lake City and Salt Lake County and determine the best strategies to reduce or eliminate them.	Pending
Deliverable 2: Design a comprehensive city and county-wide solar implementation plan to support the "Solar Salt Lake" program. This long-term plan will call for at least an additional 10,000 government, residential, and commercial installations by 2015.	Pending

Program Type: Solar America Cities
Project Title: Solar America City - Austin Solar America City Partnership
Contractor: City of Austin
Project Summary: The City of Austin will collaborate with local school districts in the development of public school curricular materials for use in conjunction with solar facilities that are already in place and additional ones that will be installed at several of the district schools. In addition to these educational and promotional activities, the City of Austin is proposing two technical studies: to assess the potential for solar power generation from roof areas of commercial and other buildings and to assess the merit of hybrid solar-wind generation that can be transferred from west Texas.

SETP Project Milestones/Decision Points	Due Date
• To educate the city's teachers and younger citizens about the benefits of clean energy • To reduce or eliminate information barriers that prevent citizens from participating in the city's extensive renewable energy and energy conservation programs. • To install highly-visible solar energy facilities at public schools. • To establish groundwork for achievement of medium- and long-term City of Austin goals by engaging in directed research projects. • To establish reasonable goals and benchmarks for distributed and central station solar projects that can be integrated into the utility's generation plan.	Pending

Program Type: Solar America Cities
Project Title: Solar America City - Sustainable Energy 2050 Plan
Contractor: City of San Diego
Project Summary: This is a 2 year Solar America City award designed to demonstrate policies, technologies and strategies requires at the local level to achieve the goals of the Solar American Initiative. This project will address issues with tariffs, data management, expedited permitting, deepening private sector involvement, training and technical expertise and long-range implementation in the City of San Diego.

SETP Project Milestones/Decision Points	Due Date
• Update and expand GIS analysis of solar installations and potential future sites. • Conduct performance analysis of around 12MW of existing PV systems. • Develop three case studies that explain the process used for designing, planning, installing and monitoring solar energy systems and provide energy and financial analyses. • Use four focus groups comprised of key stakeholders in the community to clarify the viability of installing solar energy systems. • Study the impact of solar on property values/resale. • Design and produce outreach material as a means to stimulate a robust project pipeline within the City limits. • Prepare and deliver a Citywide solar implementation plan.	2009

Program Type: Solar America Cities
Project Title: Solar America City - Solar Boston
Contractor: City of Boston
Project Summary: Solar Boston will address market demand by developing a public outreach marketing plan that targets owners of sites identified by mapping with responses to potential customer inquiries, pre-screening and site visits. Solar Boston will address market supply by planning a bulk purchase of solar infrastructure, a project-labor agreement with the International Brotherhood of Electrical Workers (IBEW) Local 103, developing a financing mechanism for the bulk installation of solar technology, and creating Solar Boston, Inc. The non-profit will then manage the bulk procurement and installation. Building on three school installations, Solar Boston will continue work to integrate solar technology development in the curriculum of the Boston Public Schools. Overall, the City of Boston's reinvigoration of Solar Boston will build on eight years of work under the Solar Boston program originally created in conjunction with the U.S. DOE's Million Solar Roofs and Solar Powers America programs, particularly Massachusetts Energy Consumers Alliance's lead role.

SETP Project Milestones/Decision Points	Due Date
The City anticipates that the city-wide bulk installation proposed for **2008-2010** to be managed by the **Solar Boston Partnership's** non-profit successor entity will result in the installation of **2 MW** solar capacity with ongoing capacity to manage **at least 1 MW solar installation per year**, with **10 MW by 2015.**	Pending

Program Type: Solar America Cities
Project Title: Solar America City - "City Planning Activities in Support of Strategic Partnership with the Department of Energy"
Contractor: City of New Orleans
Project Summary: This is a 2 year Solar America City project designed to accelerate the adoption of solar technology in New Orleans by building long term partnerships, training developers, builders and craftspeople and eliminating obstacles to solar adoption that are in the City codes and regulations.

SETP Project Milestones/Decision Points	Due Date
• Plan and initiate a publicity and outreach program to induce demand for solar amongst individuals, businesses, and institutions. • Study current and future incentives that promote and support solar technology in public and private development. • Analyze and recommend modifications and enhancements to the city's codes, regulations, and policies in order to foster the adoption of solar technologies. • Attract commercial suppliers and manufacturers of solar technologies and services, and develop a "green collar" workforce training program that offers the requisite skills necessary for the adoption of solar technology in New Orleans' marketplace. • Foster the adoption of solar technologies in municipal buildings, beginning with schools.	Pending

Program Type: Solar America Cities
Project Title: Solar America City - Solar America City
Contractor: City of Pittsburgh
Project Summary: The City of Pittsburgh's programs will be designed to complement and improve upon the state initiatives to make solar power affordable enough to be embraced by all sectors.

SETP Project Milestones/Decision Points	Due Date
• Encourage adoption of solar energy by residential and small-scale commercial users to demonstrate that the technology works and will lower their energy bills in the long run. • Identify and adapt, when appropriate, the best practices for such incentives nationwide.	Pending

Program Type: Technical Outreach
Project Title: Program Communications
Contractor: NREL
Project Summary: Outreach activities will seek to: update the EERE website with content on CSP and Solar America Cities; create SAI photo database; and completion of strategic communications planning activities.

SETP Project Milestones/Decision Points	Due Date
FY07 SETP Annual Report: Produce report on all SETP activities for FY07, including work done for SETP at all labs.	7/30/2008
• Completed EERE CSP Web sub site: Create a robust Web presence on the EERE SETP Web site to represent CSP technologies and program activities. • Exhibit at International Builders Show, ASES, and SEPA conferences. Produce exhibit, exhibit materials, and staff exhibit. • Solar America Cities Web site: Complete consulting and content editing activities related to development of Solar America Cities website. • SAI photo database: Select database tool, populate with photos, and conduct awareness campaign to inform targeted users of its existence. • Completion of strategic communications planning activities for Solar America Cities, Utility Outreach, State Outreach, and Codes & Standards.	9/30/2008

5. Concentrating Solar Power

Program Type: Parabolic Trough R&D
Project Title: Parabolic Trough R&D
Contractor: NREL
Project Summary: This series of projects intends to do a number of tests on collectors and thermal materials research.

SETP Project Milestones/Decision Points	Due Date
Demo TOP Systems in Arizona	3/19/2008
• Complete instrumentation and qualification tests for NREL optical efficiency test loop • Train FPL personnel on the Infrared HCE Survey Technique	3/31/2008
• Complete optical testing of one or more industry-supplied collector designs integrated with next-generation heat collection element • Report or technical paper on the distant observer feasibility study/prototype.	9/30/2008
Measured data for molecular heat conduction study involving inert gases, hydrogen, and their mixtures in a parabolic trough receiver at various temperatures and pressures	6/30/2008

Program Type: Parabolic Trough R&D
Project Title: Parabolic Trough R&D
Contractor: NREL/SNL
Project Summary: This project seeks to develop advanced receiver selective coatings and capabilities/tools for optical and thermal performance testing of receivers and concentrators. This project will also focus on improving access to parabolic trough information and tools for stakeholders and industry.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D
Project Title: Trough Systems Integration
Contractor: NREL
Project Summary:

- Organize trough and thermal storage R&D sessions for SolarPACES symposium and report on findings.
- Report on CSP power plant water needs.

SETP Project Milestones/Decision Points	Due Date
Organize parabolic trough and thermal storage R&D sessions for SolarPACES Symposium in the U.S.	3/31/2008
Complete report on CSP power plant water needs and how to address them.	6/30/2008
Report summarizing industry support activities	9/30/2008

Program Type: Parabolic Trough R&D **Project Title:** 3M **Awardee:** Cleanable and Hardcoat Coatings for Increased Durability of Silvered Polymeric Mirrors **Project Summary:** Improved abrasion resistance and cleanability of the front surface of a silvered polymeric mirror that decreases the rate of reflectance loss and irreversible soiling by 50% relative to an untreated surface.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D **Project Title:** Reflector Technology Development and System Design for Concentrating Solar Power (CSP) Technologies **Awardee:** Alcoa **Project Summary:** Lower trough system costs through design optimization of the collector assembly including reduced reflector weight, improved supporting structure joint design, and increased reflector stiffness.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D **Project Title:** Parabolic Trough Collectors **Awardee:** Solucar/Abengoa **Project Summary:** Development of innovative and improved parabolic trough concentrator designs that can have a major impact on cost.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D **Project Title:** Advanced Polymeric Reflectors **Awardee:** Solucar/Abengoa **Project Summary:** An advanced solar reflective material will be transitioned from laboratory scale to limited production runs at commercial scale.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D **Project Title:** High Value Mirrors **Awardee:** PPG Industries **Project Summary:** Develop mirrors that include an inorganic coating that protects the mirror from chemical attack, an organic coating that protects the mirror from mechanical attack, and a low-cost fabrication process.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D **Project Title:** Linear Fresnel Power Tower CSP Plant **Awardee:** SkyFuel **Project Summary:** Advanced CSP system using linear Fresnel reflective technology to achieve significantly lower delivered electricity costs from utility-scale solar thermal plants.	
SETP Project Milestones/Decision Points	**Due Date**
Pending contract negotiations.	Pending

Program Type: Parabolic Trough R&D **Project Title:** Advanced High-Temperature Trough Collector Development **Awardee:** Solar Millennium **Project Summary:** Design and manufacture of a higher performance, lower cost, trough collector system with the potential to operate with molten salt heat transfer fluid and storage.	
SETP Project Milestones/Decision Points	**Due Date**
Pending contract negotiations.	Pending

Program Type: Dish/Stirling R&D **Project Title:** Brayton *SolarCAT* Solar Power Conversion System **Awardee:** Brayton Energy **Project Summary:** Lower capital costs and increased system reliability through improved engine and receiver efficiency; and improved mechanical integration of engine, combustor, and receiver.	
SETP Project Milestones/Decision Points	**Due Date**
Pending contract negotiations.	Pending

Program Type: Dish/Stirling R&D **Project Title:** Dish/Stirling R&D **Contractor:** NREL **Project Summary:** Near-term goals, by 2011, the CSP subprogram will assist technology development for and validate the performance of a 25-kW commercial dish-Stirling system that will: • Achieve a design point solar-to-electric efficiency of 30% and annual solar-to-electric efficiency of 24%. • Has an installed system cost of $4500/kW, an O&M cost of 5¢/kWhr, resulting in an LCOE of 25¢/kWh.	
SETP Project Milestones/Decision Points	**Due Date**
Demonstrate 500 hour MTBI and 200 hour MTBF for dish systems	5/15/2008
Support industry in deployment of utility dish project in California	8/5/2009
Using data from the dish project, design next generation system capable of 4,000 hrs MTBF	5/10/2010
Complete design of dish-engine system capable of 4,000 hrs MTBF	6/20/2011

Program Type: Dish/Stirling R&D **Project Title:** 30KW Maintenance Free Stirling Engine **Awardee:** Infinia Corporation **Project Summary:** Six modified free piston engines combined to form a 30kW six-cylinder Stirling engine for high-performance, high-reliability dish concentrating solar power.	
SETP Project Milestones/Decision Points	**Due Date**
Pending contract negotiations.	Pending

Program Type: Thermal Storage R&D
Project Title: Storage Systems
Contractor: NREL
Project Summary:

- Produce milestone reports on nanofluids research and cost model updates integrating storage.
- Plan thermal storage test facility restoration.

SETP Project Milestones/Decision Points	Due Date
Milestone report on all research results for work being performed on the advanced nanofluid topic.	7/31/2008
Thermal Storage Test Facility Restoration Plan.	6/30/2008
Milestone report which documents all of the cost-performance results from updates to the direct two-tank, indirect two-tank and thermocline storage cost models, results from the cost-performance modeling of one or more new thermocline concepts which minimize or eliminate diffusion of the temperature gradient along the thermocline, and plans/recommendations for future modeling work will also be included in the report.	9/30/2008

Program Type: Thermal Storage R&D
Project Title: Thermal Storage R&D
Contractor: NREL/SNL
Project Summary: Lab tests indicate that thermocline storage may be the next step in storage technology for troughs. The near-term objectives of this task include,

- Develop advanced heat transfer fluids;
- Test storage-specific components such as pumps, valves, and material compatibility; and
- Systems integration and design of the thermal storage system.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Thermal Storage R&D
Project Title: Molten Salt Heat Transfer Fluid
Awardee: Solucar/Abengoa
Project Summary: Combine the use of a molten salt heat transfer fluid with molten salt thermal energy storage to reduce costs and increase the dispatchability of CSP plants.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Thermal Storage R&D
Project Title: Molten Salt Pump
Awardee: Hamilton Sundstrand SLS Rocketdyne
Project Summary: Design, build and test a long-shafted (~50 feet), molten salt pump able to operate at 1,050 degrees Fahrenheit; a critical component for both trough and tower technologies.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: Advanced CSP Concepts
Project Title: Advanced Concepts R&D
Contractor: NREL/SNL
Project Summary: The advanced concepts activity supports crosscutting activities (i.e., activities such as advanced optical materials and resource measurement) that aren't tied to a single CSP technology, as well as a supporting the "incubation" of new concepts that are in the preliminary stages of investigation. The overall objective is to develop, validate, and aid the commercialization of advanced reflector systems that can dramatically reduce the cost of concentrating solar power. The major objectives of this project are:

- To develop advanced reflector materials that are low in cost (less that $1/ft2 or $10.76/m2) and maintain high specular reflectance (90-95% into a 4-mrad cone angle) for long lifetimes (10 to 30 years) under severe outdoor environments.
- To test the durability of optical materials to determine lifetime of solar reflector materials

SETP Project Milestones/Decision Points	Due Date
Determine heat transfer fluids suitable for trough operation at 450C	3/30/2008
Cost reductions of up to 50% to the solar concentrator	2012

Program Type: Advanced CSP Concepts
Project Title: Advanced Concepts R&D
Contractor: NREL
Project Summary: Release quarterly progress reports on a number of system and subsystem CSP tests.

SETP Project Milestones/Decision Points	Due Date
Progress Report Q2 FY08: Determine optical performance, lifetimes, and cost goals for advanced reflectors that are consistent with current CSP program objectives.	3/31/2008
Progress Report Q3 FY08: Compare the durability of silvered thin-glass copper-free and lead-free mirrors after exposure to AET (Ci5000 WeatherOmeter and damp-heat at different humidity conditions) and OET (Golden, CO; Phoenix, AZ; Miami, FL; and Alice Springs, Australia)	6/30/2008
Progress Report Q4 FY08: Provide status of test results of candidate solar mirror samples and identify promising candidates and how advanced solar mirrors will help meet the cost goal for electricity.	9/30/2008

Program Type: Advanced CSP Concepts
Project Title: Central Receiver Panel Fabrication and Testing
Awardee: Hamilton Sundstrand SLS Rocketdyne
Project Summary: Manufacture and testing of a large scale (200 MW) molten salt solar receiver panel for power tower technology.

SETP Project Milestones/Decision Points	Due Date
Pending contract negotiations.	Pending

Program Type: CSP Market Transformation
Project Title: CSP Resource Assessment
Contractor: NREL
Project Summary:

SETP Project Milestones/Decision Points	Due Date
Complete an updated DNI resource web application providing access to time-series data, mapping of average DNI, and interannual variability of DNI for the Southwestern U.S.	3/31/2008

Release SAM version with dish/Stirling model, enhanced GUI and greater graphical output capability, and time-of-use rates	8/31/2008
Deploy up to 12 weather and solar radiation measurement stations at key locations designated by the CSP program, to meet the need for site-specific sub-hourly resource data made accessible from the Measurement and Instrumentation Data Center (http://www.nrel.gov/midc)	9/30/2008

Program Type: CSP Market Transformation
Project Title: CSP Market Transformation
Contractor: NREL/SNL
Project Summary: NREL and SNL will provide continued support for CSP program analysis efforts related to large-scale implementation of CSP in the Southwestern United States. Technology Acceptance activities for CSP include the 1000 MW Initiative, IEA SolarPACES, and Communications/Outreach.

SETP Project Milestones/Decision Points	Due Date
Complete deployment of DNI ground stations in pre-identified solar development zones	9/30/2008

Program Type: CSP Market Transformation
Project Title: Market Analysis and Grid Integration
Contractor: NREL
Project Summary:

- Study and provide market analysis on CSP market penetration.
- Update models to allow CSP inputs.

SETP Project Milestones/Decision Points	Due Date
Develop LP Formulation for optimized CSP Dispatch	4/30/2008
Add solar-only troughs and dishes and power-towers to the ReEDS model	5/31/2008
Conduct linear program dispatch model parametric analysis	6/30/2008
Provide projections on market impact of CSP initiative	7/31/2008
Add a possible “supergrid” scenario to the REeDS model and examining the impact on CSP generation penetration and cost.	9/30/2008

Appendix C: PV and CSP Technology Information

Photovoltaics

In 2005, the total U.S. installed solar electric generating capacity was only 0.9 GW (~0.5 PV; 0.35 CSP)[25], less than 0.1% of total U.S. generating capacity[26]. Yet, solar energy is available in all regions of the country and can provide significant amounts of energy in places like New York and Minnesota, as well as the more obvious locations like Texas and California. In fact, if every single-family home in America had a 3 kW photovoltaic (PV) rooftop system, the combined generated power of the homes would total more than 420 billion kWh of electricity-more than 35% of the entire residential electricity demand for the United States. A land mass of about 100 by 100 miles in the Southwest U.S.-less than 0.5% of the U.S. mainland land mass, or about 25% of the area currently used for the nation's highway/roadway system-could provide as much electricity as presently consumed in the United States.[27]

Photovoltaics are a highly modular technology, with the smallest element being the PV cell. Photovoltaic-based solar cells convert sunlight directly into electricity. They are made of semiconducting materials similar to those used in computer chips. The most commonly-used PV material is crystalline silicon. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. The process of converting light to electricity is called the *photovoltaic effect.*

A factory-produced package containing multiple cells and composed of glass or other materials to protect the cells is called a module, and typically produces ~10-300 Watts of electricity.

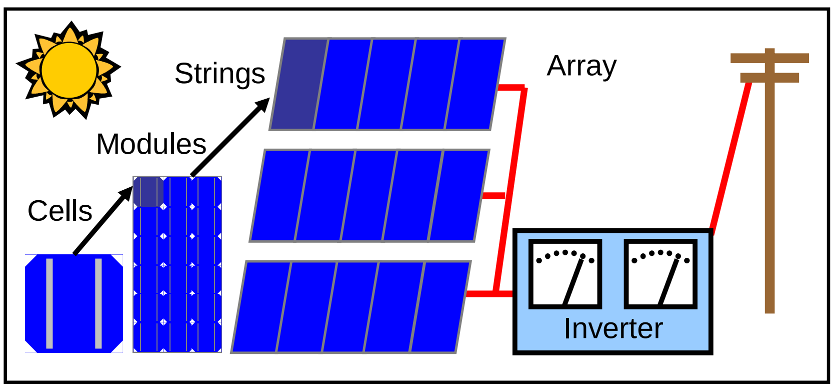


Figure C-1. Photovoltaic System Schematic

For a typical application (Figure C-1), modules are placed on a ground-mounted framework or on a building and wired in series into strings which are in turn wired in parallel to form an array. In a grid-connected system, an inverter is used to convert the DC output of the array to AC power as required by the electric power grid.

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[25] "U.S. Market Analysis." PV News (25:5). Cambridge, MA: Prometheus Institute.
[26] Solar trough capacity is 354 MW - U.S. Department of Energy, Concentrating Solar Power Funding Opportunity Announcement, May 25, 2007.
[27] "Solar Energy Technologies Program Multi-Year Program Plan 2007-2011." Office of Energy Efficiency and Renewable Energy. United States Department of Energy. January 2006. pg. 1.

Types of PV technology:
▪*Wafer-Based Crystalline Silicon* solar technology is based on the concept of fabricating discrete solar cells from silicon wafers that have been sawn from a silicon boule or ingot, or cut from a thinly grown multicrystalline sheet. The cells are then electrically interconnected to form a module. Historically and currently, wafer-based c-Si technologies have held the majority of the market for PV modules, with 94% market share in 2006.[28] As volumes of c-Si product sales have grown, as component reliability has been demonstrated, and the technology's performance has advanced, c-Si technologies have continued to show steady improvement in cost.

▪*Thin film* solar cells use layers of semiconductor materials only a few micrometers thick that are deposited via processes such as vacuum deposition. While thin-films are often deposited on glass, some manufacturers use flexible substrates which are then incorporated into building materials, such as shingles.

▪*Concentrating PV* technologies use lenses or mirrors to concentrate sunlight 25-1000 times onto a high-efficiency silicon or multi-junction solar cell. The amount of semiconductor material required is reduced by up to 300 times, and cheaper materials, such as glass and steel, are used to capture and concentrate the sunlight. Only direct sunlight can be concentrated, so CPV systems usually have large two-axis tracking structures. The target market for most CPV technologies is utility-scale systems.

For crystalline silicon the most significant technical barrier is the material costs associated with relatively thick cells. In the past few years this issue has been exacerbated with tight polysilicon feedstock supplies. In response, companies that process ingots, wafers, or cells are developing processes with higher silicon utilization. Approaches under the TPP and incubator programs include reducing head and tail losses when pulling ingots, investigating novel wafer liftoff techniques to eliminate Kerff losses, and developing improved light trapping to ensure thinner cells absorb maximal light. Other attempts to reduce silicon costs include using optimization or growth processes to increase performance of lower purity feedstock and using low concentration optics to reduce the silicon area by a factor of two or three.

Thin film solar cells have a much higher rate of light absorption and which allows material thicknesses approximately 100 times thinner that crystalline cells. The most important technical barriers manufacturers of thin film modules face involve increasing device module efficiency and developing reliable yet low cost module packaging. SAI thin film projects targeting efficiency increases are primarily focused on transitioning a prototype scale process into full commercial production. Difficulties encountered in this transition include achieving large area uniformity and high throughput rates. One advantage of thin film PV is the possibility of creating flexible modules with reduced installation costs and restrictions (i.e., rooftop penetrations). However, the downside of flexible form factors are the difficulties and risks associated with creating a robust encapsulation material. The flexible barrier material must be transparent, moisture proof,

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[28] "U.S. Solar Industry Year in Review 2006 – U.S. Solar Energy Industry Charging Ahead." Joint report: Prometheus Institute and SEIA, published 2007.

and affordable. SAI thin film projects have mitigated these risks through various approaches; by initially using a rigid glass encapsulated module while concentrating on cell performance, by perusing less flexible materials that may be more affordable and effective, and by developing very low cost building integrated products which may allow for more frequent replacement cycles.

Concentrating photovoltaic modules take advantage of the high performance offered by expensive multi-junction cells while maintaining low costs by focusing incoming light 100-1000x onto small cells. Although CPV is an old concept, the complications and costs associated with integrating the optics and cells prevented manufacturers from reaching the volume production required for the technology to gain a foothold. However, recent record efficiencies of multi-junction cells offer the possibility of unmatched power density and have renewed interest in the concentrating approach. The challenge facing CPV manufacturers is to develop robust module and tracker designs while ensuring that the final products can be mass produced with low cost automated processes. A significant risk associated with this approach has been mitigated with TPP projects where the optics and cell manufacturers are part of a single team and will work together to develop a single product. Furthermore, a systems approach allows the target market of a CPV system to drive design developments such as array dimensions, climate considerations, and electrical optimizations. Examples of specific barriers related to product reliability include dissipating heat away from the cells, sealing the module from moisture, and ensuring tracking precision.

Although the SETP acknowledges the possibility of a single PV technology becoming dominant in future years, the program currently remains committed to funding diversely across all promising technologies. In the near term, all three technology types described above are likely to achieve significant cost reductions. Additionally strong market segmentation across residential, commercial, and utility systems is likely to be a long term trend.

Concentrating Solar Power (CSP)

Figure C-2. One MW CSP Trough Plant near Tucson, AZ

CSP plants produce power by first converting the sun's energy into heat, next into mechanical power, and lastly, into electricity in a conventional generator. Concentrating Solar Power technologies are most often applied in centralized power production. Although power from CSP currently costs more than other renewable options such as wind, utilities are becoming more aware of the potential economic benefits of CSP deployment. CSP power production aligns closely with periods of peak demand, and the problems of solar intermittency can be overcome with thermal storage or hybridization with natural gas, allowing plants to dispatch power to the line when it is needed. In some regions, such as the Southwest, the widespread availability of solar energy provides flexibility in locating CSP power plants near existing or planned transmission lines.

Types of CSP Technology:

▪*Trough-electric systems* concentrate the sun's energy onto a receiver tube located along the focal line of a parabolically curved, trough-shaped reflector. Oil flowing through the receiver tube is heated to about 400°C (752°F); the heat is collected and used to generate electricity in a conventional steam Rankine cycle. Trough systems can be hybridized or can use thermal storage to dispatch power to meet utility peak load requirements. Parabolic Trough technologies have had the most commercial success in the CSP market so far.

Significant progress has been made on reducing both component costs and O&M expenses associated with trough plants in the last several years. For example, advances in thermal storage using molten salt have made it possible to provide the dispatchable power desired by the electric power industry. This ability to store solar energy makes the technology particularly attractive to utilities, as it gives them the option of using the power when they need it most.

▪*Dish/Stirling Systems* focus the sun's energy at the focal point of a parabolically shaped dish, which tracks the sun over the course of the day; temperatures reach about 800°C (1452°F). An engine/generator located at the focal point of the dish converts the absorbed heat energy into electricity. Individual dish/Stirling units currently range from 3 to 25 kW in size. Larger power plants are to be built by installing fields of these systems.

Figure C-3. Prototype 150 kW Dish/Stirling power plant at the NSTTF.

Recent market activity suggests that large deployments of dish-Stirling systems might become a reality in the U.S.:

- On August 10, 2005, Stirling Energy Systems (SES) and Southern California Edison announced a 20-year power purchase agreement leading to planned construction of a 4,500 acre, 20,000 dish plant in the Mojave Desert. The plant is slated to have an output of 500MW, and the agreement provides for possible expansion to 800MW.[29]

- San Diego Gas & Electric announced that it had also signed an agreement with SES, and intends to purchase all of the output from a 300MW, 12,000 dish plant for a period of 20 years. The deal contains provisions for the plant, which is to be located in Southern California's Imperial Valley, to be expanded by as much as 600MW in the future.[30]

▪*Solar Power Towers*, the third type of technology, includes a field of tracking mirrors, called heliostats, which reflect the sun's rays to a receiver located on top of a tall, centrally located tower. The solar energy is absorbed by the molten-salt working fluid flowing through the receiver. Power towers can be coupled with a molten-salt energy storage system, allowing energy to be stored at 565°C (1050°F). When needed, hot salt is removed from the storage tank and used to generate steam to drive a conventional Rankine steam-turbine power block.

Figure C-4. 10 MW Power Tower Pilot Project, Barstow, CA

Although power towers have long been identified by DOE as the CSP technology that generates the least cost power, it has been missing from the Solar R &D portfolio for the last five years. The Solar Program stopped funding R&D in this area because of a lack of U.S. industry activity in power towers, and instead focused its CSP resources on troughs and parabolic dish/engine technologies, where there was industry activity in both R&D and the development of large projects. A power tower has been built in Spain (where three more are under development, one of which is slated to have sixteen-hour molten salt storage)[31] and another is under development in South Africa.

[29] Stirling Energy Systems Press Release. August 10, 2005. http://www.stirlingenergy.com/news/SES%20Press%20Release%20-%20FINAL%20Aug%2011%202005.pdf
[30] San Diego Gas & Electric Press Release, 9/7/2005: http://public.sempra.com/newsreleases/viewpr.cfm?PR_ID=1877&Co_Short_Nm=SE
Stirling Energy Systems Press Release. September 7, 2005. http://www.stirlingenergy.com/news/SES%20Press%20-%20SDGE%20V%203.pdf
[31] "CSP Project Developments in Spain," SolarPaces.org, http://www.solarpaces.org/News/Projects/Spain.htm

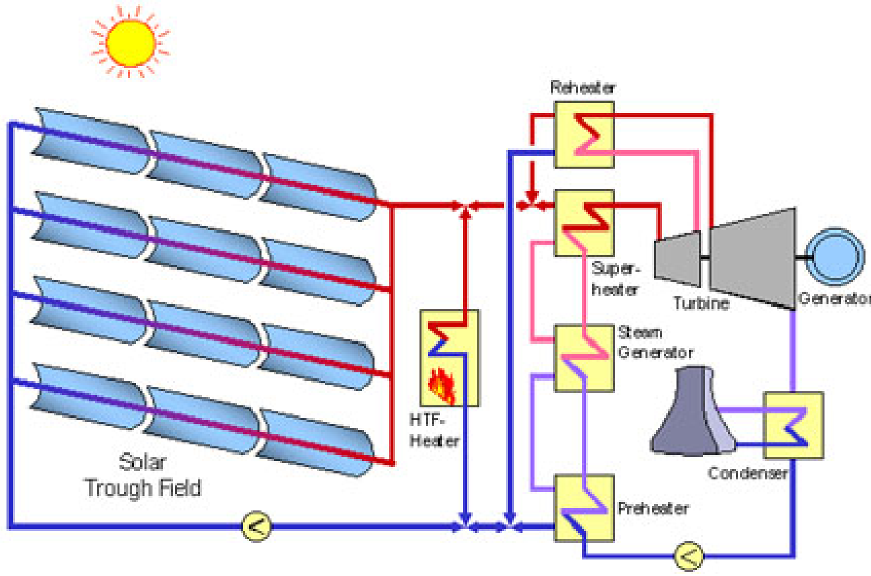

Figure C-5. CSP System Schematic

CSP Technology Cost and Performance Characteristics

▪*Troughs*

The 2007 technology baseline is a 100-MW trough plant with 6 hours of thermal storage:

- The net solar-to-electric efficiency of the last SEGS plants, built in 1990, was about 11%. The 2006 reference plant built is projected to have a system efficiency of 11.9%.
- The solar field cost and performance is based on the Solargenix DS-1 concentrator and Solel UVAC1 receiver. Both components have been field validated.
- Thermal-storage cost and performance is based on an indirect, two-tank, molten-salt storage system. Molten-salt storage has been identified as the near-term storage solution for two 50-MW trough plants to be built in southern Spain.
- LCOE ≈ 12¢/kWh, in solar resource regions of 7.65 kWh/m2-day. Although 150 MW of CSP capacity exist in regions with solar resources higher than 8.0 kWh/m2-day (i.e., Kramer Junction, CA), a more conservative solar resource is used for the reference system.

By 2011, the CSP Subprogram will assist technology development for and validate the performance of a 150-MW trough plant. A 100-MW reference plant is projected to:

1. Achieve a design point solar-to-electric efficiency of 25.6% and annual solar-to-electric efficiency of 15.5%;
2. Use an advanced thermocline thermal storage system that provides up to 6 hours of storage (capacity factor of ~0.43) and cost ~$20/kWh$_t$; and
3. Have an installed system cost of $4100/kW (including the cost of thermal storage and oversized solar field) and an O&M cost of 1.6¢/kWh, resulting in an LCOE of 8.9¢/kWh.

▪*Dishes*
The 2006 technology baseline is a unique, hand-built prototype 25-kW dish/Stirling system that is part of a 1-MW (40-dish system) power plant with the following characteristics:

1. Glass-metal solar concentrator design;
2. Net annual solar-to-electric generation efficiency of 22%;
3. Kinematic Stirling engine;
4. High O&M costs (10¢/kWh) resulting from prototype operation;
5. Solar-only system operation;
6. Demonstrated annual availability of about 80%;
7. Installed system costs of about $8600/kW; and a
8. LCOE of ~49¢/kWh (based on current prototype costs).

<u>CSP Technical Challenges and Barriers</u>
▪*Parabolic Troughs*: The solar field of a parabolic trough plant consists of long parallel rows of trough-like reflectors—typically, glass mirrors (see Figure C-4). As the sun moves from east to west, the troughs follow the trajectory of the sun by rotating along their axes. Each trough focuses the sun's energy on a pipe located along its focal line. A heat-transfer fluid—typically, oil at temperatures as high as 400°C (750°F)—is circulated through the pipes and then pumped to a central power block area, where it passes through a heat exchanger. The heat-transfer fluid then generates steam in a heat exchanger, which in turn is used to drive a conventional steam turbine generator. Beyond the heat exchanger, parabolic trough plants are just conventional steam plants. Therefore, parabolic trough plants can use thermal storage or hybridization with fossil fuel to generate electricity when the sun does not shine.


Figure C-6. SEGS Trough Plant, CA

The key technical challenges for parabolic trough technology relate to improving the efficiency and reducing the installed capital cost of the solar field, including the concentrator and solar receiver. To take advantage of the added value for firm, dispatchable power, an additional challenge is to develop a low-cost and thermally efficient energy-storage system that can dispatch power to meet system peak load. The cost of parabolic trough systems also benefits from scaling up plant size and the learning that results from volume production. The results of an independent analysis have identified the relative importance of these factors in reducing the cost of the parabolic trough technology.

▪*Dish/Stirling*: These systems track the sun and focus solar energy into a cavity receiver; the receiver absorbs the energy and transfers it to a heat engine/generator that generates electrical power (represented pictorially in Fig. C-7). In the U.S., companies are developing 3kW and 25kW systems. The systems use Stirling engines, which are high-performance, externally heated engines linked to a generator to produce electricity. Stirling engines offer high efficiency, high power density (i.e., power output per unit volume), tolerance of non-uniform flux distributions, and the potential for long-term, low-maintenance operation. Stirling engines are also considered to be potentially low maintenance because, although similar to an automotive engine, they have far fewer parts and are cleaner because the heat source is external to the engine.

Figure C-7. Dish Engine

The key technical challenges for dish/Stirling systems are to reduce system capital costs, improve system reliability to reduce O&M costs, and to reduce analytical/cost models.

Appendix D: PV Technology Roadmap Information

Wafer-Silicon PV

Wafer-silicon PV technologies are currently the dominant commercial PV technology by a huge margin, and they are likely to remain dominant for at least 10 more years. Wafer-Silicon PV applies to all bulk-silicon-based PV technologies—including those based on Czochralski, multicrystalline, float-zone wafers, and melt-grown crystals that are 100 µm or thicker, such as ribbons, sheet, or spheral silicon. The technologies offer one of the lowest costs in module capital costs ($/W) and LCOE (¢/kWh) for every application and they have the best proven reliability. Moreover, there is considerable momentum because wafer-silicon PV has the largest installed base and largest annual manufacturing capacity; as a result, the performance and costs are expected to continue to improve along the historic 81% learning curve. The current purified polysilicon feedstock shortage has recently driven up prices of the silicon substrate. But substrate prices are likely to recover in 2008 as additional feedstock manufacturing capacity comes on-line. The increased price of silicon has driven innovation in cell efficiencies, yield, and wafer thickness. Table D-1 details the current status and future goals for this technology.

Wafer-silicon PV R&D is currently focused on achieving reduced cost in $/W or ¢/kWh through the following:

- Reduced materials cost, particularly the silicon substrate
- Increased conversion efficiency
- Improved manufacturing processes and higher throughput
- Improved reliability (reduced wafer breakage, tighter performance distributions)

Table D-1 Wafer-Silicon Technology Metrics

Parameter	Present Status (2007)	Future Goal (2015)
Polysilicon costs	$45–60/kg	$20/kg
Wire sawing costs	$0.25/W	$0.15/W
Wafer size	~250 cm^2	~400 cm^2
Wafer thickness	200–250µm	120 µm
Volume manufacturing	100–200 MW/yr plants	500 MW/yr plants
Automation	Partial	Complete
Efficiency, best lab cells	25%	27%
Efficiency, commercial modules	12%–18%	15%–21%
Module manufacturing cost	$2/W (at $30/kg)	$1/W

Film-Silicon PV

Amorphous-silicon-based (a-Si:H) and crystal-silicon (c-Si) are two distinct types of supported film-silicon technologies. More broadly, film-silicon PV applies to all silicon-film technologies that rely on a supporting substrate such as glass, polymer, aluminum, stainless steel, or metallurgical-grade silicon and typically use amorphous, nanocrystalline, fine-grained polycrystalline, or epitaxial silicon layers that are 1–20 µm thick. Tables D-2 and D-3 details the current status and future goals for these technology.

There are a couple of pathways envisioned for the technology to advance: 1) for a-SI:H cells to dramatically reduce area-costs and moderately increase efficiency. Modules are currently all manufactured inexpensively with high yield over large areas and with conversion efficiencies of 5%–8%. 2) c-Si film technologies have the potential to approach the capability of wafer silicon at significantly lower cost than wafers by avoiding the costs of feedstock production, bulk crystal growth, wafer sawing, kerf loss, polishing, and the current high price supply of feedstock. Although efficiencies are still lag wafer-based silicon, a high-risk / high-payoff pathway uses c-Si films fabricated on one of several candidate inexpensive substrates such as glass, glass-ceramics, metallurgical-grade Si, or stainless steel. This wafer-replacement approach has the potential to raise efficiencies to levels competitive with polysilicon-wafer technology, while maintaining the low-cost structure of a-SI:H thin-film manufacturing.

Overall, film-silicon production – mainly of amorphous-silicon – was about 100 MW worldwide in 2006. A doubling of the annual amorphous-silicon production rate to 200 MW is likely by 2008. Production of a-SI:H and c-Si has increased at similar rates and film-silicon remains at about 5% of the total market.

Table D-2 a-Si-Based Thin-Film Technology Performance Metrics

Parameter	Present Status (2007) (costs are estimated)	Future Goal (2015)
Production volume	100 MW/yr	>5 GW/yr
Capital equipment cost	\$1–2/W @ plant capacity	\$0.7/W @ plant capacity
Substrate cost	\$12–20/m^2	\$4/m^2
Module manufacturing cost for a-Si	\$125–200/m^2	\$0.45–0.70/W or \$70/m^2 @10%–15% efficiency
Stabilized efficiency, best a-Si lab cells	13%	15%
Stabilized efficiency, commercial a-Si modules	5%–8%	10%–13%
Reliability of a-Si panels	~1%/yr degradation	1%/yr degradation

Table D-3 c-Si Film Technology Performance Metrics

Parameter	Present Status (2007) (costs are estimated)	Future Goal (2020)
Production volume	<1 MW/yr	1 GW/yr
Capital equipment cost	\$2–3/W @ plant capacity	\$0.7/W @ plant capacity
Substrate cost	\$26/m^2	\$10/m^2
Module manufacturing cost for waferless silicon	Not available \$/m^2	\$0.50/W or \$65/m^2 @ 13% efficiency
Efficiency, best supported-film c-Si lab cells	10%	16%–18%
Efficiency, best supported-film c-Si pilot modules	5%–6%	13%–16%
Reliability of Si-film panels	??%/yr degradation	1%/yr degradation

Concentrating Photovoltaics
CPV incorporates high-efficiency III-V or silicon cells with trackers and reflective or refractive optics. The recent accomplishment of >40% cell efficiencies, together with strong industry growth, has inspired substantial venture capital investment in recent years. Prototypes are being tested in preparation for large-scale deployment, yet the fundamental challenges of CPV remain – to lower cost, increase efficiency, and demonstrate reliability. To date, the total installed CPV capacity is <1 MW in the United States and a few MW worldwide—virtually all using silicon cells.

Cell cost is a substantial fraction of the total system cost of CPV. A variety of approaches to reduce the cost are available including: reduction of epitaxy costs via mechanisms including developing improved growth methods and growth precursors; reduction of substrate costs via recycling and reuse; increased use of automation in processing and testing, combined with transition to a larger substrate diameter; improved yield; and increased solar concentration.

Little information is available regarding long-term cell reliability under concentration, especially for III-V cells. Factors specific to CPV reliability include the high-flux, high-current, high-temperature operating environment encountered by the cells; weathering and other degradation of the optical elements; the bonding of concentrating optics to the solar cell; and the operation of the mechanical parts of the trackers.

As with cost and reliability considerations, efficiency must be also be addressed at the system level to reduce parasitic. Additionally, there is room for considerable efficiency improvement at the cell level in the III-Vs, even over the ~40% state-of-the-art, by developing advanced cell designs for improved spectral utilization and optimizing for higher-concentration operation. For lower-concentration systems using silicon cells, the efficiency of those cells used may be improved, as well.

Table D-4 Concentrating PV Technology Performance Metrics

Parameter	Present Status (2007)	Future Goal (2015)
$/W installed cost	$7–10/W	<$2/W
¢/kWh	>30¢/kWh	<7¢/kWh
System reliability – IEC qual. spec.	5 years	20 years
Commercial system efficiency	17%	29%–36%
Champion device efficiency	40.7% (III-V) 26.8% (Si)	48% (III-V) 28% (Si)
Commercial device efficiency	35%–37% (III-V) 20%–26% (Si)	42% (III-V) 22%–26% (Si)
Optical efficiency	75%–85%	80%–90%
III-V cell cost, $/cm^2	$10–15/cm^2	$3–5/cm^2

Cadmium Telluride PV
In comparison to wafer silicon, thin-film Cadmium Telluride (CdTe) photovoltaic technologies for flat-plate modules consume much lower amounts of expensive semiconductors and are more amenable to much higher levels of production automation. Due to these factors, CdTe PV is being produced a more competitive costs than wafer-

silicon and it is expected that as manufacturing volumes increase, the cost advantage will expand.

One current commercial thin-film CdTe manufacturing company has introduced thin-film CdTe products at >9% efficiency, with attractive pricing and availability for commercial rooftop and large-scale utility, ground-mounted systems. This is likely to remain the dominant market through 2012. This company and other emerging companies are expected to address other opportunities such as residential rooftop applications. In the near term, all forms are expected to be rigid products fabricated on low-cost, soda-lime glass substrates.

There are a few opportunities for the thin-film CdTe industry to improve the technologies. One dominant pathway is to raise power module conversion efficiency. Open-circuit voltage (V_{oc}) in CdTe solar cells is 20% below that of III-V solar cells with similar bandgaps. Enhanced V_{oc} with some improvements from short-circuit current density (J_{sc}) in the thin-film CdTe devices will most likely be the pathway to higher cell and module efficiency. Factors limiting fill factor (FF) should be analyzed and evaluated to improve solar cell and module performance. Additionally, deposition processes used for CdTe solar cells have the distinct advantage of rapidly transferring the material needed to compose the cells. Yet, this also limits the ability to introduce and control constituents to modify the electro-optical properties of the materials.

The reliability of the current glass-glass encapsulated thin-film CdTe modules appears to be comparable to conventional Si-based technology. As new technologies are added to boost efficiency, tests are needed to ensure that reliability is not sacrificed. Environmental, safety, and health (ES&H) continues to be an important aspect of the technology development and should be constantly updated and studied. Efforts should be made to increase public awareness of the perceived Cd issue.

Table D-5 Cadmium Telluride Technology Performance Metrics

Parameter	Present Status (2007)	Future Goal (2015)
Commercial module efficiency	>9%	13%
Champion device efficiency	16.5%	18%–20%
Module cost ($/W)	1.21	0.70
$/watt installed system cost	$4–5/W	$2/W
LCOE	18–22 ¢/kWh	7–8 ¢/kWh
Overall process yield	90%	95%
Identify relevant degradation mechanisms and develop appropriate ALTs for device and mini-modules metric	1.2% per year	0.75% per year

Copper Indium Gallium Diselenide

Laboratory-scale, thin-film CIGS PV solar cells are reaching efficiencies nearing 20%. With these efficiencies demonstrated, numerous start-up companies are seeking to develop low-cost, thin-film CIGS products that perform as well as the best silicon-based modules.

CIGS increasing module performance is promising and may allow it to achieve the lowest module costs and LCOE among all thin-film PV technologies. A primary challenge is to provide the science and technology needed to close the gap in efficiency between the entry-level prototype products and champion devices. A second challenge is to discover and qualify new materials and device schemes that can enhance performance, absorber bandgap and voltage, material usage, stability, yield, and process simplicity.

Issues including device sensitivity to water vapor, the limited availability of indium, and enhancing processing approaches to improve commercial module efficiency, are all significant challenges for CIGS. Building-integrated products may provide an entry channel for the technologies, taking advantage of the demonstrated capability to manufacture flexible cells (e.g., Global Solar, DayStar, Ascent Solar, NanoSolar, ISET, and SoloPower) and the potential to conform the film PV to building-material geometries. Products that have been fielded by Shell Solar, Global Solar, Würth Solar, and Showa Shell have reached manufacturing efficiencies of 11%, and acceptable reliability has been obtained for some, but not all, of these pilot products.

Overall, the following need to be addressed: (1) Enhance module efficiency, (2) Improve module manufacturing processes, (3) Discover alternative approaches and new materials, and (4) Assess and interact (which includes developing modeling and improved metrics).

Table D-6 CIGS Technology Performance Metrics

Parameter	Present Status (2007)	Future Goal (2015)
Commercial module efficiency	5%–11%	10%–15%
Champion device efficiency	19.5%	21%–23%
Module cost ($\$/W_p$)	Not established, estimated $<\$2/W_p$	$\sim\$1/W_p$
$/watt installed cost	$\$5–12/W_p$ (similar to other flat-plate technologies)	$\$3/W_p$
Reliability goal	0% to 6% annual degradation in pilot arrays	<1% annual power loss for commercial product
Overall process yield	Not available	>95%
New manufacturing methods	Pilot Flexible “roll-to-roll” manufacturing at Global Solar (initially packaged as a glass-to-glass laminate)	Develop new encapsulation schemes and appropriate accelerated life testing for flexible and rigid modules
Deposition rate and cell thickness	5 µm/h, 1.25–3 µm CIGS absorber thickness	30–40 µm/h <1 µm CIGS absorber thickness

Organic Photovoltaics

Organic photovoltaics (OPV) includes all forms of solar cells that use organic molecules—including polymers, dendrimers, small molecules, and dyes—as absorbers or transporters, either in fully organic devices or in devices that also contain inorganic nanostructures.

OPV development follows on the heels of the commercial success of organic light-emitting diodes (OLEDs). OPV technologies are attractive because of the inherent low materials cost, high-throughput processing, flexible substrates, and because of the huge variety of possible organic systems.

The primary challenge for OPV is to increase the efficiency and reliability. The limitations to efficiency are generally understood (e.g., the optical bandgap is too high; the band offset between donor and acceptor is not optimized; charge transfer, transport, and recombination are not optimized), but a rigorous fundamental understanding is lacking. Issues related to device degradation, such as photo-oxidation, interfacial instability and delamination, interdiffusion, and morphology changes are poorly understood. Development of more complex device designs, such as multijunction devices or inclusion of more exotic third-generation mechanisms into the OPV design, may be necessary to push efficiencies to competitive levels or to enable substantially higher efficiencies. The long-range goal of OPV is large-scale power generation. But as the technology develops, the potential for low-cost and flexible form-factors may enable other applications in the short term.

Table D-7 OPV Technology Performance Metrics

Parameter	Present Status (2007)	Future Goal (2020)
Champion device efficiency	5.2%	12%
Cell degradation	< 5% per 1000 h, research-scale	< 2% per 1000 h, module
Material figure-of-merit efficiency. Identification of candidate materials whose fundamental properties, such as optical absorption, band structure, and carrier mobility, allow for high theoretically attainable efficiencies.	Some material sets with improved figure-of-merit efficiencies exist.	Identification and synthesis of multiple donor-acceptor materials that meet all the fundamental requirements to achieve the Shockley-Queisser limit.

Sensitized Solar Cells

Sensitized nanostructured solar cells include both hybrid organic/inorganic and entirely inorganic structures. In some of their forms, the cells have considerable advantages over other technologies: (1) They are very tolerant to the effects of impurities because both light absorption and charge separation occur near the interface between two materials and that interface area can be quite extensive for a given footprint; (2) This relative impurity tolerance and simplicity allow for easy, inexpensive scale-up to non-vacuum- and low-temperature-based high-volume manufacturing via continuous processes; (3) The materials are inexpensive and effectively limitless; (4) They operate optimally over a wide range of temperatures; (5) Their efficiency is relatively insensitive to the angle of incident light; and (6) The range of applications are numerous because the sensitizer can take on any color with a full range of transparencies and can range from ultraviolet to infrared. Cells can be made on lightweight and flexible or rigid substrates which allows for building-integrated products.

Although the stability and light-conversion mechanisms are inadequately understood at this time, it can be said that (1) there is no expected limitation on material, (2) stable 10%-efficient modules are certainly within reach, and (3) the energy-payback period should be significantly shorter than other PV technologies. Demonstrated levels of efficiency and degradation have inspired investment, and several companies are working toward commercializing this technology.

Companies may attain 10%-efficient modules approaching by 2015. A realistic goal is that 20%-efficient laboratory-sensitized solar cells will also be achieved. To reach these and more ambitious targets, it will be essential to further advance the fundamental understanding of the factors that govern cell performance and stability.

Table D-8 Sensitized Solar Cells Technology Performance Metrics

Parameter	Present Status (2007)	Future Goal (2015)
Champion device efficiency	11%	16%
Laboratory cell degradation	<5% after stress at 80°C for 1000 h in dark or after light-soaking for 1000 h @ 1 sun at 60°C	<5% after stress at 85°C for 3000 h in the dark or after light-soaking for 3000 h @ 1 sun at 60°C
Module efficiency	5%–7%	10%
Outdoor module degradation	<15% in 4 yrs	<15% in 10 yrs
Identification of key degradation mechanisms	Degradation mechanisms are controversial	Primary degradation mechanisms identified