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.

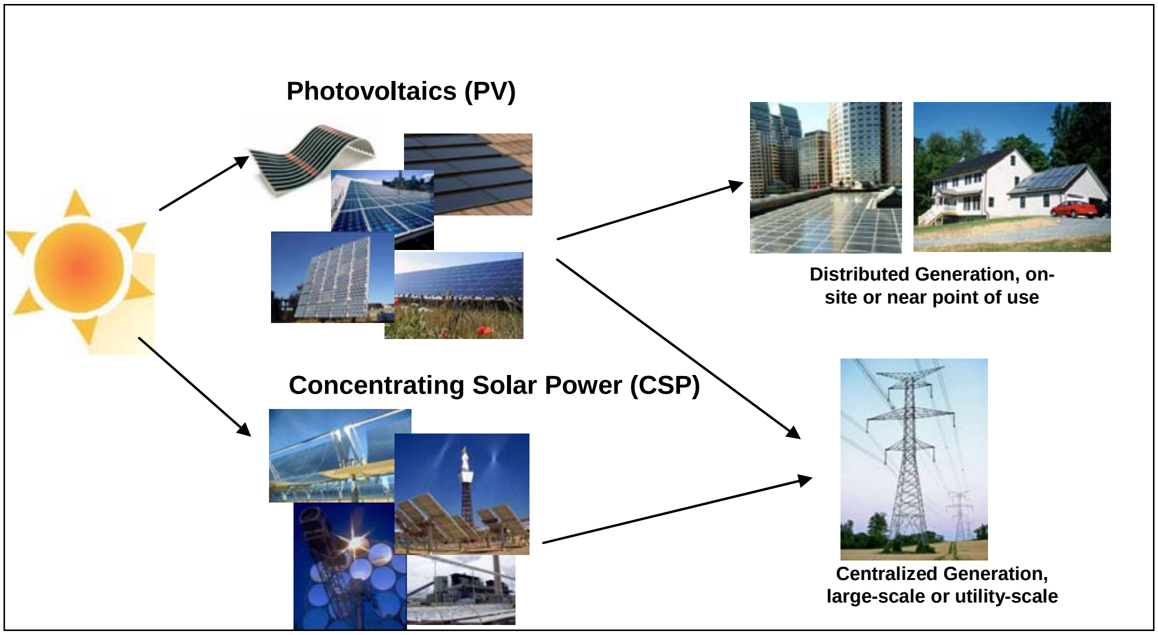

Figure 1-1. Solar Technologies for Electricity Generation

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.

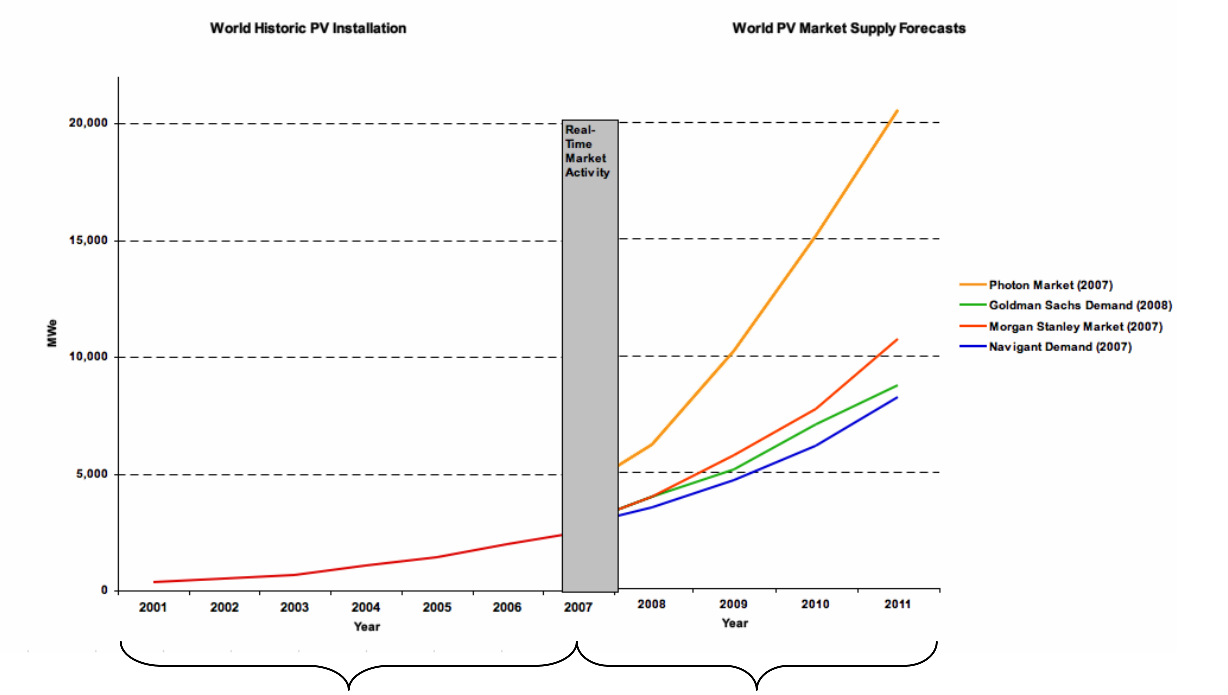

Figure 1-2. Global PV Installations[6] and Global PV Market Forecasts[7,8,9,10]

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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.

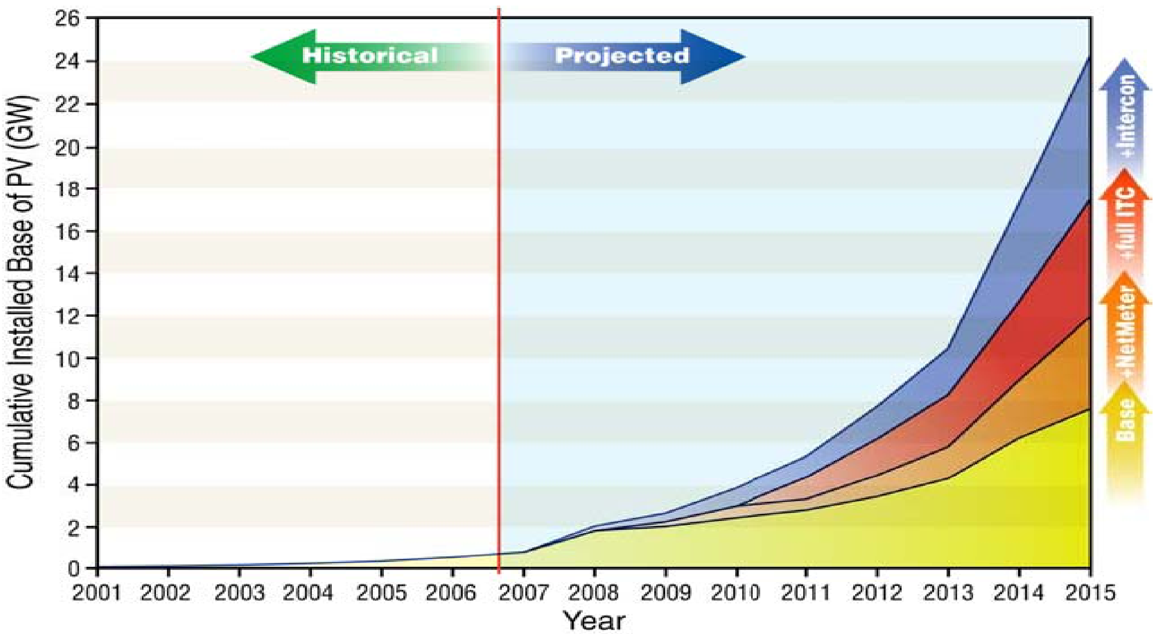


Figure 1-3. U.S. PV Installations and Policy Projections

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

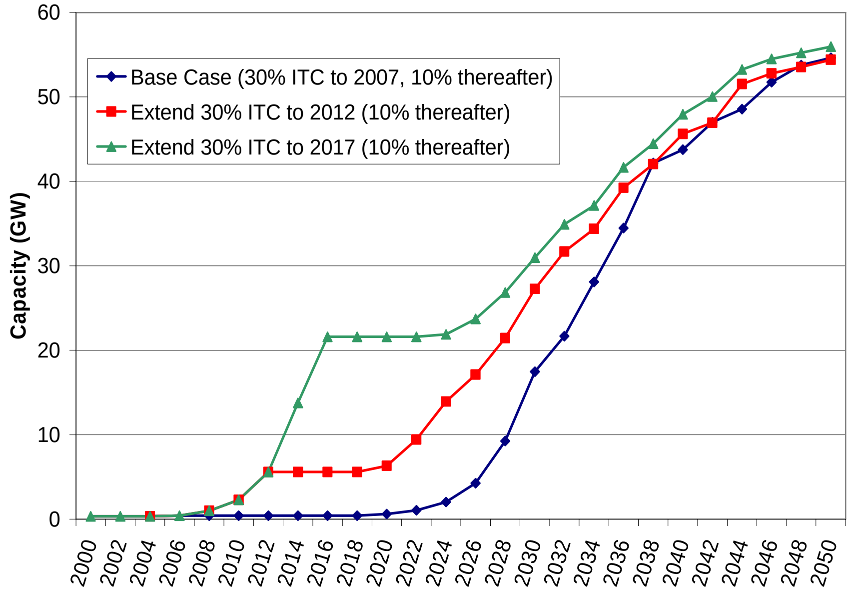


Figure 1-5. Investment Tax Credit Impact on CSP Capacity

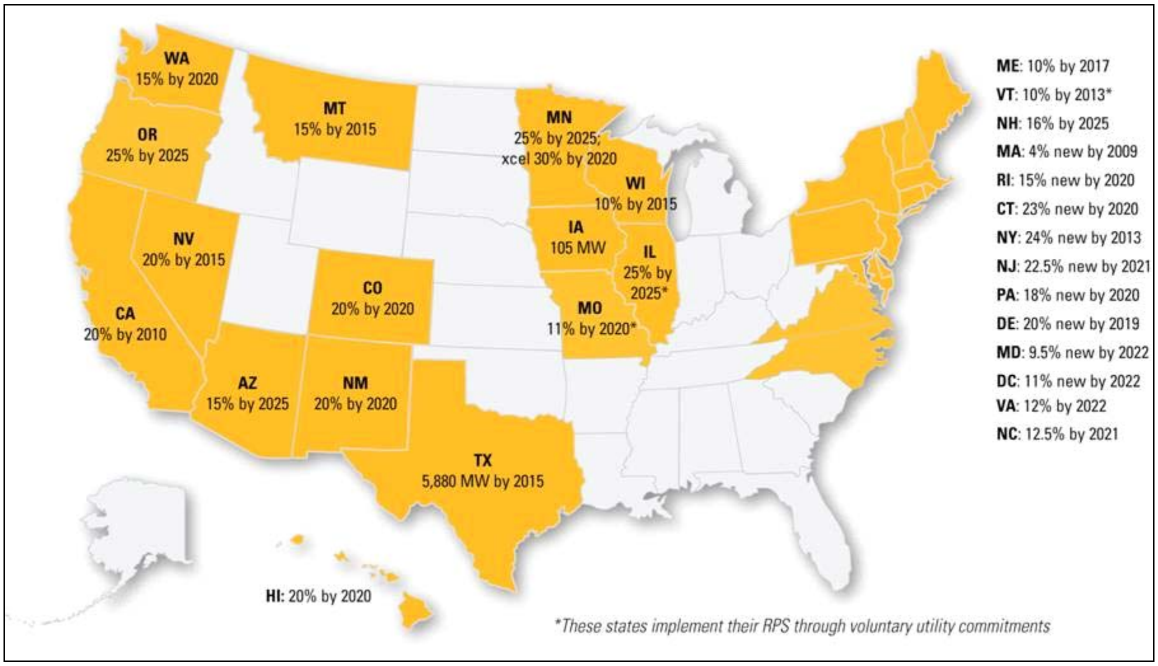
Federal and State Market Incentives

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.

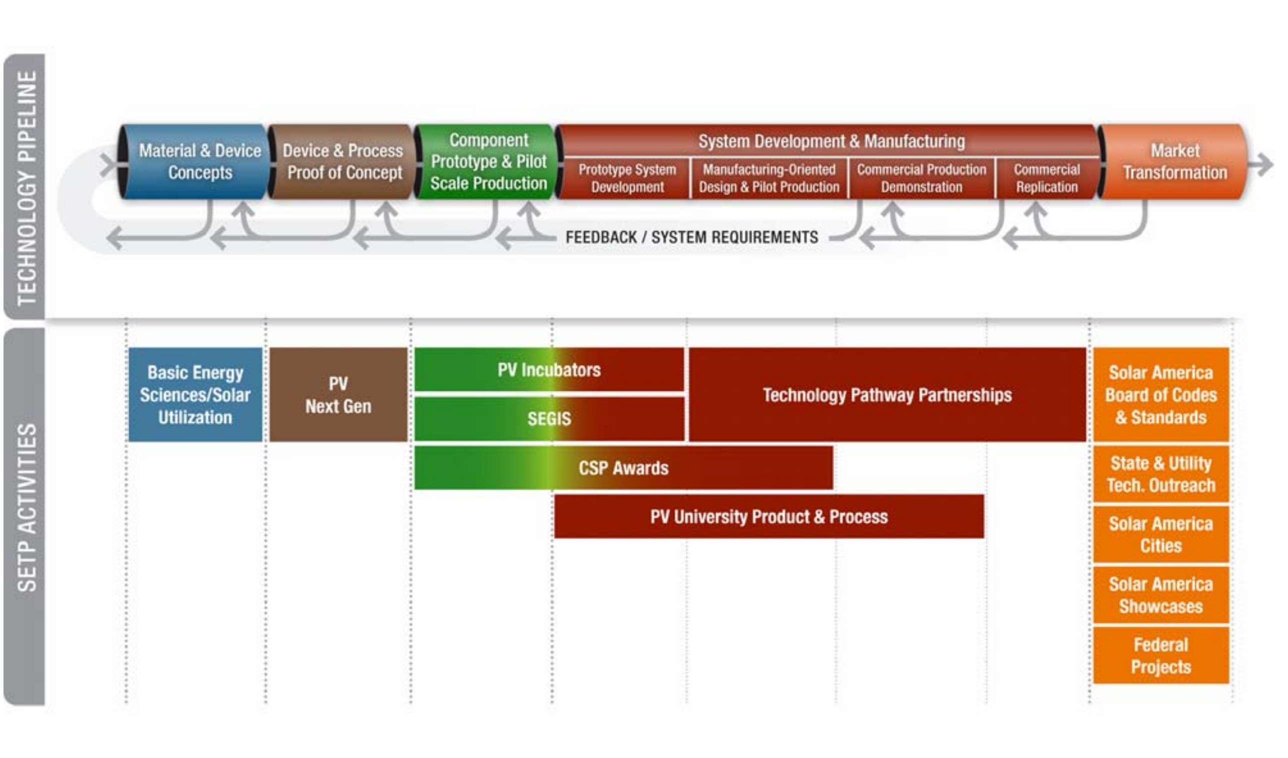


Figure 1-7. Solar Energy Technology Project/Development Pipeline Diagram

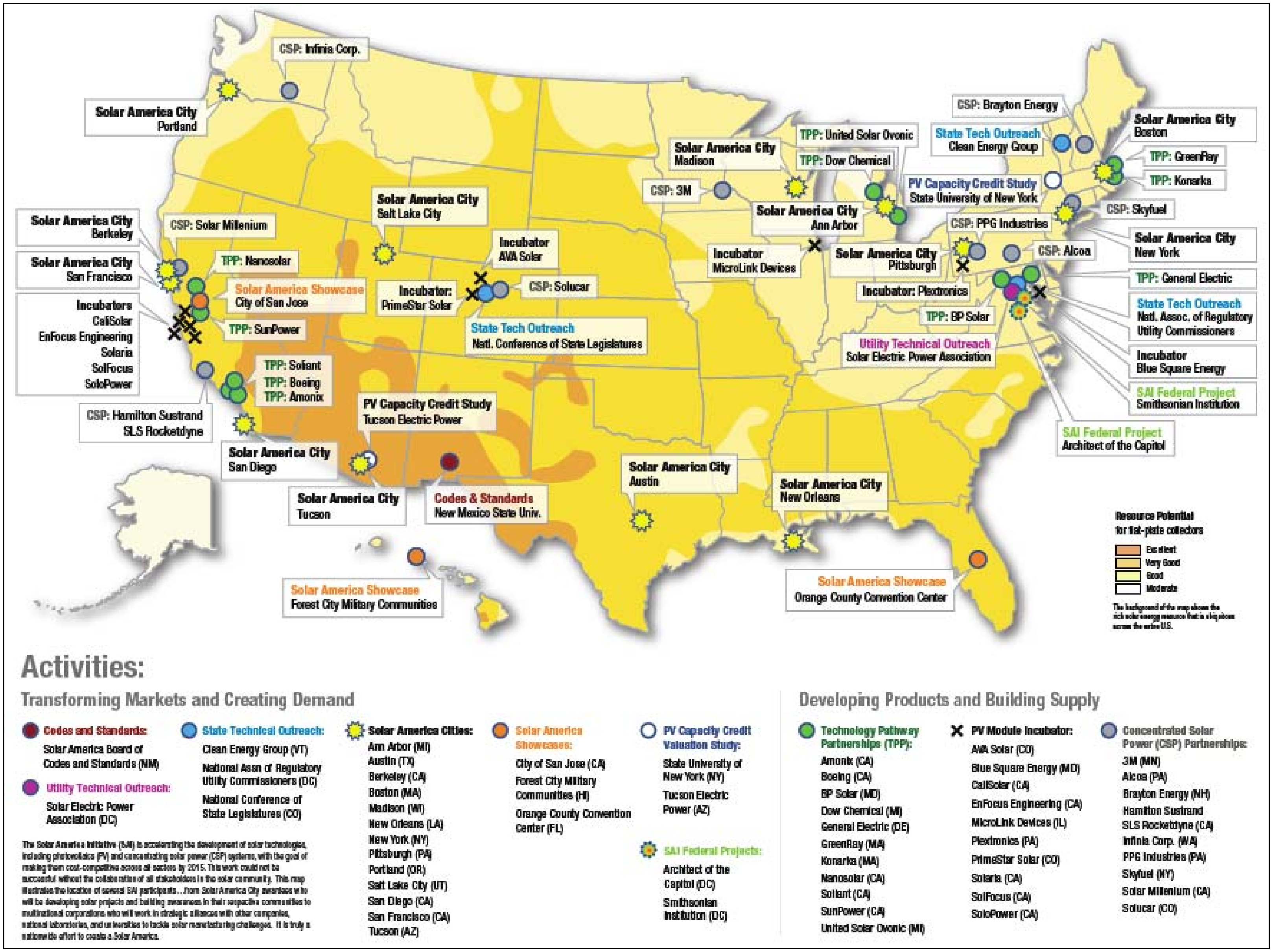


Figure 1-8. Map of Recent Solar Energy Technology Program Activities Initiated in 2007

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.