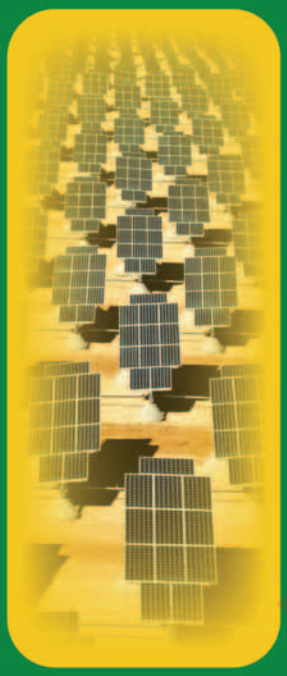
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



DOE Solar Energy Technologies Program

Overview and Highlights

Credit: U.S. Air Force photo by Senior Airman Nadine Y. Barclay/PIX 17160

Solar's Time Is Now

"We will harness the sun and the winds and the soil to fuel our cars and run our factories... All this we can do. All this we will do."

— U.S. President Barack Obama
January 20, 2009

Today, support for renewable energy, especially solar, is unparalleled with any time in U.S. history. Environmental issues such as climate change have compelled leaders around the globe to take notice of growing international concern and to work together to meet environmental challenges.

Sitting on 140 acres, the 15-megawatt (MW) PV array at Nellis Air Force Base in Nevada is one of the largest solar energy systems in the western hemisphere. President Barack Obama, Colonel Dave Belote, 99th Air Base Wing commander, and Senator Harry Reid (D-Nev.) tour the array on May 27, 2009.

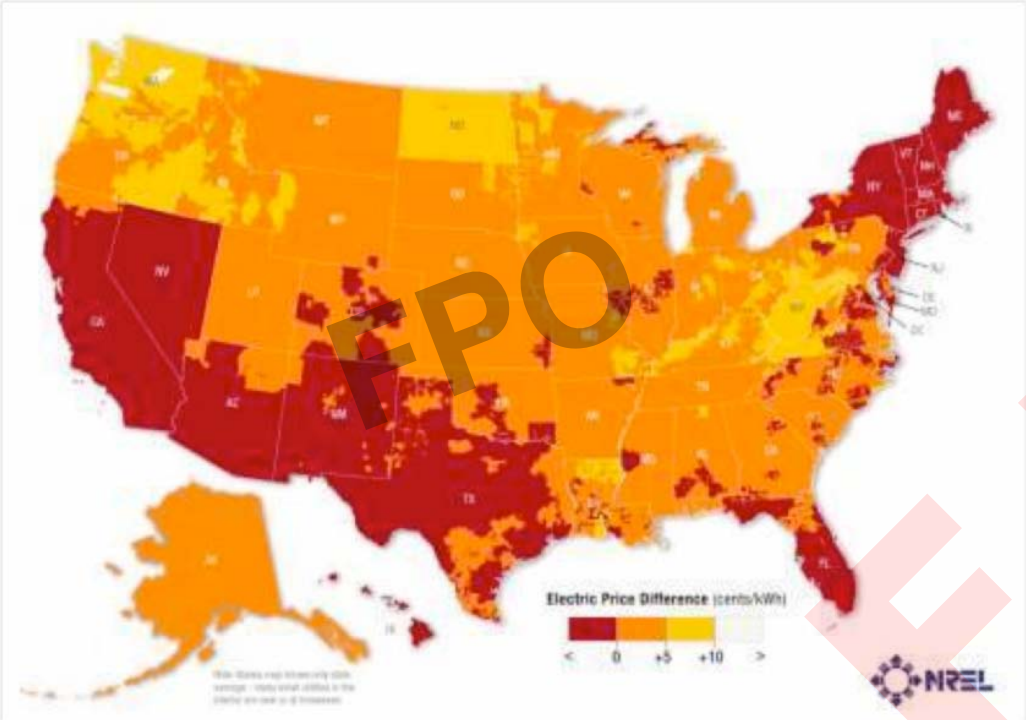
Solar technologies diversify energy supply, reduce dependence on imported fuels, improve air quality, and offset greenhouse gas emissions. A growing solar industry also stimulates the economy with jobs in manufacturing and installation. Policy-makers are recognizing that the benefits of solar surpass any state lines and geographical boundaries.

Within such a dynamic domestic and international atmosphere, the U.S. Department of Energy's (DOE) Solar Energy Technologies Program (the Solar Program) leads solar activities in the United States while strengthening global alliances. The Solar Program works through public–private partnerships to bring reliable and affordable solar energy technologies to the marketplace.

The Energy Market and the Solar Landscape

Based on Energy Information Administration forecasts and a conservative 4.7% annual inflation rate, average electricity prices in the United States will reach 16 cents per kilowatt-hour (¢/kWh) by 2015. In certain states, the price is expected to be even higher, closer to 27 ¢/kWh.

Price increases, in conjunction with projected increases in demand approaching 400 gigawatts (GW), are compelling policy-makers to reevaluate the energy market and consider alternatives to today's energy mix. Fossil fuels have traditionally been, and remain, the primary source of energy generation, but they face a future fraught with uncertainties about rising prices, unsustainable emissions levels, and siting, among others. And nuclear industry groups estimate that the next generation of nuclear plants will not be online until 2015. With financial incentives and continued R&D, though, solar has already become cost-competitive in some states and will soon become affordable in others.



This map illustrates a conservative forecast for 2015. With no incentives and a 13% real increase in the price of electricity (a moderate projection), PV becomes a financially feasible option in many states.

Four Subprograms: One Goal

Within this environment, the Solar Program's activities are aligned with the goals of the Obama Administration's aggressive energy plan.[1]

Through its four subprograms—Photovoltaics (PV), Concentrating Solar Power (CSP), Systems Integration, and Market Transformation—the larger Solar Program focuses on making solar electricity cost-competitive with conventional forms of electricity. The subprograms support the program goal of increasing the widespread adoption of solar electric technologies through applied R&D, demonstration, and market transformation activities. Because the goal requires an industry-wide effort, the Solar Program forges partnerships with national laboratories; universities; private companies; professional associations; other DOE programs; and federal, state, and local agencies across the nation. The ultimate goal of all the Solar Program's work is to give consumers and utilities cleaner, greener, affordable alternatives to traditional energy sources.

As a direct result of its portfolio of activities, Solar Program analysts project that the levelized cost of energy (LCOE)[2] will drop dramatically as the market penetration surges.

Solar Program Highlights

In recent years, the DOE Solar Program has garnered some prestigious awards for technological advances or breakthroughs. Many of the research achievements were awarded to a

[1] See http://www.whitehouse.gov/issues/energy-and-environment, accessed February 2010.

[2] LCOE is an economic assessment of the cost of an energy-generating system. It captures all the costs the system incurs over its lifetime, including costs for the initial investment, fuel, capital, and operations and maintenance, among others.

DOE national laboratory, such as the Lawrence Berkeley National Laboratory (Berkeley Lab), Brookhaven National Laboratory (BNL), the National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Sandia National Laboratories (SNL). All projects were funded by the DOE Solar Program.

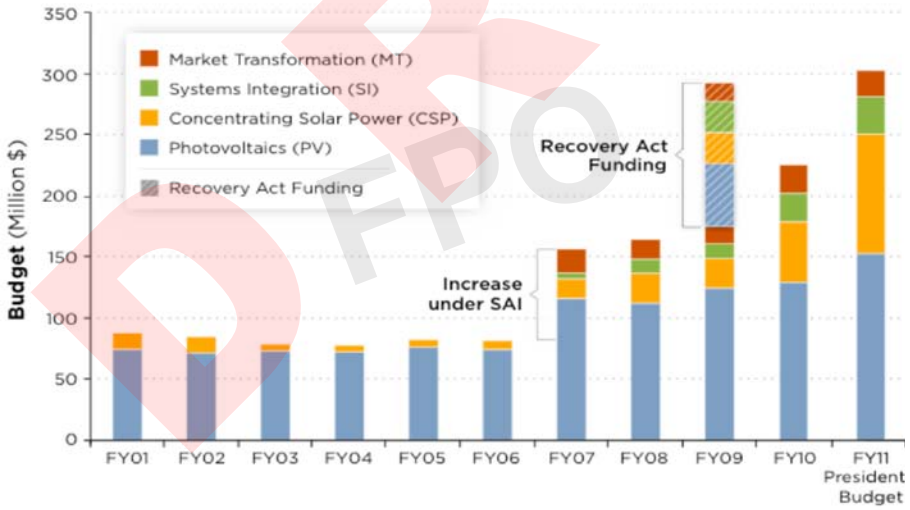
R&D 100 Awards

Bestowed by *R&D Magazine,* these awards honor the top 100 innovations in a given year and showcase the best new technologies from around the world. Here are the recent winning projects. Each is followed by the Solar Program partner(s) that received it and the year of award.[3]

- **Nanocrystal solar cells** are ultra-thin solar cells based on dense nanocrystal films with no organic materials. Their efficiency potential is about 25%, matching that of silicon cells. (Berkeley Lab and Solexant; 2009)
- The **PulseForge** 3100 tool uses a unique pulse thermal processing technique, which applies extremely high-intensity radiant heat to the surface of materials quickly (milliseconds to microseconds). This commercial tool is used for high-speed drying, curing, sintering, or annealing high-temperature materials on plastic and paper, enabling inexpensive and flexible electronics and solar applications. (ORNL; 2009)
- The **SkyTrough™** parabolic trough solar concentrating collector uses a reflector material to create a groundbreaking and low-cost system for utility-scale power generation. (NREL and SkyFuel; 2009)
- The **Ultra-Accelerated Weathering System** is a multifaceted ultraviolet solar concentrator that is used to speed up the exposure of coatings, paints, and other materials to determine their durability and resistance to weathering. (NREL; 2009)

Solar Program Budget

The Solar Program budget has steadily grown as the breadth of work has increased in recent years, and future appropriations hold even greater promise.



DOE's solar energy technologies budget, FY 2001–2011

- Inverted metamorphic multijunction solar cells are grown in a new way: upside down. The result makes use of high-energy materials with extremely high-quality crystals, especially in the upper layers of the cell where most of the power is produced. (NREL, Emcore Corp., and Air Force Research Laboratories Space Vehicles Directorate; 2008)
- A new thin-film PV manufacturing process produces hybrid copper indium gallium diselenide (CIGS) films. The process, which involves depositing two thin chemical reactant layers and rapidly heating them to bond the CIGS films to sheets of glass or other surfaces, eliminates complex manufacturing processes and lowers costs significantly. (NREL and HelioVolt Corp.; 2008)

[3] http://www1.eere.energy.gov/solar/accomplishments.html

Credit: SunPower/PIX 16802

Leading By Example

The DOE set a shining example for other federal agencies when it installed a PV system on the roof of its headquarters in Washington, D.C., in 2008. The 205-kilowatt (kW) installation on DOE's Forrestal Building is one of the largest in the nation's capital. When electricity demand is highest during the day, the PV system generates up to 8% of the building's electricity needs. In addition, a display in the lobby shows the power output of the PV system during the day and the energy produced over time. This information educates the public, yields valuable information to federal and local agencies, and demonstrates the government's commitment to lowering its own energy use and commercializing renewable energy technologies.

Here are the specifics of the DOE installation:

- The PV system consists of 891 crystalline silicon modules, each rated at 230 watts (W) with an efficiency of 18.5%.
- System output is 200 megawatt-hours (MWh) of electricity per year.
- Cost savings on DOE's electricity bill in the first year totaled $26,000.
- Carbon dioxide (CO^2) emissions are being reduced by 186 metric tons per year.

Other federal agencies are doing their part, too: 17 out of 24 federal agencies are using PV, 7 agencies have on-site wind projects, and the federal government has installed thousands of geothermal ground source heat pumps across the nation.

Credit: SunPower/PIX 14594

This 675-kW PV array covers 30,000 square feet on the roof of the Moscone Center in San Francisco, California.

Photovoltaics

PV is an adaptable and modular form of renewable energy. As continuing advancements are made in reliability and performance, and renewable electricity becomes equal to or lower in cost than power from the utility grid, demand for PV technology systems will grow, increasing its significance as part of the national energy supply.

DOE's PV subprogram is working to make PV competitive with conventional forms of electricity by 2015. To accomplish this goal, DOE has created strategic partnerships that include the national laboratories, start-up solar companies, and universities. These partnerships aim to keep the innovation pipeline full by driving down costs, diversifying products, ensuring adequate supply for rapidly growing demand, and manufacturing dependable products that consumers trust.

PV Basics

PV modules fall into three primary categories. Crystalline silicon (Si), also called wafer Si, is the leading technology, representing about 80% of all PV production. Crystalline Si cells are joined to form a solar module or panel. Thin films can be used to produce solar cells with relatively high conversion efficiencies, while using much less material than crystalline Si cells. Concentrating PV uses optics to concentrate sunlight onto a small area of solar cells. Its primary benefits are high efficiency, low cost, and low capital investment to scaleup.

Funding the Advance of PV Technology

DOE is awarding funding in a number of areas to advance new technologies, move technologies from prototype into production, and improve the manufacturing capabilities of the technologies already being mass produced.

For example, one award area, Next Generation PV Devices and Processes, emphasizes exploratory R&D on innovative PV technologies. This work is expected to produce prototype cells or processes by 2015, with full commercialization expected between 2020 and 2030. The PV Technology Pre-Incubator project helps small businesses bridge the gap between the concept verification stage of a PV technology and the development of a commercially viable prototype by 2015.

The PV Technology Incubator projects explore the commercial potential of new manufacturing processes and products produced in pilot-scale operations. Prototypes must demonstrate cost, reliability, and performance advantages.

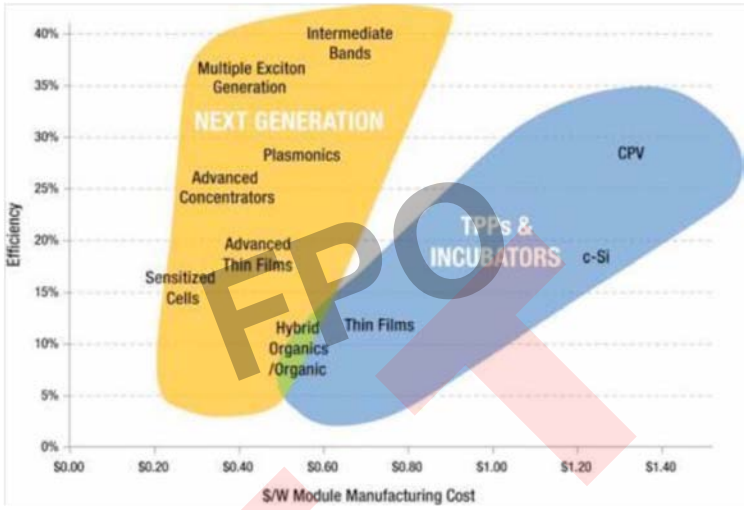
Technology Pathway Partnerships focus on PV component and system designs that are ready for mass production and capable of lowering PV's LCOE

Working to Reduce Costs

Credit: MicroLink Devices/PIX 16605

PV Technology Incubators projects focus on developing prototype PV components and systems for commercialization in 2010. MicroLink Devices, a 2007 and 2008 PV Technology Incubators project awardee, is developing high-efficiency, low-cost, multijunction solar cells for use with a concentrator. PV concentrator technologies focus more light onto a smaller solar cell to reduce cost. The technology and processes being implemented by MicroLink minimize the amount of gallium arsenide (which is very expensive) used in the solar cell, while also improving its ability to dissipate heat away from the cell. These improvements have the potential to enhance the functionality of the cell and reduce its cost by 50%, reducing the cost of the electricity it helps produce.

to grid levels by 2015. The University PV Product and Process Development effort supports industry-led teams developing new PV technologies for commercialization between 2010 and 2015 by emphasizing materials science research and process engineering. The PV Supply Chain and Cross-Cutting Technologies work aims to reduce manufacturing and product costs by improving common PV manufacturing processes and materials, which could have a substantial impact on the PV industry within two to six years. The PV Manufacturing Initiative aims to develop a highly trained solar workforce and accelerate the implementation of innovative technologies that will enable the United States to maintain a competitive edge in domestic PV manufacturing.



This graph represents the cost and efficiency potential for three of the primary partnerships: Next Generation, Technology Pathway Partnerships, and Incubator Projects. The PV subprogram is investing in all major PV cell technologies.

Research and Analysis Steps Up

Four national laboratories—working closely with private sector and academic partners—do most of the research and analysis in DOE's PV subprogram: NREL, SNL, ORNL, and BNL. Because modeling and analysis helps to move technologies from the laboratory to the marketplace, the national laboratories use the Solar Advisor Model (SAM) as a standardized tool for assessing PV system effects on LCOE. SAM is also used within DOE's Solar Program and in industry (which offers input on the model) to analyze different energy scenarios and assess the impact of technology improvements. Other DOE analysis activities are designed to explore the impacts of increased market penetration, policy changes, and technology progress.

If PV technologies are to play a major role in the nation's energy mix, they must be dependable. DOE-supported activities help the solar industry develop more reliable PV systems and make increasingly confident predictions about performance, lifetime, and system operations and maintenance (O&M) costs. National laboratories develop, validate, and provide the industry with techniques for failure analyses, accelerated tests correlated with field failure mode observation, and predictive performance models based on extensive laboratory and field data.

SAM: Simple Name, Powerful Capabilities

SAM, developed by NREL and SNL with support from the DOE Solar Program, is a modeling tool that can examine not only system performance, but can also consider several types of financing (from residential to utility-scale) for most solar technologies. SAM enables system output and LCOE to be calculated using a common platform across technologies. The solar technologies currently represented in SAM include flat plate and concentrating PV technologies as well as CSP, parabolic trough, dish-Stirling, and power tower systems. The model allows systems performance data for diverse technologies in diverse climates to be collected, which improves understanding and future modeling of key system derate and performance factors like shading and PV module operating temperature, among many others.

SAM's development is ongoing, with researchers exploring the following ways to expand the model: (1) adding more financing and performance models; (2) modeling storage in solar systems; (3) incorporating more robust reliability parameters and O&M costs; and (4) estimating model uncertainty as a function of technology, system size, and frequency of input data.

The last activity becomes increasingly important as solar reaches higher penetration levels on the grid, making the variability of solar-system output a key consideration. Understanding the dynamic output of both large-scale and distributed systems will require ongoing model improvements.

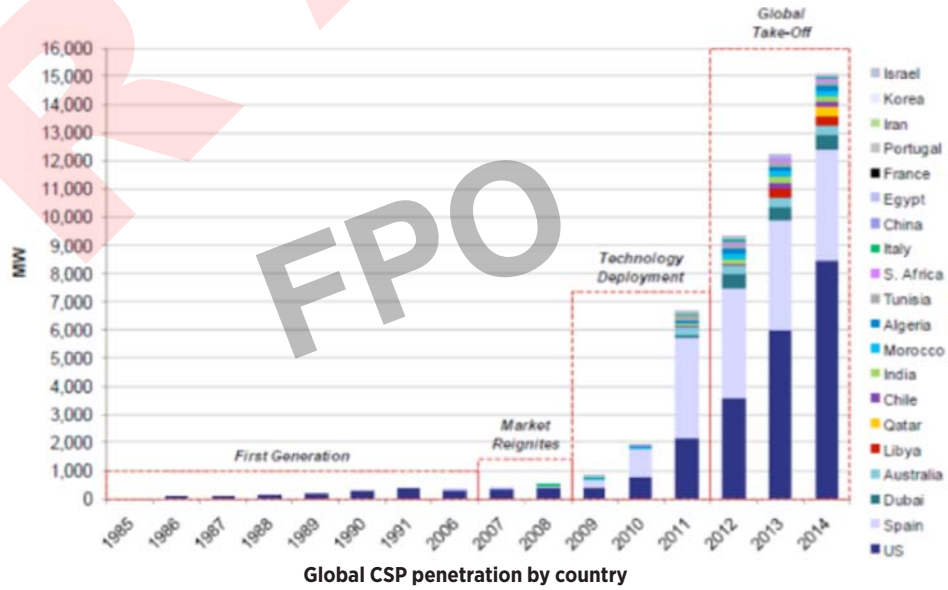
DOE is also supporting the laboratory and field testing of industry-supplied products through the national laboratories in conjunction with the development of an extensive test database, test methods in laboratories and in the field, and standards. During the past year, DOE tested products from more than 60 solar companies.

PV Highlights

- First Solar, a U.S.-based company with technology roots at NREL, became the first PV company in the world to produce 1 GW in 2009. First Solar has also joined the Desertec Initiative to demonstrate the potential of PV to convert sun into clean energy on a large scale.[4] With the ability to yield high amounts of energy under high-heat conditions, First Solar's advanced thin film technology lends itself well to the desert environment.[5]
- Applied research at the national laboratories has led to world-record PV efficiencies of 43%.
- SunPower, a DOE awardee, has demonstrated back-contacted silicon PV modules with 20% efficiency.
- DuPont is developing the first large-scale, high-volume, low-cost four-step atomic layer deposition (ALD) process to build up multiple aluminum and oxygen amorphous layers for use as an ultrabarrier for CIGS thin films.

Concentrating Solar Power

CSP offers a utility-scale, firm, dispatchable renewable energy option that can help meet the nation's demand for electricity. Worldwide, CSP activity is rapidly scaling, with approximately 14,500 MW in various stages of development in 20 countries. In the United States alone, more than 419 MW of CSP are currently in operation, with another 75 MW under construction and more than 10,000 MW under development.



Global CSP penetration by country

Source: Emerging Energy Research

[4] For more information about Desertec, visit http://www.desertec.org/en/, accessed March 2010.

[5] http://www.firstsolar.com/en/index.php

CSP Technology Basics

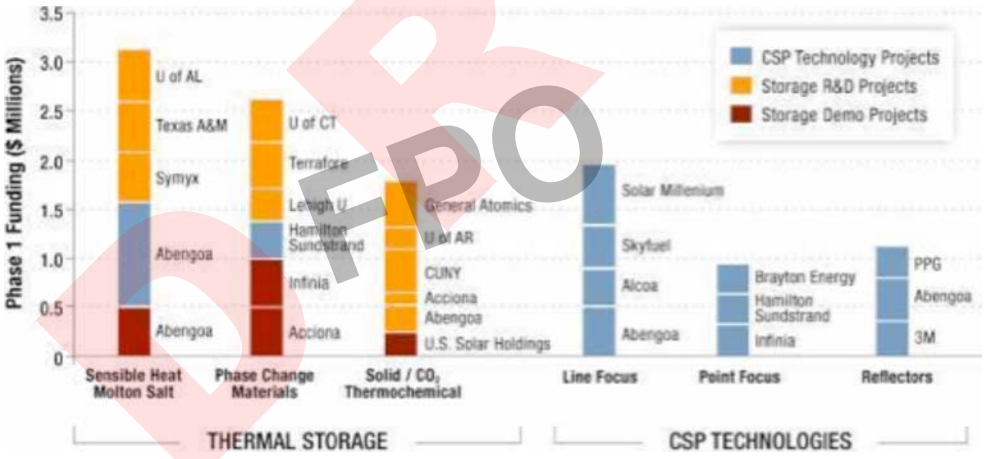
There are three types of CSP systems. Linear concentrator systems use mirrors that reflect and focus sunlight onto a linear receiver tube. The receiver contains a fluid that is heated by the sunlight and then used to create superheated steam, which spins a turbine and drives a generator to produce electricity. Dish-engine systems use a parabolic dish of mirrors to direct and concentrate sunlight onto a central engine that produces electricity. Power tower systems use numerous tracking mirrors, called heliostats, which reflect the sun's rays to a receiver located on top of a centrally located tower. A heat transfer fluid heated in the receiver is used to generate steam, which is used in a conventional turbine generator to produce electricity.

Collaborating to Lower Costs

The goals of the CSP subprogram include lowering costs and advancing technology to the point that CSP is competitive in the intermediate power market between 2015 and 2017 and in the baseload power market between 2020 and 2022. R&D is conducted through cost-shared contracts with industry, universities, and national laboratories. In addition, the CSP subprogram develops partnerships with federal and state agencies, as well as the solar industry, to encourage the deployment of CSP technologies by addressing land and transmission issues.

Offering Financial Opportunities

Since 2007, the CSP subprogram has established 27 ongoing partnerships through competitive solicitations with companies and universities by giving financial and technical assistance to each awardee. The 12 contracts awarded in 2007 focus on advanced CSP components and manufacturing concepts; the 15 contracts awarded in 2008 emphasize novel thermal energy storage concepts and improved heat transfer fluids. All of these projects represent important steps toward making CSP a cost-competitive source of power.



CSP subprogram cost-shared R&D projects

Supporting Industry

National laboratories, primarily NREL and SNL, support the CSP industry with critical R&D to meet cost, reliability, performance, and manufacturing challenges.

One of the most important avenues of support is through optical tool development, including the Video Scanning Hartmann Optical Test (VSHOT) and Theoretical Overlay Photographic Collector Alignment Technique (TOPCAT). Industry partners have used both tools to characterize and align reflectors. Resource assessment allows accurate weather and solar insolation data to be captured through improved satellite imaging, additional ground data sites, and forecasting. Other research topics include materials; thermal storage and heat transfer concepts; reflector and absorber concepts; trough, tower, and dish-engine component and system R&D; and CSP systems analysis.

Moving CSP into the Market

CSP technology continues to mature and develop at a rapid pace, but several nontechnology hurdles (primarily related to land and transmission access) stand in the way of large-scale CSP deployment in the United States. In terms of land use, CSP plants require a relatively large plot of land; for example, a 100-MW project requires almost 1 square mile of land. And that land must be selected in a way that minimizes environmental and ecological effects.

In response to these concerns, the CSP subprogram is co-leading a programmatic environmental impact statement with the U.S. Department of the Interior's Bureau of Land Management (BLM). A significant number of acres administered by BLM in desert areas of the Southwest register the necessary levels of solar radiation for CSP development. The purpose of the environmental impact statement is to identify suitable federal land in California, Arizona, New Mexico, Nevada, Colorado, and Utah for utility-scale solar project development. The California Energy Commission, the California Public Utilities Commission, the Department of Defense, and Argonne National Laboratory (ANL) are also participating. So far, 24 solar energy study areas have been identified, totaling 676,000 acres of land.

In addition to land, utility-scale CSP projects need transmission lines to carry their power from remote locations to load centers. But most transmission lines in the Southwest are already at or near full capacity, making access to transmission difficult. The CSP subprogram is working alongside DOE's Office of Electricity, the Western Area Power Administration (Western), the Western Governors' Association (WGA), and states to identify the best locations for new transmission corridors.

Tracking the Sunshine

Collaborations between the solar industry and national laboratories led to the development of a ground-breaking, low-cost system for utility-scale power generation: the SkyTrough Parabolic Trough Solar Concentrating Collector. The system overcomes the cost barriers of traditional solar concentrators by using a new low-cost, high-reflectance polymeric film instead of the traditional heavy, glass-based mirror. Concentrating parabolic troughs are mounted on a utility-scale two-axis tracker to accurately track the sun during testing. A fluid is circulated through the focal line of the concentrator and used to calculate the optical efficiency of the collectors. The system, developed by SkyFuel Inc. in Albuquerque, New Mexico, was honored by *R&D Magazine* in 2009 with an R&D 100 award.

The SkyTrough, shown here in the foggy predawn darkness in Golden, Colorado, is part of the optical efficiency test loop at the Solar Industrial Mesa Top Area near NREL.

Credit: Steve Wilcox/PIX 16903

CSP Highlights

- Received $22.7 million in funding from the *American Recovery and Reinvestment Act of 2009*[6] (the Recovery Act) to upgrade SNL and NREL facilities: SNL for thermal storage and advanced systems testing, and NREL for a materials research laboratory and advanced thermal storage facility.
- Issued a $4.7-million CSP National Laboratory Call, under which advanced thermal energy storage (TES) and heat transfer fluids research will be conducted through awards to ANL, NREL, ORNL, Los Alamos National Laboratory, Pacific Northwest National Laboratory, and Savannah River National Laboratory. These contracts, made possible by Recovery Act funding, complement and support the ongoing private sector work.

Systems Integration

With solar energy technologies supplying more electricity in the United States, integrating them seamlessly into the nation's electric power grid becomes increasingly important. Technologies for generation planning, interconnection, communication and control, and energy management are needed to allow solar electricity to feed into the grid simply, safely, and reliably. The Systems Integration subprogram works with industry, universities, and the national laboratories to overcome technical barriers to the large-scale deployment of solar technologies on the grid. The

Credit: Tom Stoffel/PIX 15558

Utility and Lab Collaboration in Colorado

The Systems Integration team is also collecting performance data on a large PV plant in Alamosa, Colorado. Sitting on 82 acres, the Alamosa Photovoltaic Plant uses Suntech solar modules to generate about 8.2 MW of power. SunEdison built, owns, and will maintain the Alamosa plant under a Solar Power Services Agreement. Xcel Energy will buy renewable energy credits and the solar power generated by the plant for 20 years. The solar power plant near the substation is unique because it consists of three types of solar technologies: single-axis tracking arrays, fixed-mount arrays, and a dual-axis tracking array with PV concentrator technology.

[6] See http://www.recovery.gov/Pages/home.aspx, accessed March 2010.

subprogram is investing primarily in five areas: technology development, system modeling and analysis, solar resource assessment, codes and standards, and system testing and evaluation.

DOE is investing in new advanced inverter, controller, and energy management technologies, and Systems Integration is also working with industry and utilities to test and demonstrate high penetration solar applications, both in the laboratory and in the field. To help better predict solar's impact on the grid, DOE is developing advanced technical and economic modeling, simulation, and analysis capabilities that will give utility personnel a better understanding of PV and CSP system power production. In addition, new ground- and satellite-based methods are being investigated for measuring, modeling, and forecasting solar radiation. Finally, DOE is supporting the development of consistent solar interconnection codes and standards and transparent regulatory implementation practices. Collaborators in this work include the Solar America Board of Codes and Standards, the national laboratories, the National Institute of Standards and Technology (NIST), and IEEE.

Clearing the Way for Solar

To help ensure the "bankability" of PV systems, the Systems Integration subprogram tests and evaluates new technologies to determine their impact on system performance and LCOE. Because component and system reliability are so important to reaching LCOE commensurate with conventional generation, the national laboratories are working diligently with industry and code-making bodies to develop test protocols to find failure mechanisms early so they do not affect the legitimacy of solar as a proven technology. These testing and evaluation activities are then used to enhance the development of models like SAM, allow validation of component/system models, and integrate various modeling platforms for collaborative development and use.

Credit: Florida Power and Light/PIX17364

The 25-MW PV plant in DeSoto, Florida.

Collaborating with Stakeholders

The Systems Integration subprogram is working with NIST to develop new standards, including additions to the distributed energy interconnection standard IEEE 1547.[7] The subprogram is also collaborating with the Electric Power Research Institute (EPRI) to develop new communications standards so utilities can communicate with and potentially control solar systems on the grid. And the national laboratories are collaborating with the National Oceanic and Atmospheric Administration (NOAA) to collect high-quality solar radiation data from ground- and satellite-based measurements, meet the need for improved atmospheric models, and develop solar radiation forecasts. Finally, the Solar Program is learning a great deal from the experiences of the Utility Wind Interest Group (UWIG), particularly because the integration of wind power into the electric transmission system is relatively mature.

[7] http://grouper.ieee.org/groups/scc21/1547/1547_index.html

National laboratories such as NREL and SNL supply a range of technical and analytical assistance to industry partners in all five areas of the subprogram. They were instrumental in tackling the first step, which was to identifying the scope of challenges for solar technologies to integrate into the grid by conducting a comprehensive analysis. The labs recently completed the Renewable Systems Interconnection (RSI) study, which consists of 14 reports, along with an executive summary, that address a range of grid-integration issues. The reports were developed collaboratively by a team of technical experts with valuable input from the industry.[8]

Investing in the Smart Grid

The Systems Integration subprogram has awarded $24 million from the Recovery Act for a three-year Solar Energy Grid Integration Systems (SEGIS) Program. SEGIS funds companies working on innovative technologies that will allow more PV systems to be integrated on the distribution system safely and reliably.

These smart grid projects focus on developing three types of PV systems, which (1) communicate with an interactive utility grid and allow for bidirectional communications, fully controllable features, power and reactive power control, and grid stability; (2) work with energy storage devices and smart appliances that support the grid and respond to utility price signals; and (3) interact with building energy management systems.

In addition, DOE has awarded $37.5 million through the 2009 Funding Opportunity Announcement for High-Penetration Solar Deployment projects. This funding opportunity solicited industry-led projects to address topics in improved modeling tools, field verification of high-penetration PV use cases, modular power architecture, and demonstration of PV and energy storage for smart grids (which use digital technology to improve reliability, security, and efficiency).

Local students were among those at the dedication of the new Lanai PV system.

Credit: Craig T. Kojima

Making the Most of Hawaii's Sunshine

The Systems Integration team is supporting several solar projects in Hawaii. Since the Hawaii Clean Energy Initiative was launched in 2008, state officials have partnered with DOE to help the state obtain 70% of its energy from renewables by 2030.

One of projects involved engineering support to the island of Lanai for installing a 1.2-MW PV system with energy storage. This solar farm covers 10 acres and includes 12 arrays of more than 7,000 panels and a tracker system, representing a very high penetration of PV onto the Lanai grid. Other projects include developing road maps for renewables on each island and integration of several grid-tied PV projects.

System Integration Highlights

- Awarded funds to 12 industry teams through the SEGIS program to develop new inverters and controllers with interfaces for smart grid technology
- Began monitoring large-scale PV performance at high-penetration sites in California, Colorado, and Hawaii to better understand how high levels of PV affect the grid and to reduce installation costs

[8] To download the reports, visit http://www1.eere.energy.gov/solar/rsi.html, accessed February 2010.

- Developed a PV Working Group that includes utilities, industry, and universities to develop analysis to understand PV variability and collect data for large-scale systems
- Began collaborating with industry leaders SunPower, BP Solar, First Solar, and Hudson Clean Energy Partners on a standardized process to evaluate and improve PV performance models.
- Awarded funds to seven projects through the High-Penetration Solar Deployment award to demonstrate the high penetration of solar technologies on the distribution system.

Market Transformation

Beyond solar technology development and successful grid integration, continued evolution of the domestic solar market will be necessary to enable the Solar Program goal of reaching 10% to 15% solar electricity use by 2030.

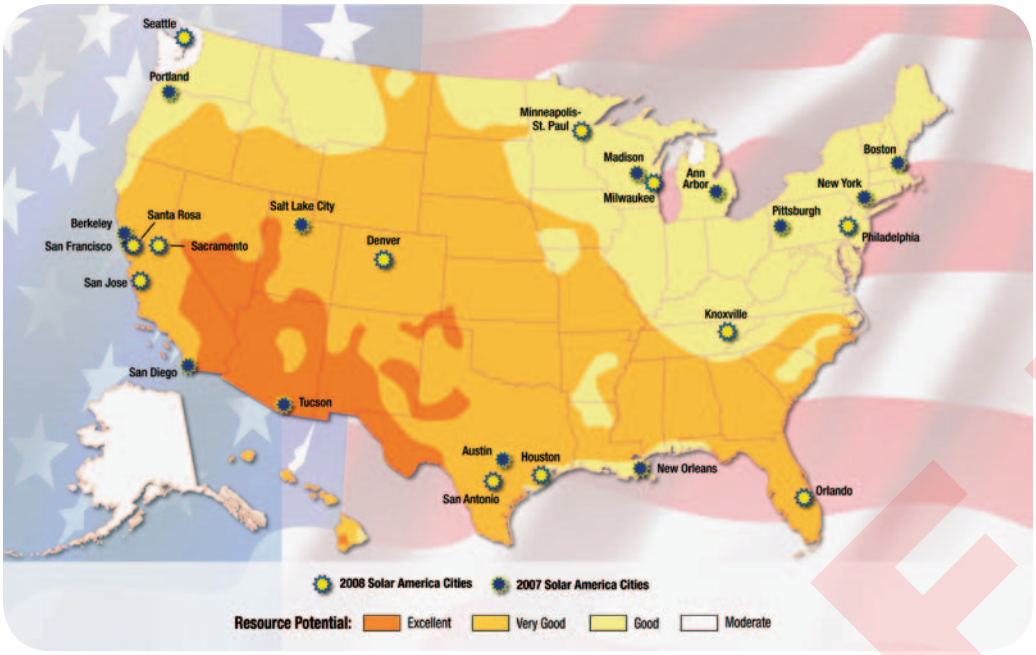
The Market Transformation subprogram contributes to this goal through non-R&D activities that assist state and local governments, create a robust solar workforce, and engage utilities and consumers. Market Transformation actively engages key stakeholders and early adopters through a diverse portfolio of activities that includes education on important issues, policy analysis, and technical assistance. Innovative outreach efforts and peer-to-peer networking quickly disseminate information about best practices and lessons learned. The subprogram is also working to update and streamline regulations and expand affordable financing.

Bringing Solar to America's Cities

Local governments, which often preside over dense centers of electricity consumption, play an important role in accelerating widespread solar energy adoption. As one way to assist local governments, the Market Transformation subprogram created the **Solar America Cities (SAC) Program**. Its four-pronged approach identifies and overcomes barriers to urban solar implementation, allowing lessons learned and best practices to be shared across the nation:

- **Solar America Cities Partnerships** are cooperative agreements between DOE and 25 large U.S. cities to develop comprehensive, citywide approaches to increasing solar energy use.
- **Solar America Cities Special Projects**, funded through the Recovery Act, tackle barriers to urban solar energy use that were identified through the 25 city partnerships.
- **Solar America Cities Technical Analyses**, conducted by national laboratories and DOE's private sector partners, yield unbiased information and tools to meet emerging challenges and capitalize on new opportunities in local solar market transformation. Analysis projects cover innovative financing approaches, methods for streamlining solar permitting, and solar-friendly building and zoning codes, among others.
- **Solar America Cities Technical Outreach** shares best practices with hundreds of other local governments.

The 25 SAC partnerships are diverse in geography, population, and market maturity, allowing DOE to identify barriers and solutions at various stages of solar market development.



Twenty-five U.S. cities are participating in the Solar America Cities Program.

City Efforts Are Paying Off

Early results from progress tracking indicate that installed solar capacity in the Solar America Cities is outpacing national market growth by a wide margin. And feedback from city leaders also indicates that the SAC program is working:

Scott Morrissey, the program manager for Greenprint Denver, said

> *With local governments across the country consistently being asked to do more with fewer resources, the Solar America Cities program is an example of a federal program that works. By providing information that supports local action and connecting Denver to a cohort of leading cities facing similar issues and challenges, the program has increased the profile of solar from a luxury to a critical means to reach Denver's environmental sustainability goals.*

Wilson Rickerson, executive vice president of the Meister Consultants Group and advisor to Boston and New York City Solar America City initiatives, commented

> *The Solar America Cities program has created the space for fundamental change and innovation in some our largest potential solar markets and provided the technical support to see it through. Three cheers to the Department of Energy for getting the program right.*

And Tria Case, university director of Sustainability for the City University of New York (CUNY) and the lead for implementing the New York City SAC plan, put it this way:

> *Through the U.S. DOE Solar America Cities program, an unprecedented partnership has been created with Con Edison, New York City, and CUNY. The SAC program brought us to the table to work together along with key partners, creating a fundamental shift in attitude that has resulted in solar now being an*

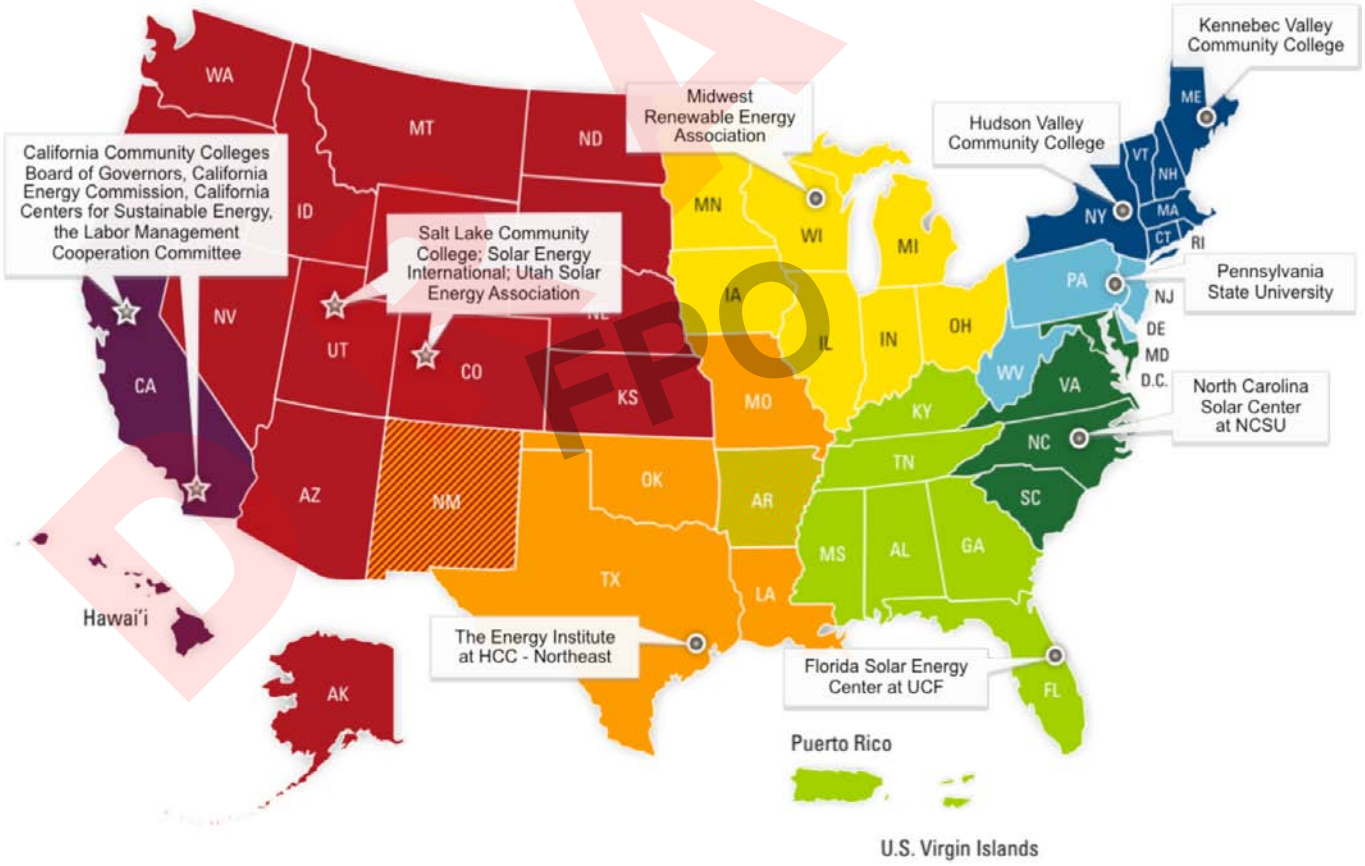
important part of city and utility energy planning. The NYC SAC team has systematically addressed issues such as technical interconnection barriers, administrative hurdles and financial disincentives to solar. Now, as we begin to implement the plan into this country's largest and most complex grid, Solar America Cities is an invaluable resource to us.

Developing a Solar Workforce

A well-trained workforce is critical to a successful solar market, ensuring high-quality installations, cost reductions, and continued consumer acceptance of solar technologies. As the U.S. solar installation industry continues to grow, employers are having difficulty finding qualified workers. And educational institutions face challenges in developing the high-quality training programs required to meet industry needs. In many cases, local educational institutions begin developing courses without sufficient expertise in solar technologies. Market Transformation workforce development activities are designed to complement and increase the effectiveness of investments in workforce development made by state and local governments and other stakeholders.

Solar Instructor Training Network

Additionally, DOE funding to the North American Board of Certified Energy Practitioners (NABCEP) and IREC supports the certification of solar installers and accreditation of solar training institutions. This work is based on industry-approved task analyses and is critical to ensuring safe, high-quality solar installations.



Over the 5-year award period, an estimated 1,400 instructors will be trained.

Engaging States and Stakeholders

Supportive state-level policies and regulations continue to be critical to establishing an effective domestic solar market. States that lead with innovative approaches have reaped the benefits of economic development and local solar market growth. Since 2008, the Market Transformation subprogram has partnered with four organizations—the Interstate Renewable Energy Council (IREC), the National Conference of State Legislatures, the National Association of Regulatory Utility Commissioners, and the Clean Energy Group—to disseminate information on solar policies and technologies to state decision-makers. Beginning in 2010, the Solar Program will significantly expand these efforts with new funding to support national and regional partnerships to reach more state decision makers with timely solar technology and policy information.

Along with states, utilities play important roles in defining the rules, procedures, and economic proposition for solar technologies within their territories. Since 2008, DOE has partnered with the Solar Electric Power Association (SEPA)[9] to disseminate information on innovative solar business models and solar integration into the electric grid to utility decision-makers. Specifically, this partnership has resulted in a variety of utility toolkits, intensive outreach efforts, and a series of reports on technology, policy, and market issues that affect utilities and the solar industry.[10] Market Transformation efforts leverage the work of the Systems Integration subprogram to ensure that utilities have access to updated solar data.

The subprogram is also working with DOE's Federal Energy Management Program (FEMP), providing technical assistance to federal agencies that install solar technologies on federal facilities. For example, the U.S. General Services Administration is tapping Recovery Act funds to install PV systems on 26 federal buildings. In addition, a manual for solar installations on federal buildings is being developed to help streamline future projects.

Credit: Forest City Military Communities, LLC/PIX 15967

This military community in Honolulu, Hawaii, uses high-efficiency solar panels installed on the roof of its Halsey Terrace Community Center to power 10 homes.

Community Center Powers Community Homes

In this Solar America Showcase project, Market Transformation technical experts worked with developer Forest City to incorporate solar water heating (SWH) and PV technologies in a project for the U.S. Navy in Hawaii. The experts supplied analysis, infrastructure assessments, information on financial options, technical construction recommendations, and project management. The technical assessment led to the installation of a 100-kW PV system and also helped the naval base and project developer take the lessons and expertise gained into new projects both in Hawaii and the continental United States.

[9] See http://www.solarelectricpower.org/, accessed February 2010.

[10] To download these reports, visit http://www.solarelectricpower.org/resources/reports.aspx, accessed March 2010.

Market Transformation Highlights

- In the fall of 2009, DOE awarded nearly $10 million in Recovery Act funds to regional solar training providers throughout the United States, starting a 5-year, $27-million program aimed at increasing the quality and availability of instruction in PV and solar heating and cooling systems.

- In January 2009, DOE bestowed three new technical assistance awards under the Solar America Showcases project. These awards provide technical assistance from solar energy experts to high-visibility, large-scale solar installations.[11]

- The annual report Freeing the Grid sets forth an A–F scorecard methodology for grading state interconnection and net metering policies. DOE funding to IREC has enabled direct support to 15 states for net metering and 19 states for interconnection. This outreach led to an average score improvement of two letter grades from 2007 to 2009 across the states IREC assisted.[12]

- Two Texas utilities have embraced solar power in a big way. Austin Energy is partnering with Gemini Solar Development to build the largest solar array in the United States on a 300-acre site at Webberville. The plant will produce 30 MW of power, enough for about 5,000 homes.[13] And CPS Energy in San Antonio has agreements in place for 41 MW of solar power, including a 27-MW solar project in West Texas and a 14-MW PV installation in southeast San Antonio.[14]

- Portland, Oregon, streamlined its solar permitting process to enable 24-hour online turn-around for standard residential systems. In San Jose, California, the city partnered with industry groups to map out the stages of the permitting process and convened workshops to discuss ways to streamline like training code officials or simplifying paperwork. And in New Orleans, the city linked its permitting database with the utility's tracking systems, so as soon as the city approves a solar installation, the utility can turn it on.

Solar Heating and Cooling

Solar heating and cooling (SH&C) technologies harness the sun's energy to generate hot water and to heat, cool, and dehumidify the interior spaces in buildings. Under this activity, DOE's collaborations with U.S. industry are aimed at using low-cost polymer materials and simplifying manufacturing, assembly, and installation to reduce the cost of energy from mild-climate and cold-climate solar water heaters by at least 50%. In addition, work continues to develop combined solar electric/solar thermal systems for homes and commercial buildings. These systems not only heat water and cool spaces, but can produce electricity as well.

The Solar Thermal subprogram is supporting the development and expansion of near-term and next-generation parabolic trough technology for centralized power generation, and is also improving the tools and testing capabilities necessary to support the needs of a growing U.S.

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[11] http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=140 and http://www.azplanning.org/newsltr/August08Vision.pdf

[12] Visit www.freeingthegrid.org to download the 2009 report, accessed April 2010.

[13] http://www.inhabitat.com/2009/06/03/us-largest-solar-power-facility-approved-in-austin/

[14] http://www.cpsenergy.com/Services/Generate_Deliver_Energy/Solar_Power/index.asp

Credit: Jim Tetro/PIX 16187

Both PV and SWH systems are installed on the roof of this 2007 Solar Decathlon competition home.

trough industry. The subprogram is also working to improve the reliability, performance, and cost of dish/engine components and systems and to develop advanced TES technologies.

In 2007, the SH&C activity was transferred from the Solar Thermal subprogram into the Building Technology Program to support its strategic goal of net-zero energy buildings.

Moving into the Market

DOE's national laboratories are working to advance trough technologies that can be deployed in the near term in sunny areas like the southwestern United States. The longer-term objective is to help make future trough plants competitive with conventional power plants.

The Parabolic Trough R&D project is working to develop a single-tank thermocline TES system, which will reduce the cost of TES by more than 50% compared with a two-tank system.

As part of the Dish/Engine System R&D project, Stirling Energy Systems (SES) and SNL are collaborating to improve dish/engine system performance, reliability, and cost and to deploy systems in the Southwest. The six-dish Model Power Plant at SNL facilitates SES dish/engine R&D, including system development and reliability improvement.

Two DOE-supported low-cost SWH systems entered the marketplace in 2007 and 2008. FAFCO, Inc., introduced its polymer-based active solar water heater in February 2007, and by 2009, more than 3,000 systems had been installed. And SunCache, developed by Davis Energy Group with DOE and NREL support, is a polymer-based passive SWH system that costs less than half of current copper, aluminum, and glass SWH systems. The system was certified by the Solar Rating & Certification Corporation (SRCC) in June 2008, and more than 250 SunCache systems have been installed in California so far.

Deployment opportunities are promising as well. To date, SES has announced power purchase agreements of 500–850 MW with Southern California Edison and 300–900 MW with San Diego Gas and Electric.

The Solar Decathlon

Originally conceived in 1999, an idea for testing the power of the sun soon grew into one of the most ambitious and inspiring events in the country—DOE's Solar Decathlon. Held every two years on the National Mall in Washington, D.C., the competition challenges teams of university students from around the world to design and exhibit energy-efficient houses powered exclusively by the sun.

Thousands of people visit the Solar Decathlon to see the one-of-a-kind houses, learn about renewable energy and energy efficiency, and understand the potential of solar-powered living.

At the same time, the Solar Decathlon teaches student participants about the benefits of energy efficiency, renewable energy, and green building technologies. The competition unfolds in three major phases:

- Building: In addition to designing houses that use innovative, high-tech elements in ingenious ways, students must raise funds, communicate team activities, collect supplies, and work with contractors.
- Moving to the Solar Village: Before the competition begins, the teams must transport their houses to the National Mall and rebuild them on site.
- Competing: During the competition itself, the teams receive points for their performance in 10 contests and open their homes to the public.

Some contests are scored by measuring performance, such as meeting certain temperature requirements. Other contests require the successful completion of tasks—which might simulate everyday activities such as cooking, washing dishes, and doing laundry. Still other contests are scored by jurors who are experts in architecture, engineering, and other appropriate fields. The jurors evaluate features that measurements cannot, such as aesthetics and design inspiration.

Today's decathletes are tomorrow's engineers, architects, and entrepreneurs—and the Solar Decathlon gives them unique training for green jobs in renewable energy and energy efficiency.

The Solar Decathlon offers participating students unique training for green jobs in renewable energy and energy efficiency.

Credit: Stefano Paltera/U.S. Department of Energy Solar Decathlon

Solar Decathlon Highlights

Team Germany, the student team from Darmstadt, Germany, won the 2009 Solar Decathlons by designing, building, and operating the most attractive and efficient solar-powered home. The University of Illinois at Urbana-Champaign took second place and Team California (Santa Clara University and California College of the Arts) came in third. Team Germany's winning "Cube House" design produced a surplus of power even during three days of rain.

Looking Ahead

The Solar Program will continue to actively support the widespread deployment of solar energy technologies through a variety of initiatives. For example, as the 2009 Solar Decathlon opened on the National Mall in Washington, D.C., Energy Secretary Steven Chu announced that up to $87 million will go into 47 projects aimed at developing new solar energy technologies, rapidly deploying carbon-free solar energy systems, and training solar installers. Of this funding, $50 million comes from the Recovery Act. DOE's national laboratories will work with universities, utilities, and local governments in four categories:

High-Penetration Solar Deployment: Seven projects will model, test, and evaluate the impact of large amounts of PV on the reliability and stability of the electric grid. These projects will help pave the way for broader adoption and growth of grid-tied solar energy systems.

Solar America Cities Special Projects: Sixteen cities have been selected for projects that will tackle specific barriers to solar adoption in urban settings and support innovative approaches that can be widely replicated.

Solar Installer Training: Nine colleges, universities, and local organizations have been selected to lead regional solar "train-the-trainer" programs. The projects will support a national ramp-up and coordinated network of training programs for qualified solar energy system installers.

Research Projects at DOE National Laboratories: Fifteen projects at the laboratories will improve technologies, devices, and processes for the PV and CSP industries. PV projects focus on developing next generation devices and processes, as well as supply chain technologies for the entire PV system. CSP projects focus on improved energy storage technologies.

All subprograms will continue supporting work that is already under way, and the sections that follow briefly summarize future plans for each subprogram.

Photovoltaics

Under a PV Manufacturing Initiative, collaborators will work to coordinate stakeholders and accelerate technology development efforts across the solar community to strengthen the PV manufacturing and supply chain industries in the United States. The primary goals include supporting manufacturing technology related to PV production and its supply chain base, developing a workforce with the required technical skills, and speeding the implementation of new cutting-edge technologies.

A Web-Based PV Database project will support developing, populating, and maintaining a PV performance database that is Web based. The database will contain operational data of grid-tied PV systems at installation sites in the field. The data will be used for monitoring and evaluating long-term cost and performance information on PV systems and components as well as for tracking progress towards reaching grid parity. The estimated budget will be approximately $1.5 million total, and the performance period will be 5 years.

The PV Supply Chain and Cross-Cutting Technologies project will focus on component and manufacturing technologies with the potential to have a near-term market impact (within two to six years of award) on a substantial segment of the PV industry. Applications either

(1) have a high impact on innovative evolutionary improvements that can be supplied across the industry at higher volumes and lower costs than current conventional technology today, or (2) propose disruptive technologies (those that improve a product or service in ways that the market does not expect) that are applicable to a narrow segment of the industry and can dramatically reduce costs.[15]

Concentrating Solar Power

A Baseload project will focus on developing prototype CSP systems with up to 18 hours of thermal storage, as well as components for CSP systems. The goal of these systems is to enable a CSP plant to produce electricity at a rate that is cost-competitive with a coal-fired power plant. If achieved, this will give utilities an alternative to coal plants in the baseload power market, helping them to reduce CO^2 emissions. Each project will include three phases: feasibility, engineering design, and prototype test/evaluation.

The CSP subprogram is also planning a Demonstration solicitation, which will focus on designating and managing a plot of land for CSP development. This project is designed to assist industry by providing the necessary land and infrastructure to demonstrate new technologies at a sufficiently large scale. This, in turn, will demonstrate commercial viability to the financial community. This activity is meant to bridge the gap between lab prototype and commercial product, a process that often leaves innovative technologies on the laboratory shelf. DOE and BLM are working together to select an appropriate land area for the demonstration site. Each demonstration project may include two phases: a small-scale demonstration in the range of 1 to 10 MW, and a full-scale demonstration of greater than 100 MW. DOE will cost-share the small-scale demonstrations and enable access to land and transmission for the full-scale demonstrations.

Some of the technologies that are likely to be studied include high-temperature troughs; low-cost thermal storage; low-water-consumption operations; innovative power conversion cycles; low-cost reflectors, concentrators, or heliostats; and concentrating photovoltaic (CPV) systems.

Systems Integration

In FY 2011, new models based on extensive operational data will be developed to fully characterize the grid impacts of 10% to 20% (by energy) penetration of solar electric technologies at the transmission and distribution levels. In addition, the SEGIS program will produce functional, pilot-production energy management systems for distributed PV systems, enabling a new level of sophistication in the integration of grid-connected PV systems, information technology, and optimal control of energy generation and use.

In addition, the subprogram will focus on the following:

- Deploying new solar resource measurement systems for collecting 1-s data to understand solar resource and system variability
- Developing advanced modeling, simulation, and analysis capabilities

[15] http://www1.eere.energy.gov/solar/upcoming_opportunities.html

- Developing new methods of forecasting and investigating the potential of storage technologies to help alleviate issues related to high levels of grid penetration
- Developing and refining integration operational methods and best practices needed for accommodating the variable nature of the solar resource on the electrical grid.

Market Transformation

The subprogram anticipates funding additional partnerships to strategic organizations that direct outreach and support to state legislators, state utility commissioners, and state clean energy funds, with a focus on both national and regional challenges. The subprogram also intends to support experts from national laboratories as they offer in-depth technical assistance on policies and issues such as feed-in tariffs, renewable portfolio standards, and financing.

DOE plans to expand its utility outreach efforts to include an emphasis on municipal utilities and electric cooperatives and to cover both PV and CSP technologies.

Solar Heating and Cooling

The main research pathways in SH&C address reducing material costs while maintaining energy performance, in combination with innovations that can leverage the benefits of other building systems such as conventional heating, ventilating, and air-conditioning (HVAC) and PV systems. Replacing copper and glass with polymers reduces material and manufacturing costs and weight, which can reduce installation costs as well. SH&C also works to integrate solar heating and cooling technologies with the building envelope to meet the space conditioning and water heating loads of zero energy buildings, with particular emphasis on systems that can be retrofitted to existing buildings.

SH&C complements its research activities with similar R&D conducted through the Solar Heating & Cooling Program of the International Energy Agency (IEA). IEA SH&C task activities include investigating polymeric materials for solar thermal applications, solar air-conditioning and refrigeration, and advanced storage concepts for solar thermal systems in low-energy buildings.

Solar Decathlon

The next Solar Decathlon will be held in Washington, D.C., in the fall of 2011. The RFP, RFP amendments, and draft rules for the 2011 competition have been released, and students from around the world are already gearing up to compete.






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