Modeling and Analysis of CSP Systems

The Concentrating Solar Power (CSP) program at the National Renewable Energy Laboratory (NREL) measures and models the solar resource, develops and uses computer models for system performance and technology deployment modeling, and investigates the environmental benefits and impacts of utility-scale solar power.

Assessing the Solar Resource

All CSP technologies use collectors to focus sunlight onto receivers in the process of converting solar energy to electricity. CSP systems rely on "seeing" the direct solar beam—known as Direct Normal Irradiance (DNI); consequently, measuring, mapping, and modeling the DNI resource are essential.

In the Solar Resource and Meteorological Assessment Project (SOLRMAP), NREL collaborates with multiple industry partners to collect precise, long-term solar resource measurements. This information helps to minimize the technical and financial risks of new solar energy projects. Industry partners fund the cost of instruments, maintenance, and station operations; NREL provides expertise for station design, instrument selection, data acquisition, quality procedures, data analysis, calibrations, and data distribution.

One objective of SOLRMAP is to acquire ground-based data that will help upgrade models that use satellite imagery to estimate solar radiation. NREL uses satellite images to generate hourly estimates of DNI and global horizontal irradiance across the United States. Higher-resolution models, now in development, feature 15- to 30-minute temporal and 4-km x 4-km spatial resolution. NREL maintains the National Solar Radiation Database and other solar data and mapping resources at www.nrel.gov/rredc/solar_resource.html.

Our primary tool for gathering and presenting DNI information is the Solar Power Prospector (http://mercator.nrel.gov/csp/). The Prospector allows users to investigate the historic solar resource for individual 12-km x 12-km grids throughout the country, as well as to examine land topography and ownership. Proposed Renewable Energy Zones (REZs), solar-suitable brownfield sites, and other information are also provided. NREL analysts use the data to develop case-specific maps of solar potential for policymakers and for related studies, such as the Western Governors' Association Renewable Energy Zones initiative.

The NREL resource assessment team is also developing methods for forecasting the solar resource. We are investigating data from sky imagers and short-term cloud-motion images to provide short-term forecasts up to six hours in the future. Standard weather forecasting models, supplemented with mesoscale models, are used for day-ahead and longer forecasts. The activities are coordinated with experts from the National Oceanic and Atmospheric Administration (NOAA), NASA, and international organizations.

Predicting Performance and Cost

With our models, users can predict the performance and cost of solar technologies at specific sites. The models can also help analysts assess the potential market penetration and economic impact of CSP under different policy and deployment scenarios.

The Solar Advisor Model (SAM) provides a consistent framework for analyzing and comparing power system costs and performance across the range of solar technologies and markets—from photovoltaic (PV) systems for residential and commercial markets to CSP and large PV systems for utility

Solar Resource and Meteorological Assessment Project (SOLRMAP) stations, like the one being installed here, collect solar resource measurements used to plan and locate new CSP plants. SOLRMAP is a collaboration between NREL and its partners in the energy industry.

PIX 16994; Credit, Tom Stoffel

markets. The software integrates an hourly simulation model with performance, cost, and finance models to calculate energy output, energy costs, and cash flows. SAM can also account for the effect of incentives on cash flows. Most of SAM's inputs can be used as parametric variables for sensitivity studies to investigate the impacts of variations in physical, cost, and financial parameters on model results. SAM can be downloaded at https://www.nrel.gov/analysis/sam/.

The Regional Energy Deployment System (ReEDS) is an electric-sector capacity expansion model developed at NREL to model the future electric grid. In 2007, this tool was used to estimate the cost and transmission requirements of generating 20% of U.S. electricity from wind power by 2030. CSP plants with storage and PV technologies have been added to the model, which is being used to perform solar deployment analyses for scenarios such as DOE's Solar Vision Study.

Originally developed in 2002 for the DOE's Wind Powering America project, the Job and Economic Development Impact (JEDI) model has been expanded to include the job and economic impacts of parabolic trough CSP facilities. The project-specific data include costs associated with constructing the facility, as well as equipment costs, other services, fees, and annual operating and maintenance costs. Users can include the portion of expenditures to be spent locally, financing terms, and local tax rates. JEDI provides reasonable default values for each of the inputs needed for the analysis, but users have the option to indicate project-specific data for most categories. The spreadsheet-based JEDI models can be downloaded at www.nrel.gov/analysis/jedi/.

Environmental Impact

The vast potential of utility-scale solar power has raised concerns about how the plants will affect the desert ecosystem. NREL is supporting the joint DOE/BLM programmatic Environmental Impact Statement (PEIS) being performed by Argonne National Laboratory (http://solareis.anl.gov/). The PEIS will identify solar power impacts and mitigation methods. The project is also helping the BLM identify preferred zones for solar development.

Although PV and dish/engine CSP systems use no cooling water, trough and power tower CSP systems preferentially use water to cool their thermoelectric power cycle. Dry-cooling technologies can reduce CSP water consumption by more than 90%, allowing CSP power plants to "grow" megawatts with less than one-twentieth the amount of water used by common southwestern crops. To save precious water resources while
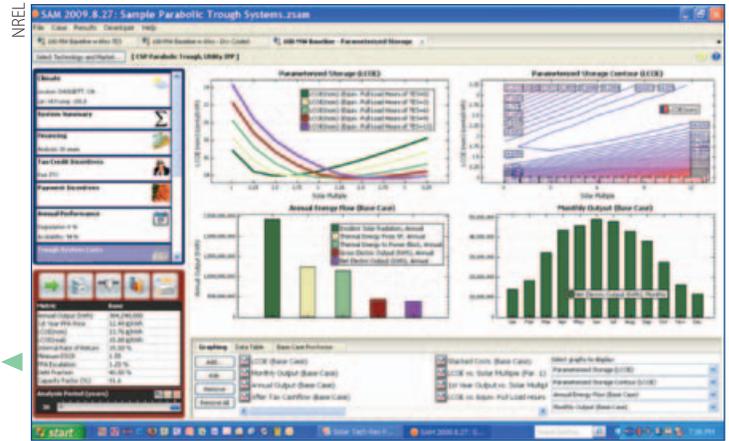
The Solar Advisor Model (SAM) enables users to analyze and compare the cost, financing, and performance of solar power systems at specific sites. Shown here is a SAM interface displaying output data in several table and graph formats.

promoting clean solar power, NREL continues to investigate the best methods for integrating dry-cooling technologies into parabolic trough and power tower technologies.

SolTrace

SolTrace is a software package that models solar power optical systems and analyzes their performance. Engineers can use it to develop complex solar optical designs that could not previously be modeled.

SolTrace can model parabolic trough collectors, point-focus concentrating systems, and power towers. It rapidly displays and saves data as scatter plots, flux maps, and performance graphs. SolTrace can model optical geometry as a series of stages, composed of optical elements that possess attributes such as shape, contour, and optical quality. It can also model any number of stages containing any number of different elements, and it features an extensive variety of available shapes and contours.

To enhance speed and portability, NREL is converting SolTrace to C++. The new version will incorporate a graphical user interface to aid in geometry design. It will interface with other solid modeling and finite-element analysis tools for input and, as an additional output option, it will provide performance data directly to the Solar Advisor Model.

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