



Solar Energy Development on Public Lands

By harnessing the sun's rays to create electricity, solar power has the potential to help transition us away from fossil fuels and combat the effects of climate change. Guiding development to the right places away from sensitive lands and ensuring best practices to minimize impacts will be crucial in establishing a sustainable clean energy future.

Technology

There are two major types of solar technology: photovoltaic (PV) and concentrating solar power (CSP), also referred to as solar thermal.

PV systems employ a range of semiconducting materials such as silicon, cadmium telluride, and gallium arsenide to convert sunlight directly into electricity. Flat-plate PV systems use fixed panels of PV cells to generate electricity. Concentrated PV (CPV) systems use a lens to focus sunlight onto a small PV cell. Both types of PV systems can use both direct and diffuse sunlight.



Source: National Renewable Energy Laboratory

Rather than creating electricity directly from sunlight, CSP systems use focused sunlight to create heat, which is then used to create electricity. And unlike PV systems, CSP systems can only utilize direct sunlight. CSP systems fall into three main categories:



Source: Department of Energy

- **Parabolic trough** systems use long, curved mirrors that have a receiver running through the center of the trough. These mirrors track the sun and concentrate sunlight onto the receiver. Fluid in the receiver, typically some type of oil, is heated and used to generate the steam needed to power a generator.
- **Dish/engine** systems consist of a large mirrored dish, a receiver, and a small engine. The dish tracks the sun and focuses sunlight onto the receiver, and the concentrated heat warms a fluid to generate electricity within the engine. Most dish/engine systems use engine technology that can be driven by any source of heat.
- **Power tower** systems use a large field of mirrors that track the sun (heliostats) and have a tower with a central receiver. The heliostats focus sunlight on the receiver, where molten salt is heated and used to create steam to power a generator.

PV and CSP technologies can generate and store thermal energy at both small, distributed scales (<1 megawatt (MW)) and utility scales. For instance, PV modules can be mounted directly onto buildings for distributed generation. Alternatively, both PV and dish/engine CSP units can be arranged in large arrays for central generation. Parabolic trough and power tower systems are best suited for utility-scale central generation of at least 50 MW because they use large, conventional generators. They can also use molten salt thermal storage or be hybridized with natural gas systems in order to provide power when the solar resource is not available.

Efficiency

The efficiency of an energy system is defined by how much of the available energy in a resource (in this case, photons in sunlight) is converted into electricity. PV and CSP systems have similar average annual efficiencies. In fact, commercial PV systems average between 7 to 17 percent efficiency, while some experimental PV cells have reached efficiency levels of almost 40



Source: Department of Energy

percent.¹ Comparatively, the efficiencies of parabolic trough systems are about 11 percent,² dish/engine systems (using a Stirling engine) are about 22 percent,³ and power tower systems are approximately 17 percent.⁴ In January 2008, a record 31.25 percent solar-to-grid conversion efficiency was set by a Stirling engine system.⁵

Supply & Demand

Deployment

According to the Department of Energy's (DOE) preliminary 2007 statistics, the national electric net summer capacity of solar was 498 MW.⁶ The vast majority of this capacity (403 MW) is located in California, with a significant amount in Nevada (78 MW) and smaller amounts in Arizona and Colorado (9 MW and 8 MW, respectively).

Parabolic trough systems are the most advanced of the CSP systems, and four have been operating in the Mojave Desert in California for the past 15 to 20 years. New parabolic trough projects are currently being developed in Nevada. There are six test dish/engine systems at Sandia National Laboratories in New Mexico, but none are yet in commercial operation.⁷ A 10

¹ U.S. Department of Energy Solar Energy Technologies Program. "Solar FAQs—Photovoltaics." 2007.

http://apps1.eere.energy.gov/solar/cfm/faqs/third_level.cfm/name=Photovoltaics/cat=The%20Basics

² U.S. Department of Energy. "Solar Energy Technologies Program Plan 2007-2011). January 2006. page 65.

http://www1.eere.energy.gov/solar/pdfs/set_myp_2007-2011_proof_2.pdf

³ Ibid. page 66.

⁴ Sandia National Laboratories. "R&D 100 Awards Entry Form." 2000. <http://www.azsolarcenter.com/links/faqs/solar.pdf>

⁵ Sandia National Laboratories. "Sandia, Stirling Energy Systems set new world record for solar-to-grid conversion efficiency." February 2008.

<http://www.sandia.gov/news/resources/releases/2008/solargrid.html>

⁶ Energy Information Administration. "Renewable Energy Consumption and Electricity Preliminary 2007 Statistics. May 2008.

http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table8.html

⁷ U.S. Department of Energy National Renewable Energy Laboratory. "Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California." April 2006. <http://www.nrel.gov/csp/pdfs/39291.pdf>

MW commercial power tower plant operated in California from 1982 to 1989 and successfully used thermal storage during its last two years. There are no commercial power tower plants in the US, although an 11 MW plant opened in Spain in 2007.

Resource Potential

There is significant potential for solar energy development in the U.S. According to the DOE, the solar resources available in the southwest are more than sufficient to meet all U.S. electricity demand, even using currently available technologies and operating at 10 percent efficiency.⁸ However, because many CSP plants need 5-10 acres of land per MW,⁹ supplying even part of the 1,000 gigawatts of electricity the U.S. consumes annually will require the dedication of large tracts of land to solar energy generation.



Source: National Renewable Energy Laboratory

According to the Department of the Interior (DOI), the majority of federal lands in the contiguous U.S. have a high potential for CSP and/or PV solar energy production. A 2005 report by the DOI identified 74 percent of federal lands in the conterminous U.S. as having a high potential for PV, and 67 percent as having high potential for CSP.¹⁰ A similar report, released in 2005 by the National Renewable Energy Laboratory and the Forest Service, identified almost 850,000 acres on 20 forest units with high-potential for CSP and over 2 million acres on 26 units with high-potential for PV. Identified areas were located in Arizona, California, Colorado, Michigan (PV only), Nevada and Utah.¹¹

Despite the significant solar potential on public lands, there are currently no solar energy projects under development on public lands in the United States. But since early 2005, however, energy developers have been applying for permits to develop solar energy projects on Bureau of Land Management (BLM) lands. Currently, the 220 pending applications for solar energy projects on BLM land cover 2.3 million acres across six states.¹² Most applications for permits on public land have been in California.

Permitting Process

Federal

In May 2008 the BLM and DOE announced a programmatic Environmental Impact Statement (PEIS) to develop a program to process future solar applications on public lands.¹³ The program would assess the impacts of solar energy development as well as develop a set of policies for minimizing impacts of the projects on federal, state, tribal, and private land. The PEIS focused on six states with high solar energy potential: Arizona, California, Colorado, Nevada, New Mexico and Utah. Of these six states, only Utah does not have any applications.

⁸ U.S. Department of Energy Solar Energy Technologies Program. "Learning About PV." 2008. <http://www1.eere.energy.gov/solar/myths.html>

⁹ National Renewable Energy Laboratory. "Parabolic Trough FAQs." July 2008. <http://www.nrel.gov/csp/troughnet/faqs.html#land>

¹⁰ U.S. Department of the Interior. "Renewable Resources for America's Future." January 2005. http://www.doi.gov/initiatives/renewable_energy.pdf

¹¹ U.S. Department of Agriculture et al. "Assessing the Potential for Renewable Energy on National Forest System Lands." January 2005. <http://www.nrel.gov/docs/fy05osti/36759.pdf>

¹² Bureau of Land Management. "Renewable Energy and the BLM: SOLAR."

http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS_REALTY_AND_RESOURCE_PROTECTION_/energy.Par.78074.File.dat/09factsheetmap_Solar.pdf

¹³ U.S. Department of Energy and U.S. Department of the Interior. "Solar Energy Development Programmatic EIS." <http://solareis.anl.gov/>

State

Solar energy projects on public lands are also subject to state and local regulations. These vary by state, but most involve acquiring an installation permit or other zoning regulations, property taxes on installed systems, and various siting laws and environmental reviews to assess impacts on wildlife.¹⁴ Many states also require additional review and a certification processes if the energy generated will count towards the state’s Renewable Portfolio Standard.

Impacts

Environmental Quality and Land Use

PV cells contain small amounts of toxic and flammable materials like lead, but the potential impacts from these materials are greatest during manufacturing and decommissioning.¹⁵ CSP systems use coolants, which can cause fire or gas contamination if an accidental leakage occurs.¹⁶

CSP development requires large-scale landscape changes, as land must be graded to a slope of less than five percent and all vegetation must be removed to reduce the risk of fire.¹⁷ The grading and clearing is particularly significant because of the large size of most CSP plants. In fact, nearly 1,000 acres of land are needed for a 100 MW parabolic trough plant with storage.¹⁸ The removal of vegetation from such a large area could lead to the destruction and fragmentation of sensitive desert habitats, reinforcing the importance of compliance with the National Environmental Policy Act and the Endangered Species Act in all solar projects.

Parabolic trough and central tower systems both use steam to power a conventional generator. These types of plants can either be “wet cooled” with water or “dry cooled” with air. Using up to 1,000 gallons per MWh, wet cooled plants equal or even exceed water intensive nuclear and coal plants – see Table 1. Though they are slightly less efficient, dry-cooled plants are preferable in many arid solar development areas as wet cooled plants have the potential to strain water resources. In addition to using dry-cooling, another potential solution to water concerns is to site CSP arrays on degraded agricultural lands that retain their water rights.

Table 1. Water Use by Power Plant Type¹⁹

Power Plant Type	Water Use (Gallons/MWh)
Nuclear	620
Coal	670
Combined Cycle Natural Gas	250-300
Parabolic Trough (Wet Cooled) ²⁰	1,000
Parabolic Trough (Dry Cooled) ²¹	80
Dish/Stirling	4.4
Photovoltaic (PV)	4.4

¹⁴ For a more detailed list, see both the Database of State Incentives for Renewables and Efficiency and the Solar Energy Industry Association’s state fact sheets. <http://www.dsireusa.org/Index.cfm?EE=1&RE=1> and http://www.seia.org/cs/state_fact_sheets

¹⁵ U.S. Department of Energy and U.S. Department of the Interior. “

Solar Energy Development Environmental Considerations.” <http://solareis.anl.gov/guide/environment/index.cfm>

¹⁶ Ibid.

¹⁷ Western Governors’ Association Western Renewable Energy Zones – Zone Identification and Technical Analysis Work Group. “Resource Criteria for Development of Candidate Study Areas” p. 9, 11. <http://www.westgov.org/wga/initiatives/wrez/zita/ZITA%20TC%20criteria%20presentation.ppt>

¹⁸ Abengoa Solar. “Concentrating Solar Power: Parabolic Trough.”

http://www.abengoasolar.com/sites/solar/en/technologies/concentrated_solar_power/parabolic_trough/index.html

¹⁹ Unless otherwise noted, the reference for data in this table is: *Fuel from the Sky: Solar Power’s Potential from Western Energy Supply*, Dr. Arnold Leitner, Senior Consultant, RDI Consulting, NREL/SR-550-32160. July 2002. p. 34 <http://www.nrel.gov/csp/pdfs/32160.pdf>

²⁰ U.S. Department of Energy Energy Efficiency and Renewable Energy. “Cooling for Parabolic Trough Power Plants.” 2006.

<http://www.nrel.gov/csp/troughnet/pdfs/40025.pdf>

²¹ Ibid.

Emissions

Although solar generation technologies produce very little carbon compared to traditional fossil fuels, they are not emissions-free. Current estimates suggest that further technological improvements could reduce energy inputs by an additional 25 percent. Life-cycle carbon dioxide emissions for solar PV are in the 25-40 g/kWh range, mainly due to the processing of silicone and the energy used in manufacturing.²² This is far better than lifecycle emissions from coal-fired power plants that can be up to 1,022 g/kWh depending on the technology.²³

A 2006 California study estimated that if 4,000 MW of CSP solar were deployed in the state to replace combined cycle natural gas production, carbon dioxide would be reduced annually by 7,600,000 tons. The reduction in emissions would be even greater if coal or simple cycle natural gas production were replaced.²⁴

Distributed Solar Power

As an alternative to larger solar development, distributed solar power has the potential to mitigate development issues associated with solar energy. For instance, distributed solar power can reduce the need to build new transmission lines or upgrade existing ones; be configured to meet peak power needs; diversify the range of energy sources in use; increase the reliability of the grid network; and distributed solar power can be located close to the user with a scaled generation to match the energy used by the consumer.



Source: National Renewable Energy Laboratory

²² Alsema, E.A. and M.J. de Wild-Scholten. "The Real Environmental Impacts of Crystalline Silicon PV Modules: An Analysis Based on Up-To-Date Manufacturers Data." Energy Research Center of the Netherlands. June 2005. http://www.nrel.gov/pv/thin_film/docs/8bo53_alsema.pdf

²³ U.S. Department of Energy National Renewable Energy Laboratory. "Life Cycle Assessment of Coal-fired Power Production." June 1999. <http://www.nrel.gov/docs/fy99osti/25119.pdf>

²⁴ National Renewable Energy Laboratory. "Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California." April 2006. <http://www.nrel.gov/docs/fy06osti/39291.pdf>

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