An Analysis of Siting Opportunities for Concentrating Solar Power Plants in the Southwestern United States

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Abstract

In 2002, Congress asked the U.S. Department of Energy to “develop and scope out an initiative to fulfill the goal of having 1000 megawatts (MW) of new parabolic trough, power tower, and dish engine solar capacity supplying the southwestern United States [1].” The major purpose of a large solar installation initiative would be to accelerate the transition of concentrating solar power (CSP) generation technologies to a point where they could establish sustainable markets. A recommendation was made at the North American Energy Summit in April 2004 that the Western Governors’ Association (WGA) form a task force to coordinate the development of 1000 MW of new CSP capacity. A formal declaration of the WGA-led effort was presented and accepted at the WGA annual meeting held in Santa Fe, New Mexico, in June 2004.

In this paper, we present a review of the solar resource for Arizona, California, Nevada, and New Mexico. These four states have the greatest number of “premium” solar sites in the country and each has a renewable portfolio standard (RPS), or in Arizona’s case an environmental portfolio standard. In addition, we present information on the generation potential of the solar resources in these states, and present regions within each state that may be ideally suited for developing large-scale CSP plants because of their proximity to load and access to unconstrained transmission.

Southwest Overview

Southwest Solar Resource

The direct-normal solar energy resources in the southwestern United States, shown in Figure 1, are among the best in the world. Unlike other solar technologies based on flat surface collectors, such as conventional photovoltaic systems and solar water heaters, CSP requires direct-normal solar radiation. The direct-normal component of sunlight emanates directly from the solar disk and does not include diffuse or “blue-sky” radiation.

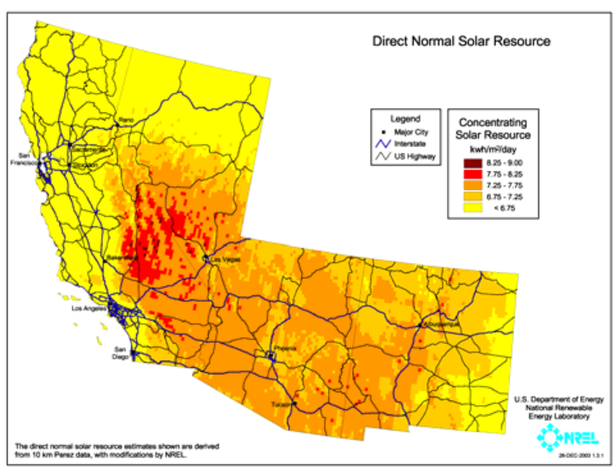


Figure 1. Direct normal solar radiation in the southwestern United States.

The direct-normal resource shown in Figure 1 was derived from a new, high-resolution solar resource data set that was developed with satellite data and correlated to good ground station data. Annual solar direct normal incident (DNI) estimates are provided on a grid of 0.1 degree in both latitude and longitude (nominally, 10 km). These estimates were created with the Perez irradiance model [2].

Concentrating Solar Power Generation Potential

Not all the land area shown in Figure 1 is suitable for large-scale CSP plants because such plants require relatively large tracks of nearly level open land with economically attractive solar resources. Geographical information system data were applied on land type (urban, agriculture, etc.); ownership (private, state, federal); and topography. The terrain available for CSP development was conservatively estimated with a progression of filters as follows:

- Lands with less than 6.75 kWh/m^2/day of average annual direct-normal resource were eliminated to identify only those areas with the highest economic potential.
- Lands with land types and ownership that were incompatible with commercial development were eliminated. These included national parks, national preserves, wilderness areas, wildlife refuges, water, and urban areas.
- Lands with slope greater than 3% and, alternately with 1%, and with contiguous areas smaller than 10 km^2 were eliminated to identify lands with the greatest potential for low-cost development.

Figures 2 through 5 show the progression of applying these filtering criteria.

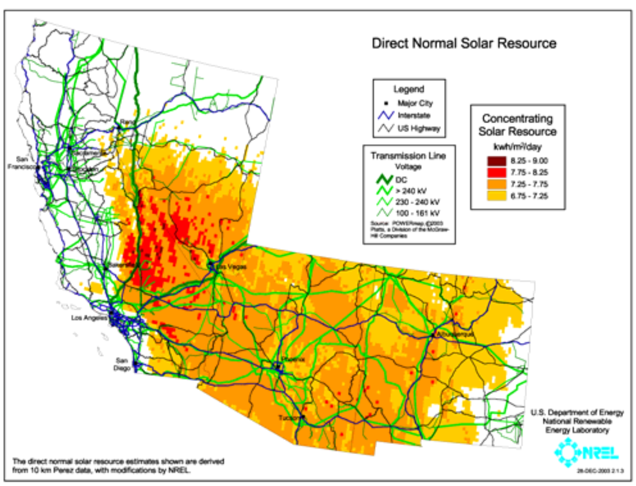


Figure 2. Annual average direct-normal solar resource > 6.75 kWh/m^2/day

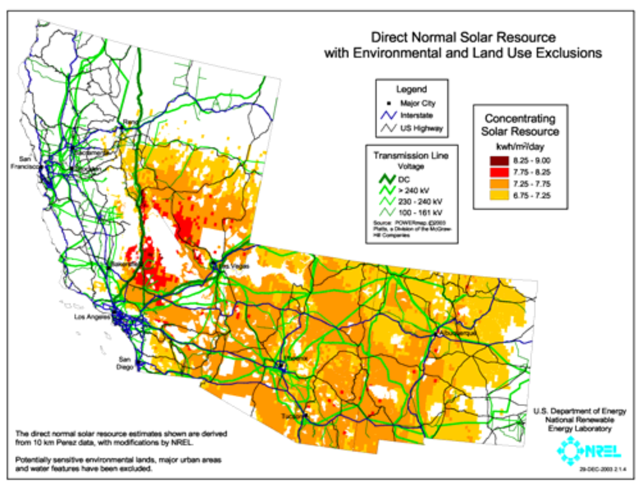


Figure 3. Additional filter for land use exclusions.

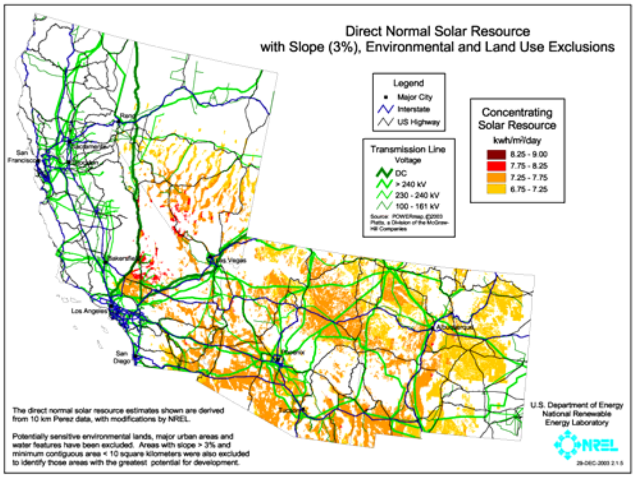


Figure 4. Additional filter for slope > 3% and minimum contiguous land area < 10

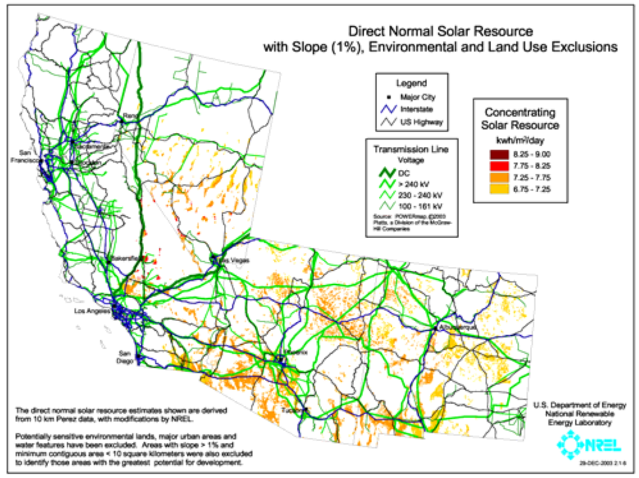


Figure 5. Additional filter for slope > 1% and minimum contiguous land area < 10

The resulting land area and associated CSP generation capacity when all filters were applied are given in Table 1.

Table 1. Suitable Land for CSP Plants and the Associated Generation Potential.

	Available Area (mi^2)	Capacity (MW)*
Arizona	25,527	3,267,456
California	6,421	821,888
Nevada	5,807	743,296
New Mexico	23,640	3,025,920
Total	**61,395**	**7,858,560**

* CSP power plants require approximately five acres of land area per megawatt of installed capacity

The data in Table 1 show that, even if we consider only the high-value resources, there are more than 7 million MW of solar generation capacity in the Southwest. Currently, there are about 100,000 MW of generation capacity in these four states. Each state has enough land illuminated by only the highest solar radiation levels, such that only a small segment would be enough to generate its current electricity needs.

Transmission Constraints for the Four-State Region

The United States is divided into a number of transmission control regions. The largest is the WECC, which covers the western third of the United States. The electric grid in the WECC is essentially isolated from the rest of the grid in the United States. The four states in this assessment are all part of the larger WECC control system and have high-voltage transmission lines that interconnect the states to move power from regions with coal and hydroelectric resources to population centers. Siting of a new solar power plant would need to consider how it fits into the transmission system.

California Transmission

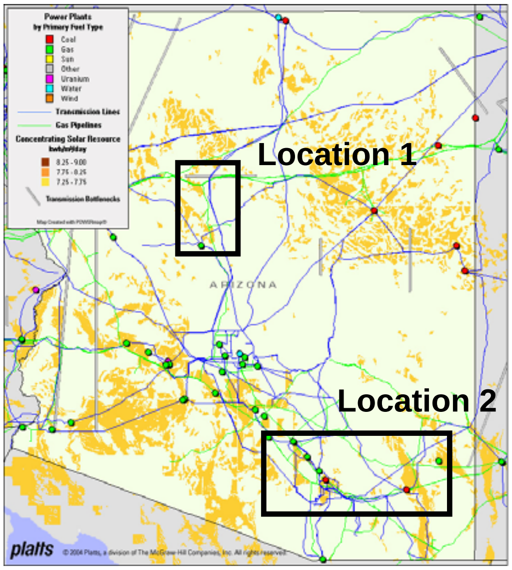
The transmission infrastructure in California includes two high-voltage, direct-current lines: one connects Los Angeles to hydroelectric generation in northern Oregon; the other connects Los Angeles to coal generation in central Utah. However, the bulk of California's infrastructure is operated at 500-kV and 230-kV. In general, during peak summer conditions, power flows into California from Arizona and Nevada, but during the winter the flows typically shift from California to the Pacific Northwest. Path 15, a transmission path in central California, is the most binding constraint in the south to north transmission. Power flows from the Four Corners region through Arizona, and power delivered from the Palo Verde nuclear power plant and other gas-fired generations in Arizona, create a significant bottleneck along the California-Arizona border. Power that flows through Las Vegas en route to southern California, and power that flows between northern Nevada and northern California, have resulted in a bi-direction east to west transmission bottleneck along the California-Nevada border.

Arizona, New Mexico, and Nevada Transmission

The Arizona, New Mexico, and Nevada transmission grid consists of 500-kV, 345-kV, 230-kV, and lower voltage transmission infrastructure. Almost the entire 500-kV transmission infrastructure is in Arizona. Load centers are in central and southern Arizona, southern Nevada, and central New Mexico. These correspond to the metropolitan areas of Phoenix and Tucson in Arizona; Las Vegas, Nevada; and Albuquerque, Santa Fe, and Las Cruces in New Mexico. Historically the highest generating resource centers have been located at Palo Verde, Arizona, northern Arizona, and the Four Corners areas. These result in predominant power flows from northeast to southwest in Arizona and from northwest to southeast in New Mexico during peak periods. The general direction of these flows is not likely to change in the foreseeable future. The region has substantial interconnections with California, one 230-kV connection with Utah, and connections with Colorado.

Potential Development Locations in the Four-State Region

The resource and land exclusions shown in Figure 5, together with the regional transmission constraints and proximity to urban load centers described earlier, led to the following preliminary recommendation of regional development centers for large-scale CSP installations. These recommendations are described graphically in Figures 6-9.



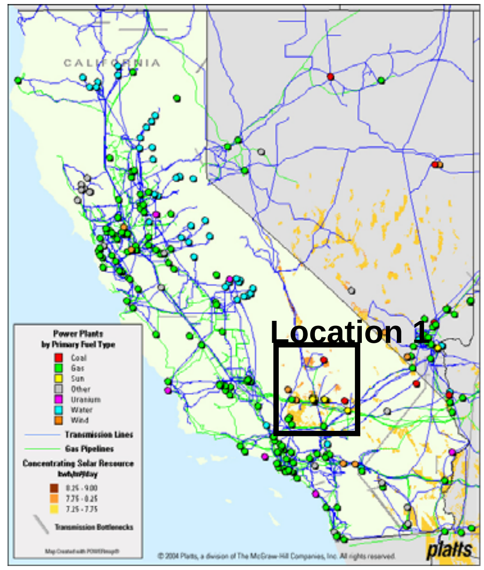


Figure 6. Arizona Siting Analysis

Figure 7. California Siting Analysis

Arizona

Potential Development Location 1

There may be potential to site a new plant north of Phoenix, perhaps in the Prescott Valley region, which lies inside the Path 54 bottleneck created by power flows from the Four Corners region to Phoenix and southern California. A plant sited in this location may be able to serve demand in Phoenix without facing any transmission bottlenecks. In addition, the northern branch of the El Paso natural gas pipeline could offer an opportunity for solar plant hybridization.

Potential Development Location 2

The southeastern corner of Arizona may offer the same opportunities. A plant placed in a high-quality solar resource location east of Tucson may be able to serve that population center's load without facing any bottlenecks. Exports into New Mexico, however, would likely be off limits because of the Path 47 bottlenecks and limited transmission capacity between southern Arizona and New Mexico.

California

Potential Development Location 1

As a result of the large number of constraints both within California, and leading into and out of the state, the most suitable location for a new solar plant is in southern California in the vicinity of the solar electric generating system plants. This area contains extremely good solar resources, and some lines may have enough transmission capacity to move power from the plant to the large load centers in southern California. Further, the Pacific Gas & Electric natural gas pipeline system and the Kern River Expansion pipeline run through this region.

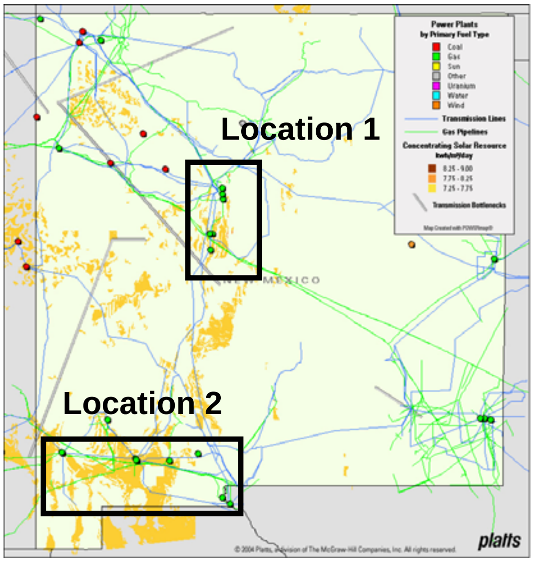


Figure 8. New Mexico Siting Analysis

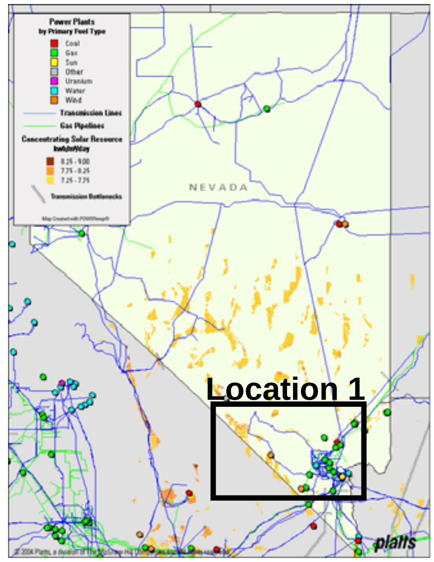


Figure 9. Nevada Siting Analysis

New Mexico

Potential Development Location 1

A new plant designed to serve Albuquerque would have to be built within the Path 48 constraint. Los Lunas and the surrounding region south of Albuquerque may be one candidate location. These areas possess high-quality solar resources and the transmission capacity to move power to Albuquerque. Also, the northern El Paso natural gas pipeline moves through this area. A plant located in this area may be able to serve local demand despite the near-term surplus of power.

Potential Development Location 2

The southwestern corner of the state contains an abundance of coal-fired generation, natural gas pipeline infrastructure, and transmission capacity. These factors, combined with the Las Cruces and El Paso population centers, may make this area a candidate for a new solar plant.

Nevada

Potential Development Location 1

Unfavorable solar resources, limited transmission infrastructure, and bi-directionally constrained power flows between northern Nevada and northern California, make northern Nevada a less desirable location for a new solar power plant. However, in southern Nevada the most favorable development scenario may involve the construction of an in-state solar resource to serve native load close to the Las Vegas population center. This would avoid aggravating transmission bottlenecks into and out of the state. Favorable solar resources west of Las Vegas, along with limited transmission infrastructure (a 138-kV line), might be suitable for upgrade to support a new solar facility.

Summary and Next Steps

The solar energy resource in the southwestern United States is enormous and largely untapped. As demonstrated in Table 1, there is no shortage of economically suitable land. At its June 2004 meeting, the Western Governors Association recognized the 1000 MW CSP Initiative as one of its projects and formed a regional task force to coordinate the efforts of the interested states, which include New Mexico, Nevada, California, Arizona, Colorado, and Utah. Nevada has already contracted 50 MW of trough power that is likely to become part of the initiative. New Mexico has formed a solar power task force to develop a plan for deploying CSP power. Under the leadership of the WGA, other states are expected to start to explore ways in which they too can support the deployment of large-scale CSP power projects.

To fully identify favorable solar power plant siting opportunities, additional factors such as land ownership, road access, and local transmission infrastructure capabilities and loadings must be examined in greater detail. This will involve discussion with local experts and utility specialists, and may include visits to prospective locations. In addition, the impact of solar resources on the transmission system must be fully analyzed by constructing security-constrained load flow model scenarios. Finally, state-level policies and regulatory frameworks must be assessed to determine the favorability of renewable resource development in a particular state. The availability and relative cost of other renewable power technologies must be considered in this context.

References

[1] DOE Fiscal Year 2002 Energy and Water Development Appropriation.

[2] Perez, R.; Ineichen, R.; Moore, K.; Kmiecik, M.; Chain, C.; George, R.; Voignola, F. (2002): "A New Operational Satellite-to-Irradiance Model," *Solar Energy* 73, 5 pp. 307-317.

[3] Energy Information Agency (EIA) Existing Electric Generating Units in the United States by State, Company and Plant, 2003 (Preliminary Data), data downloaded from www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html.