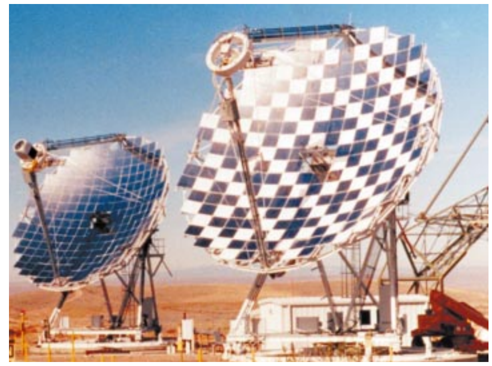
Research and Development Advances in

Concentrating Solar Power

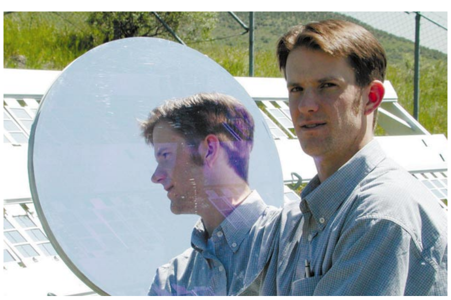
Using technology pioneered by DOE, industry began the commercialization of Concentrating Solar Power (CSP, also known as Solar Thermal Power) in the mid 1980s with construction of 354 MW of commercial grid-connected solar power. Continuing cooperative research and development (R&D) by DOE's CSP Program and industry have made CSP the lowest cost solar power option in the world today. Technology roadmaps for the future outline the R&D path to full competitiveness of CSP with conventional power generation technologies within a decade.



Component development and testing at Sandia National Laboratories and the National Renewable Energy Laboratory have led to improved and validated optical materials, mirror facets, concentrator structures, receivers, and control systems for all CSP technologies.

The potential of solar power in the Southwest U. S. is comparable in scale to the hydropower resource of the Northwest. A desert area 10 by 15 miles could provide 20,000 MW of power, while the electricity needs of the entire U. S. could theoretically be met by an area 100 miles on a side. CSP was conceived as a means to harness this energy to provide large-scale, domestically secure, and environmentally friendly electricity. CSP technologies use mirrors to concentrate the sun's energy to produce electric power with conventional turbines or heat engines. DOE-sponsored R&D rapidly advanced the technology in the aftermath of the energy shortages of the 1970s, leading to early commercial implementation of CSP by industry in the mid-1980s. The 354 MW of parabolic trough plants installed in the California desert, called SEGS (solar electric generating systems), continue to operate at or above their design specifications, demonstrating the capability of CSP technology to meet electric utilities'requirements for grid-scale power. Since the SEGS plants went online, research, development, and field validation efforts sponsored by DOE and industry have led to major advances in system performance, reliability, lifetime, and cost. In addition, they have expanded the capabilities of CSP with features such as storage and hybridization (supplemental fossil-fuel firing) needed to compete in dispatchable power markets. These advances have not only made the trough technology used at the SEGS plants more competitive, but have brought other CSP technologies, such as power towers and solar dishes, to the brink of commercialization. R&D efforts planned for the next several years are targeted to further reduce costs and enable major market penetration by CSP over the next decade. With R&D playing a key role, concentrating solar power can provide ***BIG solutions to BIG problems*** in electricity supply, both domestically and internationally.

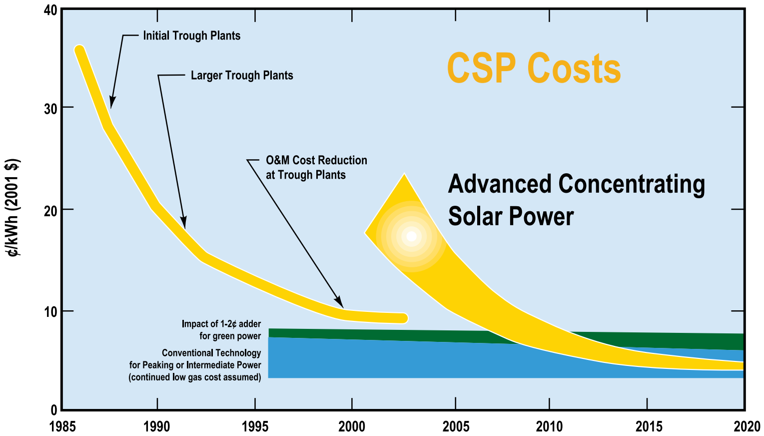
CSP research and development have …



Optical materials development efforts support major advances in system performance. Advanced reflectors, for example, not only reduce the cost of mirrors, but also lead to revolutionary cost-saving concentrator designs. Accelerated testing technology allows better understanding of failure modes and more rapid design cycles.

… improved system performance. SEGS technology was able to enter the market in an era of high (and rising) energy prices. However, as conventional supplies increased and energy prices fell the late 1980s, renewable technologies such as CSP could not compete without substantial cost reductions. In the early 1990s, a cooperative research project by the SEGS operators and the CSP program improved system operations and maintenance (O&M) procedures, reduced parasitic power requirements, and improved collector efficiency such that overall O&M costs were reduced by 30%. Recent implementation of improved absorber surfaces coupled with design improvements have allowed industry to begin production of a new receiver, which testing has demonstrated will improve trough plant performance an additional 20% without increasing costs. In parallel with these trough system improvements, power tower research (validated with large-scale testing at the National Solar Thermal Test Facility, Solar One, and Solar Two) increased annual efficiency of power towers by over 25%, while at the same time lowering cost and improving durability and dispatchability. Similarly, advances in heat-pipe receivers, converters, mirror technology, and system integration being developed for dish technology have demonstrated 20% improvement in system performance, as well as improved operating characteristics and the potential for better durability.

… improved system reliability and lifetime. The continued excellent performance of the SEGS plants has amply demonstrated the lifetime and reliability (much of it resulting from DOE-sponsored R&D on O&M issues) needed by this technology for success in the marketplace Continuing R&D is underway to help power tower and dish systems achieve this same high level of reliability. Recent power tower research has, for example, proven advanced pumps, valves, heat trace, and receiver materials that dramatically simplify system design, completely eliminating many of the higher maintenance components of a commercial plant and significantly improving the projected lifetime of others. Likewise, the focus of most of the advanced solar dish R&D in the past several years has been on reliability issues in areas such as receivers, converters, and controls, with extensive operations and reliability tracking leading to the identification of both problems and potential solutions. Improved heat-pipe receivers, advanced converters (such as solid-state PV devices with no moving parts), and expert control systems are being developed to eliminate key potential failure modes and thus increase mean-time-between-failure and lifetime.



… decreased system costs. Early commercial trough plants produced power for about 35¢/kWh (in 2001 dollars) in niche markets. As continuing R&D improved plant performance and O&M costs and economies-of-scale for larger plants kicked in, power from the most recent plants dropped to about 11¢/kWh, the lowest-cost solar power in the world. While the costs of new plants built with advanced technologies may initially be slightly higher than this, they will drop rapidly with the construction and successful operation of the first few plants, demonstrating a learning curve similar to that seen at the SEGS plants and resulting in costs below 8¢/kWh within 5 years. Industry's trough technology roadmap lays out a detailed strategy to combine technology advances in receivers, reflectors and structures, thermal storage, and plant optimization to reduce costs to less than 5¢/kWh by 2015, making CSP fully competitive in global mega-markets.

… enabled major new CSP features to expand potential markets. Because it is a thermal technology with cost-effective thermal storage or natural gas hybridization, CSP can deliver power to the utility grid when that power is most needed, not just when the sun is shining. This dispatchability can not only contribute to decreases in levelized energy costs, but can also dramatically increase the value of solar energy by achieving firm capacity payments for peaking and intermediate power. Utilizing limited natural gas firing, for example, the SEGS plants' capacity routinely exceeds 100% of design during peak demand periods. Advanced hybridization R&D is investigating higher temperature systems for integration with combined cycle plants, and systems research is optimizing the fossil/solar integration. Large-scale thermal storage systems utilizing molten salt have demonstrated 99% efficiency in power tower testing at Solar Two and are being used as a major feature in the first commercial power tower systems proposed for the Southwest U. S. and Spain. Storage not only allows high-value dispatch of power, but decreases costs by permitting use of smaller turbines. Current research is underway to apply this technology to troughs, providing dispatchability without fossil fuel input. Finally, in the dish area, hybrid operation (with natural gas, landfill gas, and hydrogen) has been demonstrated in recent dish/Stirling testing, and advanced hybrid heat-pipe receivers are being developed to allow concurrent solar/fossil operation. Advanced dish systems utilizing advanced converters (such as PV cells optimized for concentrated solar energy) are being developed for distributed power markets.

System validation testing is a critical part of CSP's R&D program. The Solar Two project, for example, helped industry validate the cost and efficiency of storage, prove the durability and performance of an advanced receiver material, and develop improved system designs that significantly reduce system complexity and costs. While utility deregulation initially delayed adoption of this technology, evolving international and domestic opportunities are making power towers an option for near-term, large-scale plants.

...a key role to play in the future commercialization of CSP. Nearly 250 MW of new international CSP capacity are currently under design (supported in part by the World Bank/GEF and Spanish solar premiums), while U. S. industry is simultaneously pursuing opportunities that could produce 1000 MW of CSP in the Southwest U. S. by 2006. Because CSP uses conventional technologies and materials (glass, concrete, steel, and standard utility-scale turbines), production capacity can be rapidly scaled to several hundred megawatts/year, using existing industrial infrastructure. Capacity additions of 20,000 MW by 2020 are realistic with several developers producing at these rates. To ensure the success of the initial plants and thus enable large-scale construction of additional plants, U. S. industry requires continuing access to the research base on which these plants will be designed and future costs reduced. A robust CSP research and development program supporting industry's needs for new materials, advanced component development, and systems testing and analysis is critical to this success. It will help assure that U. S. industry, not foreign competitors, will be the future suppliers of U. S. (and the World's) solar power.

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Sun•Lab

Sandia National Laboratories and the National Renewable Energy Laboratory, working together as Sun•Lab, provide technical expertise and R&D support to the Department of Energy's Concentrating Solar Power Program and the CSP industry.

Sun•Lab's mission is to facilitate the success of U.S. industry in developing competitive concentrating solar power products for domestic and international markets. Its critical objectives in fulfilling this mission are conducting research and development activities necessary for the success of CSP technology; supporting the successful commercial development of CSP technology by U.S. industry through technology transfer and providing access to unique capabilities within Sun•Lab; and providing objective data, analysis, and technical recommendations on CSP to key stakeholders and decision makers.

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