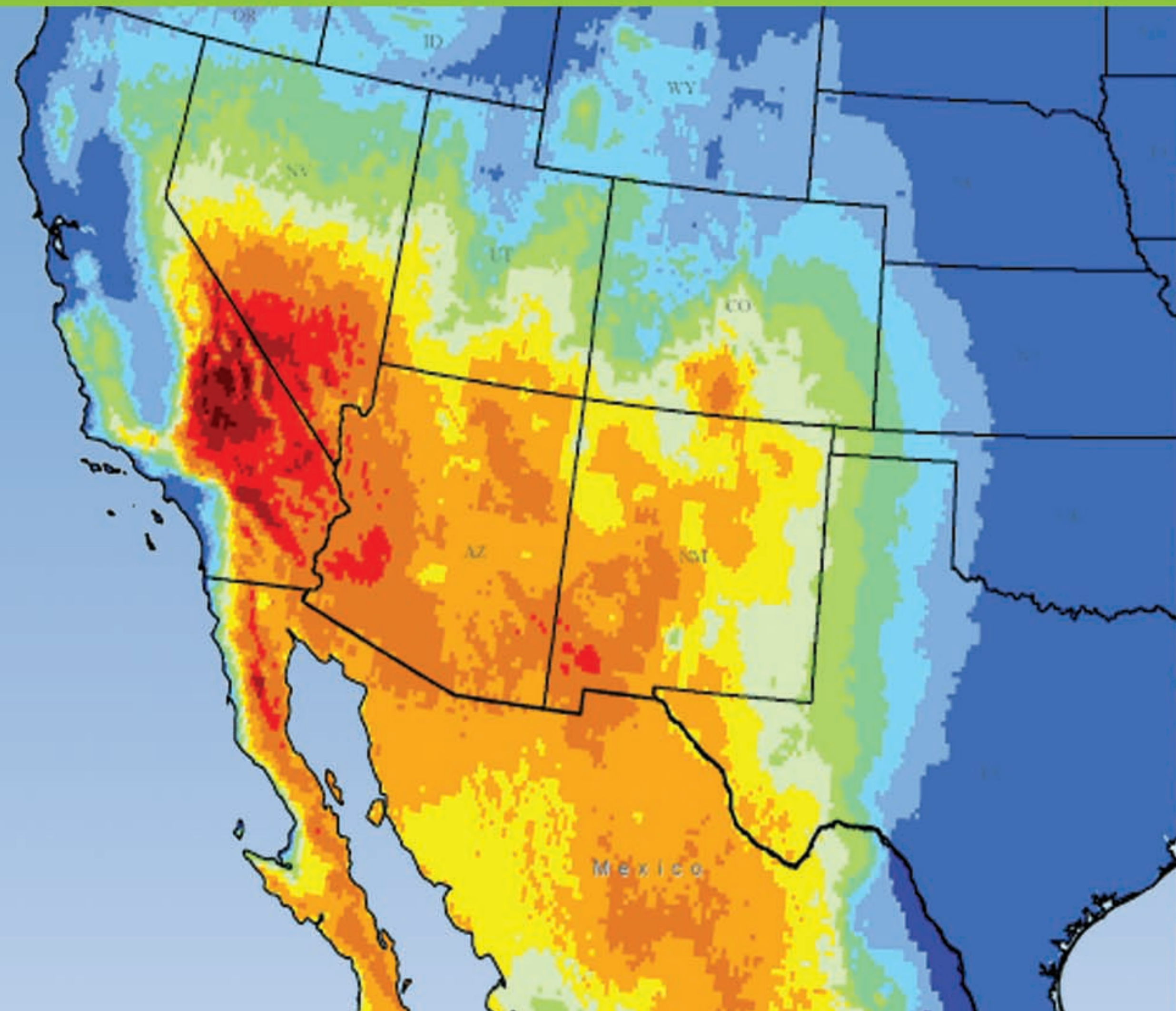
DOE/GO-102007-2400

Report to Congress on

Assessment of Potential Impact of Concentrating Solar Power for Electricity Generation

(EPACT 2005 – Section 934(c))

February 2007



U.S. Department of Energy

Energy Efficiency and Renewable Energy

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Solar Energy Technologies Program

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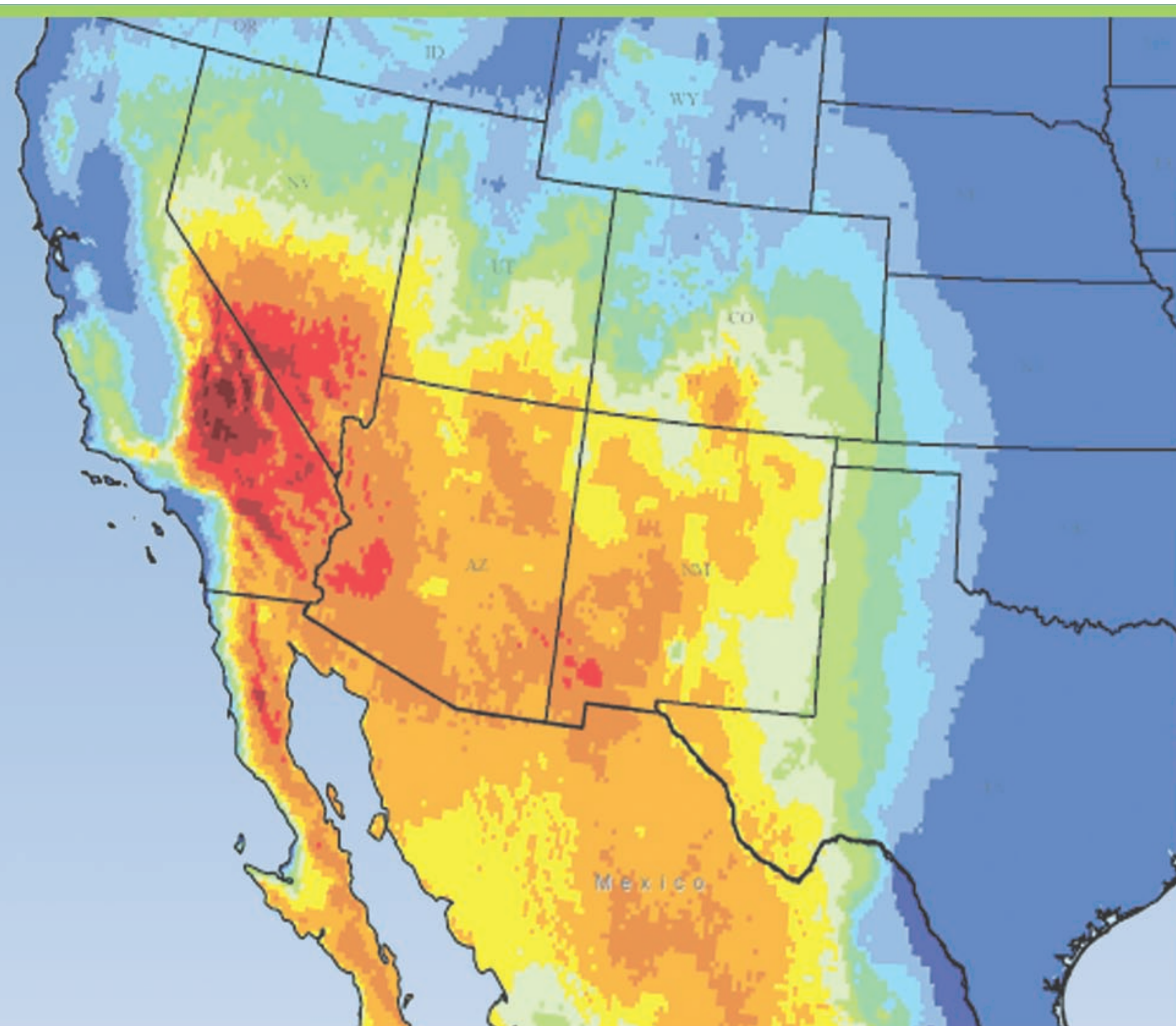

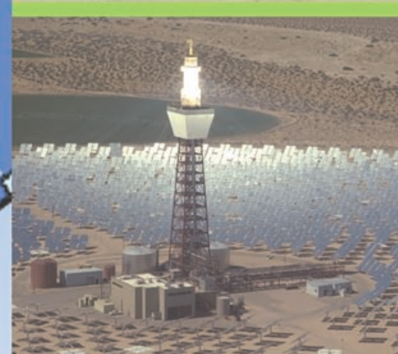

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Solar Energy Technologies Program

Executive Summary

The Energy Policy Act of 2005, section 934(c), directed the Secretary of Energy to:

(1) assess conflicting guidance on the economic potential of concentrating solar power for electricity production received from the National Research Council in the report entitled "Renewable Power Pathways: A Review of the U.S. Department of Energy's Renewable Energy Programs" and dated 2000 and subsequent reviews of that report funded by the Department; and

(2) provide an assessment of the potential impact of technology used to concentrate solar power for electricity before, or concurrent with, submission of the budget for fiscal year 2008.

This report summarizes the Department of Energy's (DOE) assessment of these issues.

The reports discussed in this document assess whether concentrating solar power (CSP) plants can become cost competitive with fossil fueled plants and how much this would cost taxpayers (excluding sunk costs). One report estimates that deployment incentives could cost $1.5 to $2.0 billion over 14 years. The reports also estimate that at the end of that period CSP could provide hundreds of gigawatts of electricity at 5 to 6 cents/kWh without further subsidies while also providing economic, environmental, and security benefits. Federal policymakers must weigh the benefits of subsidizing increased CSP deployment against the cost to taxpayers and electricity ratepayers.

Assessment of Conflicting CSP Reports

Between 2000 and 2003, four reports attempted to assess the potential for CSP technology. The first report, from the National Research Council (NRC), recommended that DOE halt most of its work on CSP because further cost reductions and deployment were not likely. The main conclusions of the following three reports were:

- Large-scale deployment of CSP technology could significantly reduce its cost.
- Policy incentives would be required to spur the initial deployment of CSP.
- Research and development could significantly reduce the cost of CSP technology.

NRC 2000 Report:

- In 2000, the NRC assessed the potential for CSP technology in a scenario without government incentives.
- The NRC report concluded that "the likelihood of major breakthroughs that will affect cost and performance is small," that there was a "lack of interest in the private sector," that "the absence of buyers for a U.S. solar thermal facility speaks for itself, and that there is no reason to expect the situation to change in the next 10 to 20 years."[1]

DOE's 2002 Report

- In 2002, DOE responded to congressional guidance by issuing a report, prepared in consultation with industry, which sought to answer the question of what

incentives would be required to make the deployment of 1,000 MW of CSP possible.
- The report concluded that the CSP industry could build 1,000 MW if between $1.5 and $2.0 billion in Federal and State financial incentives were available over a 14-year period, and that the deployment of 1,000 MW could potentially reduce the cost of CSP to as low as 6 cents per kilowatt-hour (kWh).[2]
- This report contained a fundamentally different assessment of the potential future of CSP; the NRC was pessimistic that any CSP development will occur in the next 10 to 20 years while DOE was optimistic that government incentives could spur the development of CSP and make it economically viable in the future.
- However, both the NRC and DOE reports agreed that some level of government intervention would be required to drive the deployment of CSP.

Sargent & Lundy Report:
To resolve the differing conclusions of the initial NRC and DOE reports, DOE commissioned an independent engineering firm to conduct, "in close collaboration with the NRC," a detailed assessment of the economic potential of parabolic trough and power tower technologies.[3] The engineering firm Sargent & Lundy (S&L) was selected to conduct this analysis on the basis of its independence from the CSP industry and its highly regarded performance in conducting due diligence studies for the fossil power industry, among other factors.[4] S&L's report concluded that:
- "CSP technology is a proven technology for energy production, there is a potential market for CSP technology, and that significant cost reductions are achievable assuming reasonable deployment of CSP technologies occurs."[5]
- The cost of electricity from CSP was currently in the range of 10 to 12.6 cents/kWh, and costs could be reduced to 3.5 to 6.2 cents/kWh by 2020 without new research breakthroughs.[6]
- "Policy-based incentives are needed for initial introduction of technologies and that both R&D and deployment of technology are necessary."[7]

NRC 2002 Response to the S&L Report:
DOE asked the NRC to review a draft of the S&L report. In the critique, the NRC:
- Agreed with S&L that CSP costs could be reduced to 3.5 to 6.2 cents/kWh by 2020, given that deployment proceeded at the rate assumed by S&L[8]
- Cautioned that the deployment rate assumed by S&L may be overly optimistic, in turn making S&L's cost reduction timeline overly optimistic
- Agreed with S&L's conclusion that technology improvement was a necessary step to making CSP economically competitive, but that technology improvement alone was insufficient to achieve economic competitiveness
- Agreed with S&L that policy-based incentives are necessary to make CSP economically competitive; however, neither the S&L report nor the NRC response addressed what level or magnitude of policy-based incentives would be required to achieve economic competitiveness.
- Noted that, since the publishing of its previous report in 2000, in which it had concluded that the commercial prospects for CSP "were not very promising," advances had been made: "Significant progress has been made in understanding

the potential impacts of thermal storage technologies, thin film glass mirrors, improved heat collection units, improved trough support structures, and other technical opportunities to improve CSP technology."[9]

- Noted the commencement of planning for CSP projects in Spain and South Africa.[10]

Assessment of the Potential Impact of CSP

Just as R&D advancements and the availability of a detailed analysis changed the technical conclusions from the first to the second NRC assessments, events that occurred after the second NRC report have since changed the outlook for CSP deployment. Foremost among the changes are policies initiated by States and the Federal Government:

- Many States have implemented renewable portfolio standards (RPS's) which encourage the deployment of solar technologies, including CSP. Nevada's RPS specifically encourages the deployment of solar technologies. California leads the country with an RPS that requires that 20 percent of the State's power come from renewable energy by 2010.[11]
- The Federal Government, through Section 1335 of the Energy Policy Act of 2005 (EPACT 2005), established a 30 percent investment tax credit for solar installations.[12]

Since the NRC report in 2002, several CSP projects have been developed or are in the planning stage. All these projects are a result of the state RPS's. A 64 MW project, for example, is under construction in Nevada and is expected to become operational during 2007. It will be the largest solar project built in the U.S. since 1991.

Increased deployment of CSP could have several benefits:

- Adding CSP to the generation mix of a State would contribute to expanding a domestic energy supply, better air quality, and a hedge against possible future tax on carbon emissions.
- All CSP technologies can be deployed as large centrally-located power plants, the type of systems that utilities have operated for years and with which they are most comfortable, while some CSP technologies can also be deployed as smaller-scale distributed generation resources.
- CSP could have local economic development benefits because long-term fuel costs associated with conventional electricity generation (e.g. natural gas, coal) are replaced by operations and maintenance costs (i.e. labor).[13,14,15] CSP thus provides a hedge against the volatile costs seen in energy prices during the past several years.[16]

A DOE report for the Western Governors' Association (WGA) in 2005 provided an assessment of the potential impact of CSP. It found that by using only available land with the most intense sunshine, over 6,800 GW of electricity could be generated in the Southwest.[17] To put this in perspective, the electric generating capacity of the entire country is currently about 1,000 GW.[18] The report emphasized that the analysis was done only to indicate the size of the solar resource, not to indicate it would be possible or practical to build solar plants to produce that much power.

For cost-competitive CSP, both R&D and deployment are required:

- Projections by the S&L study indicate that, with continued R&D and incentives that encourage deployment, CSP costs could become competitive with the costs of conventional natural gas-fired power plants over the next ten years.
- DOE's survey of the CSP industry indicated such incentives could range between $1.5 and $2.0 billion. This cost estimate does not account for utility pass-through of any increased costs to utility customers (i.e. ratepayers).

Federal policymakers must carefully weigh the potential benefits of CSP against the significant cost to taxpayers in terms of industry subsidies and the cost to ratepayers in those states where CSP would initially provide electricity at costs higher than conventionally produced electricity.

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1.0 Introduction

This report responds to section 934(c) of the Energy Policy Act of 2005 which requested that the Secretary of Energy:

(1) assess conflicting guidance on the economic potential of concentrating solar power for electricity production received from the National Research Council in the report entitled "Renewable Power Pathways: A Review of the U.S. Department of Energy's Renewable Energy Programs" and dated 2000 and subsequent reviews of that report funded by the Department; and

(2) provide an assessment of the potential impact of technology used to concentrate solar power for electricity before, or concurrent with, submission of the budget for fiscal year 2008.

2.0 Task I: Assessment of Conflicting CSP Reports

Between 2000 and 2003, four reports were released that attempted to assess the commercial potential of CSP. A timeline of these reports is provided in Table 1.

Table 1. List of Pertinent Publications

Publication	Author	Date
"Renewable Power Pathways: A Review of the U.S. Department of Energy's Renewable Energy Programs"	NRC	2000
"Feasibility of 1,000 Megawatts of Solar Power in the Southwest by 2006"	DOE	August 2002
"Critique of the draft Sargent & Lundy Assessment of Cost and Performance Forecasts for Concentrating Solar Power"	NRC	November 2002
"Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts"	S&L	May 2003

NRC Assessment of CSP in 2000[19]

In 2000, the National Academies' National Research Council (NRC) conducted an evaluation of DOE's renewable energy programs of which one program was the Concentrating Solar Power Program. In its report, the NRC reached the following recommendations regarding CSP technologies (see Figure 1):

- *For all intents and purposes, power-tower and power-trough technologies could be deployed today. However, no buyers have come forward for initiating commercial operations in the United States.*
- *The Office of Power Technologies [now, Solar Energy Technologies Program] should limit or halt its research and development on power-tower and power-trough technologies because further refinements would not lead to deployment.[20]*
- *Solar dish/engines seem destined for niche operations and likely to be used in hybrid systems with other power-generation technologies in remote off-grid areas.*

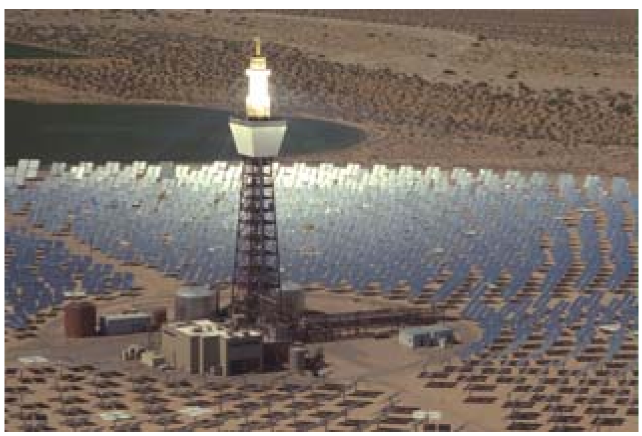
- *The Office of Power Technologies should reassess the market prospects for the solar dish/engine technologies to determine whether continued research and development would result in a technology that warrants further expenditures.*[21]

Parabolic Trough

80 MW Project, Kramer Junction, CA

Dish Engine

150 kW Project, Albuquerque, NM



Power Tower

10 MW Project, Barstow, CA

Figure 1. Images of CSP Technologies; Source: NREL

At the time the NRC evaluated CSP, no CSP projects had been built in nearly ten years and none were pending. This led to the conclusions that "the likelihood of major breakthroughs that will affect cost and performance is small" and that there was a "lack of interest in the private sector, even in a proven technology, such as solar-trough systems." The NRC went further to add that "the absence of buyers for a U.S. solar thermal facility speaks for itself, and that there is no reason to expect the situation to change in the next 10 to 20 years."[22]

Prior to the NRC report in 2002, the last CSP plant to be built was an 80 MW trough plant built in the Mojave Desert in California in 1991. It was the ninth trough plant in a group called the Solar Energy Generating System (SEGS), which has a total capacity of 354 MW and continues to operate today. The expiration of Federal solar tax credits in 1990 along with a drop in the cost of electricity production partly due to deregulation rendered any further trough projects uneconomical in California during the subsequent 15 years.[23]

The 2000 NRC review found that a major hurdle facing CSP technologies was that they must be relatively large to be competitive, and that large installations are expensive. Parabolic troughs have demonstrated performance and reliability over 20 years of operation in California,[24] and the technical feasibility of power tower systems was proven during the mid-1990's with the 10 MW Solar Two project.[25] Both technologies, however, require scales approaching those of fossil-fueled power plants to achieve cost competitiveness with conventional means of electricity generation. Just as for new generation fossil and nuclear plants, such large first-of-a-kind CSP plants are expensive. This led the NRC to conclude "unless there is a significant market intervention by the Federal and/or State governments, an economically feasible project in the United States will not be possible."[26] In addition, it would take several projects to bring the cost down to competitive levels. During a period of restructuring in the utility sector in the 1990s and into the new millennium, there was little incentive for taking a risk on expensive new technologies. A 100 MW CSP plant, for example, could cost $300 million. Further, deregulated utilities had few resources to invest in new technologies. The CSP industry was faced with the conundrum that its technology was too expensive to be deployed even though deployment could have led to lower cost for future CSP installations. This is the same challenge faced by many other innovative power plant technologies as they enter the competitive, commodity-based energy market.

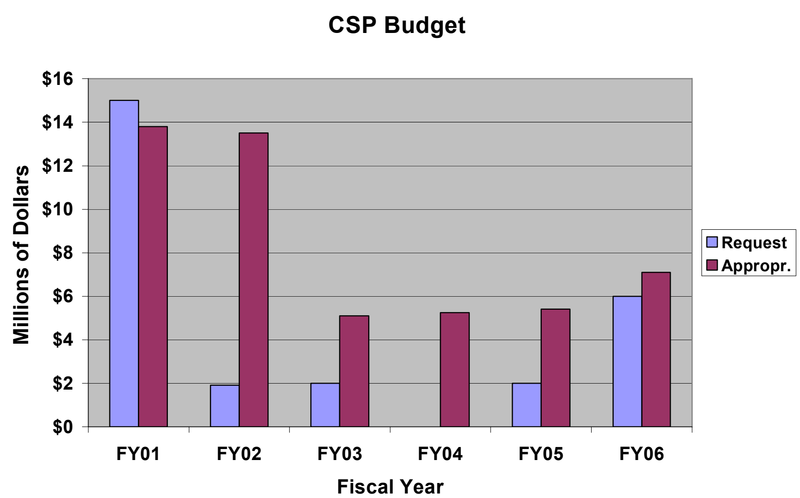


Figure 2. CSP Budgets

The NRC further concluded that "the likelihood of major breakthroughs that will affect cost and performance is small and/or not commensurate with the potential payoff."[27] The report thus indicated that there was little industry support for CSP, that it was too costly to be deployed, and that further R&D would not significantly lower the cost.

Although some in the CSP industry strongly objected to the NRC findings,[28] in the wake of the NRC report the decision was made by DOE to request phasing out of all CSP activities. DOE's budget requests for CSP from fiscal year (FY) 2002 through FY 2004 reflected this decision. As shown in Figure 2, the CSP request dropped from $15 million for FY 2001 (made in February 2000) to $1.9 million for FY 2002 (made in February 2001) following the NRC's report. Every year, however, Congress has provided funding levels above DOE's request and has required DOE to conduct additional assessments of CSP.

DOE's 2002 CSP Report

Language in the FY 2002 Energy and Water Development Appropriation Bill directed DOE to "scope out an initiative to fulfill the goal of having 1,000 MW of new parabolic trough, power tower, and dish engine solar capacity supplying the Southwestern U.S. by 2006."[29] In response, DOE prepared a report that summarized the CSP industry's estimate of the conditions that would be required to build 1,000 MW of new CSP capacity in the Southwest. This report was entitled "Feasibility of 1,000 Megawatts of Solar Power in the Southwest: Report to Congress."[30]

Largely based on data from Luz International's construction of 354 MW of parabolic troughs in California between 1984 and 1990, the solar industry indicated it could build the 1,000 MW in a five-year period if between $1.5 and $2.0 billion in Federal and State financial incentives were available over a 14-year period. The CSP industry felt the technology was ready for large scale deployment. The industry provided a list of possible incentives (e.g., a 30 percent investment tax credit, a 1.7 cent per kWh production tax credit, and a solar energy loan guarantee program) that would enable it to finance and build the solar power plants. DOE concurred in the industry's ability to build the plants if the incentives were made available, but DOE did not support the Federal government providing the cost of the subsidy that would be required. DOE doubted if it could be done by 2006 because the industry's proposed incentives required enactment by Congress and state legislatures. Moreover, even if Congress provided the CSP industry's requested subsidies, significant installations by 2006 were unlikely because of the time required for the incentives to be put in place and for industry to arrange financing and obtain permits. Industry also indicated its opinion that the establishment of 1,000 MW of CSP would enable the establishment of manufacturing capability and provide "learning curve" cost reductions that could bring the cost of CSP to as low as 6 cents/kWh without further incentives.[31]

The NRC and DOE assessments are in agreement that some level of government intervention would be required for CSP to become economically feasible. Nevertheless, the reports do contain fundamentally different assessments of the future of CSP, with the NRC pessimistic that any CSP development would occur in the next 10 to 20 years and the DOE optimistic that government incentives could spur development in the CSP industry that would make it economically viable in the near future.

To resolve the differences between the NRC and DOE studies and to ensure a thorough and rigorous evaluation of the potential of CSP technologies, DOE commissioned a new report in 2002; a detailed technical analysis by an independent engineering firm. DOE also asked an NRC panel to review and comment on a draft report of the independent engineering firm, and this critique constitutes a second NRC report. The engineering firm Sargent and Lundy (S&L) was selected to conduct this analysis on the basis, among other factors, of its independence from the CSP industry and its recognized performance in conducting due diligence studies for the fossil power industry. This approach let engineers experienced in due diligence perform the detailed analysis. In its second report the NRC's committee members commented on the assumptions, methodology, data and its validation, and the results in S&L's draft report.

Sargent and Lundy Study[32]

S&L examined available industry and national lab analyses, developed its own analyses, and used its own engineering expertise to evaluate CSP's potential. S&L assumed deployment rates that it believed were relatively low, ranging from 2.8 to 5 gigawatts (GW) over 15 years. S&L found that the levelized cost of energy (LCOE) for CSP was currently in the range of 10-12.6 cents/kWh or, stated another way, about $2,400-$3,000/kW. S&L concluded that costs could be reduced to between 3.5-6.2 cents/kWh by 2020.[33] LCOE is a measurement of the cost of producing energy from a technology, and includes the net present value of all capital, O&M, fuel, and other costs.

The cost reduction found by S&L was due to three factors: technology development, plant size, and mass production. Figure 3 shows an S&L scenario in which the LCOE from trough technologies is reduced as the technology is deployed. Deployment is important because it enables industry to build increasingly larger power plants which incorporate economies of scale and build components in large enough quantities to take advantage of savings due to mass production.

S&L concluded that "CSP technology is a proven technology for energy production, there is a potential market for CSP technology, and that significant cost reductions are achievable assuming reasonable deployment of CSP technology occurs."[34] However, S&L also found that "policy-based incentives are needed for initial introduction of technologies and that both R&D and deployment of technology are necessary."[35]Analysis of incentives required to reach market acceptance was outside the scope of the S&L report.

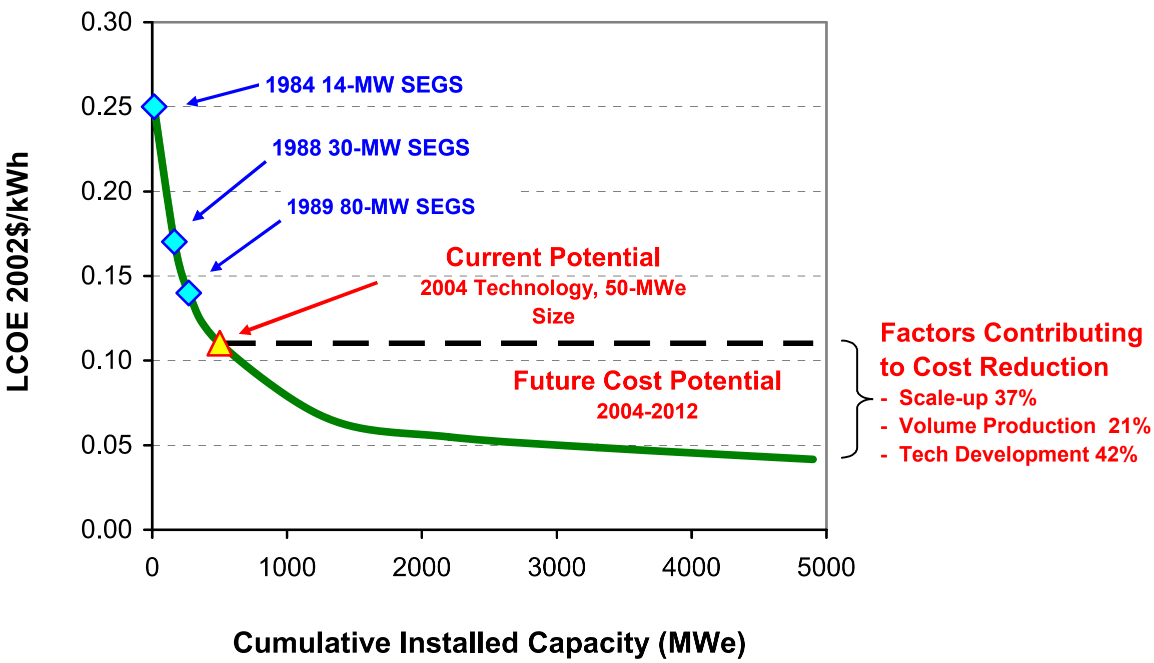


Figure 3. Sargent and Lundy Cost Forecast

NRC Review of the S&L Report[36]

The NRC committee concluded that "since 1999, significant progress has been made in understanding the potential impacts of thermal storage technologies, thin film glass mirrors, improved heat collection units, improved trough support structures, and other technical opportunities to improve CSP technology."[37] The NRC found the S&L analysis plausible and agreed with S&L that CSP costs could be reduced to 3.5 to 6.2 cents/kWh by 2020, given that deployment proceeded at the rate assumed by S&L.[38]

The NRC committee gave S&L high marks for maintaining a credible process, avoiding any conflicts of interest, and responding to committee requests. The committee interviewed several industry representatives during the process of evaluating the S&L report, gathering information which augmented what they found in the report. The committee raised some issues and requested additional information of S&L, which was provided in the final report.[39]

The major issue that the NRC raised was the question of whether the deployment figures used by S&L in projecting cost reductions could be achieved. S&L determined that a deployment of 2.6 GW would result in the cost of electricity from a solar trough plant being reduced from 12.6 to 6.2 cents/kWh. In its critique, the NRC concluded that "without substantial incentives, it is very unlikely that CSP trough and tower markets will evolve, and that if CSP markets are ever to reach cost competitiveness, market incentives for CSP would again have to be created."[40] Due to the high costs of first-of-a-kind plants, the committee felt there was little chance that 2.6 GW would be deployed and, because of this, they disagreed with S&L's cost projections. However, the NRC agreed with S&L that deployment, should it occur, would affect cost reduction.

Thus, the NRC continued to believe that CSP technology was too expensive to be deployed without policy-based incentives. An analysis of what type and quantity of incentives would be required to spur deployment of CSP was outside the scope of S&L's and the NRC's statements of work. It had been determined by DOE that this was a policy issue and was not appropriate for a technical analysis of CSP.[41]

3.0 Task II: Assessment of the Potential Impact of CSP

The arid region from southern California to west Texas has solar energy resources that are among the best in the world (see Figure 4). A study done by DOE for the Western Governors' Association[42] determined that the seven States in the Southwest (AZ, CA, CO, NV, NM, TX, and UT) have the combination of solar resource and available suitable land to generate up to 6,800 GW[43] (see Table 2). To put this in perspective, the electric generating capacity of the entire country is about 1,000 GW.[44] In California alone, there are nearly 6,800 square miles of land available that could be used to establish a solar capacity of about 870 GW; for comparison, California's total generation capacity in 2002 was about 52 GW.[45]

Table 2. Potential Solar Capacity in Southwest

State	Land Area (mi^2)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	19,279	2,467,663	5,836,517
CA	6,853	877,204	2,074,763
CO	2,124	271,903	643,105
NV	5,589	715,438	1,692,154
NM	15,156	1,939,970	4,588,417
TX	1,162	148,729	351,774
UT	3,564	456,147	1,078,879
Total	53,727	6,877,055	16,265,611

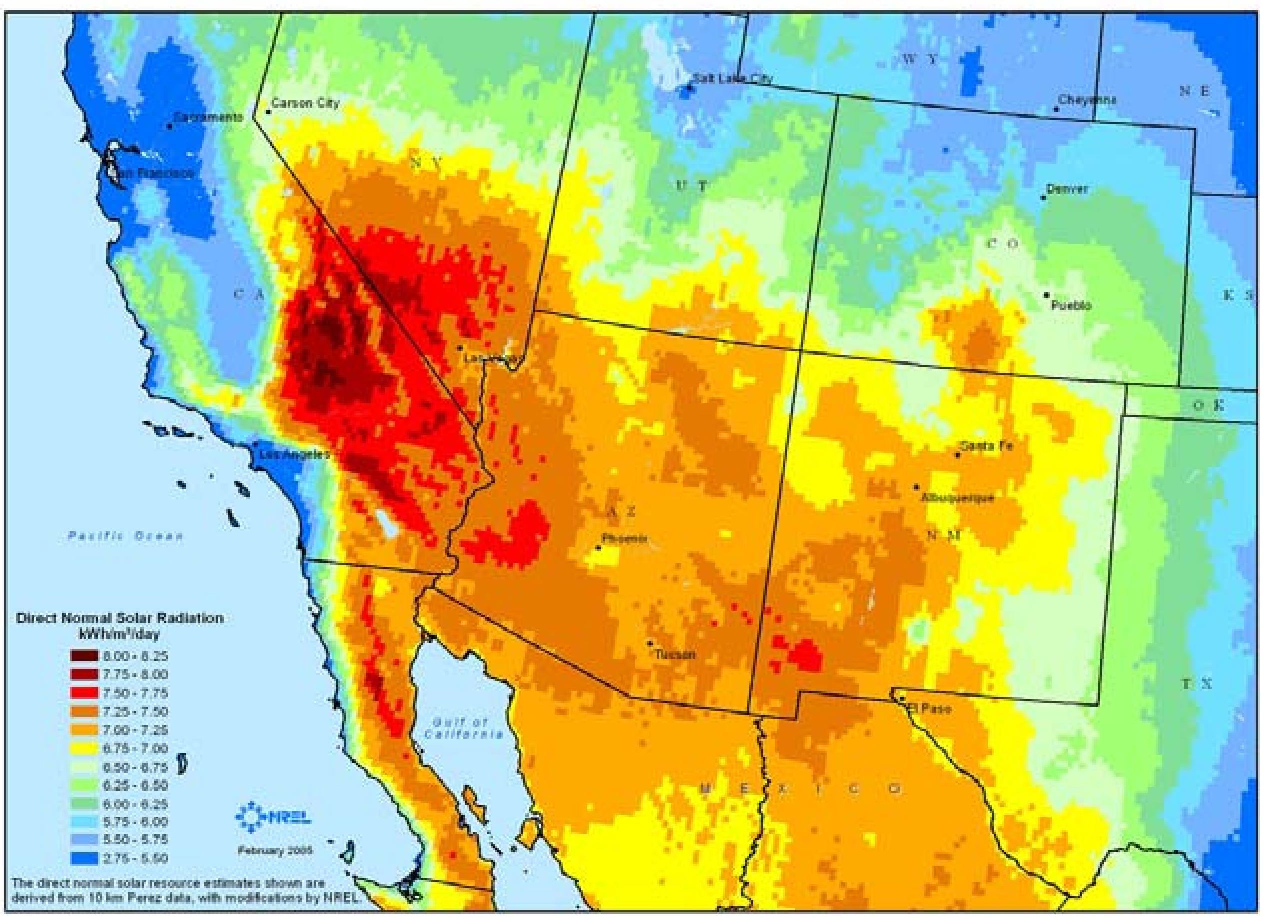


Figure 4. Solar Insolation in the Southwest; Source: NREL

These numbers were based on a Geographic Information Systems analysis to identify candidate areas in the Southwest. Several filters were used to determine which land was suitable for CSP plants:

- Only lands with an average daily solar resource of 6.75 kWh/m^2 or above
- 500 contiguous acres of land minimum
- Land with 1 percent or less slope
- Excluded designated urban areas, national parks, national preserves, wilderness areas, wildlife refuges, or water

A more accurate analysis would have required filters for land ownership, road access, and access to transmission. Discussions with federal, state, and local governments would also be required to determine if there were plans to designate public lands for a specific use. All of these factors would reduce the solar capacity listed in Table 2. The 6,877,055 MW total solar capacity was meant to show that the maximum solar potential of the Southwest is much more than is presently needed, not what was either possible or practical.

Energy potential, however, is not meaningful unless it can be brought to market at a reasonable cost, which CSP technologies cannot currently do. DOE's Solar Energy Technology Program has been working to reduce the cost of CSP technologies through R&D. Much of this effort has been focused on parabolic trough and dish/engine systems. The key technical challenges for parabolic trough technology relate to improving the efficiency and reducing the installed capital cost of the solar field, including the concentrator and solar receiver. To take advantage of the added value for dispatchable power, an additional challenge is to develop a low-cost energy storage system that enables utilities to generate power to meet grid demand. The key technical challenges for dish/engine technology are improving the solar collector (e.g. optics and controls) and increasing the reliability of the engine (e.g. valves, seals, and controls). DOE also developed a strategy that called for a Federal-State partnership in which DOE provides R&D support and the States provide incentives to enable deployment. DOE's role in deployment would be to provide the States and their utilities information about CSP technology.

Recent policy developments at the federal and state level have improved the commercial potential of CSP technologies. These policy changes have played a significant role in spurring the development of several CSP projects in the Southwestern U.S. In turn, cost reductions that are likely to be achieved through these projects may help lead to further CSP deployment.

Recent Policy Developments

At the federal level, the establishment of a 30 percent investment tax credit for qualified solar energy installations through Section 1335 of the Energy Policy Act of 2005 (EPACT 2005) has helped to significantly reduce the cost of CSP projects.[46] The investment tax credit currently applies to projects placed in service by December 31, 2007.

State policies have played a major role in creating a market that is favorable for CSP deployment. Six Southwestern States (CA, NM, AZ, TX, CO, and NV) have established incentives to promote the use of renewable energy, including solar energy technologies. Because CSP technology operates most efficiently in low-latitude regions where the skies are clear, the Southwest offers the best sites for CSP plants in the U.S.

Chief among the state policies to promote renewables are renewable portfolio standards (RPS's) which require that a specific portion of a state's electricity consumption be met by renewable energy by a certain year. California's RPS goal, for example, is 20 percent of total generation from renewable resources by 2010.[47] Table 3 lists the requirements of the RPS's in the six Southwestern States.[48]

Nevada's RPS requires each electricity provider to generate 9 percent of its electricity from renewable sources by 2007 and 20 percent by 2015. Furthermore, it requires that 5 percent of the electricity obtained from renewable sources in each year must be acquired from solar energy systems.[49] In addition to its RPS, New Mexico has established a Task Force to assess the feasibility of a CSP project. Recommendations from the Task Force to the Governor are currently pending.[50]

Table 3. RPS Requirements in Southwestern States

State	Requirement
Arizona	15% by 2025
California	20% by 2010
Colorado	10% by 2015
Nevada	20% by 2015, 5% Solar
New Mexico	10% by 2011
Texas	5,880MW (~4.2%) by 2015

It is important to note that unless a state RPS has a carve-out requirement for solar, utilities will most often pursue the cheapest renewable energy projects, which to date has been wind energy in most states. However, these policies have led to the establishment of several CSP projects since 2004. A list of those projects is provided in Appendix A.

In addition to state activities establishing RPS's, in June 2004 the Western Governors' Association (WGA) established the Clean and Diversified Energy Initiative for the West. Its goal is to develop 30,000 MW of clean energy in the West by 2015. Under the auspices of the WGA, a Solar Task Force comprised of industry, utility, environmental, and State and Federal government representatives developed a set of policies and incentives it felt were necessary to enable sufficient deployment to bring the cost of CSP down to levels competitive with fossil fuel-generated electricity.[51] Although DOE supported the WGA team that wrote the report, the report was not an independent assessment funded by DOE. The report was submitted to the WGA. It was not submitted to DOE and DOE does not necessarily agree with the report's policy recommendations. A summary of the WGA Solar Task Force report is provided in Appendix B.

Benefits of CSP for Utilities

Although CSP costs more today than other renewable options such as wind, there are several reasons for utility interest in CSP:

- CSP electricity production aligns closely with periods of peak electricity demand, reducing the need for investment in new generating plants and transmission system upgrades.
- Thermal storage or the hybridization of CSP systems with natural gas avoids the problems of solar intermittency and allows the plant to dispatch power to the line when it is needed.
- The widespread availability of solar energy throughout the Southwest provides utilities with flexibility in locating CSP plants near existing or planned transmission lines.
- Placing CSP plants on the "right" side of congestion can reduce grid congestion and increase grid reliability.
- Large centrally-located power plants are the types of systems that the utilities have operated for years and with which they are most comfortable.
- Once the CSP plant is built, its energy costs are fixed; this stands in contrast to fossil fueled plants that have experienced large fluctuations in fuel prices during the last several years.

Arizona Public Service, in its description of the Southwestern Utility Consortium CSP Initiative,[52] gave the following reasons why the consortium of 10 Southwestern utilities is considering developing a CSP plant in Arizona:

- Solar energy is Arizona's greatest renewable resource
- CSP is the most effective solar technology
- CSP's peaking capacity when paired with storage or natural gas
- Its potential for cost competitiveness in the near future

Utilities are also concerned that there may eventually be constraints on greenhouse gas emissions. Because CSP plants do not emit carbon dioxide, they allow utilities to generate electricity without emitting that greenhouse gas. Utility concerns about future greenhouse gas regulations are being fueled by actions taken throughout the country. In September 2006, California enacted the California Global Warming Solutions Act of 2006, which requires California to reduce its greenhouse gas emissions by 25 percent by 2020.[53] As of October 2006, more than 300 mayors representing over 50 million Americans had agreed to take steps to reduce greenhouse gas emissions.[54] Constraints on greenhouse emissions may make fossil fuel-generated power more expensive, thereby improving the economics of CSP projects.

CSP also helps utilities come into compliance with existing Federal, State, and local air quality regulations. The environmental impact of solar energy depends on what fuel source was used to generate the electricity it is replacing. Relative to a typical natural gas combined cycle plant, the cleanest source of fossil-fueled electricity, a 100 MW CSP plant with 6 hours of storage reduces NO_x emissions by 7.4 tons/year, CO emissions by 4.5 tons/year, and CO_2 emissions by 191,000 tons/year.[55] It should be noted, however, that this environmental analysis did not include a complete life cycle analysis that took into account the emissions resulting from constructing the power plants or from making the materials that went into the plants.

The environmental benefits of CSP and other renewables have likely been a factor in spurring the State and Federal governments to create incentives for their use. As the next section explains, the economic development benefits of CSP also give some state governments a reason to provide policy incentives for CSP.

Benefits of CSP for Southwestern States

Adding CSP to the generation mix of a State contributes to a reliable and diverse energy supply, a better use of natural resources within the State, and better air quality. CSP can also serve as a hedge against the high and volatile costs seen in energy prices the past several years. In California, for example, the average cost of natural gas in 1999 was about $2.20 per million BTU's. It rose to over $8/MMBtu in 2001, fell to $3/MMBtu in 2002, and back up to $7/MMBtu by 2005.[56] In contrast, the solar energy used as fuel by CSP systems is stable. The power purchase agreement determines the cost of CSP power for the duration of the agreement (typically for 20 years). Being an indigenous resource, solar energy is not subject to disruptions of supply or market conditions that can plague natural gas (and to a lesser extent, coal-fired) power plants.

CSP also provides for a growing industry that can provide an economic stimulus to the State.[57] Several States recommended that it would be useful if DOE provided an assessment of the economic development benefits of CSP. As a result, economic studies were done for Nevada, New Mexico, and California. In each case the State was asked to select an expert organization to perform the study. This was done to assure the analysis was done by independent experts that were credible to the State. Nevada and New Mexico each selected one of their universities to do the analysis based on its expertise in doing similar analyses for the State. There was no peer review of these reports other than that done by the States. California did not recommend an organization, but was comfortable with the expertise of the organization selected by DOE. This report did undergo a peer review.

The studies were limited to the economic impact of building and operating CSP plants. In particular, the studies estimated the number of jobs that could be created and the potential addition to gross state product. The California report was expanded to compare the economic impact of CSP to combined cycle and simple cycle natural gas plants. This showed the net economic benefit of CSP versus building similar sized natural gas plants. The Nevada and New Mexico studies did not make this comparison, but compared a scenario in which CSP was built against a scenario in which no new generation capacity was built.

Of course, such analyses are most useful at a State level and not the Federal level. The economic impact of CSP for a State depends on its portfolio of natural resources. If a State has large reserves of natural gas or coal, the shift to solar energy could result in a net loss of jobs. To be credible and useful for Federal policymakers, employment studies need to look at nationwide impacts on employment and be conducted by independent experts.

Nevada Economic Study

This study was done to help the State of Nevada estimate the economic impact of building CSP plants. It found that if ten 100 MW plants were built in Nevada over an 11-year period, the following benefits could be expected: [58]

- An initial employment increase of 3,830 jobs, rising to a peak of 6,940 jobs during construction, with nearly 2,000 permanent jobs for the operation and maintenance of the plants[59] (see Figure 5)
- Total personal income increase of $9.37 billion
- Gross State Product increase of $9.85 billion

The report concluded that "CSP generation is a potential source of economic development throughout the State. Rural Nevada has been shedding high-paying natural-resource-based jobs for the past decade. Solar power generation does not contribute to global warming or diminish air quality, but provides opportunities for the skilled labor force that has been left unemployed in rural Nevada. Thus, tallying the economic and environmental benefits of solar-power generation, it is clear that it could be an important contributor to sustainable economic development in rural Nevada."[60] Of course, whenever there is a large investment in a capital project, the number of local jobs will increase, so the analysis may be somewhat misleading unless it compares the results to an alternative investment of the same magnitude that achieves the same goal. The analysis did not identify who would pay for the investment (Federal or State taxpayers or ratepayers). Finally, the report did not estimate jobs potentially lost elsewhere in the U.S.

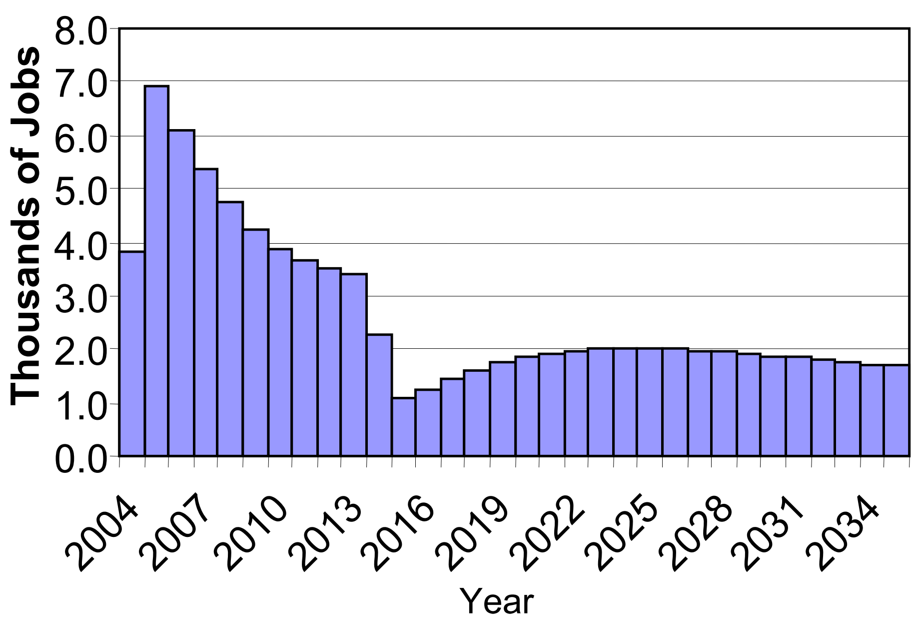


Figure 5. Estimate of Jobs Generated by Building 1000 MW of CSP in Nevada, [55]

New Mexico Feasibility Study[61]

This study assessed the feasibility of creating a solar power industry in New Mexico and included an assessment of the economic and fiscal impact on the State. One scenario had five 100 MW plants built over a ten-year period. The benefits of that scenario included:

- Creation of 11,696 jobs during the construction phase (direct and indirect) and 397 permanent operation and maintenance (O&M) jobs
- Net revenue increase to State and local governments of $1.22 billion over 30 years

The study also included a detailed analysis of which components could be manufactured within the State and which would likely be imported from other States or overseas. The report concluded "Building a beachhead [solar] industry holds tremendous economic impact for New Mexico."

California Economic Benefits Study[62]

Although there are similarities to the above referenced Nevada and New Mexico reports, the California study had a broader scope. It provided an assessment of CSP technologies and California's solar resource, determined the environmental and energy benefits of CSP, and estimated the economic impact to the state. The California study also compared the economic impact of CSP with natural gas power plants. Because California's need for electrical power is much greater than Nevada and New Mexico, the study examined deployment scenarios of 2,000 MW and 4,000 MW assumed to be built between 2008 and 2020.

The study found that building between 2,000 and 4,000 MW of CSP would have the following effects:

- $7 to $13 billion in new investment, of which an estimated $2.8 to $5.4 billion would be spent in California
- An increase in Gross State Product of between $13 and $24 billion
- The creation of 1,500 to 3,000 jobs

Moreover, the study found that a CSP plant requires an approximately 67 percent larger workforce than a comparably sized combined cycle plant. During construction, the impact of each 100 MW of CSP on gross State product is significantly higher than that of a similarly sized combined cycle gas plant ($628 vs. $64 million).

The report concluded that "investment in CSP power plants delivers greater return to California in both economic activity and employment than corresponding investment in natural gas equipment. Each dollar spent on CSP contributes approximately $1.40 - $1.50 to California's gross State product; each dollar spent on natural gas plants contributes $0.90 - $1.00 to the gross State product."[63] This is because of the savings accrued over the lifetime of the plant from not having to purchase natural gas from out of state to keep the plant operating. During 2004, California imported 32 percent of its energy from other States or Canada.[64] The use of CSP enables California to use an energy resource abundant within the State. This keeps more money in the State and helps strengthen its economy. Adding CSP also diversifies its sources of energy, lessening its reliance on any one source. The California report also references a study that indicates that decreasing the demand for natural gas (e.g., by using CSP) reduces its price to the benefit of all natural gas consumers.[65]

4.0 Summary

Between 2000 and 2003, four reports were released on the potential for CSP. An assessment of the main issues raised by these reports leads to the following conclusions:

1. Further technology development and deployment could reduce the cost of CSP: The S&L study quantified the significant cost reductions that are possible with continued technology development and deployment. It concluded that there were three elements that could reduce the cost of CSP from approximately 12 cents/kWh today to about 5 cents/kWh by 2020: technology development (42 percent), building larger plants (37 percent), and volume production (21 percent). All four studies mentioned in this report are in agreement that the costs of CSP would fall with greater levels of deployment.

2. CSP requires policy incentives for initial deployment: All the reports emphasized that in the near-term, deployment of CSP depends on the establishment of policy incentives that offset the current higher cost of solar energy. The CSP industry provided a list of incentives it stated were necessary to initiate deployment. These were included in DOE's 2002 report. Six southwestern States have now established renewable portfolio standards, and the Federal Government has created an investment tax credit that encourages the deployment of CSP. These policies have resulted in the establishment of CSP projects in California, Arizona, and Nevada that could result in 2,000 MW by 2010.

Development of CSP could provide energy, economic, environmental, and security benefits. The following factors could make CSP an attractive option for the Southwestern States if policymakers determine that these benefits outweigh the costs.

1. **Energy**: CSP could provide hundreds of gigawatts of clean power.

2. **Economic**: Analyses for California, Nevada, and New Mexico estimate that there could be significant benefits in job creation and additions to gross state product accruing from building and operating CSP plants. It is expensive to build a CSP plant and it requires a relatively large number of people to operate and maintain it. Counter balancing this, however, is the absence of a fuel cost. Much of the money that would otherwise be spent on monthly fuel costs, instead is spent on salaries. States and the Federal government have indicated their concern over the rising and volatile price of fossil fuels and their impact on the economy.

3. **Environmental**: CSP plants do not emit criteria pollutants or greenhouse gases, an issue of growing concern throughout the Federal and State governments. Thus, CSP could be an element of potential future policies related to climate change.

4. Security: The addition of CSP to a State's portfolio increases its energy diversity and makes use of a local resource. Solar power is a domestic resource not subject to depletion. Placing CSP plants on the "right" side of congestion can reduce grid congestion and increase grid reliability.

The reports discussed in this document have identified a path by which power from CSP plants can become competitive with fossil fueled plants. In DOE's 2002 report, industry estimated the cost of incentives required to achieve this goal would be between $1.5 and $2.0 billion over 14 years. At the end of that period CSP could potentially provide electricity at 5 to 6 cents/kWh without further subsidies.

Federal policymakers must carefully weigh the potential benefits of CSP against the significant cost to taxpayers in terms of industry subsidies and the cost to ratepayers in those states where CSP would initially provide electricity at costs higher than conventionally produced electricity.

Appendix A. Recent and Ongoing Projects

In 2005 and 2006, several CSP plants were built or entered the planning phase in the Southwestern U.S. These projects represent a very small fraction of the enormous energy potential in the western U.S. A DOE report done for the Western Governors' Association found that by using only available land with the most intense sunshine, over 6,800 GW of electricity could be generated in the Southwest. This is nearly 7 times the electric generating capacity of the entire country.
These plants, as well as all other CSP plants that have been deployed in the U.S. since 1985, are listed in Table 4.

In 2005, Arizona Public Service Company (APS) deployed a 1 MW trough plant at the company's Saguaro Power Plant near Tucson, AZ, as pictured in Figure 6. This was the first commercial trough plant built since 1991.

Figure 6. One MW CSP Trough Plant near Tucson, AZ

Nevada Power signed a power purchase agreement for a 64 MW trough plant in Boulder City, NV. The project, called Nevada Solar One and shown in Figure 7, will be the largest solar project built since 1991 and the third largest solar power plant in the world. Construction started in 2006 and operation is estimated to begin early in 2007.

Figure 7. Nevada Solar One near Boulder City, NV

In August 2005, Southern California Edison (SCE) signed a power purchase agreement for 500 MW of CSP dish-engine systems on a 4,500 acre site near Victorville, CA, with an option to expand the project to 850 MW. Figure 8 provides an artist's rendering of a field of dish-engine CSP systems.

In September 2005, San Diego Gas & Electric (SDG&E) signed a power purchase agreement for a 300 MW dish-engine project in California's Imperial Valley near El Centro, CA, with an option of expanding the project to 900 MW.[66]

Figure 8. Artist's Rendering of Multi-MW Dish-Engine CSP Field

In August 2006, the Pacific Gas and Electric Company initiated plans with Luz II, LLC, to purchase at least 500 MW of solar energy beginning in the spring of 2010.[67]

In October 2006, APS announced that it was part of a group of 10 Southwestern utilities from Arizona, New Mexico, Nevada, Colorado, Texas, and California that was considering aggregating their future need for solar power in order to benefit from the lower costs associated with larger CSP plants.[68] APS listed several reasons why the utilities are working together:

- CSP facilities experience greatest cost effectiveness around 250 MW
- Few utilities have the appetite for large solar facilities
- Joint development allows greater scale and lower prices
- Joint ownership is familiar to most utilities

In November 2006, SDG&E announced that it had signed a contract with Bethel Energy LLC to "add nearly 100 MW of renewable electricity to SDG&E's energy portfolio."[69]

Each of the four reports assessing the potential of CSP emphasized the importance of deployment in reducing costs. Both of the National Research Committee reports concluded it was unlikely that CSP would ever be deployed. Recent policy changes, in particular the establishment of renewable portfolio standards by several states, have led to the CSP deployment activities listed above.

Table 4. List of CSP Plants in the U.S.

Name	Type	Net Output (MWe)	Location	Status	Owner/ Operator
SEGS I	Parabolic Trough w/ 3 hours of thermal storage	13.8	Mojave Desert, Daggett, CA	Operation began in 1985 (thermal storage no longer in operation – damaged in 1999 fire)	Sunray Energy
SEGS II	Parabolic Trough w/ auxiliary natural gas boiler	30	Mojave Desert, Daggett, CA	Operation began in 1986 – natural gas augments solar power as necessary	Sunray Energy
SEGS III	Parabolic Trough w/ auxiliary natural gas boiler	30	Mojave Desert, Kramer Junction, CA	Operation began in 1987 – natural gas augments solar power as necessary	Florida Power & Light
SEGS IV	Parabolic Trough w/ auxiliary natural gas boiler	30	Mojave Desert, Kramer Junction, CA	Operation began in 1987 – natural gas augments solar power as necessary	Florida Power & Light
SEGS V	Parabolic Trough w/ auxiliary natural gas boiler	30	Mojave Desert, Kramer Junction, CA	Operation began in 1988 – natural gas augments solar power as necessary	Florida Power & Light
SEGS VI	Parabolic Trough w/ auxiliary natural gas boiler	30	Mojave Desert, Kramer Junction, CA	Operation began in 1989 – natural gas augments solar power as necessary	Florida Power & Light
SEGS VII	Parabolic Trough w/ auxiliary natural gas boiler	30	Mojave Desert, Kramer Junction, CA	Operation began in 1989 – natural gas augments solar power as necessary	Florida Power & Light
SEGS VIII	Parabolic Trough w/ auxiliary natural gas HTF heater	80	Mojave Desert, Harper Lake, CA	Operation began in 1990 – natural gas augments solar power as necessary	Florida Power & Light
SEGS IX	Parabolic Trough w/ auxiliary natural gas HTF heater	80	Mojave Desert, Harper Lake, CA	Operation began in 1991 – natural gas augments solar power as necessary	Florida Power & Light
Solar One	Power Tower	10	Barstow, CA	Operated from 1982 to 1988	DOE
Solar Two	Power Tower w/ Molten Salt Storage	10	Barstow, CA (Retrofit of Solar One)	Operated from 1996 to 1999	DOE/SCE
Nevada Solar One	Parabolic Trough	64	Boulder City, NV	Under Construction - Operation will begin in 2007	Solargenix
Stirling Energy Systems SES I	Dish - Stirling Engine	500	Mojave Desert, CA	Under Development - (May be expanded to 850MW): 20-yr PPA with Southern California Edison	Sterling Energy Systems
Stirling Energy Systems SES II	Dish - Stirling Engine	300	Imperial Valley, CA	Under Development - (May be expanded to 600MW): 20-yr PPA with San Diego Gas & Electric	Sterling Energy Systems
Saguaro Solar Generating Station	Parabolic Trough	1	Tucson, AZ	Started Operation in 2006	Arizona Public Service
Sandia Labs/SES Test Facility	Dish - Stirling Engine	0.15	Albuquerque, NM	Six-dish test facility –installation completed in January 2005	Sterling Energy Systems
PG&E/Luz II, LLC	Parabolic Trough	500	TBD	Under Development –Planned to be operational by 2010	TBD
SDG&E/Bethel Energy LLC	Parabolic Trough	100	TBD	Under Development –Planned to be operational by 2010	TBD

Appendix B. WGA Report

The Western Governors' Association (WGA) established the Clean and Diversified Energy Initiative for the West in order to develop 30,000 MW of clean energy in the West by 2015. The WGA formed a Solar Task Force comprised of industry, utility, environmental, and State and Federal government representatives to develop a set of policies and incentives necessary to enable sufficient deployment to bring the cost of solar energy down to levels competitive with fossil fuel-generated electricity.[70] Initially it was estimated that CSP would provide 1,000 MW towards that goal, but the Solar Task Force recommended that it be increased to 4,000 MW.[71]

For the task force's report, data from Pacific Gas & Electric was used to compile a blended average of electricity prices that takes into account the fraction of CSP generation that falls into baseload and peak periods (called a market price referent, or MPR), as well as the sensitivity of electricity prices to natural gas price fluctuations. This data shows that the market price of conventional electricity is about 5.5 cents/kWh when the price of natural gas is $5/MMBtu and that it increases as the price of natural gas increases.[72] The cost of electricity is 8 cents/kWh when natural gas reaches $9/MMBtu.

The WGA task force recommended that the 30 percent Federal investment tax credit be extended to ten years and made available to utilities, and that States exempt CSP plants from property and sales taxes, extend power purchase agreements to 30 years, and make power purchase agreements larger (e.g., 500 MW) to accelerate scale-up cost reductions. The report cautions that if these incentives are not available, CSP deployment may require the establishment of a production tax credit or buy-down.

However, if these incentives are in place, the task force estimated that 4,000 MW of CSP could be deployed, reducing the levelized cost of energy from CSP to under 6 cents/kWh (see Figure 9). This would place the cost of CSP within the competitive range with fossil fuel-fired power plants at current natural gas prices.

In addition to the Solar Task Force, the WGA formed six other task forces: wind, clean coal, biomass, geothermal, energy efficiency, and transmission. Each task force wrote a report. The reports were submitted to the WGA in 2006.

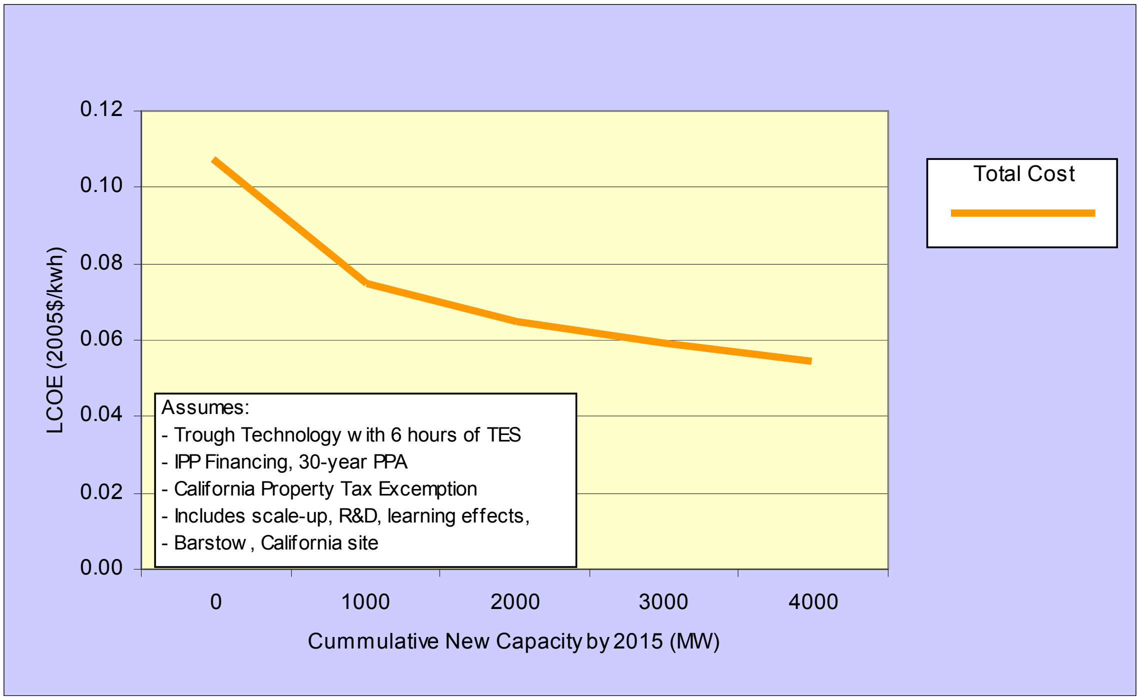


Figure 9. WGA Task Force's Forecast for CSP Cost

Appendix C. Acronyms and Abbreviations

Term	Definition
CPUC	California Public Utilities Commission
CSP	Concentrating Solar Power
DOE	Department of Energy
EPACT	Energy Policy Act
GW	Gigawatts (1,000,000 kilowatts)
kWh	Kilowatt-hour
LCOE	Levelized Cost of Energy
MW	Megawatts (1,000 kilowatts)
NRC	National Research Council
NREL	National Renewable Energy Laboratory
O&M	Operation and maintenance
PV	Photovoltaic
R&D	Research and development
RPS	Renewable portfolio standard
S&L	Sargent and Lundy LLC
SEGS	Solar Energy Generating System
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SunLab	SunLab comprises researchers from Sandia National Laboratories and the National Renewable Energy Laboratory working together on Concentrating Solar Power for the Department of Energy
WGA	Western Governors' Association

Endnotes

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