1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVE

Several years ago, the National Research Council (NRC) issued a report (Hubbard 2000) recommending that the Department of Energy (DOE) should “limit or halt its research and development on power-tower and power-trough technologies because further refinements would not lead to deployment.” Unfortunately, the report provided no analysis or description of the various advanced technology options, their costs, or their associated technical risks that the NRC considered in arriving at these conclusions.

To examine the possible factors contributing to the NRC recommendations, the DOE had the Concentrating Solar Power (CSP) Program (which provides funding for trough and tower research and development) peer reviewed in the fall of 2001. This review concluded that “the CSP Program can play an important role in catalyzing further CSP technology advances, which will further improve CSP economics and market penetration” (Tester 2001).

In order to resolve the differing conclusions between the NRC report and the Peer Review, and in accordance with its own strategic program review recommendations, the Office of Energy Efficiency and Renewable Energy (EERE), a part of the DOE, contracted Sargent & Lundy (S&L) to conduct a “due diligence-like” analysis of both trough and tower technologies and to have the results of the “due diligence” analysis reviewed by a new panel assembled by the NRC.

The objective of this evaluation was to assess the cost-reduction potential of CSP technology over the next 10 to 20 years. The analysis proceeded along the following steps:

1. Examination of the current trough and tower baseline technologies that are examples of the next plants to be built, including a detailed assessment of the cost and performance basis for these plants.
2. Analysis of the industry projections for technology improvement and plant scale-up out to 2020, including a detailed assessment of the cost and performance projections for future trough and tower plants based on factors such as technology research and development (R&D) progress, economies of scale, economies of learning resulting from increased deployment, and experience-related operation and maintenance (O&M) cost reductions resulting from deployments.
3. Assessment of the level of cost reductions and performance improvements that, based on S&L experience, are most likely to be achieved, and a financial analysis of the cost of electricity from such future solar trough and tower plants.

Sargent & Lundy, with technical support from its expert consultants, reviewed available information and data to make our independent assessment. The detailed review was performed by S&L, with only technical input from our consultants, so that we maintain as much independence as possible from the industry and from our expert consultants.

Sargent & Lundy is not an active participant in the solar market. However, our experience includes design of the power block and civil/structural portions for the Solar Electric Generating Station (SEGS) VIII and IX in 1988–1989. Any future involvement in CSP plants would entail a similar scope (design of the power block and civil/structural portions). S&L's core competence is as an architect-engineer and designer for the power block. Although we may be a participant in the project, our independence is maintained since any work would be a small portion of our overall business.

1.2 SCOPE OF WORK

Sargent & Lundy received and organized data from the DOE, National Renewable Energy Laboratory (NREL), Sandia National Laboratories (SNL), and members of the CSP industry. These data included technology assessments and supporting studies for troughs and towers.

The first meeting with the NRC panel to discuss the work approach and agree on the focus of the work scope occurred on August 12, 2002. Before the meeting, S&L, with approval from NREL, proceeded with the review based on our contractual work scope. Among the technical experts within the industry from whom we received guidance, including support on a subcontract basis, were Dave Kearney for Trough Technology and Pat DeLaquil for Tower Technology.

The work scope was modified during the first NRC meeting to focus on cost reductions and technology improvements. S&L's scope of work included "estimate the expected competitiveness of these technologies (CSP) in peaking, cycling, and baseload applications for operation as grid-connected generators, comparing CSP technologies with other technologies commercially used for such service today (e.g. combined-cycle natural gas fired power plants)." S&L had completed considerable work in this area before the August 12, 2002 meeting. The DOE stated that it was not the intent, nor should it be the intent, to include this in the work scope. The analysis of competing technologies will be addressed separately by the DOE. S&L's evaluation or assessment focused on cost reduction, improvements in technology and financial analysis of levelized energy cost (LEC). Our evaluation review was based on our examination of relevant data, technical assistance from our subcontractors, our experience in the power industry and due diligence process, and industry input. The evaluation review is an independent evaluation of the reasonableness and feasibility that cost reductions and technology improvements can be achieved based on available information and our experience. The evaluation review does not include detailed engineering or detailed bottom-up cost estimates.

Sargent & Lundy issued the final draft report ‘Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts’ in October 2002. The National Research Council (NRC) Committee for the Review of a Technology Assessment of Solar Power Energy Systems reviewed the report. The results of the NRC review were published in ‘Critique of the Sargent & Lundy Assessment of Cost and Performance Forecasts for Concentrating Solar Power’ dated October 12, 2002. S&L was authorized by NREL to update the report to expand the executive summary to provide more information as suggested by the NRC and perform additional sensitivity analysis. S&L response to the NRC issues and observations are included in Appendix I.

1.3 METHODOLOGY

A summary of the methodology for performing this evaluation is provided in this section. A detailed discussion of the methodology and example is included in Appendix B.

1.3.1 Data Collection

Sargent & Lundy received relevant documents from NREL and SNL for our independent review. During the review process, additional documents were gathered from industry sources, the Internet, and our internal S&L library. The list of documents is included in Appendix A.

1.3.2 Review of SunLab Cost Model

Sargent & Lundy reviewed the SunLab cost model and determined that the SunLab cost model approach and methodology is reasonable. The SunLab cost model was developed based on industry cost data and engineering evaluation. S&L evaluated the assumptions in the SunLab cost model: efficiency improvements, capital cost for the near-term deployment, and cost reductions through the year 2020. The review of cost reductions included technology improvements, increase in the size of the plant (scale-up), and production volume.

The cost model was compared to S&L’s internal cost database, as appropriate (e.g., turbine, equipment, and commodities such as steel prices).

Differences between the SunLab and S&L cost estimates were a result of different assumptions. For example, S&L increased the duration between the deployment of the next generation plant from 1 year to 2 years to account for lessons learned and an adequate time for steady-state operation. The differences in assumptions are identified in the main body of the report.

1.3.3 Technical Improvements

Projected technical improvements that reduce costs by improving plant efficiency or by reducing initial capital costs were evaluated with respect to probability of the improvement and the estimated magnitude of cost reduction. The projected technical improvements investigated were those identified in the SunLab models, and the probability and magnitude of cost reductions are based on data from DOE, NREL, SNL, and members of the CSP industry, including technology assessments and supporting studies for troughs and towers.

1.3.4 Economy of Scale

Economy of scale was used, as appropriate; to estimate or evaluate cost estimates for components. Scaling factors were used to estimate the cost of a new size or capacity from the known cost for a different size or capacity.

1.3.5 Volume Production (Volume and Learning Curve)

Experience curves define how unit costs decrease with cumulative production. The specific characteristics of the experience curve are that the cost declines by a constant percentage with each doubling of the total number of units produced (Neij 1997).

Many of the previous studies that assessed the cost reduction potential for tower and trough technologies based their findings on experience curves (World Bank 1999). As pointed out in the Teagan report (2001), “the review documents do not make a strong case that the cost of technologies (particularly the solar field) can be reduced to a point that they approach economic viability….” His primary example was the collector field: “the ‘learning curve’ arguments put forth lack sufficient backup to be credible given the fact that the materials of construction are already commodities and the fabrication techniques, for the most part standard.” He also stated that he believed cost reductions are likely “via a combination of ‘learning curve’ and technology refinement.” In response, S&L performed a thorough review of the cost reduction potential for heliostats. Heliostat cost reduction potential is more difficult to estimate since it is not based on actual costs of significant volume, whereas trough costs and the cost reductions are known based on actual SEGS construction data and recent costs for replacement during operations and maintenance. Our detailed evaluation of cost reduction potential is provided in Appendix E.5.

Sargent & Lundy reviewed the engineering assumptions, industry data, and studies that constitute the basis of the SunLab Cost Model for the major cost drivers. The review was not based on just applying an experience curve, but an engineering review. We reviewed the assumptions and made adjustments as deemed appropriate based on our experience. We calculated the progress ratio and compared it to actual experience curves from other industries. The calculated progress ratio value was then used to determine estimated costs for a range of deployments.

1.3.6 Operation and Maintenance Costs

Sargent & Lundy reviewed the SunLab cost model against interviews and actual data provided to us during a site visit to Kramer Junction and our knowledge and internal database of O&M costs for electric power plants. We reviewed the SunLab assumptions and made adjustments as appropriate based on our experience and information provided by Kramer Junction.

1.3.7 Financial Modeling Analysis Methodology

The financial model used for developing generating costs is a spreadsheet pro forma financial model of the type used in competitive industry to support power project planning and financing. S&L regularly reviews such models as part of our due diligence practice, working with lenders and investors in project financing. In some cases we also support project developers by writing and maintaining such models for them.

The main analysis engine is a standard income statement that includes calculations of energy production, revenues, operation and maintenance expenses, fuel expenses, depreciation, insurance, property taxes, interest, investment tax credit, and income tax. The investment tax credit for solar technologies is represented. Once after-tax income was determined in the income statement, depreciation was added back and payback of debt principal was subtracted to obtain cash available for dividends. The dividend stream and equity investment into the project was combined to compute the equity internal rate of return for the project. All evaluations were done on a lifetime $/MWh evaluated cost basis, covering 30 years of service.