

**CONCENTRATED SOLAR POWER  
ECONOMIC BENEFITS/EMPLOYMENT IMPACTS  
ASSESSMENT**

**FINAL REPORT**

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### Concentrated Solar Power Economic Benefits/Employment Impacts Assessment

#### 1.0 Study Background and Objective

Several conflicting perceptions are currently floating within the solar community regarding overall impact of using concentrated solar power (CSP) and other renewable energy technologies on job market in terms of creation of direct and indirect jobs. The Center for Global Change at the University of Maryland projects that the solar water heating manufacturing industry created more jobs per million dollars of annual expenditure in comparison to coal, gas, oil, and electric utility sectors (*source: article "Jobs Benefits of Expanding Investment in Solar Energy" in the Solar Industry Journal, 4<sup>th</sup> Quarter 1992*). Moreover, the Canadian Association of Renewable Energies (CARE) has summarized key findings from a recently completed European-Union wide study on impacts on employment in Europe to 2020. This summary of findings presented in CARE's newsletter (*Issue# 153, dated October 23-27, 2000*) indicates that renewable technologies are more labor intensive than conventional technologies for the same energy output, but any jobs that are displaced as a result of subsidies to deploy renewable energy are significantly less than corresponding job gains elsewhere in the economy. These perceptions clearly point to the fact that there is a need to come up with an acceptable analysis that will help in substantiating that renewable energy technologies, CSP in particular, are capable of providing more jobs than conventional technologies.

With this objective in mind, SENTECH undertook this analytical study and used a widely acceptable input-output (I/O) model to help in determining as to how many indirect jobs would be created for every direct job when commercially available CSP technology is deployed. Therefore this study utilized job multipliers from the best available I/O model suitable for power generation applications as well as used the best available information related to the creation of direct jobs by talking to CSP experts and relevant published materials.

#### 2.0 Summary of Key Findings

SENTECH staff examined several past analytical studies (see Appendix 1, 2, and 4, and a list of reports on page 7) dealing with renewable energy impacts on economy and job market. The staff determined early on, after looking at analytical studies performed by the Wisconsin Energy Bureau and by the American Council for an Energy-Efficient Economy, that an Input-Output model should be used. In addition, the 80 MWe Solar Electric Generation System (SEGS) type parabolic trough plant currently operating successfully since 1990 in California was selected to analyze the job creation effects.

Extensive search was undertaken to screen relevant information for plant design, architecture and engineering (A&E), component manufacturing, construction, and O&M of operational SEGS plants in California since 1985. Pilkington Solar International's report Status Report on Solar Thermal Power Plants (ISBN 3-9804901-0-6, January 1996), Sandia's report Final Report on O&M Improvement Program for CSP (SAND99-1290, June 1999), DOE Nevada Operations Office's report Nevada Test Site (NTS) Solar Feasibility Study (April 1994) and several old Luz SEGS presentations (1990-91) were

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found to be the best among available information sources. SENTECH analysis used the input-output model using the Department of Commerce (DOC) Bureau of Economic Analysis (BEA) RIMS II Regional Multipliers for California.

*This analysis was hampered due to lack of availability of actual current employment data by the fact that the last commercial trough manufacturer (Luz) went bankrupt in 1991 and no new SEGS type commercial parabolic trough systems have been installed since then. In addition, no commercial-scale CSP power tower and dish/engine system have been installed to date. However, it was determined, after talking to various CSP industry players, that adequate historical data relevant to plant design and A&E, construction, installation and O&M of 80 MWe SEGS plant exists to analyze direct as well as indirect job potential impacts.*

### Several key findings emerged as a result of this study:

- There were almost 1,800 direct jobs associated during the peak of SEGS VIII and IX plant construction during 1990. Out of these 1,800 direct jobs, 400 jobs were dedicated to the advanced R&D and manufacturing of trough components overseas. Nearly 500 skilled and unskilled workers were used during the construction of the last SEGS 80 MWe plant. Almost 100 jobs were linked with the plant design, detailed systems drawings, and architecture & engineering (A&E) activities. Remaining 800 jobs were associated with procurement of turbine generator, system power block, and balance of system and other subsystems associated with the 80 MWe SEGS trough plant in California in 1990. (*Sources: Luz SEGS 1990-91 reports by Dave Kearney and Mike Lotker; Nevada Test Site (NTS) Solar Feasibility Study, April 1994; and phone conversation with Mr. Dave Kearney in March 2001*).
- Pilkington Solar International's Status Report on Solar Thermal Power Plants (ISBN 3-9804901-0-6, January 1996) and Sandia's "Final Report on O&M Improvement Program for CSP" (SAND99-1290, June 1999) indicate that an 80 MWe SEGS parabolic trough plant requires a staff of 20 for operations and maintenance (O&M). Sandia's study also states that this staff requirement can be reduced to 13 employees, without creating any negative impact on plant performance, by following O&M cost reduction steps learned during joint work between Sandia and the operators of five SEGS plants at Kramer Junction, California in 1996.
- Similar 80 MWe SEGS type plant, if constructed and operated in a developing country, will require regular O&M staff of 31. This O&M staff number can be reduced to 16 if efficient plant O&M procedures are strictly followed in developing country location (*source: Sandia's "Final Report on O&M Improvement Program for CSP" {SAND99-1290}, June 1999*).
- BEA's input/output model's RIMS II job multiplier tables relevant to California were applied to project total employment impact of an 80 MWe SEGS type parabolic trough system. ***Overall results indicate that the average total employment (including both direct and indirect jobs) of 2.66 will be generated for each direct job.*** The total direct-effect employment multiplier for plant O&M emerged as the

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highest at 5.66 among five categories, namely plant design, trough component manufacturing and R&D, manufacturing of turbine generators and other subsystems, plant construction, and plant O&M (see Exhibit 1). Multipliers for the other four categories are in the range of 2.25 and 2.89. *Note, however, some of the employment occurs sequentially and not at the same time. Also note that the plant operation and maintenance jobs are “permanent jobs” for the duration of the plant’s useful life. In addition, Exhibit 1 shows that an 80 MWe SEGS type parabolic trough plant design and construction will yield 4,724 total jobs for 1,800 direct jobs. The total jobs figure will increase to 4,837 when 20 direct jobs for plant O&M are added to the original figure of 1,800 direct jobs.*

**Exhibit 1. Estimates of Total Employment for a 80 MWe CSP SEGS Type Trough Plant, Using Multipliers from BEA’s RIMS II Model for California, 1992 Industry Structure, 1997 Regional Data.**

SEGS Plant Activity	Direct Employment (Jobs)*	Total Direct-Impact Employment Multiplier	Total (Jobs)
Plant design, A&E	100	2.25	225
Turbine generator, power block and other subsystems	800	2.89	2,312
Manufacturing and advanced R&D of trough components	400	2.28	912
Plant construction	500	2.55	1,275
<b>Subtotal Employment (Jobs)</b>	<b>1,800</b>		<b>4,724</b>
Plant operation and maintenance (O&M)	20	5.66	113
<b>Total Employment (Jobs)</b>	<b>1,820</b>		<b>4,837</b>

\* Sources: Luz SEGS 1990-91 reports by Dave Kearney and Mike Lotker; Nevada Test Site Solar Feasibility Study, April 1994; and phone conversation with Dave Kearney in March 2001.

- Measuring jobs per million dollars of annual expenditure, using an average total cost of \$253.2 million (in 1990\$) for each of the last two 80 MWe SEGS type plants construction in 1990 and using total jobs of 1800, yielded 7.11 jobs per million for CSP trough system. Comparing this number with the similar information from an analysis conducted in 1990 by the Center for Global Change at the University of Maryland (see Exhibit 3 on page 10) indicate that *CSP jobs at 7.11 for each million dollars are more than total jobs per million created by electric utilities (4.73), by coal mining (4.38), by natural-gas utilities (2.64), and by oil & gas exploration (1.51).*

### 3.0 Study Approach and Relevant Data Collection

SENTECH analysis used the Department of Commerce (DOC) Bureau of Economic Analysis (BEA) RIMS II Regional Multipliers for California since most of commercial trough plants are located in that state. The Regional Input-Output model was useful in predicting indirect employment effects (job creation potential) from future CSP projects in California as well as in other parts of the southwest USA. SENTECH study looked at an 80 MWe SEGS trough plant using approximately 500,000 square meters of trough collectors as state-of-the-art system similar to what was used at SEGS VIII and IX plants in Harper Lake, California. Parabolic trough plant was selected over power tower and dish/engine systems because of commercial maturity of trough plants. A quantitative analysis was performed that included documented sources of data and passed analyses utilizing Input-Output modeling that have been used in the past to show job creation potential with additional investments in renewable energy and energy efficiency technologies.<sup>1</sup>

SENTECH's approach began with an exhaustive literature review searching many of the areas in the attached Appendix 1 and 2 of sources and

#### CSP Background

CSP technologies, including parabolic troughs, power towers, and dish/engine systems, convert sunlight into electricity efficiently and with minimum effect on the environment. These technologies generate high temperatures by using mirrors to concentrate sun's energy up to 5000 times its normal intensity. This heat is then used to generate electricity for a variety of market applications, ranging from remote/distributed power needed as small as few kilowatts to grid connected applications of up to 200 MW or more. In larger CSP plants, standard power-generating equipment such as a conventional steam turbine extracts the heat energy from the fluid to generate electricity. In smaller systems, a stand-alone engine/generator produces the electricity. The main difference between a solar plant and a conventional plant is the source of heat: solar energy in place of a conventional fuel supply system.

Research and development (R&D) efforts in the U.S. have improved the performance and reliability of CSP systems and reduced both the capital installed costs (\$/kW) and energy costs (\$/kWh) of CSP systems to one-fifth the cost of early systems. Capital cost for CSP trough plant was reduced from \$4,300/kWe for the 14 MWe SEGS I system, to less than \$3,000/kWe for the 80 MWe SEGS VIII and IX systems. Estimated projected capital cost for the next-generation 200 MWe trough system is expected to be nearly \$2,000/kWe. This large reduction is expected to be as direct result of lower cost components and increased system efficiency currently being pursued under the US Trough Initiative.

CSP industry has installed parabolic trough power plants with a total generating capacity of 354 MWe. These nine trough plants are generating power for the last fifteen years and have provided dividends to its investors. Successful operation of these electric power plants has resulted in enough power to meet the residential needs of 500,000 people and saving the energy equivalent of 2,3 million barrels of oil annually. In addition, electric power generated from all SEGS plants is capable of replacing nearly 6.5 billion cubic feet of natural gas annually. This is equivalent to the elimination of an estimated 160 tons of NO<sub>x</sub> and nearly 380,000 tons of CO<sub>2</sub> emissions.

<sup>1</sup> ACEE reports and Wisconsin Renewable Energy. (1) Goldberg, et al. 1998. Energy Efficiency and Economic Development in Illinois. American Council for an Energy-Efficient Economy. (2) Nadel, et al. 1997. Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania. American Council for an Energy-Efficient Economy. (3) Geller, et. al. 1992. Energy Efficiency and Job Creation. American Council for an Energy-Efficient Economy. The Economic Impacts of Renewable Energy Use in Wisconsin. Department of Administration. Division of Energy and Intergovernmental Relations. Wisconsin Energy Bureau. April 1994.

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potential sources. This information ranges from published articles by experts on solar energy and employment impacts to forecasts regarding the growth and market share of the CSP industry by experts. We also had discussions with solar developers and discussions with leading solar organizations and solar energy experts.

Data collection efforts focussed on other published studies that linked energy technologies to job creation. The American Council for an Energy-Efficient Economy (ACEE) report<sup>2</sup> (e.g., Energy Efficiency and Economic Development series) has a series of reports that focused on energy efficiency, economic development, and employment. The ACEE studies used the Input-Output model that we have used in our analysis.

SENTECH made contact with the Florida Solar Energy Center (FSEC), the Bureau of Economic Analysis Input/Output Modeling Team, and the University of North Carolina/Interstate Renewable Energy Coalition (IREC).

SENTECH evaluated state energy offices analyses of job creation impact on the penetration of renewable energy. Specifically, past analyses by Wisconsin Energy Bureau and FSEC were examined. The Wisconsin study looked at the economic impacts of renewable energy use and the FSEC study examined job creation based on expansion of the solar market in Florida.

Tom Williams and Hank Price of the National Renewable Energy Laboratory (NREL); Greg Kolb of Sandia National Laboratories (SNL); and Dave Kearney (Kearney & Associates) were contacted. Further detailed research was carried out on studies using the Input/Output Modeling approach and BEA's Regional Multipliers.

### ***Additional sources of research included:***

- Pilkington Solar International's Status Report on Solar Thermal Power Plants (ISBN 3-9804901-0-6), January 1996.
- Sandia National Lab's Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants (SAND99-1290), June 1999.
- DOE Nevada Operations Office's report Nevada Test Site (NTS) Solar Feasibility Study, April 1994.
- Research on utilities employment based on data from the Department of Labor, Bureau of Labor Statistics.
- Recent Improvements and Performance Experience at the Kramer Junction SEGS Plants. Cohen, Kearney, and Cable. [www.kjcsolar.com](http://www.kjcsolar.com).
- Parabolic-Trough Technology Roadmap: A Pathway for Sustained Commercial Development and Deployment of Parabolic-Trough Technology. Price and Kearney. January 1999.
- EPRI/U.S. DOE Renewable Energy (Parabolic Trough) Technology Characterizations. 1997 and 2000.

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<sup>2</sup> (1) Goldberg, et al. 1998. Energy Efficiency and Economic Development in Illinois. American Council for an Energy-Efficient Economy. (2) Nadel, et al. 1997. Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania. American Council for an Energy-Efficient Economy. (3) Geller, et. al. 1992. Energy Efficiency and Job Creation. American Council for an Energy-Efficient Economy.

### 4.0 Input-Output Model Methodology

SENTECH determined that BEA's Input-Output model should be used based on examining past studies that have evaluated energy technologies and job creation potential (e.g., ACEE studies and the Wisconsin study).<sup>3</sup> SENTECH specifically selected to analyze the job creation effects of the SEGS plants located in California. CSP technologies are currently located in California, and future CSP technologies will likely be located in the climatically favorable Southwest Region. SENTECH continued contact with the Bureau of Economic Analysis Input/Output Modeling Team.<sup>4</sup> Further detailed research was done on studies using Input/Output Modeling and BEA's Regional Multipliers. SENTECH received the Input/Output data from BEA and performed analysis of this information including multiple runs of the data. SENTECH prepared graphs and analyzed the output of the model.

Data on employment within the solar sector was difficult to gather. Often companies hold employment information, as business confidential, thus there was limited data available. Also, suppliers and component manufacturers of CSP technologies have had their assets transferred overseas. Again, employment data is not readily available. Due to limited funds and data availability we have not provided a detailed labor analysis for each CSP plant. We are using historical data based on the latest SEGS system.

The Input/Output method is a widely accepted method that has been used by many researchers to determine employment effects of various economic situations. Effective planning for public- and private-sector projects and programs at the State and local levels requires a systematic analysis of the economic impacts of the projects and programs on affected regions. In turn, systematic analysis of economic impacts must account for the inter-industry relationships within regions because these relationships largely determine how regional economies are likely to respond to project and program changes. Thus, regional input-output (I-O) multipliers, which account for inter-industry relationships within regions, are useful tools for regional economic impact analysis.<sup>5</sup>

RIMS II is based on an accounting framework called an I-O table. For each industry, an I-O table shows the distribution of the inputs purchased and the outputs sold. A typical I-O table in RIMS II is derived mainly from two data sources: BEA's national IO table, which shows the input and output structure of nearly 500 U.S. industries, and BEA's

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<sup>3</sup> (A) The Economic Impacts of Renewable Energy Use in Wisconsin. Department of Administration. Division of Energy and Intergovernmental Relations. Wisconsin Energy Bureau. April 1994.

(B) Goldberg, et al. 1998.; Energy Efficiency and Economic Development in Illinois. American Council for an Energy-Efficient Economy.

(C) Nadel, et al. 1997. Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania. American Council for an Energy-Efficient Economy.

(D) Geller, et. al. 1992. Energy Efficiency and Job Creation. American Council for an Energy-Efficient Economy.

<sup>4</sup> Personal Communication with Richard Kane of the Bureau of Economic Analysis.

<sup>5</sup> Regional Multipliers. A User Handbook for the Regional Input-Output Modeling System (RIMS II). U.S. Department of Commerce. Economics and Statistics Administration. Bureau of Economic Analysis. Third Edition. March 1997.

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regional economic accounts, which are used to adjust the national IO table in order to reflect a region's industrial structure and trading patterns.

To effectively use the multipliers for impact analysis, users must provide geographically and industrially detailed information on the initial changes in output, earnings, or employment that are associated with the project or program under study. The multipliers can then be used to estimate the total impact of the project or program on regional output, earnings, or employment.

Efforts were undertaken to establish the equivalency of BEA's RIMS II sectors with the five concentrated solar power activities dealing with plant design and A&E, turbine generator and other subsystems, component manufacturing and R&D, plant construction, and plant O&M. The six digit RIMS II sectors were linked to the standard industrial classification (SIC) 4-digit industries that are capable of providing detailed definition of solar powered turbine-generator set, solar energy collectors, solar heaters, and other categories (Exhibit 2).

**Exhibit 2: Assignment of RIMS II Sectors to Concentrated Solar Power (CSP) Activities**

CSP Activity	RIMS II Classifications		1987 SIC Code	Notes
	6-digit industry	Code		
Plant design, A & E	Engineering, architectural, and surveying services	73.0302	8711, 8712	SIC 8711, engineering services; SIC 8712, architectural services
Turbine generator and other subsystems	Turbines and turbine generator sets	43.0100	3511	SIC 3511 includes solar-powered turbine-generator sets
Manufacturing and advanced R&D of trough components	Heating equipment, except electric and warm-air furnaces	40.0300	3433	SIC 3433 includes solar energy collectors (liquid or gas), and solar heaters
Plant Construction	Other new construction	11.0900	1629	SIC 1629 includes central station, light and power plant construction
Plant operation and maintenance	Electric services (utility)	68.0100	4931	Electric services account for the major part, but less than 95%, of SIC 4931, "Electric and other services combined"

Sources: U.S. Department of Commerce, Bureau of Economic Analysis, *Benchmark Input-Output Accounts of the United States, 1987*, (November 1994), Appendix B. Detailed Standard Industrial Classification (SIC) Code definitions can be searched from <http://www.osha.gov/oshstats/sicser.html>.

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Past studies have used varying methods to show the benefits of solar energy technologies, in some studies these methods have been analytical and quantitative in nature. Other studies have not provided detailed analysis of the job creation potential. The Center for Global Change at the University of Maryland raised the issue that “Employment patterns resulting from conventional energy technologies are dominated by the capital-intensive nature of the industry. When measured in jobs per million dollars of annual expenditure, coal, oil, gas, and nuclear technologies support among the fewest jobs of any economic activity.” For example, in Exhibit 3 the solar water heating manufacturing industry created nearly 10 jobs per million dollars of annual expenditure, while electric utilities had less than 5 jobs.

**Exhibit 3. U.S. Direct Jobs Per Million Dollars of Annual Expenditure, 1990<sup>6</sup>**

Industry	Jobs per \$ Million of Annual Expenditure
Construction	13.30
Solar Water Heater Manufacturer	9.90
Manufacturing	8.65
Electric Utilities	4.73
Coal Mining	4.38
Natural Gas Utilities	2.64
Oil and Gas Exploration	1.51

*Measuring CSP jobs per million dollars of annual expenditure* required coming up with total cost of SEGS VIII and IX plants installed in California during 1990. Pilkington Solar International’s Status Report on Solar Thermal Power Plants (Table 4-1 on page 37 of Pilkington report) provided figures of \$2,890/kW and \$3,440/kW respectively for the SEGS VIII and IX plants. These cost per kilowatt numbers yielded overall cost of \$231.2 million and \$275.2 millions respectively. These cost figures from the last two SEGS plants provided an average total cost of \$253.2 million in 1990\$ for an 80 MWe CSP trough plant. Using this average cost of \$253.2 million and using total resulting jobs of 1,800, **yielded 7.11 jobs per million dollars expenditure for CSP SEGS type trough plant**. Comparing this number with the similar information contained in Exhibit 3 table clearly indicate that **CSP jobs at 7.11 for each million dollars are more than jobs created per million by electric utilities (4.73), by coal mining (4.38), by natural-gas utilities (2.64), and by oil & gas exploration (1.51).**

### 5.0 Results from BEA Input/Output Model for CSP

There have been many previous studies that address job creation potential. SENTECH’s study purpose was to create a well-documented estimate of employee impacts from concentrated solar power (CSP) projects. This section provides the results of our analyses using the Input-Output models based on California data for the last “Two” SEGS type plants of the same approximate size of the SEGS VIII and IX plants (each 80 MW system with 486,000 meters squared of solar field size).

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<sup>6</sup> Frank Muller and Skip Laitner at the Center for Global Change, University of Maryland published a paper titled “Jobs Benefits of Expanding Investment in Solar Energy” in Solar Industry Journal, 4<sup>th</sup> Quarter 1992.

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*SENTECH analyzed direct, indirect, and total job creation potential.* Indirect jobs can be defined as the growth of jobs in the community as a result of economic growth. Direct jobs include:

- Manufacturing solar component and advanced component R&D
- Design and construction of the power plant
- Supply of spare and replacement parts for the power plant
- Long-term operation and maintenance of the plant

The following sectors are involved in the direct labor pool:

- Design professionals
- Skilled trades (such as licensed contractors with electrical, plumbing and construction skills)
- Engineers
- Lower-skilled labor – assembling and manufacturing

Direct job information relevant to 80 MWe SEGS trough system design, manufacturing and construction was scattered. The data for O&M was the most abundant based on several recent studies of the technologies.

- Pilkington Solar International's Status Report on Solar Thermal Power Plants (ISBN 3-9804901-0-6), Sandia's Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants (SAND99-1290), and Nevada Test Site (NTS) Solar Feasibility Study dated April 1994.
- Recent Improvements and Performance Experience at the Kramer Junction SEGS Plants. Cohen, Kearney, and Cable. [www.kjcsolar.com](http://www.kjcsolar.com).

The solar industry offers jobs for construction labor, skilled trades, and engineering and design professionals. The skilled trades include licensed contractors with electrical, plumbing and construction skills. Engineers and designers also play an important role in the solar energy industry. At the peak installation of SEGS trough plants in 1990, Luz had 1,800 workers involved in the plant design, manufacturing and R&D, construction, A&E, balance of plant and other subsystems, and installation. Of these 1,400 were in California and the remaining 400 were in component manufacturing facilities overseas. This peak employment period coincided with the installation and operation of the last 80 MWe SEGS trough plant in 1990. These 1,400 people were employed in management, balance of systems, boiler manufacturing, and architecture and engineering activities.

**5.1 Component Manufacturing.** Component manufacturing of SEGS trough type CSP technology was mostly in Luz facilities in Israel for evacuated tube receivers and in Flabsol/Flabeg of Germany for concentrating glass mirrors. Future incentives to buy products from the U.S. and locate factories in the U.S. can result in higher employment numbers. Based on figures contained in past Luz presentations, indications are that 400 employees were involved in manufacturing and R&D activities. Using total direct-impact employment multiplier of 2.28 for manufacturing activities from RIMS II I/O model would yield 912 total jobs.

**5.2 Plant Design and A&E.** An 80 MWe SEGS type trough plant design, detailed systems drawings, and architecture and engineering (A&E) activities employed nearly 100 employees by Luz company in 1990-91 (*source: conversation with Dave Kearney {a former Luz executive} in March 2001*). Future plant design activities may benefit from the latest computerized design techniques and other advancements that will require fewer employees for the plant design than the last SEGS 80 MWe plant. Using total direct-impact employment multiplier of 2.25 from RIMS I/O model would yield 225 total jobs associated with the plant design and A&E activities.

**5.3 Turbine Generator, Power Block, and other subsystems.** An 80 MWe SEGS parabolic trough plant also requires subsystems and systems associated with power block, heat exchangers and heat recovery systems. Screening of past Luz/SEGS reports and a recent discussion with Dave Kearney confirmed that there were almost 800 direct jobs associated with turbine generator, power block and other subsystems. Using total direct-impact employment multiplier of 2.89 from RIM I/O model would yield 2,312 total jobs associated with turbine generator, power block, and other subsystems.

**5.4 Plant Construction.** There were extensive plans and schedules for construction (e.g., in SEGS VIII Technical Description on page II-38, March 1989). SENTECH was not able to get a copy of the detailed numbers for construction forces because LUZ went out of business and the information is business confidential. The maximum work force peaked at 500 persons during the last 80 MWe SEGS plant construction days (*sources: Luz presentations at Solar90 Conference by Mike Lotker in March 1990 and Pilkington Solar International's Status Report on Solar Thermal Power Plants {ISBN 3-9804901-0-6} dated January 1996*). We must realize that construction is a temporary effort and the job potential numbers are based on full time jobs being created. Using the Input-Output model we find that the job creation potential based on 500 temporary construction jobs would generate 1,275 total jobs in the local economy.

**5.5 Operations and Maintenance.** SEGS (III-VII) trough plants, currently being operated by Kramer Junction Company (KJC), have achieved nearly 40% reduction in O&M costs as a direct result of a 50/50 cost-shared program with DOE's CSP Program. It shows that O&M costs declined from \$0.055/kWh to \$0.03/kWh, while net production increased almost one-third. KJC is expecting cost-savings of \$42 million over the next 20 years based on this O&M cost reduction effort completed in 1996.

We have analyzed Pilkington Solar's Status Report on Solar Thermal Power Plants and Sandia Report gives specific staffing levels for operation and maintenance of a 80 MW system with a 500,000 square meter solar field.<sup>7</sup> Exhibit 4 provides a detailed O&M staff requirements for an 80 MWe system (*source: Pilkington Solar International's Status Report on Solar Thermal Power Plants (ISBN 3-9804901-0-6) January 1996*).

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<sup>7</sup> Pilkington Solar's Status Report on Solar Thermal Power Plants and Sandia Report SAND9901290 Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants.

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*Exhibit 4. O&M Staffing in Developed Countries (U.S. or Europe) solar field of 500,000 square meters<sup>8</sup>*

Staff	Nominal #	Reduced #	Level	Direct Rate \$K/yr	35% Burdened	Annual \$K Nominal	Annual \$K Reduced
Solar Field Manager	1	0	Senior	50	67.5	67.5	0
Maintenance Supervisor	1	1	Skilled	45	60.8	60.8	60.8
Welder (2 shifts)	1	1	Skilled	40	54.0	108.0	54.0
Mech Tech (4 10 <sup>th</sup> days)	2	1	Experienced	35	47.3	189.0	47.3
I&E Tech (4 10 <sup>th</sup> days)	1	1	Skilled	40	54.0	108.0	54.0
Lead Mirror Wash Supervisor	1	1	Skilled	45	60.8	60.8	60.8
Equip Operators 1 shift	4	2	Experienced	35	47.3	189.0	94.5
Field Operator (status)	5	3	Experienced	30	40.5	202.5	121.5
<b>Total</b>	<b>20</b>	<b>13</b>				<b>985.5</b>	<b>492.8</b>

Based on the nominal staff of 20 employees for the above 500,000 facility (which is roughly equivalent to the SEGS VIII facility of 464,340 meters squared. The total number of jobs created based on a nominal staff of 20 would be 113. Exhibit 5 provides a summary of direct, indirect, and total job creation potential.

**Exhibit 5. Estimates of Total Employment for the 80 MWe CSP SEGS Type Trough Plant, Using Multipliers from BEA's RIMS II Model for California, 1992 Industry Structure, 1997 Regional Data.**

CSP Activity	Direct Employment (Jobs)*	Total Direct-Impact Employment Multiplier	Total (Jobs)
Plant design, A&E	100	2.25	225
Turbine generator, power block and other subsystems	800	2.89	2,312
Manufacturing and advanced R&D of trough components	400	2.28	912
Plant construction	500	2.55	1,275
<b>Subtotal Employment (Jobs)</b>	<b>1,800</b>		<b>4,724</b>
Plant operation and maintenance	20	5.66	113
<b>Total Employment</b>	<b>1,820</b>		<b>4,837</b>

\* Sources: Luz SEGS 1990-91 reports by Dave Kearney and Mike Lotker; Nevada Test Site Solar Feasibility Study, April 1994; and phone conversation with Dave Kearney in March 2001.

<sup>8</sup> Cohen, Kearney, and Kolb. Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants. SAND99-1290. June 1999.

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**5.6 International.** There have been many successes with CSP technology internationally. For example, The World Bank/GEF has made a financial commitment-in-principle in 1999 of \$200 million to support CSP projects in Egypt, India, Mexico, and Morocco. It is beyond the scope of this project and beyond that data collected to provide detailed analysis of job growth potential.

Cohen, Kearney, and Kolb state that in developing countries salaries and productivity are lower. Also, staff is usually larger in developing countries than developed staff. The salaries are based on a 30 percent reduction from the developing country example, whether or not these are valid numbers remains to be seen.

The Input-Output analysis could be used to predict international job growth potential. The data we have collected is based on the California economic situation and would not provide valid data to input to our current model. Specific information would need to be collected on the economic status of the country and area that are to be analyzed. In general, we can conclude based on the Cohen, Kearney, and Kolb paper that staffing levels are higher for CSP projects in developing countries (see Exhibit 6). Also, it is apparent that salaries are much lower in these countries. The effect of lower salaries and the current economic situation in specific countries makes it difficult to provide an accurate analysis of indirect job impacts.

**Exhibit 6. O & M Staffing in Developing Countries for solar field of 500,000 sq m<sup>9</sup>**

Staff	Nominal #	Reduced #	Level	Burdened Rate \$K/yr	Annual \$K Nominal	Annual \$K Reduced
Solar Field Manager	1	1	Senior	20.3	20.3	20.3
Maintenance Supervisor	1	1	Skilled	18.2	18.2	18.2
Welder (2 shifts)	2	1	Skilled	16.2	64.8	16.2
Mech Tech (4 10 <sup>th</sup> days)	4	2	Experienced	14.2	113.4	28.4
I&E Tech (4 10 <sup>th</sup> days)	2	1	Skilled	16.2	64.8	16.2
I&E Tech (4 10 <sup>th</sup> days)	4	2	Unskilled	8.5	68	17.0
Lead Mirror Wash Supervisor	1	1	Skilled	18.2	18.2	0.0
Equip Operators 1 shift	6	2	Experienced	14.2	85.1	42.5
Field Operator (status)	10	3	Experienced	12.2	121.5	60.8
<b>Total</b>	<b>31</b>	<b>16</b>			<b>574.3</b>	<b>219.5</b>

<sup>9</sup> Cohen, Kearney, and Kolb. Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants. SAND99-1290. June 1999.

### 6.0 Conclusions

Several key results emerged from this analytical study:

- **1,800 direct jobs were associated during the last SEGS plant design and construction in 1990-91 in California.** Out of these 1,800 total direct jobs, 400 jobs were dedicated to the manufacturing and advanced R&D of trough components overseas. Nearly 500 jobs were associated during construction of the last 80 MWe SEGS trough plant. Almost 100 jobs were linked with the plant design, detailed systems drawings, and architecture & engineering (A&E) activities. Remaining 800 jobs were associated with procurement of turbine generator, system power block, and balance of system and other subsystems associated with the last SEGS trough plant in California.
- **20 person O&M staff is needed to operate an 80 MWe SEGS trough plant. This staff requirement can be reduced to 13 employees without creating any impact on plant performance (Sandia's SEGS O&M cost reduction study SAND99-1290).** On the other hand a similar 80 MWe SEGS type plant, if constructed and operated in a developing country, will require regular staff of 31 and reduced staff of 16 for O&M (source: Pilkington Solar International's Status Report on Solar Thermal Power Plants {ISBN 3-9804901-0-6} January 1996).
- **Overall results, using BEA's input/output model's RIMS II job multiplier tables relevant to California, indicate that the average total employment (including both direct and indirect jobs) of 2.66 will be generated for each direct job. In addition, Exhibit 5 shows that an 80 MWe SEGS type parabolic trough plant design and construction will yield 4,724 total jobs for 1,800 direct jobs. The total jobs figure will increase 4,837 when 20 direct jobs for plant O&M are added to the original figure of 1,800 direct jobs.** The total direct-effect employment multiplier for plant O&M emerged as the highest at 5.66 among plant design, trough component manufacturing and R&D, manufacturing of turbine generators and other subsystems, plant construction, and plant O&M categories. **Also note that the plant O&M jobs are "permanent jobs" for the duration of the plant's useful life.**
- **Measuring jobs per million dollars of annual expenditure yielded 7.11 jobs per million for the CSP SEGS type trough system (used an average total cost of \$253.2 million in 1990\$ for the last 80 MWe SEGS trough plant and resulted generation of 1,800 direct jobs).** Comparing this number with the similar information from the Center for Global Change at the University of Maryland clearly indicate that **CSP jobs at 7.11 for each million dollars are more than total jobs created per million dollars by electric utilities (4.73), by coal mining (4.38), by natural-gas utilities (2.64), and by oil & gas exploration (1.51).**

In summary, this analysis quantifies direct, indirect and total jobs associated with the construction of an 80 MWe CSP trough type plant in California. This analysis also measured total number of jobs associated with each million dollars spent during the construction of an 80 MWe CSP system in California during 1990-91.

### Appendix 1: Sources

- Pilkington Solar International's Status Report on Solar Thermal Power Plants (ISBN 3-9804901-0-6), January 1996.
- Sandia National Lab's Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants (SAND99-1290), June 1999.
- DOE Nevada Operations Office's report Nevada Test Site (NTS) Solar Feasibility Study, April 1994.
- Jobs Benefits of Expanding Investment in Solar Energy. The Center for Global Change at the University of Maryland. Frank Muller, et. al. Solar Industry Journal. Fourth Quarter 1992.
- Trends in Renewable Energies (Results of EU-wide Study). Issue #153. Week of October 23-27, 2000. Canadian Association for Renewable Energies.
- Research on utilities employment based on data from the Department of Labor, Bureau of Labor Statistics.
- Recent Improvements and Performance Experience at the Kramer Junction SEGS Plants. Cohen, Kearney, and Cable. [www.kjcsolar.com](http://www.kjcsolar.com).
- Parabolic-Trough Technology Roadmap: A Pathway for Sustained Commercial Development and Deployment of Parabolic-Trough Technology. Price and Kearney. January 1999.
- EPRI/U.S. DOE Renewable Energy (Parabolic Trough) Technology Characterizations. 1997 and 2000.
- The Economic Impacts of Renewable Energy Use in Wisconsin. Department of Administration. Division of Energy and Intergovernmental Relations. Wisconsin Energy Bureau. April 1994.
- Solar Energy and Energy Efficiency Jobs for Florida. FSEC-RR-32-93. David Block. Florida Solar Energy Center. February 1993.
- The Jobs Connection. Emerging Energy Technologies are Creating Thousands of New Jobs and Boosting Local Economies. Bruce Green. NREL in Review. Winter 1994-1995.

### Appendix 2: Potential Sources

- SIC codes approved by Occupational Safety and Health Administration 3433 Solar energy collectors, liquid or gas; 1711 – Solar heating apparatus – contractors; 3674 Solar cells, 5074 Solar heating panels and equipment wholesale
- Bureau of Labor Statistics
- Department of Commerce (DOC) Bureau of Economic Analysis (BEA) – The Regional Input-Output Modeling System gives indirect job analysis
- National Renewable Energy Laboratory (NREL)
- American Solar Energy Society (ASES)
- International Solar Energy Society (ISES)
- Interstate Renewable Energy Council (IREC)
- Solstice, crest
- Energy Information Administration (EIA)
- International Energy Agency (IEA)
- Renewable Energy Policy Project
- Sandia National Laboratory – National Solar Thermal Test Facility
- U.S. Environmental Protection Agency (EPA)
- California Energy Commission (CEC)
- Florida Solar Energy Center (FSEC)

### Appendix 3: Industry Aggregation for RIMS II Multipliers

#### Farm and agricultural services, forestry, and fishing:

- 1 Farm products and agricultural, forestry, and fishing services
- 2 Forestry and fishing products

#### Mining:

- 3 Coal mining
- 4 Oil and gas extraction
- 5 Metal mining and nonmetallic minerals, except fuels

#### Construction:

- 6 Construction

#### Manufacturing:

- 7 Food and kindred products and tobacco products
- 8 Textile mill products
- 9 Apparel and other textile products
- 10 Paper and allied products
- 11 Printing and publishing
- 12 Chemicals and allied products and petroleum and coal products
- 13 Rubber and miscellaneous plastic products and leather and leather products
- 14 Lumber and wood products and furniture and fixtures
- 15 Stone, clay, and glass products
- 16 Primary metal industries
- 17 Fabricated metal products
- 18 Industrial machinery and equipment
- 19 Electronic and other electric equipment
- 20 Motor vehicles and equipment
- 21 Other transportation equipment
- 22 Instruments and related products
- 23 Miscellaneous manufacturing industries

#### Transportation and public utilities:

- 24 Transportation
- 25 Communications
- 26 Electric, gas, and sanitary services

#### Wholesale and retail trade:

- 27 Wholesale trade
- 28 Retail trade

#### Finance, insurance, and real estate:

- 29 Depository and non-depository institutions and security and commodity brokers
- 30 Insurance
- 31 Real estate

#### Services:

- 32 Hotels/other lodging places, amusement & recreation services, & motion pictures
- 33 Personal services
- 34 Business services
- 35 Eating and drinking places
- 36 Health services

#### Households:

- 37 Households

### Appendix 4: Summary of Past Solar/Renewable Studies

A recent European Union (EU) study evaluated the additional economic benefits from renewable energy use with specific regards to the potential for employee creation and the development of a strong export industry. The study, which was carried out in 1998 and 1999, purposed was to evaluate and quantify the employment and economic benefits of renewable energy in the EU. The analysis addressed both direct and indirect jobs. The study also looked at jobs displaced in conventional (e.g., fossil or nuclear) energy plants as well as, jobs lost because of subsidies provided to renewables that could otherwise fund employment in other sectors of the economy. The analysis used the RIOT model or the Renewables Enhanced Input-Output Tables.

Key findings of the study include:

- The modeling prediction estimate that this increase in energy provided from renewable sources can result in the creation of over 900,000 new jobs by 2020. 385,000 jobs are predicted to be created by 2020 from provision of renewable energy, and a further 515,000 jobs from biomass fuel production. This increase takes account of the direct and indirect subsidy effects on employment, and jobs displaced in conventional energy technologies.
- Renewable energy technologies are in general more labor intensive than conventional energy technologies, in delivering the same amount of energy output.
- Jobs displaced as a result of subsidies to support renewable energy deployment are significantly less than corresponding gains (both direct and indirect impacts) elsewhere in the economy.
- Job gains are the greatest in the agriculture and manufacturing industrial sectors. The conventional energy supply industry is predicted to lose less than 2% of its work force by 2020 as a consequence of the shift to a greater use of energy from renewable sources.
- All technologies generate a net increase in jobs during the construction phase. For some technologies however there are net employment losses during the operational phase.

Above listed results from the EU-wide study were also reported in the Trends in Renewable Energy newsletter (issue# 153, dated October 23-27, 2000) published by the Canadian Association for Renewable Energies (CARE).<sup>10</sup>

SEIA Solar Fact-sheets have shown that:

- The rapidly, growing, high-tech U.S. solar energy industry creates thousands of jobs for Americans. With over 60% of solar technology sales in exports, the jobs that are created stay in the U.S. and help reduce the trade deficit.

Additional claims regarding renewable technologies and job creation potential have been cited:

- In 1995, over 45,000 jobs were directly or indirectly related to energy efficiency and renewable energy programs.<sup>11</sup>
- The use of solar and renewable energy is expected to double by the year 2010 which would create more than 350,000 net new jobs, as many as employed by the nation's largest automaker.<sup>12</sup>

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<sup>10</sup> Canadian Association for Renewable Energies. Trends in Renewable Energies. Issue #153. Week of October 23-27, 2000.

<sup>11</sup> The UPVG Record. Fall 1996.

<sup>12</sup> Joint 1992 study by the American Gas Association, the Alliance to Save Energy, and SEIA.

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- The solar industries directly employ nearly 20,000 people and support over 150,000 jobs in diverse areas such as glass and steel manufacturing, electrical and plumbing contracting, architecture and system design, battery and electrical equipment.
- 3,800 jobs are created for every \$100 million in solar cell (PV) sales. This translates to 12,160 jobs in 1995 alone.
- Solar thermal power plants create two and one-half times as many skilled, high paying jobs for the communities in which they operate as do conventional power plants that use fossil fuels.

Solar creates high-wage, skilled jobs in the U.S. here are some examples:

- In Wisconsin, a 75 percent increase in renewable energy use would result in more than 62,000 new jobs and \$1.2 billion in new wages.
- In Nevada, the number of jobs created by the Solar Enterprise Zone by the year 2000 could be 10,000.
- In Long Island, New York, using energy conservation and solar energy would create four times more jobs in the local economy than using oil, natural gas, or electricity for energy needs.

The Wisconsin Energy Bureau recently found that the use of renewable energy generates about three times more jobs, earnings, and sales output than the level of imported fossil fuel use and investment. Given a 75% increase in the state's use of renewable energy, the bureau found that the state would realize more than 62,000 new jobs, \$1.2 billion in new wages, and \$4.6 billion in new sales for Wisconsin businesses. The state currently imports 94% of its energy.

A Florida study showed that "aggressive industrial development efforts could, in a 10 year period, increase the value of Florida's solar energy industry from \$93 million per year to \$400 million per year, thereby creating 4200 new jobs."<sup>13</sup> The study also showed that "broad use of energy-efficiency and renewables can create 20,600 to 28,8000 jobs in Florida during the same 10 year period."

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<sup>13</sup> Block, David. Solar Energy and Energy Efficiency: Jobs for Florida. Florida Solar Energy C (FSEC). February 1993.