

Appendix G
Evaluation of O&M Costs – Tower

G. EVALUATION OF O&M COSTS – TOWER

G.1 OPERATION AND MAINTENANCE COSTS

The SunLab O&M estimate is based on the actual costs from SEGS and adjusted accordingly for tower solar field and technology. The reduction in O&M cost is primarily a result of the increase in annual plant capacity factor, as shown in Table G-1. The plant capacity increases directly as a result of the increases in thermal storage. Increasing the size (MWe) and utilization (capacity factor) of the power plant incurs very little increase in O&M expenses (\$/year). This is because the quantity and complexity of the equipment remain constant and staffing remains fairly constant. Our review of conventional fossil power plants show this “economy of scale” in staffing for increases in plant size.

Solar O&M expenses and staff increase with the field size. There are significant cost improvements from increases in solar system efficiency, which reduce the solar field size (see Section E.4.2).

Table G-1 — SunLab CSP Tower Technology O&M Cost Estimate

	Solar One	Solar Two	Solar Tres	Solar 50	Solar 100	Solar 200	Solar 220
Net Power, MWe	10	10	15	50	100	200	220
Plant Capacity Factor, %	N/A	19%	78%	76%	73%	74%	73%
Annual Net Generation, GWh/yr	N/A	16.6	93.3	335	642	1,292	1,406
Thermal Storage, hrs	0	3	16	16	13	13	12.7
Solar Field, m ²	71,100	81,400	231,000	709,000	1,311,000	2,606,000	2,642,000
Number of Heliostats	1,818	1,912	2,432	7,463	8,858	17,608	17,851
Staff	32	33	31	38	47	67	67
Average Annual Cost (with burden)	\$71	\$71	\$62	\$56	\$50	\$42	42
Staff Cost	\$2,272	\$2,343	\$1,922	\$2,128	\$2,350	\$2,814	\$2,814
Annual Material & Services Cost	\$1,000	\$400	\$600	\$900	\$1,200	\$1,900	\$1,900
Total O&M Cost, \$k	\$3,272	\$2,743	\$2,522	\$3,028	\$3,550	\$4,714	\$4,714
Total O&M Cost, \$/kWhe	N/A	\$0.165	\$0.027	\$0.010	\$0.006	\$0.004	\$0.003

G.2 O&M STAFF

The staffing in the SunLab model was reviewed, and it is a reasonable estimate. The staffing compares with SEGS power-generating facilities and the recent O&M Cost Reduction Study performed at Kramer Junction (KJCOC 1999). The staffing for tower technology is shown in Table G-2.

Table G-2 — Staffing for Tower Technology

	SunLab			Sargent & Lundy		
	Solar Tres USA	Solar 100	Solar 200	Solar Tres USA	Solar 100	Solar 200
Administrative	—	—	—	7	7	7
Plant Operations	—	—	—	11	11	11
Power Plant Maintenance	—	—	—	7	7	7
Solar Field Maintenance & Wash Crew	—	—	—	8	21	42
Total	31	47	67	33	46	67

The power block staffing (33 minus 8 for solar field equals 25) is comparable to the industry average for a 120-MWe combined-cycle power plant. The total staffing for a 120-MWe combined-cycle power plant is 25 based on the SOAPP model.

The staffing was determined to be reasonable based on the following evaluation:

- The administrative staff would be the same for the increased plant size.
- The increase in plant size from 50 MWe to 220 MWe will not require additional operations or maintenance staff for operations and maintenance of the power plant. The difference between 50 and 220 MWe does not increase the quantity or complexity of the equipment.
- The increase in the solar field maintenance staff, including mirror wash crew, is required to support the increase in the solar field. For Kramer Junction, approximately 0.03 maintenance staff is required per 1,000 m² of solar field aperture area.

G.3 O&M MATERIAL AND SERVICE COST

G.3.1 Service Contract

The service contracts include typical contracts and costs expected for this type of facility, including control computers, office equipment, waste disposal, road maintenance, and vehicle maintenance, and are shown in Table G-3. The contract for weed control, road maintenance, and vehicle maintenance was scaled up to account for the larger field area.

Table G-3 — Service Contracts

	Solar Tres	Solar 50	Solar 100	Solar 200	Solar 220
Control System Computers	\$24,000	\$24,000	\$24,000	\$24,000	\$24,000
Personal Computer/Office Equip.	\$5,000	\$5,000	\$5,000	\$5,000	\$5,000
Nitrogen Supply	\$27,000	\$27,000	\$27,000	\$27,000	\$27,000
Sanitary Service	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000
Waste Disposal	\$34,000	\$34,000	\$34,000	\$34,000	\$34,000
Weed Control	\$55,000	\$70,232	\$107,995	\$174,689	\$176,375
Road maintenance	\$27,000	\$34,478	\$53,016	\$85,756	\$86,584
Vehicle Maintenance	\$2,000	\$2,554	\$3,927	\$6,352	\$6,414
Total	\$180,000	\$203,264	\$260,939	\$362,798	\$365,372

G.3.2 Raw Water and Chemicals

The estimate is based on water usage and chemical costs from SEGS VI/VII as shown below in Table G-4. Water and chemical usage for the power plant thermal is consistent with industry averages for power plants. The additional usage for solar (e.g. mirror wash) is based on the O&M Cost Reduction Study (KJCOC 1999). Raw water cost is based on actual costs reports at SEGS of \$0.00122 per gallon (\$0.32 per m³). The main difference between the SunLab reference case and S&L's case is the cost of raw water. SunLab estimated the cost to be \$0.021 per m³), which is about 15 times less than the S&L estimate.

Table G-4 — Water Usage and Chemical Costs

Raw Water Cost	\$0.32 per m ³
Cooling Water Chemical Cost	\$0.043 per m ³ cooling tower make-up

Demineralizer Chemical Cost	\$0.540 per m ³ Condensate make-up
Cooling Tower Make-up	2.90 m ³ /MWhe
Power Cycle Condensate Make-up	0.17 m ³ /MWhe
Demineralizer Blowdown	10%
Mirror Wash Water Consumption	0.022 m ³ (water)/ m ² (of collector) /year

G.3.3 Parts and Material

Parts and material for the conventional power plant range between 0.3% and 0.4%, depending on the age and type of facility. S&L used 0.35% of the capital cost for parts and materials related to the power block and balance of plant.

Parts and material for the solar field are based on the O&M study (KJCOC 1999) for 500,000 m² and adjusted for the increase in solar size. The estimate is reasonable since it is based on the recent O&M Cost Reduction Study performed at Kramer Junction, incorporates the latest cost information from Kramer Junction, and was adjusted to account for tower technology. Parts and material costs for a solar field are shown in Table G-5.

Table G-5 — Parts and Material Costs for a Solar Field

	Unit Cost (\$)	Replace (%)	\$/m ² -yr
Mirrors	26	0.5%	\$0.130
LOCs	200	0.5%	\$0.010
Hdr. Drives	4,500	0.5%	\$0.093
Miscellaneous	5% of total equipment costs		\$0.01
HTF Pump Seals	1,200	2	\$0.05
Total	—	—	\$0.25

G.3.4 Miscellaneous

Miscellaneous costs include administration costs (such as safety, training, travel, supplies, and telephones) and vehicle fuel and repair (see Table G-6). The cost of \$253,000 per year is reasonable for this size of power plant. S&L projected increases for vehicle and fuel to account for the larger number of vehicles needed to support maintenance of the larger collector fields.

Table G-6 — Miscellaneous Costs

	Solar Tres	Solar 50	Solar 100	Solar 2002	Solar 220
Vehicle Fuel	\$17,000	\$21,708	\$33,380	\$53,995	\$54,516
Vehicle Parts and Supplies	\$28,000	\$35,755	\$54,980	\$88,933	\$89,791
Site Improvements	\$2,000	\$2,000	\$2,000	\$2,000	\$2,000
Safety & Training School	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000
Travel	\$5,000	\$5,000	\$5,000	\$5,000	\$5,000
Office Supplies	\$28,000	\$28,000	\$28,000	\$28,000	\$28,000
Telephones	\$67,000	\$67,000	\$67,000	\$67,000	\$67,000
Rental Equipment	\$34,000	\$34,000	\$34,000	\$34,000	\$34,000
First Aid Equipment	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000
Other Miscellaneous	\$56,000	\$56,000	\$56,000	\$56,000	\$56,000
Total	\$253,000	\$265,463	\$296,360	\$350,927	\$352,307

G.3.5 Capital Equipment

Capital equipment (see Table G-7) covers the equipment required to operate and maintain the facility (including dump truck, operator vehicles, mirror washing equipment, and tractor). The cost of the equipment is based on the recent O&M Cost Reduction Study performed at Kramer Junction (KJCOC 1999) and on Kramer Junction's latest information. The quantity of equipment is scaled-up to account for the increase in the size of the field.

Table G-7 — Capital Equipment

	Cost *	Number	Solar Tres	Solar 50	Solar 100	Solar 2002	Solar 220
			\$/m ²	\$/m ²	\$/m ²	\$/m ²	\$/m ²
Dump Truck	\$30,000	1	\$0.01	\$0.02	\$0.02	\$0.04	\$0.04
SF Operator Vehicle	\$20,000	3	\$0.02	\$0.03	\$0.05	\$0.08	\$0.08
Mirror Wash Rig - Twister	\$100,000	2	\$0.04	\$0.05	\$0.08	\$0.13	\$0.13
Mirror Wash Rig - Deluge	\$30,000	1	\$0.02	\$0.03	\$0.05	\$0.08	\$0.08
Mirror Container Carrier	\$17,000	1	\$0.01	\$0.01	\$0.01	\$0.02	\$0.02
Tractor	\$20,000	1	\$0.01	\$0.01	\$0.02	\$0.03	\$0.03
Total			\$0.12	\$0.15	\$0.23	\$0.37	\$0.38

* Capital equipment cost was calculated based on a 5-year equipment life.

G.3.6 O&M Cost Comparison

The comparison between the SunLab cost estimate and S&L's estimate is shown in Table G-8. The major differences are the following:

- Sargent & Lundy scaled-up the cost of contracts associated with increase in field size (e.g., weed control).
- Sargent & Lundy scaled-up the cost of fuel and maintenance of vehicles to account for the increase in field size.
- Sargent & Lundy assumed that the average burdened rate would not decrease between Solar 100 and Solar 220.
- Raw water cost used by S&L is based on actual costs reports at SEGS of \$0.00122 per gallon (\$0.32 per m³). SunLab estimated the cost to be \$0.021 per m³, which is about 15 times less than the S&L estimate.
- Sargent & Lundy included a contingency of 10%.

Table G-8 — Comparison of O&M Cost Estimates: SunLab vs. S&L

	Current	SunLab Estimates			S&L Estimates		
	1987/1999	2004	2008	2020	2004	2008	2020
Plant Characteristics	Solar One/Two	Solar Tres	Solar 100	Solar 220	Solar Tres	Solar 100	Solar 220
Net Power, MWe	10	15	100	220	15	100	220
Plant Capacity Factor, %	19.0%	78.0%	73.2%	72.9%	78.0%	73.2%	72.9%
Annual Solar-Electric Efficiency	7.6%	13.7%	16.6%	18.1%	13.0%	16.5%	17.3%
Thermal Storage, hrs	3	16	13	13.1	16	13	13.1
Solar Field, m ²	81,400	231,000	1,311,000	2,642,000	233,772	1,354,452	2,771,730
O&M Characteristics							
Number of Staff (FTE)	35	31	47	67	33	46	67
Avg. Burdened Labor Rate, \$/yr	\$71	\$62	\$50	42	\$62	\$50	\$50
Staff Cost, \$/yr	\$2,485	\$1,922	\$2,350	\$2,814	\$2,046	\$2,299	\$3,364
Ann. Material & Services Cost, \$/yr	\$750	\$600	\$1,200	\$1,900	\$686	\$2,065	\$4,277
Total O&M Cost, \$/yr	\$3,235	\$2,522	\$3,550	\$4,714	\$3,041	\$5,127	\$9,132
Total O&M Cost, \$/kWhe	\$0.194	\$0.027	\$0.006	\$0.003	\$0.033	\$0.008	\$0.006

Note: the Solar One/Two values are a blend from both plants to provide a "best available" estimate for a typical salt plant of this size with utility operations.