3. POWER GENERATION MARKET AND DEPLOYMENT FORECAST

The projections for electrical power consumption in the United States and worldwide vary depending on the study, but there will be a significant increase in installed capacity due to increased demand through 2020. Trough and tower solar power plants will compete with technologies that provide bulk power to the electric utility transmission and distribution systems. The following market entry barriers are the most significant to overcome:

- Market expansion of trough and tower technology will require incentives to reach market acceptance (competitive). Incentives include environmental (CO_2 emission credits), favorable tax credits, favorable peak energy tariff, premium consumer pricing, loan guarantees, low interest loans, and grants. Both tower and trough technology currently produce electricity that is more expensive than conventional fossil-fueled technology. Analysis of incentives required to reach market acceptance is not within the scope of the report.
- Significant cost reductions will be required to reach market acceptance (competitive). Cost reductions occur from technical improvements, increase in plant size (scaling), and volume production (learning curves). This report focuses on the potential of cost reductions with the assumption that incentives will occur that will support deployment through market expansion.

3.1 POWER GENERATION MARKET

There are several recent studies that discuss the market for CSP technology (Teagan 2001; World Bank 1999; EERE 2002). A number of international and national project developments for commercial or commercial-entry trough or tower power plants typically in the capacity range of 15 MWe to 100 MWe are being pursued by the industry. These entry opportunities largely arise from activities of the Global Environment Facility,* selected nations and U.S. programs on Renewable Portfolio Standards, or other incentives to encourage renewable energy systems.

A summary of the current market is as follows:

- **Global Environmental Facility.** The Global Environmental Facility (GEF) has identified CSP technology as one of their renewable energy options, and has approved four $50M grants for CSP solar power plants in India, Egypt, Morocco, and Mexico.
- **United States.** The parabolic trough industry (specifically Duke Solar Energy) is aggressively pursuing individual IPP projects opportunities in Nevada, California, Arizona, and Oregon as

* The Global Environment Facility (GEF) helps developing countries fund projects and programs that protect the global environment. Established in 1991, GEF is the designated financial mechanism for international agreements on biodiversity, climate change, and persistent organic pollutants. GEF also supports projects that combat desertification and protect international waters and the ozone layer. GEF funding comes via the World Bank and UNDP.

large as 80-MWe steam Rankine cycle projects to as small as 1-MWe organic Rankine cycle systems. From a more general perspective, Congress asked DOE with the fiscal year 2002 funding authorization to "develop and 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 United States by 2006" (EERE 2002). DOE, the CSP industry, and SunLab have collaborated on the development of a report to Congress on the implementation of a plan to achieve this goal. In early 2002, the Western Governors' Association expressed its high interest in the implementation of 1,000 MW of CSP in the Southwest in a letter directed to Congress.

- **South Africa.** ESKOM, the national utility in South Africa, has been comparing troughs and towers to select a single technology for their first CSP plant in South Africa. In September 2002, their board approved the recommendation to proceed with the central receiver technology only. Their plan is to gather the cost inputs in sufficient detail to take a proposal to their Board of Directors by the end of this year proposing a 100-MW central receiver station with molten salt thermal storage to be sited somewhere in the northwest part of the country, probably in the vicinity of the city of Upingt.
- **Spain.** In August 2002, the Spanish Government approved a modification of Royal Decree 2818 providing substantial incentives for the erection of IPP solar thermal power plants fueled exclusively by solar radiation, i.e., no hybrid operation. This modification of Royal Decree 2818 grants a premium of €0.12 above the market price for electricity generated from solar thermal energy in facilities with a maximum unit power of 50 MW. Four projects have been proposed by industry, as follows: 10-MWe tower project based on European technology; 15-MWe tower project based on U.S. technology; 10-MWe trough prototype based on U.S. technology; two 50-MWe trough projects based on European technology. Work is now proceeding on the commercial financing and development of these projects.
- **Israel.** The Israel Ministry of National Infrastructures, which is also responsible for the energy sector, decided in November 2001 to propose CSP as a strategic ingredient into the Israel electricity market over the next several years, with a minimal power unit of 100 MWe. There is an option to increase the CSP contribution up to 500 MWe at a later stage, after the successful operation of the first unit. The plant is to operate in hybrid mode, 4,400 hr/yr, 50% of which is solar and the rest natural gas. A final decision on the plan is expected in late 2002.

Industry participation is also an indicator of market potential. There are a number of companies actively participating in research and development, marketing, and engineering in support of tower and trough technology. Nexant, Boeing, and Duke Solar are the key participants in the United States. Internationally, the key participants are Solel, Flabeg, Solar Millennium, and Fichtner.

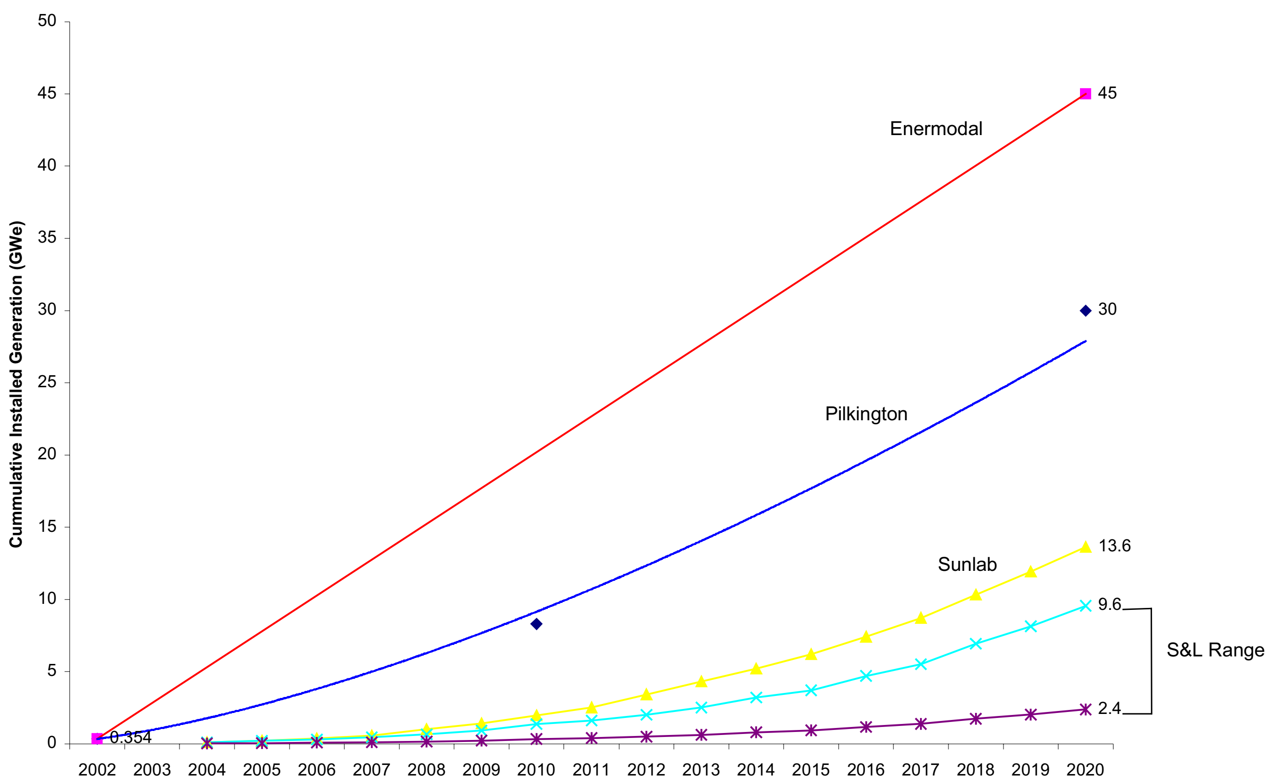
3.2 DEPLOYMENT FORECAST

Cost reductions occur from technical improvements, increase in plant size (scaling), and volume production (learning curves). All three are dependent on deployment (development) of CSP technology. Deployment requires movement through various phases: pilot testing, commercial validation, commercial niche market,

market expansion, and market acceptance (Morse 2000). Deployment provides a means for continued research in technology improvements, cost reductions due to increased production, and economy of scale from constructing larger plants. The cost reduction analysis provided in this report is based on the assumption that trough and tower plants will be constructed. S&L's review is based on a deployment range between 2.4 gigawatts-electrical (GWe) and 9.5 GWe of installed tower and trough solar power plants. The major cost reduction is from the increased size of the plant and increased electrical production. The cost reduction associated with increased volume production between 2.6 GWe and 9.5 GWe (from year 2004 to 2020) is about 10%.

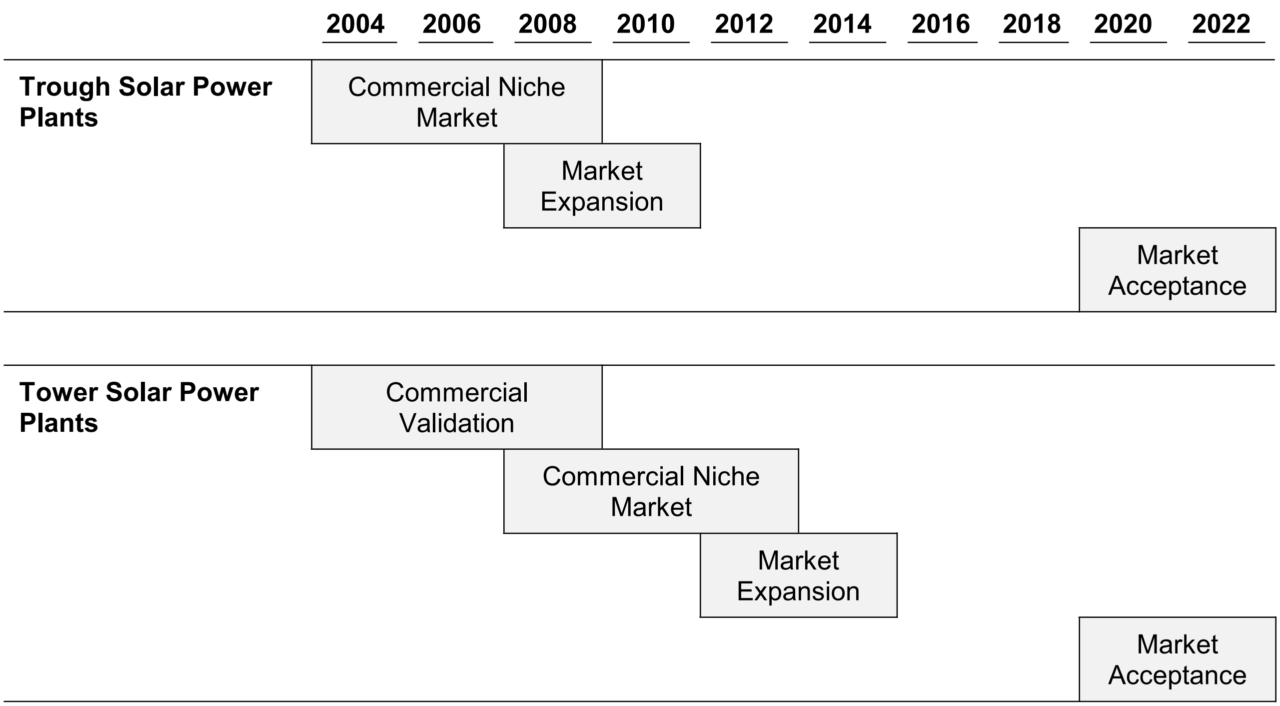
Estimates of tower and trough solar power plants deployment have been identified in several reports (Morse 2000). Comparison of these estimates and the SunLab and S&L estimates are shown in Figure 3-1.

Figure 3-1 — Summary of CSP Worldwide Deployment Forecast



The commercialization path for trough and tower technologies was presented in the Morse report (2000) as occurring in five phases: pilot testing, commercial validation, commercial niche market (entry), market expansion, and market acceptance. The program to move CSP technologies through commercial niche market and market expansion to market acceptance is shown in Figure 3-2:

Figure 3-2 — CSP Path to Market Acceptance



3.3 TROUGH

Sargent & Lundy's review and assessment of the SunLab deployment projections for trough solar power plants is included in Appendix D.2. While the trough technology was commercialized for a brief period, no trough plants have been built in nearly a decade. Trough solar plants are a proven technology, and 354 MW of trough technology generation at the SEGS plants have and are still being operated commercially.

The following Table 3-1 shows a case of two scenarios set forth by SunLab that are representative of how systems would be deployed commercially if a market existed. The first assumes one plant built per year. The second assumes a doubling of cumulative installed capacity with each new technology case introduced. This second case is an aggressive development scenario; however, if the projects were financially competitive, this represents a plausible development scenario. The second case is the type of scale-up that Luz envisioned and actually achieved with the SEGS plants to some degree, building multiple plants in the same year.

Table 3-1 — Trough Deployment Scenarios

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Installed (MWe)	Cumulative (MWe)
Technology Cases		X			X			X					X					X		
Case 1 Deployment Scenario: One Plant per Year Deployment																				
2004 Technology	100 MW	1	1	1															300	650
2007 Technology	100 MW				1	1	1												300	950
2010 Technology	150 MW							1	1	1	1	1							750	1,700
2015 Technology	200 MW												1	1	1	1	1		1,000	2,700
2020 Technology	400 MW																	1	400	3,100
Total																			**2,750**	
Case 2 Deployment Scenario: Cumulative Capacity Doubled with Each New Technology Case																				
2004 Technology	100 MW	1	1	1															300	650
2007 Technology	100 MW				1	2	2	1											600	1,250
2010 Technology	150 MW							1	1	2	2	2							1,200	2,450
2015 Technology	200 MW												1	2	2	3	3	1	2,400	4,850
2020 Technology	400 MW																	1	400	5,250
Total																			**4,900**	

The actual strategy employed by the plant suppliers can be significantly diverse, with more emphasis on near-term cost reduction with a minimum of risk. The suppliers may opt to provide multiple plants in the 50-MWe to 100-MWe size range with no thermal storage but with a supplemental steam generator, replicating the proven technology of the existing SEGS plants. The suppliers can rely more on initial production volume to reduce costs as opposed to efficiency and technology improvements and scale-up factors. Minimizing or eliminating thermal storage, with its current elevated cost, appreciably reduces the total direct cost of the plant as discussed later in this section of the report. The suppliers' strategy will vary depending on the extent of trough plant deployment.

3.4 TOWER

Sargent & Lundy's review and assessment of the SunLab deployment projections for tower solar power plants is included in Appendix E.2. The first step will be deployment of the first commercial power tower facility in Spain (Solar Tres). The Solar Tres design and cost estimate are based on the successful demonstration projects Solar One and Solar Two. "Commercial" is defined as when a power plant is providing electrical power to customers. The next commercial plant will be Solar 50, which is a significant increase in plant size. The net electrical output increases 36.5 MWe (factor of 3.7) and the thermal capacity increases by 260 MWt (factor of 3.2). Solar 50 is the first commercial plant of sufficient size to allow a number of larger plants to be developed. The next commercial steps include Solar 100 and Solar 200. Solar 200, which consists of a net electrical capacity of 200 MWe and thermal capacity of 1,400 MWt (12.7 hours operation at peak output), is about the optimum size monolithic single receiver plant based on physical limitations of technology (specifically, the distance from the heliostat to the receiver). Larger plants are feasible with multiple power towers deployed. The final deployment is Solar 220, which considers an advanced heliostat design and advanced electrical turbine-generator.

Table 3-2 shows two scenarios: projection by SunLab and projection by S&L.

Table 3-2 — Power Tower Deployment Projections, SunLab and S&L

	MWe\ Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Installed (MWe)	Cumulative (MWe)
SunLab – 8.7 GWe																				
Solar Tres	13.5	1																	13.5	14
Solar 50	50			1	2	3													300	314
Solar 100	100					1	2	3	4	4	4	4	2	2	1				2,700	3,014
Solar 200	200									1	1	1	3	3	4	4	5		4,400	7,414
Solar 220	220															1		5	1,320	8,734
		13.5	0	50	100	250	200	300	400	600	600	600	800	800	900	1,020	1,000	1,100	8,734	

	MWe\ Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Installed (MWe)	Cumulative (MWe)
S&L – 2.6 GWe																				
Solar Tres	13.5	1																	13.5	14
Solar 50	50						1		1	1	1								200	214
Solar 100	100										1		1	1	1				400	614
Solar 200	200														1		1	1	600	1,214
Solar 220	220																		0	0
		13.5	0	0	0	0	50	0	50	50	150	0	100	100	300	0	200	200	1,214	