ZCA Assumption – Installation Timeline

Two brief critiques on Stage 1 & 2 timelines, followed by supporting comments and excerpts from references.

Page 57, Section 3.1.6

"Stage 1 (2010-2015): *It is proposed that a target of 8,700 MW is set for installation by 2015, to be distributed across a number of the 12 sites depending on least cost opportunities for prioritising transmission infrastructure. An equal distribution across the 12 sites would end up with 725 MW at each one. This will involve fast tracking of site acquisition, and other planning measures in order to meet these tight timeframes. The plants will include 17 hours of storage — to provide 55 TWh/yr. The Torresol / SolarReserve towers and receivers would be built in module sizes such as 50, 75, 100, 150 and 200 MW. The first-of-a-kind plants will take 2.5 years to construct, as seen with SolarReserve's Rice and Tonopah projects."*

Brief Critique
No construction has begun with Rice & Tonopah. **Both projects are yet to break ground.**

Tonopah / Crescent Dunes - 100MW – (not scheduled to have 17h storage, scheduled for 10h) FOAK Solar 100 in USA. Not fully approved by planning dept yet. Break ground estimated as 2011 & online 2014.

http://solarreserve.com/news/SolarReservePUCNApprovalAnnouncement072810.pdf

RSEP Rice 150MW FOAK for Solar 150 in USA. Still in planning phase / not fully approved yet, planning schedules until at least early 2011, break ground estimated as 2011 & online 2014.

http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=61&

http://www.energy.ca.gov/sitingcases/ricesolar/documents/applicant/afc/Volume_1/RSEP_2.0_Proj_Description.pdf

"Stage 2 (2015-2020) *: During stage 2, a constant rate of around 6,000 - 7,000MW/yr of construction will see the completion of the bulk of the required CST capacity, around 30 Solar 220 units per year, tailing off towards the end of the decade. It is expected that the construction time of a Solar 220 module will drop to 1.5 years, as the industry experience streamlines the rollout. The Andasol projects already completed in Spain took 1.5 years to construct"*

Brief Critique
Incorrect, Andasol's is not fully complete and is also parabolic trough technology. Andasol's are 50MW solar troughs, 7.5 hours storage with 12% fossil fuel (according to NREL - http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=ES). Construction in Spain, not in Australia. Andasol 2 is still being commissioned and Andasol 3 is under construction since Feb 2007 (3.5 years, expected grid connection mid 2011) :

http://www.solarmillennium.de/Press/Press_Releases/Turbine__condenser_and_generator_on_their_way_to_Andasol_3,lang2,50,1860.html.

Supporting Critique against Stage 1 & Stage 2 Assumptions – Sargent & Lundy 2003

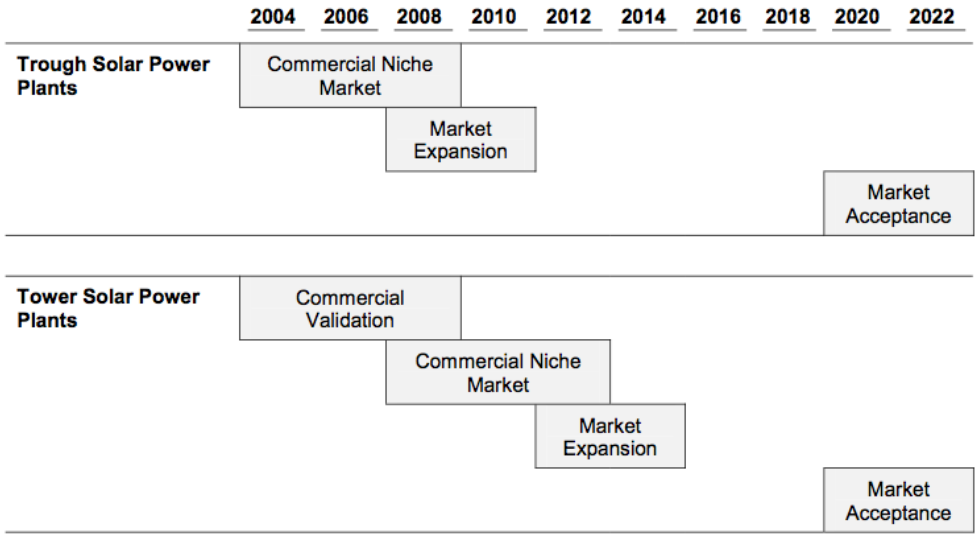
Sargent & Lundy LLC Consulting Group, 2003, 'Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts', pp ES-3, commissioned by US National Renewable Energy Laboratory, http://www.nrel.gov/csp/pdfs/34440.pdf

S&L (2003) Section 3.2 DEPLOYMENT FORECAST (pages 3-2, 3-3,3-4)

"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 S & L (2003) document is referenced and referred to many times by ZCA 2020. However the original deployment timelines compared to the current status of the power tower program do not support ZCA's rollout. **The power tower program is now 7 years behind schedule** as FOAK Solar Tres / Gemasolar 17MW is not expected online until 2011. S & L (2003) Fig 3-2 is reproduced below, Gemasolar is the 1st plant in the commercial validation phase, originally scheduled for 2004.

Figure 3-2 — CSP Path to Market Acceptance



S & L (2003) Section 3.4 TOWER (pages 3-6 & 3-7)

"*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."*

Table 3.2 gives original FOAK power tower deployment estimates (SunLab & S&L) along with number of plants out to 2020. The power tower program is now 7 years behind schedule for Solar Tres / Gemasolar. Note also there is no Solar 150 specified in the timeline by S & L 2003.

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	

The following table compares the S&L (2003) estimates with current planned projects for FOAK solar power tower plants. The timeframes for development roll out and the **7 year delay** in the tower power schedule make it unlikely that Solar 150 will be completed in parallel with Solar 100. It is also unlikely that Solar 220's will be online before 2020.

	Solar Tres / Gemasolar 17MW :	**Solar 50 /** Alcázar	**Solar 100 / Tonopah**	**Solar 150 / RSEP**	**Solar 200**	**Solar 220**
SunLab	2004	2006	2008	None	2012	2018
S & L	2004	2009	2013	None	2017	After 2020
online estimated	2011 Torresol / Kolb, G (2010),	2011 construction, no completion estimate SolarReserve	*2014 Solar Reserve*	*2014 Solar Reserve*		

The following table compares ZCA 2020 & S & L (2003) original cumulative deployment estimates in (MW)

	2015	**2020**	**Cumulative**
SunLab	3914	4820	8734
S & L	314	1214	1528
ZCA 2020	8700 (Stage 1)	33800 (Stage 2)	42500

The original cumulative SunLab estimate to 2020 is 8734MW. The current status of the power tower program is 7 years behind schedule for getting FOAK Solar Tres / Gemasolar 17MW online. For comparison, ZCA Stage 1 is requiring 8700MW by 2015, **from a program already 7 years behind schedule** and just as FOAK Solar 100 would complete its **estimated** first year online.

For reference some sections are quoted directly from S & L (2003) in relation to the original deployment timeline for FOAK plant and the reasons for time between FOAK plants. S&L (2003) are stating that after FOAK Gemasolar goes online, the earliest they'd be prepared to build a 17MW tower in USA is 3 years later. Assuming that Gemasolar goes online early 2011, **that would mean the USA's first 17MW power tower with 15h storage would go online in 2014** according to S & L original deployment timeline:

S&L (2003) Section 5.8.1 DEPLOYMENT page 5-50

"S&L's estimate corresponds to the SunLab Reference Cases with near-term deployment in 2004, mid-term deployment in 2010, and long-term deployment in 2020 for comparison. Sensitivity analysis was done to consider the more realistic deployment of the first commercial plant being placed in service in 2006. The earliest a plant would be operational in the United States is 2009 based on the first commercial plant going in service in 2006 in Spain or South Africa, operational experience of at least one year, and two years for design enhancements, manufacturing, and construction."

5.8.1.1 Near Term (2004)
"The SunLab near-term deployment projection is based on the first commercial plant (Solar Tres) being built in Spain in 2004. Upon successful completion of Solar Tres, a 50-MW plant will be built in 2006."

5.8.1.2 Mid Term (2010)
"The SunLab mid-term deployment projection is five 50-MW plants and six 100-MW plants being deployed in the years 2007 through 2010.

The S&L mid-term deployment projection is one 50-MW plan being deployed in the years 2007 through 2010. The S&L projection is based on Solar Tres being deployed in 2006 and the first 50-MW plant being deployed in 2009. The S&L projection took into consideration additional time between the first plant and subsequent plants of the same size. The first plant of each size will take longer to complete and reach steady-state operation.

Sargent & Lundy projects one 50-MW plant being deployed in 2009 and one 100-MW plant being deployed in the years 2007 through 2010. SunLab projected the first 50-MW plant for 2006, whereas S&L projected it for 2007. SunLab projected the first 100-MW plant for

2008, whereas S&L projected it for 2010. Our estimate takes into consideration the time to identify and incorporate lessons learned into the subsequent plants."

5.8.1.3 Long Term (2020)

"The SunLab long-term deployment projection is twenty-one 100-MW plants with improved technology being deployed in the years 2011 through 2017; twenty-two advanced technology 200-MW plants in the years 2012 through 2019; and six 220-MW advanced technology plants in the years 2018 to 2020. The SunLab total long-term deployment is 8,734 MW installed capacity.

The S&L long-term projection is three 50-MWe plants, four 100-MWe plants, and three 200-MWe plants being deployed in the years 2011 through 2020. The S&L total long-term deployment is 1,214 MW installed capacity."

S & L (2003) E.2 DEPLOYMENT page E-5, E-6

"The deployment projections used by SunLab to develop their cost estimate is based on deployment (commercial operation) of Solar Tres in 2004 with successive initial deployments in 2006 for Solar 50, 2008 for Solar 100, 2012 for Solar 100 and 2018 for Solar 220 (see Table E-3). Deployment is dependent on Solar Tres being successful and on incorporating lessons learned into Solar 50 design. The duration between initial deployments from Solar Tres to Solar 50 and from Solar 50 to Solar 100 in the SunLab model allows only one year of operation. The duration between initial deployments should be at least two years to allow time to resolve operational issues, achieve dependable steady-state operation, and operate for a reasonable amount of time. The S&L deployment projection taking these issues into consideration is shown in Table E-4. S&L's projection is more conservative than the SunLab projection of 8.7 GWe. The S&L projected range is from a maximum deployment of 4.7 GWe to a minimum deployment of 1.2 GWe. The S&L base case is a deployment of 2.6 GWe."

S & L (2003) therefore based their cost estimates on a 2 year gap between deployment of FOAK's from Solar Tres/Gemasolar to Solar 220. Table E.3 & E.4 are reproduced below, as it is easy to see the FOAK plant online estimates in the tables.

Table E-3 — Power Tower Deployment Projection – SunLab

	MWe\ Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Installed (MWe)	Cumulative (MWe)
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
Total		13.5	0	50	100	250	200	300	400	600	600	600	800	800	900	1,020	1,000	1,100	8,734	

Table E-4 — Power Tower Deployment Projection –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)
4.7 GWe																				
Solar Tres	13.5	1																	13.5	14
Solar 50	50				1		1	2	2										300	314
Solar 100	100							1		1	2	2	3	4					1,300	1,614
Solar 200	200											1		1	2	3	3	3	2,600	4,214
Solar 220	220															1		1	440	4,654
Total		13.5	0	0	50	0	50	200	100	100	200	400	300	600	400	820	600	820	4,654	
2.6 GWe																				
Solar Tres	13.5	1																	13.5	14
Solar 50	50				1		1	1	1	2	2								400	414
Solar 100	100							1		1	1	1	2	2	2				1,000	1,414
Solar 200	200												1		1	1	1	2	1,200	2,614
Solar 220	220																			
Total		13.5	0	0	50	0	50	150	50	200	200	100	300	200	300	200	200	400	2,614	
1.2 GW																				
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
Total		0	0	13.5	0	0	50	0	50	50	150	0	100	100	300	0	200	200	1,214	

In addition to the 2003 report another report referenced in ZCA 2020 is Sargent & Lundy, Assessment of Concentrating Solar Power Technology Cost and Performance Forecasts (2005)
http://www.trec-uk.org.uk/reports/sargent_lundy_2005.pdf

"Because no commercial power tower plants have been built, there is more uncertainty in the cost, performance, and technical risk of tower technology than for troughs." (p14)

Estimated deployment times and thermal storage times are different from ZCA 2020 report. A summary of Table 6 : "Technology Development Projection for Tower Technology" from S&L (2005) is given below. **Note : there is a reduction of storage times for Solar 100 and 220 to 13h**. **The ZCA report claims that 17h storage will be available.**

Case	**Baseline**	**Near-Term**	**Mid-Term**	**Long-Term**
Project	**Solar two**	**Solar Tres**	**Solar 100**	**Solar 220**
In service date	**1996**	**2006**	**2008**	**2020**
CF	19%	78%	73%	73%
ThermalStorage hr	3	16	13	13

This reduction in cost effective storage time to 13h is supported in Kolb (2010), in a report from the most recent Solar Technologies Peer Review Meeting. Held on May24-27, Washington DC, this was a meeting with all industry partners and Sandia National Labs, to develop a road map for power tower technology :

Kolb, G (2010), Solar Power Tower R&D, US DOE, EE&RE available at :

http://www1.eere.energy.gov/solar/review_meeting/pdfs/prm2010_snl_kolb.pdf

Page 7 of Kolb (2010) **confirms that Gemasolar is not yet built, and that only 35MW of capacity is installed globally, none with salt storage.**

Page 22 of Kolb (2010) notes that R & D is required to reduce tech risk for **1st commercial power tower projects, as there are none built to date :**

"Expand R&D collaboration with power tower companies to reduce technical risk of 1st commercial projects
– During design phase
– During startup, test, and evaluation phases
• Develop and implement an R&D plan for the labs that address the TIO's identified in the March 2010 Roadmap Meeting
• Perform analysis and test prototype hardware to support development of next-generation power towers"

Conclusion

Solar power tower technology is 7 years behind schedule and FOAK Solar Tres / Gemasolar 17MW is yet to go online after it was first estimated to do so in 2004. The ZCA 2020 roll out time frames are completely inconsistent with S&L (2003), S&L (2005) & Kolb (2010). According to Kolb (2010) the US DOE is currently writing a final draft for *Power Tower Road Map*, due out August 2010.