




Current and Future Costs for Parabolic Trough and Power Tower Systems in the US Market

Preprint

Craig Turchi and Mark Mehos
National Renewable Energy Laboratory

Clifford K. Ho and Gregory J. Kolb
Sandia National Laboratories

Presented at SolarPACES 2010
Perpignan, France
September 21-24, 2010

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Conference Paper
NREL/CP-5500-49303
October 2010

Contract No. DE-AC36-08GO28308

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information

P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/ordermethods.aspx

Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721

Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

CURRENT AND FUTURE COSTS FOR PARABOLIC TROUGH AND POWER TOWER SYSTEMS IN THE US MARKET

Craig Turchi[1], Mark Mehos[1], Clifford K. Ho[2], and Gregory J. Kolb[2]

[1] National Renewable Energy Laboratory, 1617 Cole Blvd, MS 5202, Golden, Colorado, USA,
1-303-384-7565, craig.turchi@nrel.gov

[2] Sandia National Laboratories, Albuquerque, New Mexico, USA

Abstract

NREL's Solar Advisor Model (SAM) is employed to estimate the current and future costs for parabolic trough and molten salt power towers in the US market. Future troughs are assumed to achieve higher field temperatures via the successful deployment of low melting-point, molten-salt heat transfer fluids by 2015-2020. Similarly, it is assumed that molten salt power towers are successfully deployed at 100MW scale over the same time period, increasing to 200MW by 2025. The levelized cost of electricity for both technologies is predicted to drop below 11 cents/kWh (assuming a 10% investment tax credit and other financial inputs outlined in the paper), making the technologies competitive in the marketplace as benchmarked by the California MPR. Both technologies can be deployed with large amounts of thermal energy storage, yielding capacity factors as high as 65% while maintaining an optimum LCOE.

Keywords: parabolic trough, molten salt, power tower, MPR, LCOE

1. 0 Introduction and Background

The Solar Advisor Model (SAM, https://www.nrel.gov/analysis/sam/) is a full-year system analysis model developed to assist solar stakeholders in assessing the performance and cost of photovoltaic (PV) and concentrating solar power (CSP) electricity generation systems. SAM incorporates modules that estimate 8760-hour performance of different PV and CSP systems based on design parameters and climate files that include solar and weather data for the selected location. SAM also includes algorithms to estimate the levelized cost of electricity (LCOE) based on a variety of selectable financial and incentive assumptions.

In 2009 and 2010, updated SAM modules were developed for trough and power tower systems. The improvements include a more thorough modeling of dry-cooling performance, solar field heat losses, and time-of-delivery cost impacts. This report uses estimated current and predicted future cost and performance data for parabolic troughs and molten salt power towers in the new SAM modules to predict the LCOE for these technologies over the next five to fifteen years. Results are compared to the California Market Price Referent (MPR), a tool developed by the California Public Utilities Commission to provide a benchmark market price for generation technologies in the state [1].

2.0 Approach

Despite the construction of trough plants such as Nevada Solar One and Andasol 1, public cost data for trough systems are lacking. In 2009, NREL undertook a detailed cost analysis to update the parabolic trough cost model within SAM. For this task NREL contracted with WorleyParsons Group, Inc. (Golden, Colorado, USA), an experienced multinational engineering firm. NREL provided WorleyParsons with nominal design specifications for the reference plant: 100MW with 6 hours of thermal energy storage in Daggett, CA. Using this guidance, WorleyParsons completed a design and cost assessment of a parabolic trough plant with wet cooling or optional dry cooling. The wet-cooled plant represented the base case for the analysis; a dry-cooled plant with the same nominal capacity was also examined. During this period, at the request of the US Department of Energy (USDOE), NREL formed a Trough Roadmap group consisting of laboratory and industry representatives [10]. The Roadmap is designed to outline the current state-of-the-art and future direction of parabolic trough technology, thereby providing a guide to government research. NREL used WorleyParsons' analysis and feedback from Trough Roadmap members to develop a cost spreadsheet detailing 48 cost items associated with the following general categories: site preparation, solar field, heat transfer fluid system, thermal storage system, and power block [2]. This report provides the baseline 2010 parabolic trough costs discussed here.

The potential of molten salt Power Towers (Central Receivers) to reach higher temperatures and incorporate large amounts of thermal energy storage provides an inherent advantage versus the current parabolic trough technology. Research and demonstration at Solar Two in the 1990s and subsequent R&D has led to proposed molten salt power tower projects in Spain and the US. Recently, researchers at Sandia National Laboratories have worked with the USDOE and industry representatives to draft a Power Tower Roadmap outlining the potential and likely future path of power tower development [3]. Based on this input, current and future cost and performance for power towers have been outlined. In the scenarios provided in this paper, the "current" or baseline power tower case is given as 2015, in contrast to the baseline trough case date of 2010. This difference reflects the difference in maturity of the two technologies.

Costs are presented for total installed cost and LCOE. SAM is used to generate LCOE based on the anticipated performance, capital cost, and operating costs for the technologies. Maintaining a common set of financial assumptions is critical to any LCOE analysis. The inputs listed in Table 1 were applied for all cases examined in this study. Although the US investment tax credit (ITC) is set at 30% through 2016, a 10% value is assumed for consistency in this analysis.

Location	Daggett, CA, USA	US Investment Tax Credit	10%
Analysis Period (years)	30	Federal depreciation	MACRS
Inflation rate	2.5%	Contingency on direct costs	10%
Real Discount Rate	8%	Indirect Costs incl. Sales Tax	24.7%
Composite Income Tax Rate	40.2%	Debt Fraction	54%
Insurance	0.5%	Minimum Return on Equity	14%
Loan term (years)	20	Minimum Debt Service Coverage Ratio	1.4
Loan rate	8%		

Table 1. Common assumptions used in all analyses.

3.0 Results and Discussion

3.1 Parabolic Trough Cost and Performance

2010 Baseline Parabolic Trough
SAM's physical trough model was used to estimate the 2010 and future year costs of the parabolic trough technology. The baseline 2010 plant is a wet-cooled, superheated steam power block that uses synthetic oil HTF (see Table 2). Two cases are shown: a system without storage and one assuming indirect storage into a 2-tank molten salt (sodium nitrate/potassium nitrate solar salt) system. The no-storage case is included because this leads to the lowest LCOE with the present cost of thermal energy storage. Solar field outlet temperature is 391°C. The collectors were 5-m aperture, SolarGenix SGX-1 selected from the SAM library. Conceptually this plant is similar to Andasol 1, albeit at 100MW capacity.

2015 Parabolic Troughs
The near-term, 2015 case looks at two different configurations: (i) the scale up of the conventional oil-HTF trough to 250MW and (ii) a 100MW, molten-salt-HTF trough deployed at a field temperature of 450°C. The two cases share the same solar field and O&M costs, but have different storage costs and power cycle efficiencies. Mirror reflectance is assumed to improve from 93.5% to 95% due to deployment of newer reflective surfaces now in development. Both plants are assumed to be dry cooled.

The transition to larger oil-HTF plants is underway by developers working in the US. Cost of the larger power block is assumed to scale at the 0.7 power [4], which leads to a savings in the cost per kW, as well as O&M costs. At the same time, power block cost will increase if one adopts dry cooling. WorleyParsons [2] concluded that a larger than usual air-cooled condenser reduces the overall cost penalty associated with dry cooling in a solar plant. The resulting air-cooled condenser cost is roughly seven times that of an evaporative cooling tower; however, about a third of this additional cost is recovered by elimination of the blowdown holding/evaporation ponds [2]. The oversized air-cooled condenser is justified because of the relatively high cost of the solar field. That is, it is better to pay for more condenser area than more solar field area to achieve the same overall energy output. It is estimated that dry-cooling increases the cost of the 110MW gross turbine to $1140/kW; when scaled to a dry-cooled 280MW gross case, this cost falls to $875/kW.

The current oil HTF is limited to about 390°C by its thermal stability. A transition to higher solar field temperatures yields key advantages in power cycle and storage efficiency and molten salts are seen as a promising way to achieve these goals [5]. (Cycle efficiency can also be raised via direct steam generation [6].) For this early deployment of salt HTF, solar field temperature is assumed to be 450°C, but the specific HTF salt composition is not defined. For the analysis the physical properties of commercial Hitec® salt (7% $NaNO_3$, 53% KNO_3, 40% $NaNO_2$) are used. The 450°C temperature is selected as a compromise temperature that minimizes stability and corrosion concerns for the salt HTF, minimizes heat loss concerns from the receivers, and provides a substantial boost to power cycle and storage efficiency.

Low-melting salts under development are likely to have costs greater than Hitec® (approx $1.5/kg). For this analysis the cost of the salt is assumed to be similar to that of the current synthetic oil ($4.5/kg) and the 2015 design retains an indirect 2-tank storage system with solar salt due to the high cost of the HTF. A reduction in storage cost results from the larger temperature differential in the storage system (150°C versus 90°C), with its associated decrease in salt inventory and tank volume. HTF system costs are lower due to a significant reduction in piping and insulation, although freeze protection is required.

2020 Parabolic Trough
The 2020 case assumes a molten salt HTF at a field temperature of 500°C, similar to a configuration being tested by Enel at the 5MW Archimede Plant in Sicily. The higher temperature further improves power cycle efficiency and lowers storage cost. Direct storage of the HTF in a thermocline system is assumed. No adjustment in performance is applied, which implicitly assumes improvement in the ability to maintain a sharply stratified thermocline and/or sliding pressure turbine operation with minimal efficiency impacts as has been suggested by Kolb [7]. Advanced collector designs, perhaps employing larger aperture troughs, have reduced solar field cost to $\$190/m^2$. The low cost of storage drives system designs to incorporate more storage. Operating experience and manufacturing volume are also assumed to push O&M and capital costs lower.

Figure 1 plots the LCOE for parabolic troughs as a function of capacity factor. High capacity factor is a valuable attribute for a technology aspiring for extensive grid penetration; at lower levels of deployment high capacity factor is not overly important, as the demand for power-on-peak dominates the economics. Figure 1 is generated by varying the solar multiple and storage hours for the cost and performance assumptions given in Table 2 and selecting the conditions that provide the minimum LCOE. Solar multiple for the cases ranges from 1.0 to 4.4. (Solar multiple is the ratio of solar field thermal energy output to turbine gross thermal energy demand at design point conditions). In Figure 1, plants with capacity factors less than about 30% have no storage. While a solar multiple equal one gives the lowest installed cost, such designs are not optimal from an LCOE perspective, and even plants with no storage are designed with a solar multiple greater than 1.0. In these cases, a solar multiple of about 1.3 is found to minimize LCOE for a plant with no storage (capacity factor = 26% in Figure 1). The ability to oversize the solar field with respect to the power block is a useful feature for trough and tower plants and allows the plants to run at design point over a greater fraction of the year. For a solar multiple > 1 and no storage, excess solar energy has to be dumped by defocusing collectors, whereas if storage is available the energy is diverted into storage. This is one reason plants with storage achieve higher annual solar-to-electric efficiency.

	2010	2010	2015	2015	2020
Design Inputs:					
Turbine MWe (gross/net)	111/100	110/100	280/250	110/100	280/250
HTF	Syn. Oil	Syn. Oil	Syn. Oil	Salt	Salt
Solar Field Temperature (°C)	391	391	391	450	500
Solar Multiple	1.3	2.0	2.0	2.0	2.8
Thermal Storage Hours	0	6	6	6	12
Cost & Performance Inputs:					
System Availability	94%	94%	96%	96%	96%
Turbine efficiency (cooling method)	0.377 (wet)	0.377 (wet)	0.356 (dry)	0.379 (dry)	0.397 (dry)
Collector Reflectance	0.935	0.935	0.95	0.95	0.95
Solar Field ($/m2)	295	295	245	245	190
HTF System ($/m2)	90	90	90	50	50
Thermal Storage ($/kWh-t)	-	80	80	50	25
Power Block ($/kWe - gross)	940	940	875	1140	875
O&M ($/kW-yr)	70	70	60	60	45
Cost & Performance outputs:					
Capacity Factor	26%	41%	43%	43%	60%
Installed Cost ($/W)	4.6	8.0	7.9	6.6	6.5
LCOE (cents/kWh, real)	17.3	17.9	16.5	14.2	9.9

Table 2. Estimated current and future costs for Parabolic Trough Systems. Representative cases at 6 and 12 hours of storage are shown.

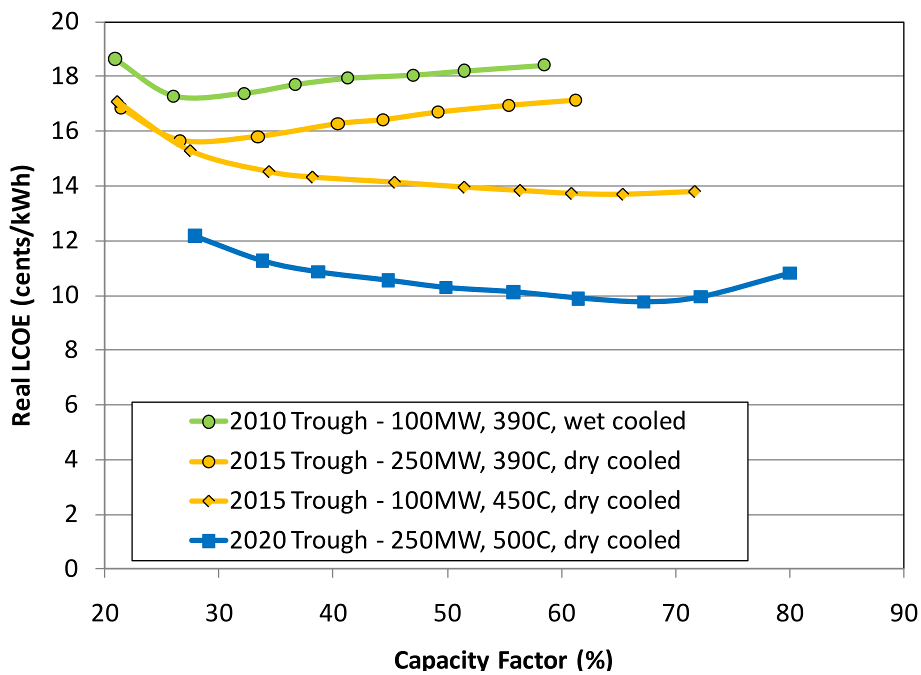

Figure 1. Parabolic Trough LCOE versus Capacity Factor. 2015 highlights the effect of a transition from oil to salt HTF.

For the oil-HTF plants running at 390°C, increasing trough capacity factor by adding storage leads to a uniform increase in LCOE due to the relatively high cost of storage. Transitioning to a salt HTF at 450°C, LCOE falls steadily from 14.2 to 13.7 cents/kWh over the range of capacity factor from 40% to 65%. In the 2020 scenario, more storage leads to higher capacity factor and decreasing LCOE until a capacity factor of around 70%. At this point, further increases in capacity factor require a large enough solar multiple to maintain generation throughout the winter; however, this design forces energy dumping in the summer. One can avoid this pitfall by building the plant with the troughs oriented on an east-west axis rather than the conventional north-south alignment. Such a change allows for a more uniform seasonal generation profile and is the lower LCOE option at very high capacity factors (see Figure 2). In the near term, the strong demand for power during summer peaks will continue to favor north-south orientation.

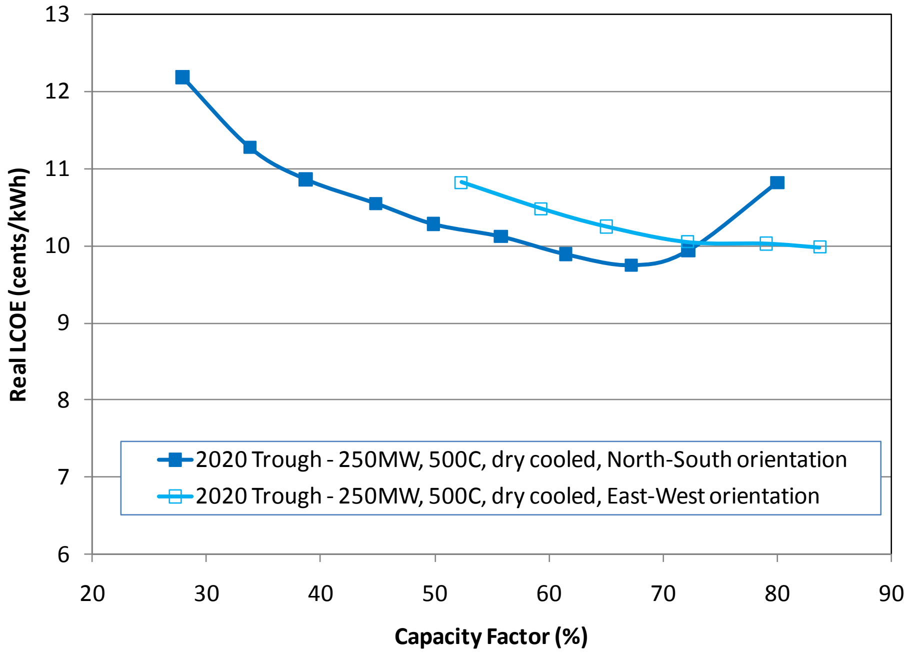

Figure 2. For capacity factors greater than about 72%, troughs with an east-west axis yield the lowest LCOE.

3.2 Power Tower Cost and Performance

2015 Baseline Molten Salt Power Tower

Power tower costs were estimated on the basis of a previous Sandia heliostat cost analysis [8], insight and experience of Sandia researchers, and input from the Power Tower Roadmap members. Where possible, subsystem costs, e.g., steam power block cost, are taken from the parabolic trough cost study [2]. The analysis is limited to molten salt towers. The cases assume large heliostats (148 m^2) consistent with the Sandia study; however, the general conclusions are not dependent on heliostat size.

Table 3 outlines the estimated costs for molten salt power towers from 2015 through 2025. The baseline 2015 case assumes a solar salt HTF with direct 2-tank storage. The power block steam temperature is 565°C. Consistent with the future trough cases, dry cooling is used and mirror reflectance is assumed to achieve 95%. Power block cost is estimated based on values from [2] assuming a 110MW gross capacity, dry-cooled system.

2020 Molten Salt Power Tower

The 2020 case in Table 3 retains the same power block and cycle conditions, but increases storage hours and solar multiple. Storage cost is based on a direct thermocline; however, no adjustment in performance is considered. As with troughs, this implicitly assumes improvement in the ability to maintain a sharply stratified thermocline and/or sliding pressure turbine operation with minimal efficiency impacts. System availability increases and O&M costs decrease due to operating experience. Solar field costs drop as improved heliostat designs are developed and deployed. Manufacturing experience and scale also help lower solar field costs.

Significantly, achievement of the 2020 case is contingent more on deployment and experience than on R&D breakthroughs.

2025 Molten Salt Power Tower

The 2025 tower case assumes 200MW capacity and successful integration of a high temperature, supercritical power cycle. This cycle is assumed to be a supercritical steam Rankine cycle, although supercritical carbon dioxide Brayton cycles are also being investigated. A slight power block cost increase is calculated based on the current ratio of superheated-steam to supercritical-steam power blocks for coal plants [9]. This cost per kW increase is offset by the scaling advantage of doubling in size to 220MW (gross). Using the same 0.7 scaling factor described in the trough section, gross power block cost drops to $975/kW. The supercritical-CO_2 Brayton cycle has the potential for a simpler, lower cost power block, but this technology is far from commercial. Further reductions in solar field costs are anticipated.

	2015	**2020**	**2025**
Design Inputs:			
Turbine MW_e (gross/net)	111/100	111/100	220/200
Solar Field Temperature (°C)	565	565	650
Solar Multiple	1.8	2.6	2.8
Thermal Storage Hours	6	12	12
Cost & Performance Inputs:			
System Availability	91%	94%	96%
Turbine efficiency (dry cooled)	0.416	0.416	0.47
Collector Reflectance	0.95	0.95	0.95
Solar Field ($/m2)	200	143	120
Tower/Receiver ($/kW$_t$)	200	200	170
Thermal Storage ($/kWh$_t$)	30	20	20
Power Block, ($/kW$_e$ - gross)	1140	1140	975
O&M ($/kW-yr)	65	50	50
Cost & Performance outputs:			
Capacity Factor	43%	60%	65%
Installed Cost ($/W)	6.3	7.3	5.9
LCOE (cents/kWh, real)	13.7	10.9	9.4

Table 3. Estimated current and future costs for Molten Salt Power Tower Systems. Representative cases at 6 and 12 hours of storage are shown.

Figure 3 plots the LCOE for power towers as a function of capacity factor in a fashion similar to that shown above for troughs. As indicated in the figure, the LCOE of molten salt power towers always benefits from inclusion of storage. This behavior results from the inherent design of the molten salt power tower – adding storage consists of merely increasing the size and inventory of the salt tanks. Of course, adding storage normally entails an increase in solar multiple too, with the associated increase in total solar field and tower/receiver cost. The overall impact to LCOE is a net decrease as the additional collected solar energy is used to run the same power block for a greater fraction of the year. LCOE decreases with capacity factor until levels of 65% to 70% where seasonal generation differences force the dumping of energy during the summer. Solar multiple in Figure 3 ranges from 1.0 to 3.4. At high solar multiple the 200MW tower starts to run into limitations with respect to tower height, receiver size, and/or heliostat distance. In these studies tower height was restricted to less than 330 m, receiver height to less than 30 m, and heliostats were allowed no further than 2800 m from the tower.

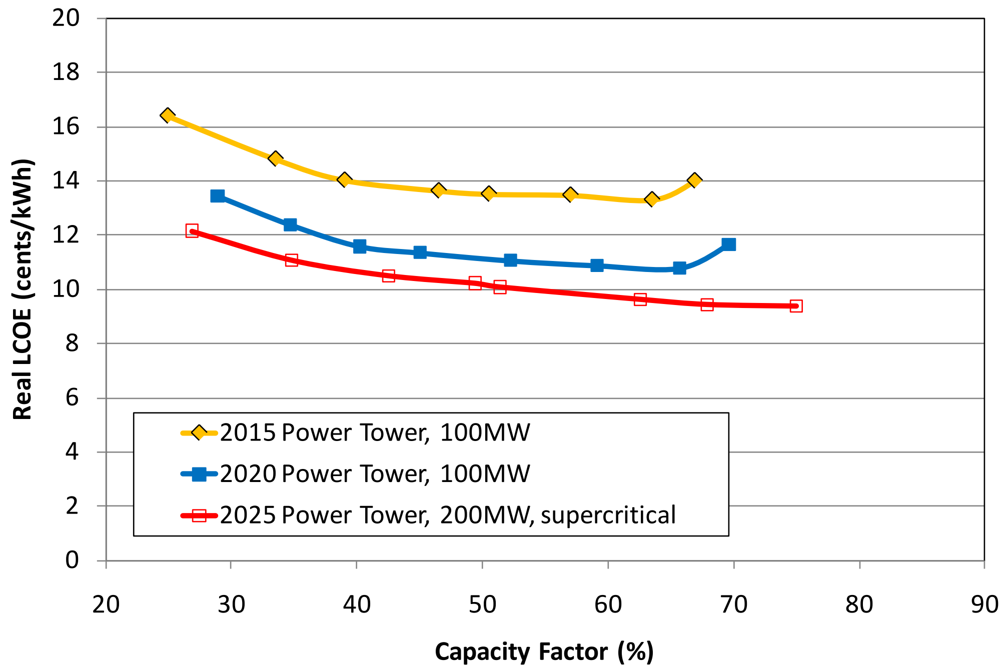

Figure 3. Molten Salt Power Tower LCOE versus Capacity Factor.

3.3 Comparison of Trough and Tower Cases

A comparison of Figures 1 and 3 indicates similar LCOE values for the two technologies over the next ten years. While oil-HTF troughs have an established track record, the assumption of salt-in-the-field brings a higher level of technical risk. For their part, no large power towers have yet been built. Thus both technologies present technical risk to the project developer and financier, albeit in different form. Comparing the 2020 cases, power tower success is contingent more on deployment and experience than on R&D breakthroughs. In contrast, parabolic troughs require successful deployment of salt-in-the-field technology.

Based on these cost projections it is anticipated that both technologies will compete in the US intermediate-load (30%-60% capacity factor) market. This market cost is often represented by the Market Price Referent (MPR), developed and maintained by the California Public Utility Commission [1]. The MPR represents the market price of electricity in California and is used to benchmark the costs of renewable energy projects. The MPR uses as a proxy the long-term ownership, operating, and fixed-price fuel costs for a new 500MW natural-gas-fired combined cycle gas turbine. The baseload proxy is adjusted to account for the value of different generation profiles by applying utility time-of-delivery (TOD) factors. Converting the MPR to a real dollar basis and applying the TOD factors for the anticipated generation profile for Daggett, CA, yields an MPR that ranges from 10-13 cents/kWh over the next ten years. The range reflects the different TOD factors for the major California utilities as well as a slight escalation over time (above inflation). Thus, solar technologies that can achieve an LCOE at or below 10-13 cents/kWh should be competitive with natural gas combined cycle systems. Based on the analysis presented here, both troughs and towers can achieve this target – with predicted 2020 LCOEs at 10 to 11 cents/kWh.

In the longer term, the ability to achieve higher operating temperatures may give tower technologies an efficiency and cost advantage versus parabolic troughs if new thermal cycle technologies can be integrated with the power tower heat source. While utility-scale photovoltaic systems are on a trajectory to achieve lower energy costs, the CSP cases presented here have capacity factors 2-3 times greater than utility-scale PV systems. The advantage thermal energy storage offers for reliability and dispatch flexibility is expected to allow these CSP technologies to maintain a competitive edge with respect to PV systems. While these factors are minor at low penetration, they become essential for renewable energy systems to achieve higher grid penetration.

Acknowledgements

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

References

[1] California Market Price Referent, information and model available at http://www.cpuc.ca.gov/PUC/energy/Renewables/mpr

[2] Turchi, C., "Parabolic Trough Reference Plant for Cost Modeling with the Solar Advisor Model (SAM)," Technical Report, NREL/TP-550-47605, July 2010.

[3] Gary, J.A., Clifford K. Ho, Thomas R. Mancini, Gregory J. Kolb, Nathan P. Siegel, and Brian D. Iverson, "Development of a Power Tower Technology Roadmap For DOE," SolarPACES 2010.

[4] "Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts," Sargent & Lundy LLC Subcontractor Report, NREL/SR-550-34440, October 2003.

[5] Kearney, D. B. Kelly, U. Herrmann, R. Cable, J. Pacheco, R. Mahoney, H. Price, D. Blake, P. Nava, N. Potrovitza, "Engineering aspects of a molten salt heat transfer fluid in a trough solar field," *Energy*, **29**, pp. 861-870 (2004).

[6] Pitz-Paal, R., J. Dersch, B. Milow, F. Téllez, A. Ferriere, U. Langnickel, A. Steinfeld, J. Karni, E. Zarza, and O. Popel, "Development Steps for Parabolic Trough Solar Power Technologies with Maximum Impact on Cost Reduction," *Journal of Solar Energy Engineering*, **129**, November 2007.

[7] Kolb, Gregory J., "Evaluation of Annual Performance of 2-Tank and Thermocline Thermal Storage for Trough Plants," SolarPACES 2010.

[8] G.J. Kolb, et al., "Heliostat Cost Reduction Study," SAND2007-3293, Sandia National Laboratory, Albuquerque, NM, USA, June 2007. http://infoserve.sandia.gov/sand_doc/2007/073293.pdf

[9] Klara, J., "Cost and Performance Baseline for Fossil Energy Plants," DOE/NETL-2007/1281, Volume 1: Bituminous Coal and Natural Gas to Electricity, Revision 1, August 2007.

[10] Kutscher, C., M. Mehos, C. Turchi, G. Glatzmaier, and T. Moss, "Line-Focus Solar Power Plant Cost Reduction Plan," National Renewable Energy Laboratory, Technical Report, Draft April 2010.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
October 2010	Conference Paper	

4. TITLE AND SUBTITLE:
Current and Future Costs for Parabolic Trough and Power Tower Systems in the US Market: Preprint

5a. CONTRACT NUMBER
DE-AC36-08GO28308

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Craig Turchi, Mark Mehos, Clifford K. Ho, and Gregory J. Kolb

5d. PROJECT NUMBER
NREL/CP-5500-49303

5e. TASK NUMBER
SS10.2340

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

8. PERFORMING ORGANIZATION REPORT NUMBER
NREL/CP-5500-49303

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES

14. ABSTRACT *(Maximum 200 Words)*
NREL's Solar Advisor Model (SAM) is employed to estimate the current and future costs for parabolic trough and molten salt power towers in the US market. Future troughs are assumed to achieve higher field temperatures via the successful deployment of low melting-point, molten-salt heat transfer fluids by 2015-2020. Similarly, it is assumed that molten salt power towers are successfully deployed at 100MW scale over the same time period, increasing to 200MW by 2025. The levelized cost of electricity for both technologies is predicted to drop below 11 cents/kWh (assuming a 10% investment tax credit and other financial inputs outlined in the paper), making the technologies competitive in the marketplace as benchmarked by the California MPR. Both technologies can be deployed with large amounts of thermal energy storage, yielding capacity factors as high as 65% while maintaining an optimum LCOE.

15. SUBJECT TERMS
parabolic trough; molten salt; power tower; MPR; LCOE

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			
Unclassified	Unclassified	Unclassified	UL		**19b. TELEPHONE NUMBER** *(Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

F1147-E(10/2008)