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Costs of PV and Concentrating Solar Thermal Generation in California

CEC Workshop: Cost of New Renewable and Fossil-fueled Generation in California

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1 » Introduction

2 » PV System Cost Projections and Assumptions

- Crystalline with Tracking
- Fixed Axis Thin Film

3 » CSP System Cost Projections and Assumptions

- Parabolic Trough with and without storage
- Power Tower with and without storage

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Navigant developed cost estimates for PV and CSP systems in California installations, encompassing four technologies at large scale.

	Installation Size	Technology	
Photovoltaics	20 MW	Crystalline with Tracking	
	100 MW	Fixed Axis Thin Film	
Concentrating Solar Power	250 MW	Parabolic Trough	With Storage
			Without Storage
	100 MW	Power Tower	With Storage
			Without Storage

Font Colors Shown: correspond to trend lines on subsequent slides

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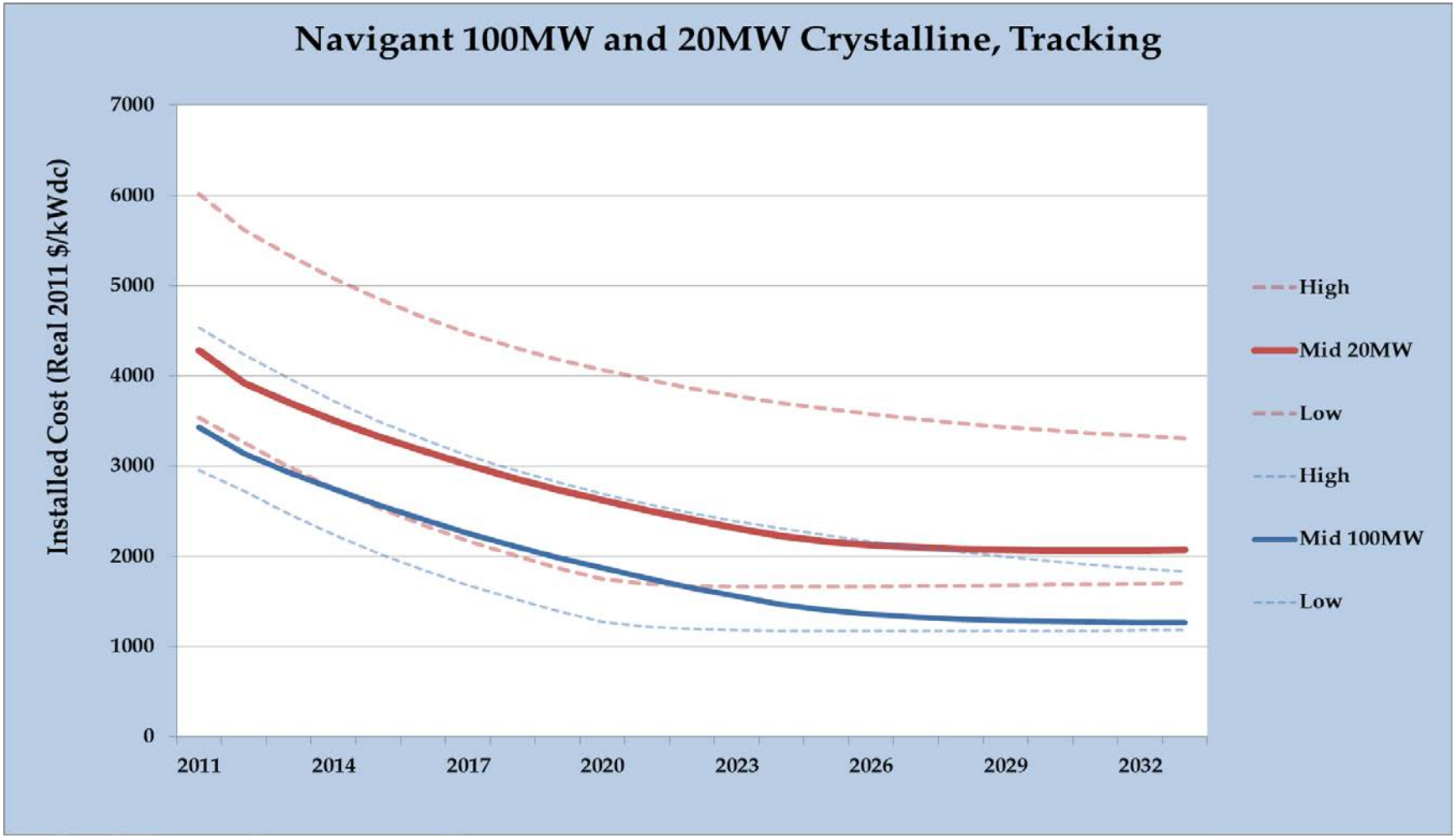
Ground mounted crystalline PV array installed costs with tracking are projected to decline from 3.5 to 1.5 $/Wpdc by 2025.



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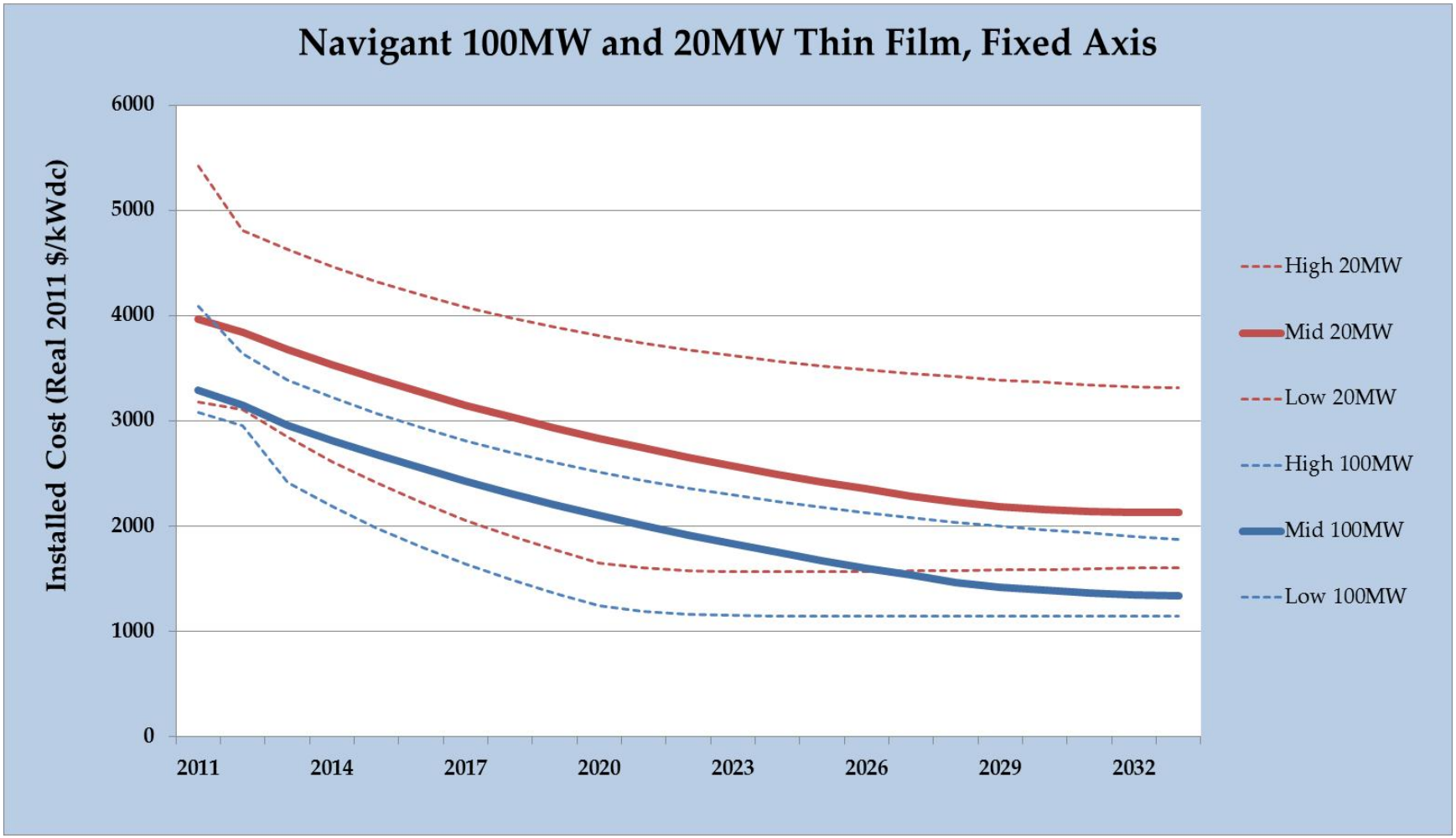
Thin film costs are projected to be slightly lower due to the lack of tracking.



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All PV costs were based on current module and other component prices, with projections based on published literature.

Crystalline Tracking & Thin Film	Key Assumption	Source	Values
Current PV Costs	Component Prices	SEPA price bulletins, 5/2012; Module Manufacturer stock annual and quarterly reports (10Ks/10Qs)	See graph
	Capacity Factor	based on gross capacity and SAM modeling.	Crystalline Tracking- 25.9%, P50 Fixed Thin Film – 20%, P50
	Onsite Transformer and Transmission	Derived from three california IOU escalation factors, netting out inflation	.14 $/Wp
Cost Projections	Low	SunShot Vision Study, DOE 2/2012	See graph
	High	PV System prices, NREL, Goodrich	See graph

Note: see Appendix for all citation details.

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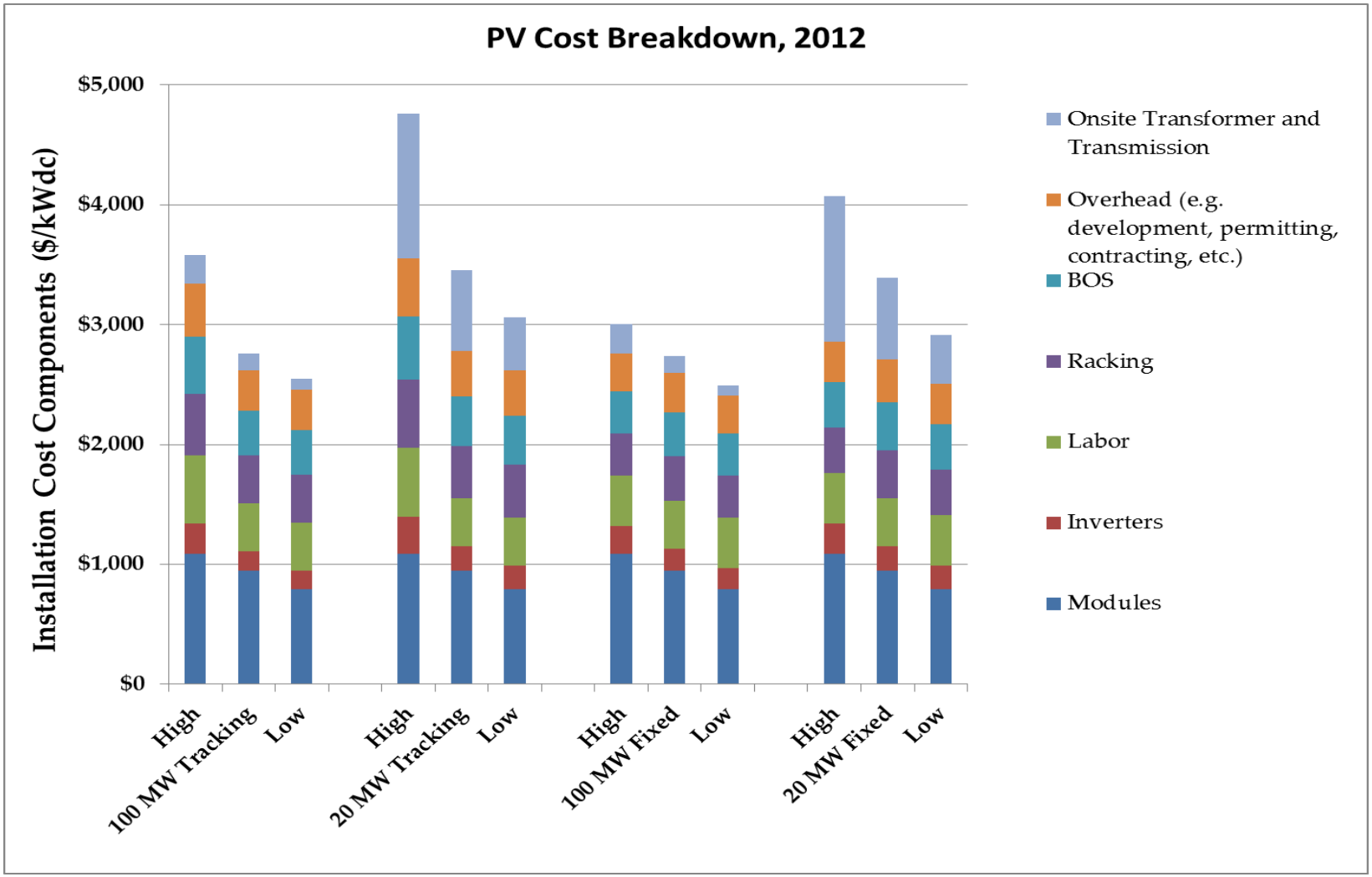
20 MW installations have significantly higher onsite transformer and transmission costs.



Note: the instant costs shown above are slightly lower than the installed cost curves, which also include interest during construction, debt arrangement fees and construction insurance.

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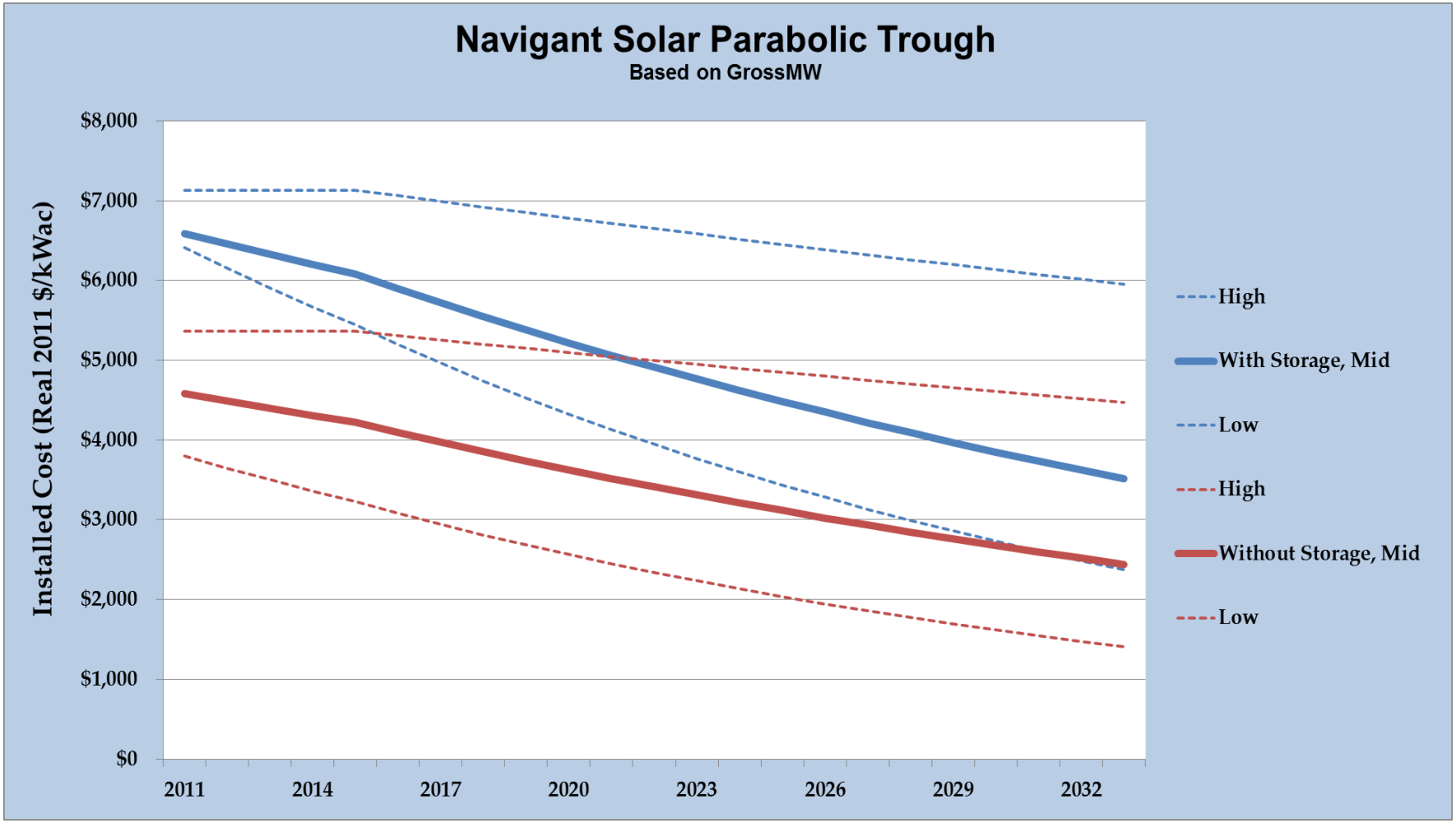
Parabolic trough costs are projected to decline more slowly than PV.



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Parabolic trough data was an amalgam of DOE loan guarantee published costs #s, and current studies in the literature.

Parabolic Trough	Key Assumption	Source	Values
Current Costs	Total Cost	Recent DOE loan guarantee projects NREL Black and Veatch 2011 study AEMO Energy Tech Cost Review	See graph
	Capacity Factor	Same studies	27% w/o storage 43% w/storage
	Component Cost Breakdowns	Percentages applied from NREL Black and Veatch 2011 study and NREL's SAM model,	.14 $/Wp
	Configuration	Storage assumption based on current practice Dry cooling is captured by the "high" estimate	10 hours of storage
Cost Projections	Low	NREL Black and Veatch 2011 study AEMO Energy Tech Cost Review	See graph
	Maintenance Projections	SEGS cost reduction study by Sandia	70 $/kw-yr

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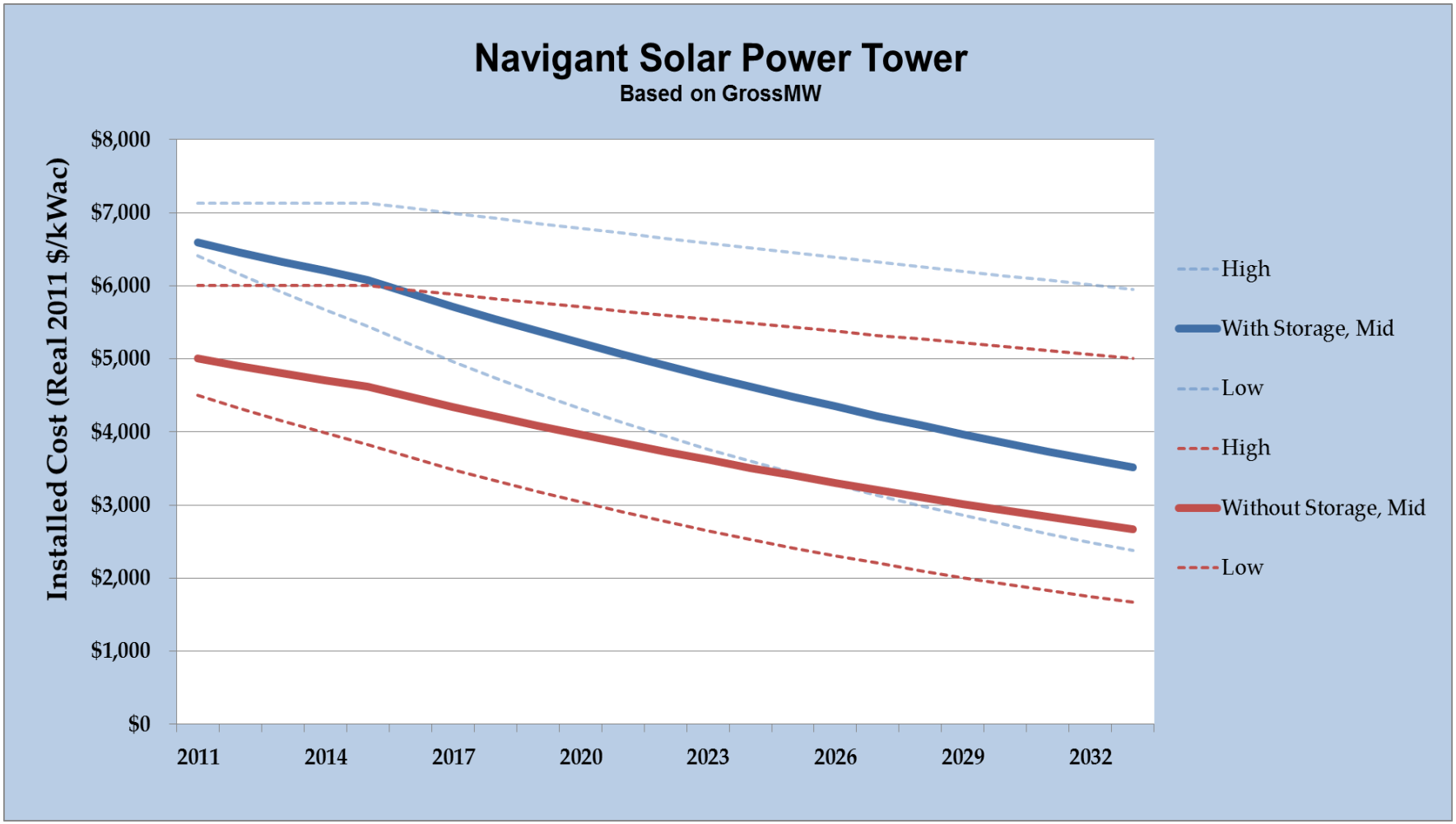
Power tower costs, as a more nascent technology, have wider uncertainty bands.



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Power tower data was similarly an amalgam of DOE loan guarantee published costs #s, and current studies in the literature.

Power Tower	Key Assumption	Source	Values
Current Costs	Total Cost	Recent DOE loan guarantee projects; NREL Black and Veatch 2011 study; SAM model sample estimates	See graph
	Capacity Factor	Same studies	31% w/o storage 40% w/storage
	Component Cost Breakdowns	Percentages applied from NREL Black and Veatch 2011 study; and Sandia "Power Tower Technology Roadmap"	See graph
	Storage Configuration	Assumption based on current practice	10 hours
Cost Projections	Low	AEMO Energy Tech Cost Review, AT Kearney, IEA, US DOE, NREL Black and Veatch Study	See graph
	Maintenance Projections	Sandia "Power Tower Technology Roadmap"	65 $/kw-yr

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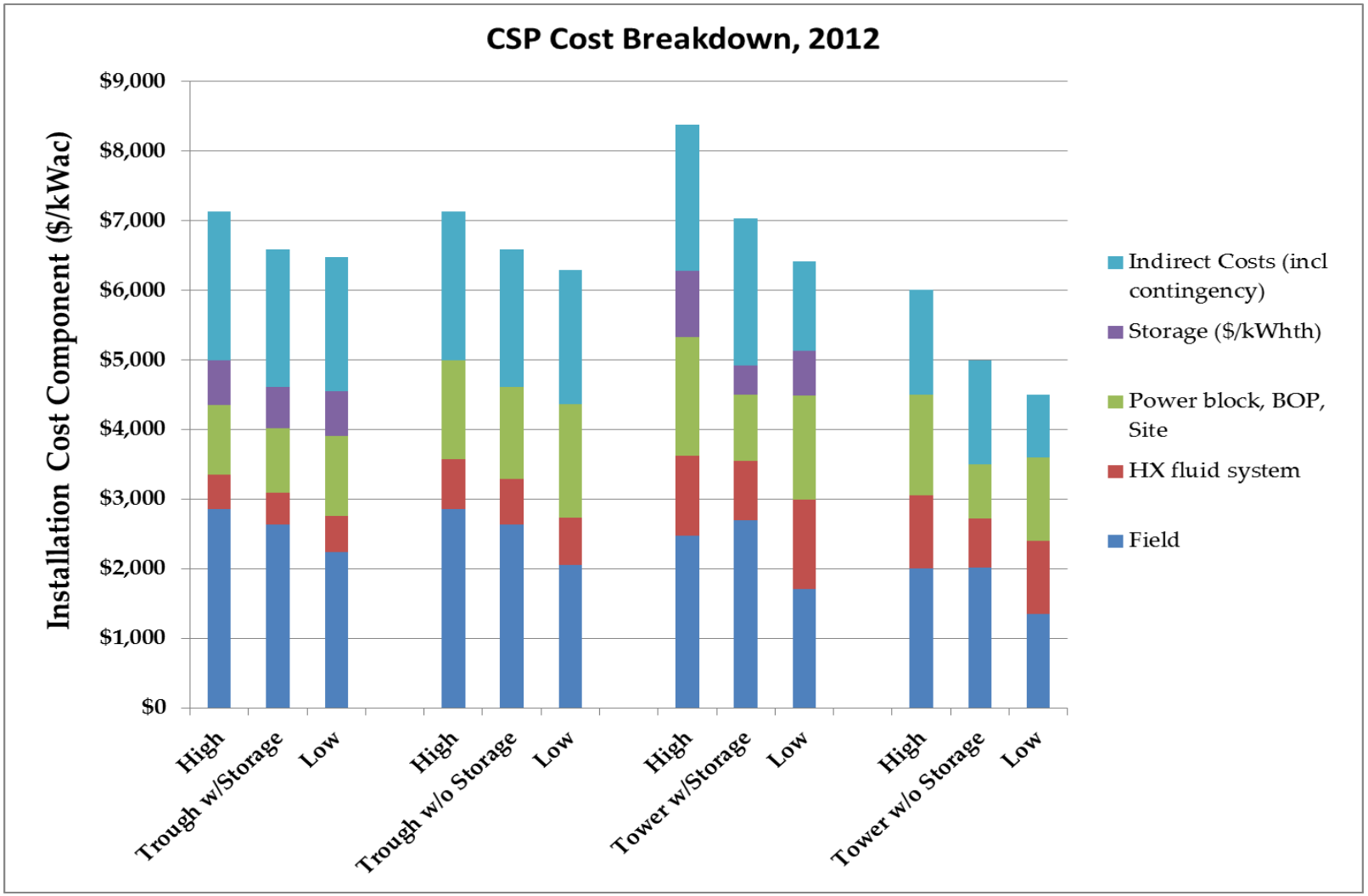
Concentrating solar power breakdowns include five major components.



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Crystalline and Thin Film Photovoltaics (PV), 20MW and 100 MW – Navigant Case	
Low, Mid, High Cost cases reflect low end, averages, and high end of these aggregated sources	Centralized Solar Projects and Pricing Update Bulletin (Q1 2012), Solar Electric Power Association (SEPA), May 2012 http://www.solarelectricpower.org/resources/publications.aspx#Centralized_Solar_Projects_QB_February2012
	Goodrich et. al., Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities, National Renewable Energy Laboratory, February 2012. http://www.nrel.gov/docs/fy12osti/53347.pdf
	SunShot Vision Study, U.S. Department of Energy, February 2012. http://www1.eere.energy.gov/solar/sunshot/index.html
	Module manufacturer annual (10-K) and quarterly reports (10-Q)
Cost trends over time	
Low	US DOE's Sunshot Program goals
Mid	Centralized Solar Projects and Pricing Update Bulletin (Q1 2012), Solar Electric Power Association (SEPA), May 2012
High	Assumes that the ITC is not extended in 2016 and innovation in the solar industry slows down along with installations
O&M Costs	
	US Department of Energy. SunShot Vision Study. February 2012
	Electric Power Research Institute. Addressing Solar Photovoltaic Operations and Maintenance Challenges - A Survey of Current Knowledge and Practices. July 2010
	Bond rating reports for Topaz solar farm.
	Yates, Tarn and Hibberd, Bradley; Levelized Cost of Energy; April, 2012; SolarPro Magazine, April/May 2012 issue
Transmission to First Interconnection	2012 Final Generator Interconnection Unit Cost Guides from PG&E, SCE and SDG&E. The data is available at http://www.caiso.com/informed/Pages/StakeholderProcesses/ParticipatingTransmissionOwnerPerUnitCosts.aspx. High, Mid, Low cost scenarios based on gen-tie line lengths of 5, 10, and 20 miles in rural/desert areas with low population density.

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250MW Parabolic Trough Solar Thermal With Storage – Navigant Case	
Mid 2011 Installed Cost	DOE Loan Guarantee, Solana Project. https://lpo.energy.gov/?projects=abengoa-solar-inc and http://www.nrel.gov/csp/solarpaces/, assuming a 28%:73% equity : debt ratio
High 2011 Installed Cost	Cost and Performance Data for Power Generation Technologies, February 2012, prepared for NREL by Black and Veatch
Low 2011 Installed Cost	Melbourne Energy Institute Technical Paper Series,Renewable Energy Technology Cost Review, May 2011, p 39. AEMO dataset
Instant Costs were back calculated from installed costs as per the text	
CSP Costs Projections Over Time	Melbourne Energy Institute Technical Paper Series,Renewable Energy Technology Cost Review, May 2011, p 4. Compares IEA, AEMO, ATK, and US DOE cost curves
Cost Component Breakdowns	Cost and Performance Data for Power Generation Technologies, February 2012, prepared for NREL by Black and Veatch
O&M Costs	"Final Report on the Operation and Maintenance Improvement Program for Concentrating Solar Power Plants", Cohen, Kearney, & Kolb, June 1999, Sandia
250MW Parabolic Trough Solar Thermal Without Storage – Navigant Case	
Mid 2011 Installed Cost	Average between High and Low
High 2011 Installed Cost	DOE Loan Guarantee, Mohave Solar project. https://lpo.energy.gov/?projects=abengoa-solar-inc and http://www.nrel.gov/csp/solarpaces/, assuming a 25%:75% equity : debt ratio
Low 2011 Installed Cost	DOE Loan Guarantee, Genesis Solar project. https://lpo.energy.gov/?projects=abengoa-solar-inc and http://www.nrel.gov/csp/solarpaces/, assuming a 25%:75% equity : debt ratio
100 MW Power Tower Solar Thermal With Storage – Navigant Case	
Mid 2011 Installed Cost	"Cost and Performance Data for Power Generation Technologies", February 2012, prepared for NREL by Black and Veatch
High 2011 Installed Cost	DOE Loan Guarantee, Crescent Dunes project. https://lpo.energy.gov/?projects=abengoa-solar-inc and http://www.nrel.gov/csp/solarpaces/, assuming a 25%:75% equity : debt ratio
Low 2011 Installed Cost	NREL / Solar Advisory Model (SAM), 2012, Power Tower Defaults

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100 MW Power Tower Solar Thermal Without Storage – Navigant Case		
Mid 2011 Installed Cost	DOE Loan Guarantee, Ivanpah project. https://lpo.energy.gov/?projects=abengoa-solar-inc and http://www.nrel.gov/csp/solarpaces/, assuming a 22.6%:77.4% equity : debt ratio	
High 2011 Installed Cost	+20%	reflecting typical contingencies on construction projects of this nature.
Low 2011 Installed Cost	-10%	
O&M Costs	P26, Table 6, "Power Tower Technology Roadmap and Cost Reduction Plan", Kolb, Ho, Mancini, and Gary, Sandia Report # SAND2011-2419, April 2011.	
Instant to Installation Cost		
Construction Interest, Debt Fee, Construction Insurance	NREL's Renewable Energy Finance Tracking Initiative, 2H 2011 Summary, April 26, 2012 available at https://financere.nrel.gov/finance/REFTI	

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