Utility-Scale Solar 2012

An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States

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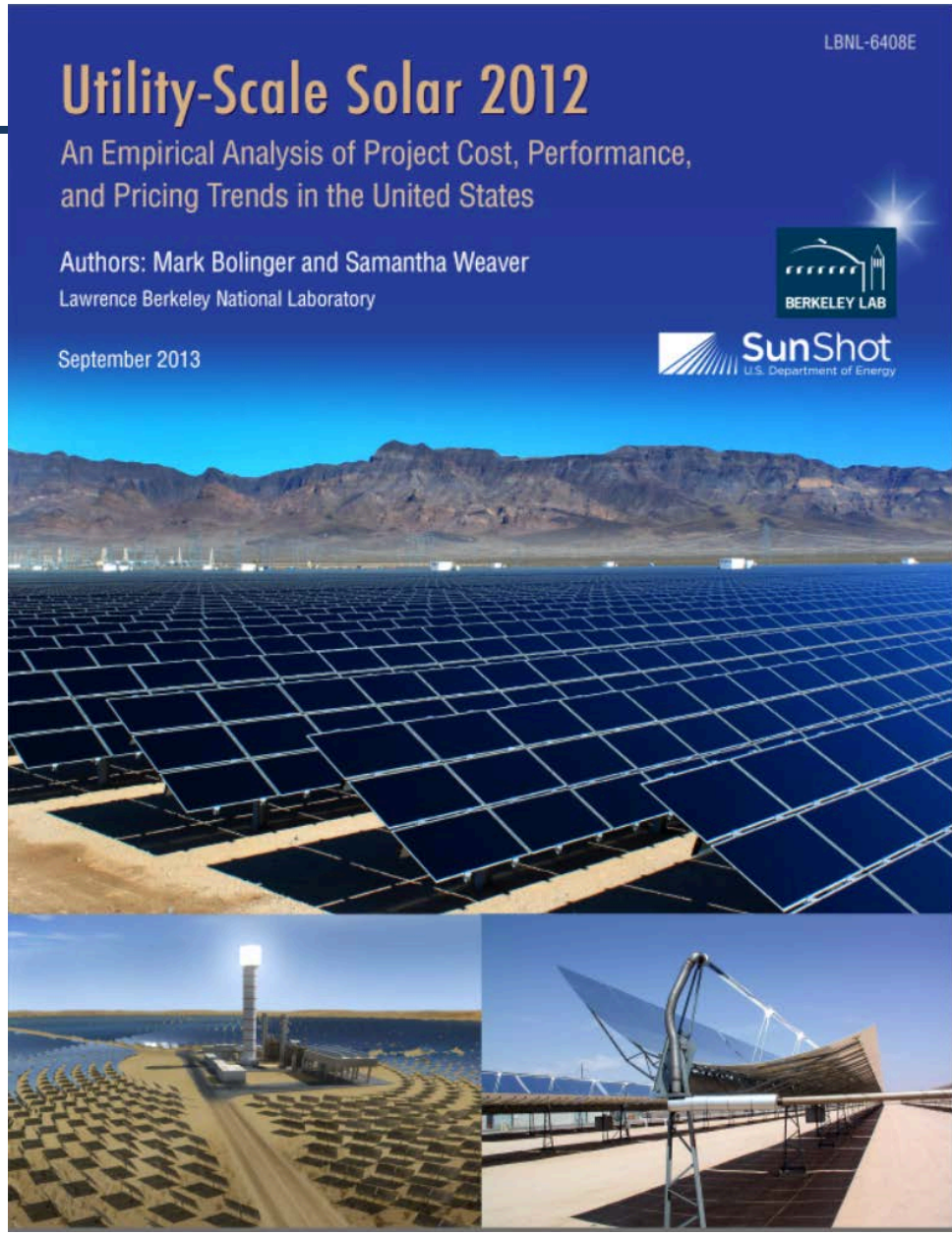
September 2013



This research was supported by funding from the U.S. Department of Energy's SunShot Initiative.

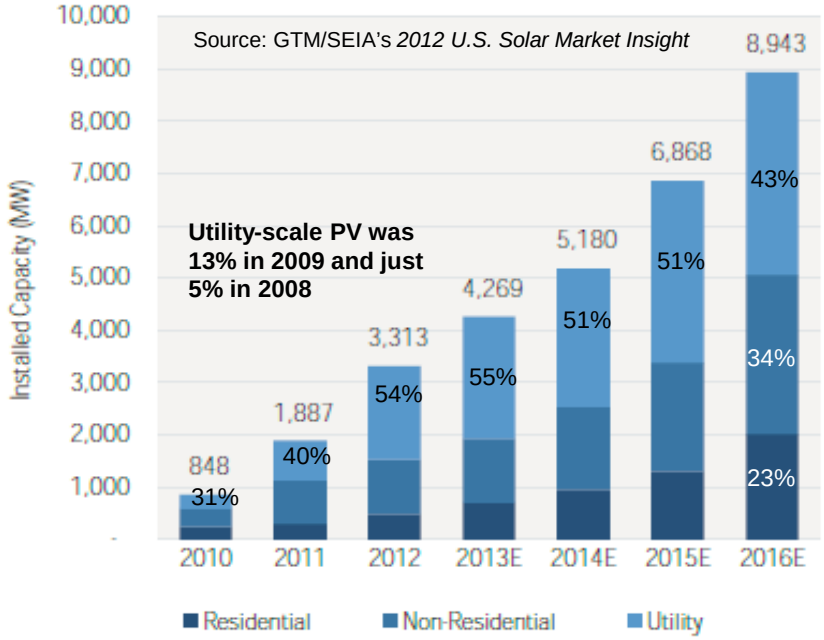
Presentation Outline

- Recent market growth has resulted in a critical mass of project-level data ripe for analysis
- Key findings from this inaugural edition
  - Installed Costs/Prices
  - Operating (O&M) Costs
  - Performance (Capacity Factors)
  - Power Purchase Agreement ("PPA") Prices

A few background notes about this first edition:

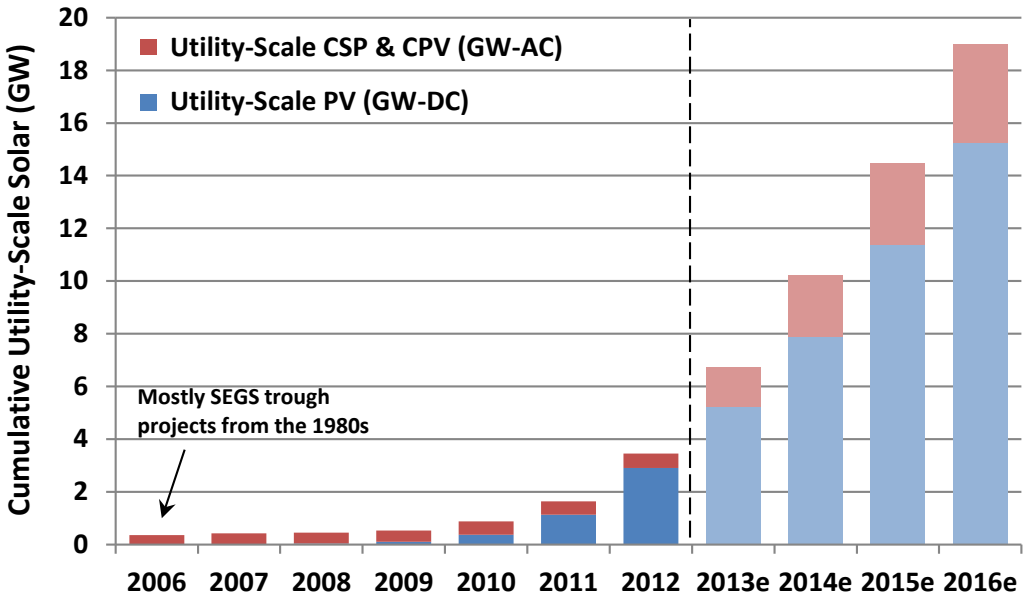
- Certain data (e.g., O&M costs) were still rather limited for this first edition, but are expected to become more widely available in future years
- For this first edition, we define "utility-scale" as any ground-mounted project that is larger than 2 MW_{AC} (we may raise this threshold for next year's second edition)

Utility-Scale Solar: Young But Growing Like a Weed



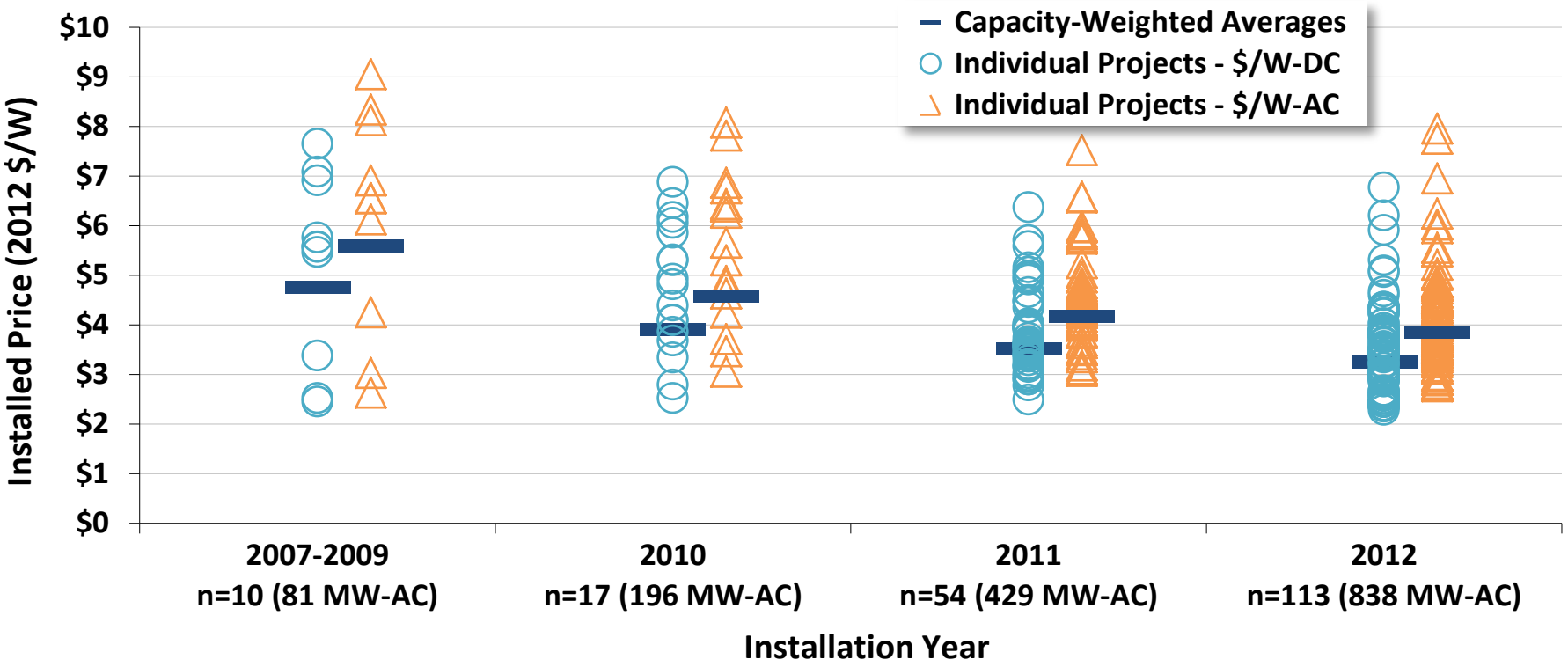
- In the United States, utility-scale PV increased from just **5%** of total annual PV installations in 2008 to **54%** in 2012 (chart left)
- 2012 was the first year in which utility-scale PV made up the largest segment of the U.S. PV market – a distinction that it is projected to retain through at least 2016

- Including CSP/CPV, cumulative installed utility-scale solar capacity could double in 2013, and again by 2015 (chart right)
- More than 18 GW of utility-scale solar projected to be online by the end of 2016
  - 2013-2016 GTM/SEIA utility-scale solar projections account for 35%-40% of the total announced and contracted pipeline that they track (or 118% of just the contracted pipeline)



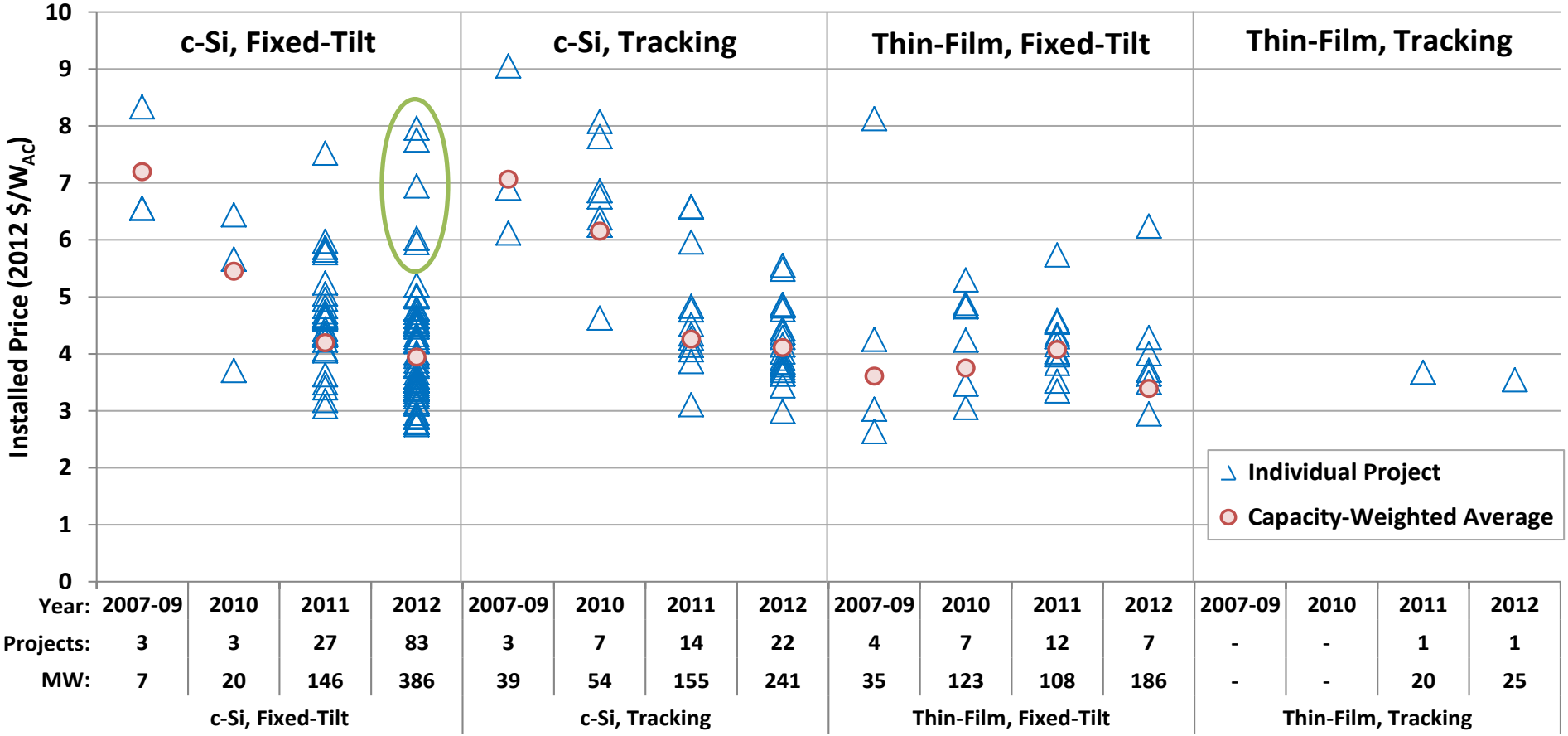
Source: GTM/SEIA's *U.S. Solar Market Insight* reports

Installed Prices Have Fallen, But Pace of Decline Slowed in 2012



- Installed prices are shown here in both DC and AC terms, but because AC is more relevant to the utility sector, all metrics used in the rest of the report (and this slide deck) are expressed solely in AC terms
- Anecdotal evidence of further installed price declines in 2013/2014
  - **Example:** PNM recently filed for regulatory approval of 23 MW_{AC} of thin-film PV projects to be built in 2014 at a contracted price of just \$2.03/W_{AC}, compared to \$2.29/W_{AC} for 20 MW_{AC} of PV currently under construction in 2013 and \$4.15/W_{AC} for 22.5 MW_{AC} built in 2011

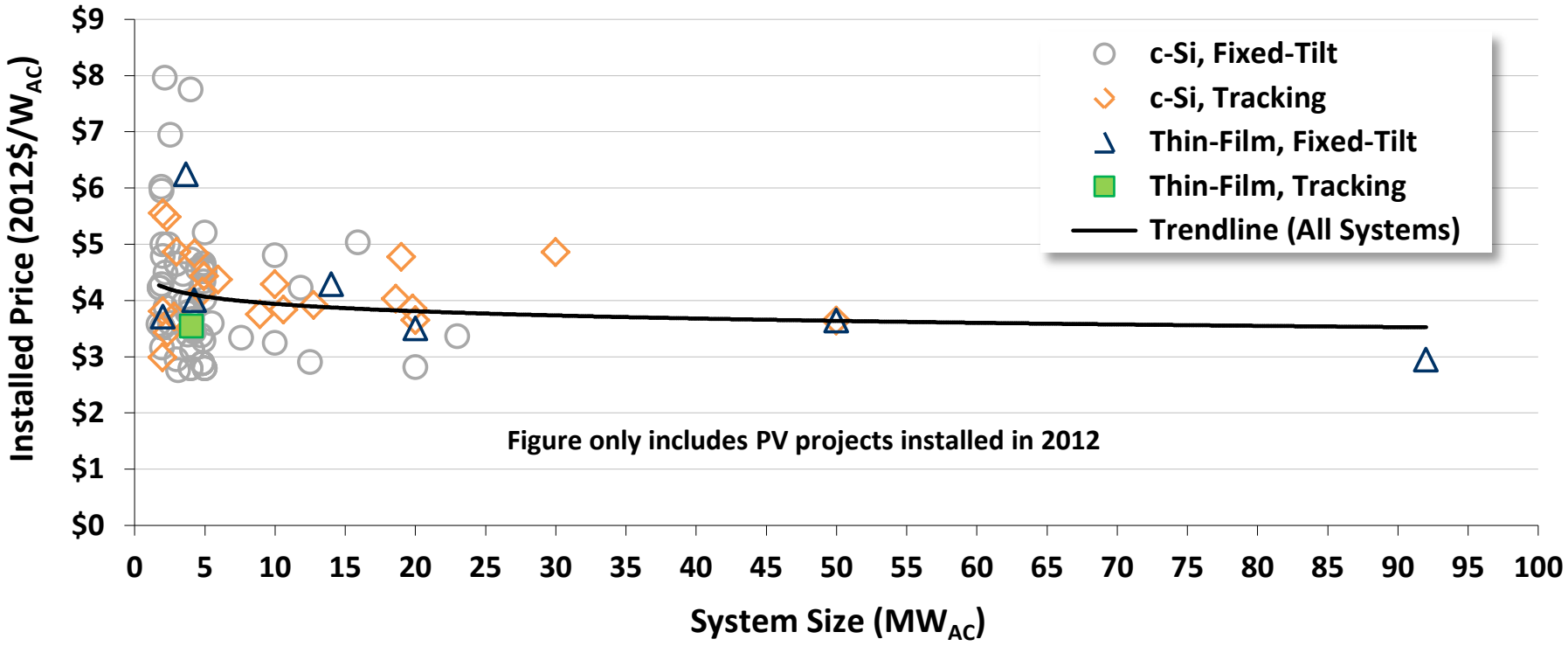
Installed Price Decline Led By c-Si, While Thin-Film Prices Held Steady



	c-Si, Fixed-Tilt				c-Si, Tracking				Thin-Film, Fixed-Tilt				Thin-Film, Tracking			
Year:	2007-09	2010	2011	2012	2007-09	2010	2011	2012	2007-09	2010	2011	2012	2007-09	2010	2011	2012
Projects:	3	3	27	83	3	7	14	22	4	7	12	7	-	-	1	1
MW:	7	20	146	386	39	54	155	241	35	123	108	186	-	-	20	25

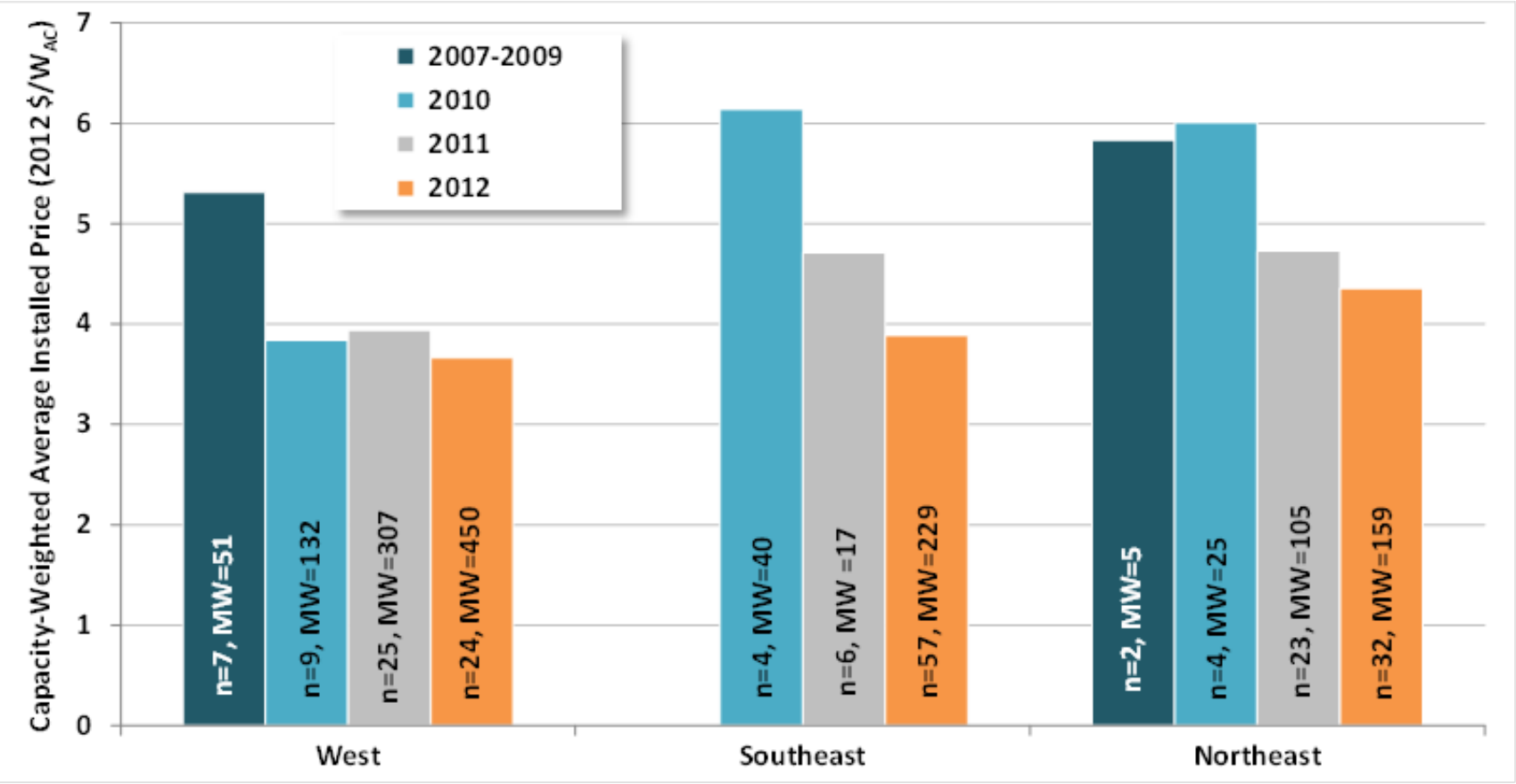
- An explosion of c-Si projects (particularly fixed-tilt) as prices have converged
- Not much installed price difference between fixed-tilt and tracking
  - Could relate to DC/AC nameplate ratio – DC often oversized for fixed-tilt systems (raises price in AC terms)
- Circled high-priced c-Si/fixed-tilt outliers in 2012 are often small, behind-the-meter, and/or installed on top of capped landfills (i.e., high-value and/or customized installations)

Economies of Scale Most Evident At Low End of System Size Range



- For many projects, the basic modular unit is a 1-1.5 MW "power block"
  - A pre-fab package of components (modules, trackers, inverters, controllers, SCADA) that is easily scalable
  - e.g., SunPower's 1.5 MW "Oasis" power block – a complete solar project "in a box"
- Once you move beyond installing a few power blocks, economies of scale appear to diminish (or perhaps be offset by higher costs elsewhere)

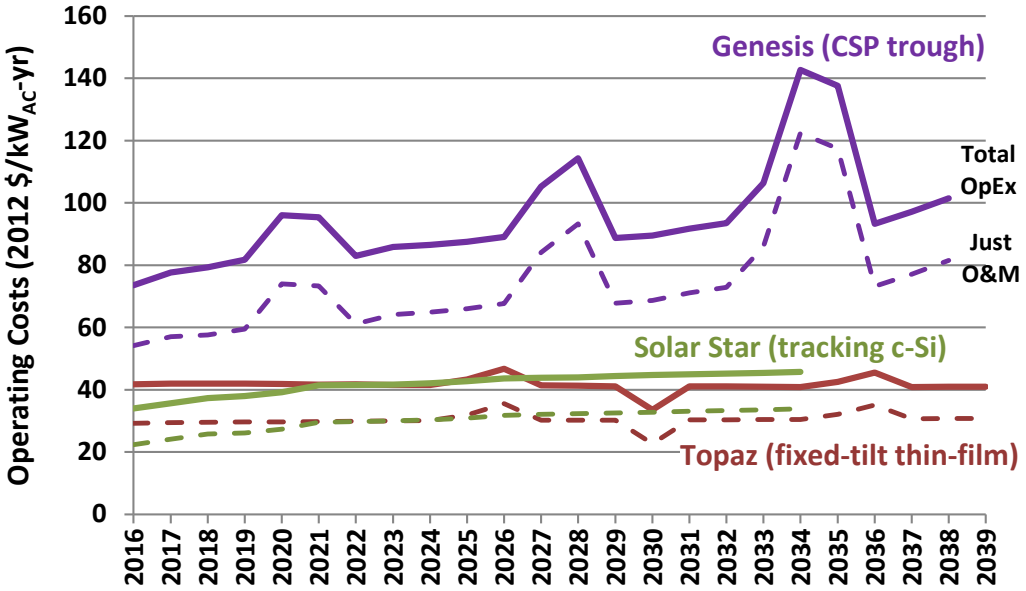
Installed Prices By Region: Convergence With the West

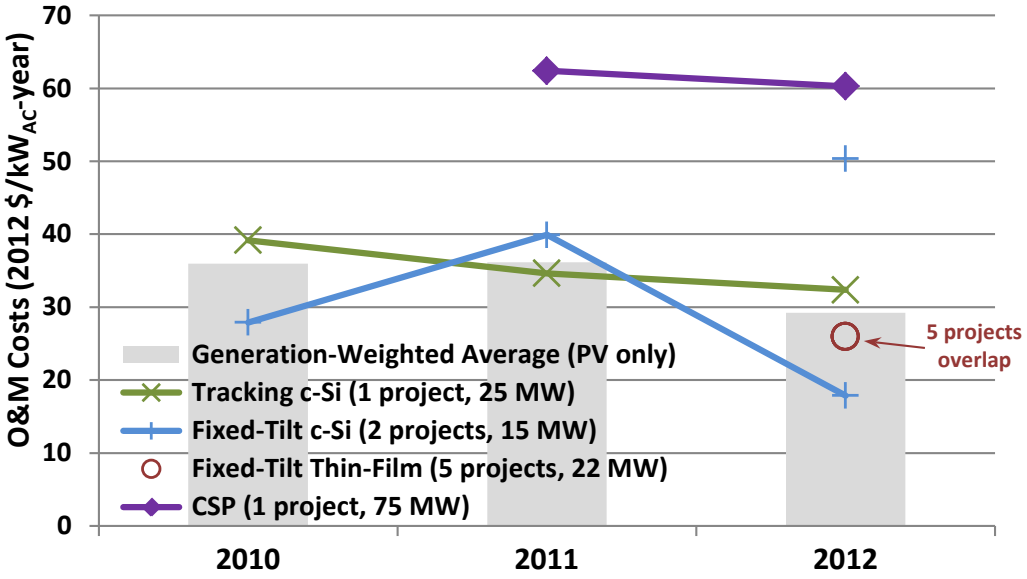


$2/W$_{AC}$ diff in 2010 declined to $0.8/W$_{AC}$ in 2011 and $0.2-$0.7/W$_{AC}$ in 2012

- Southeast and Northeast have had more of a learning curve to travel down
- Bigger projects in the West perhaps more likely to get bogged down in costly permitting and environmental issues

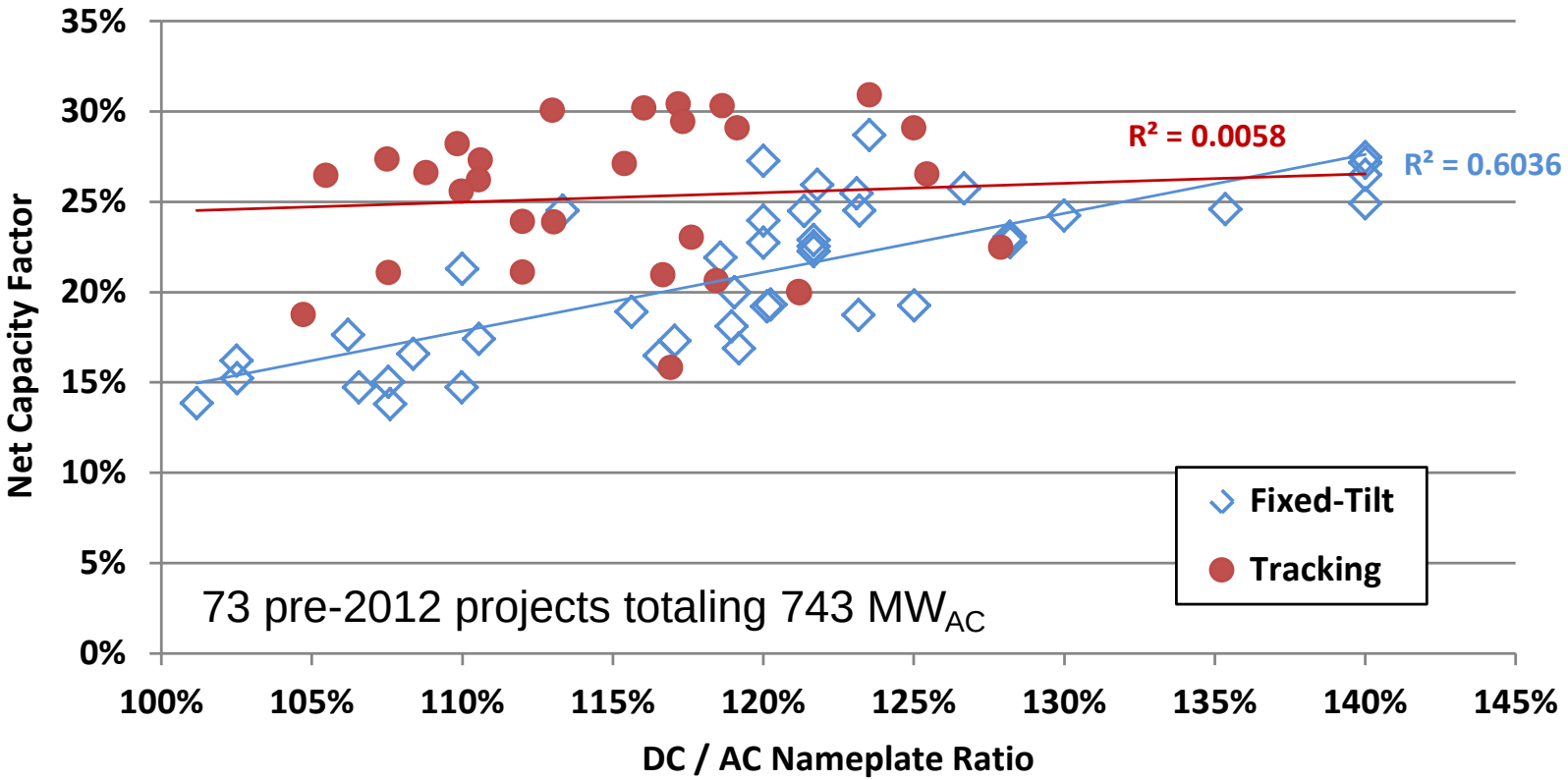
O&M Cost Data Still Very Thin, But Largely Consistent With Early Years of Cost Projections





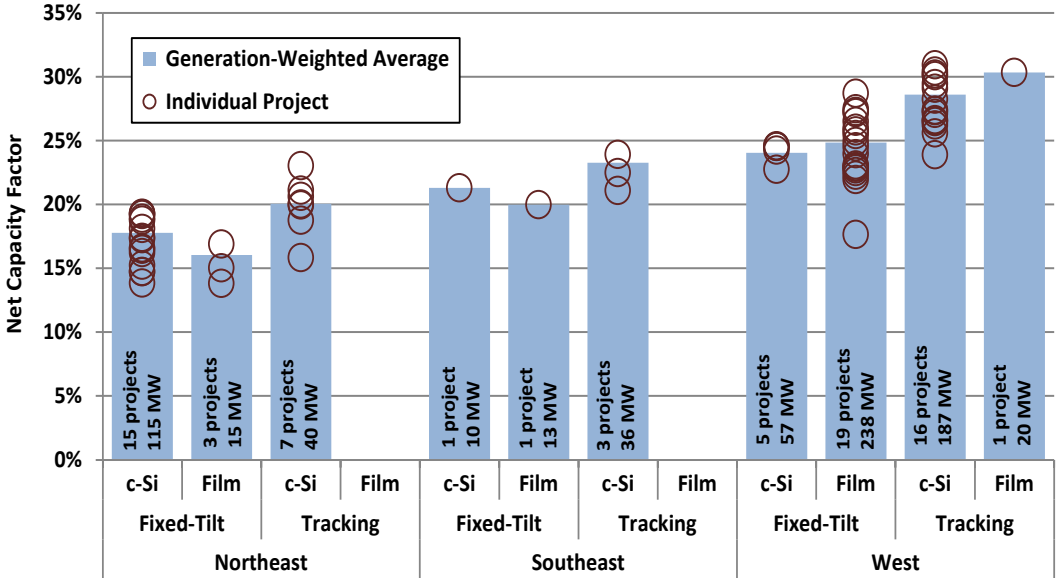
- Due to limited empirical data at this early stage in the market, this first edition compares ***projected*** project-level O&M costs pulled from bond rating agency research (top graph) to what limited empirical data are available so far (bottom graph)
- Results suggest that actual operating costs (from a VERY limited sample) are consistent with early year projections: \$20-\$40/kW$_{AC}$-year for PV, and ~\$60/kW$_{AC}$-year for the lone CSP parabolic trough project in the sample

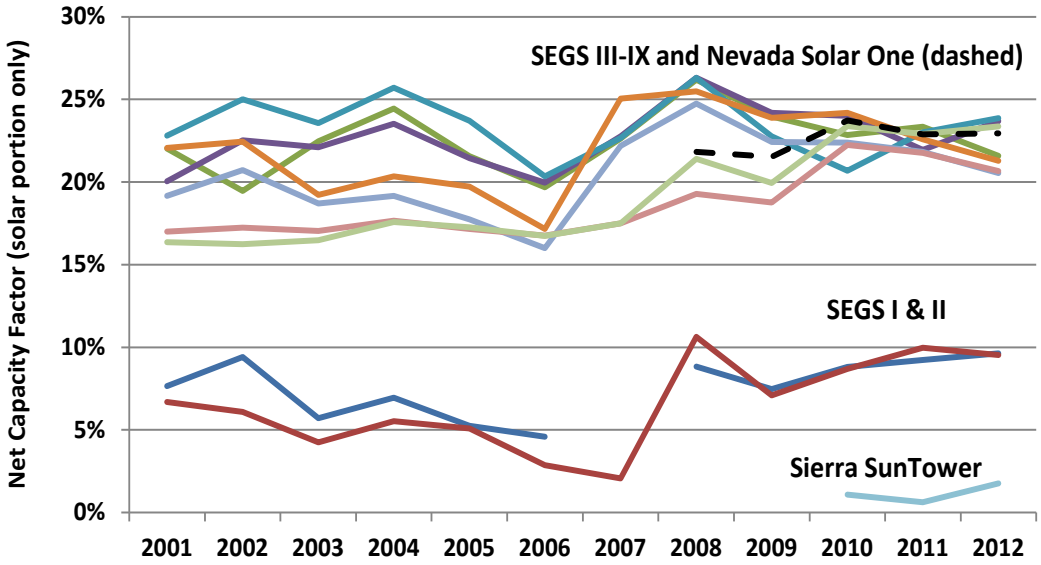
Oversizing DC Array Boosts PV Capacity Factor



- With the decline in module prices, some projects have oversized the PV array relative to inverter capacity as a way to broaden/flatten the generation profile throughout the day, thereby also boosting capacity factor (in AC terms)
- This surrogate/synthetic form of “tracking” makes less sense (both cost- and performance-wise) for projects already using tracking systems

More on PV and CSP Capacity Factors



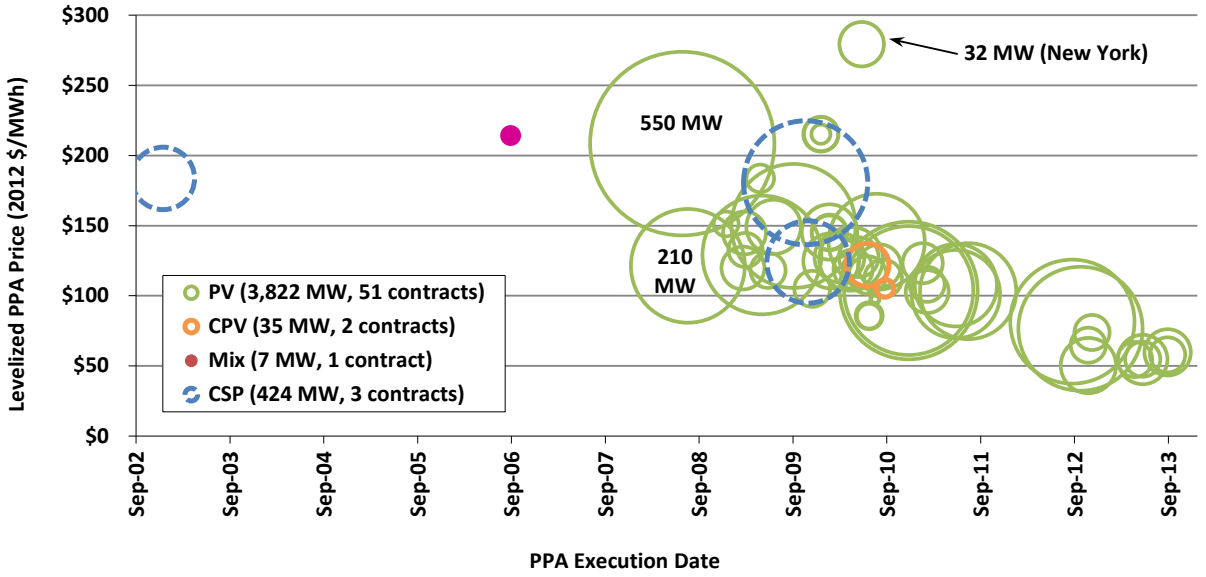


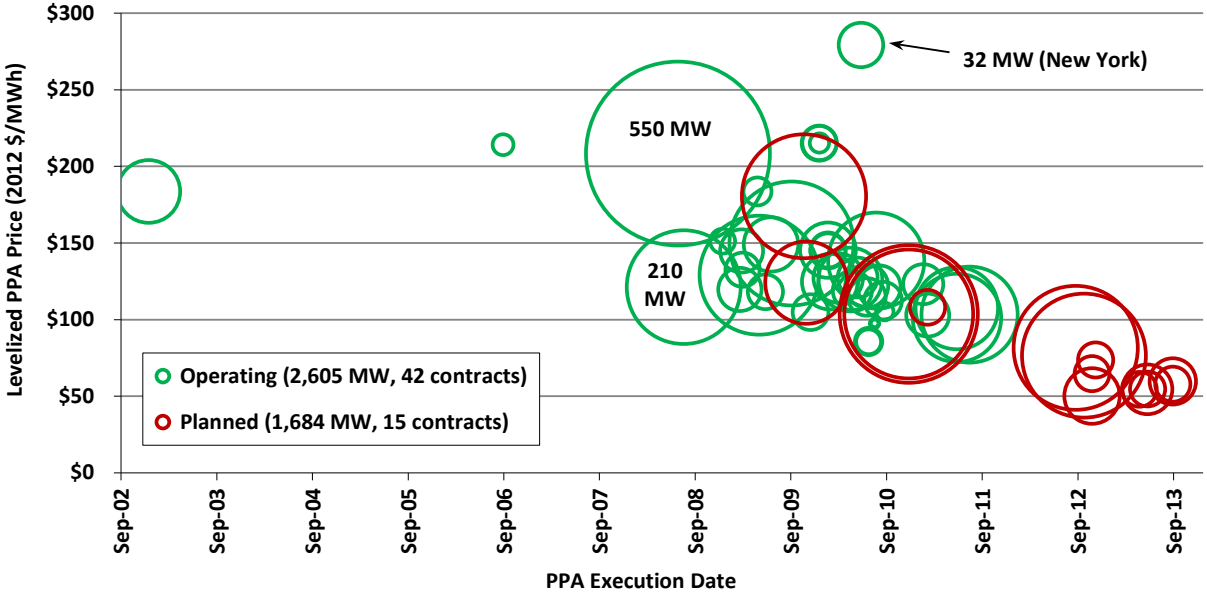
Top Graph (PV): NCF's highest in the West; tracking boosts NCF by ~20%; thin-film appears to beat c-Si in the West (higher temps), but not elsewhere

Bottom Graph (CSP):

- SEGS plants from the 1980s still going strong (on par with 2007's Nevada Solar One)
- SEGS III-IX performance has converged in recent years due to 1603-funded upgrades at the two lowest-performing projects
- SEGS I and II also upgraded, but have lower capacity factors due to smaller collector fields
- Sierra SunTower pilot-scale "power tower" has not met performance expectations

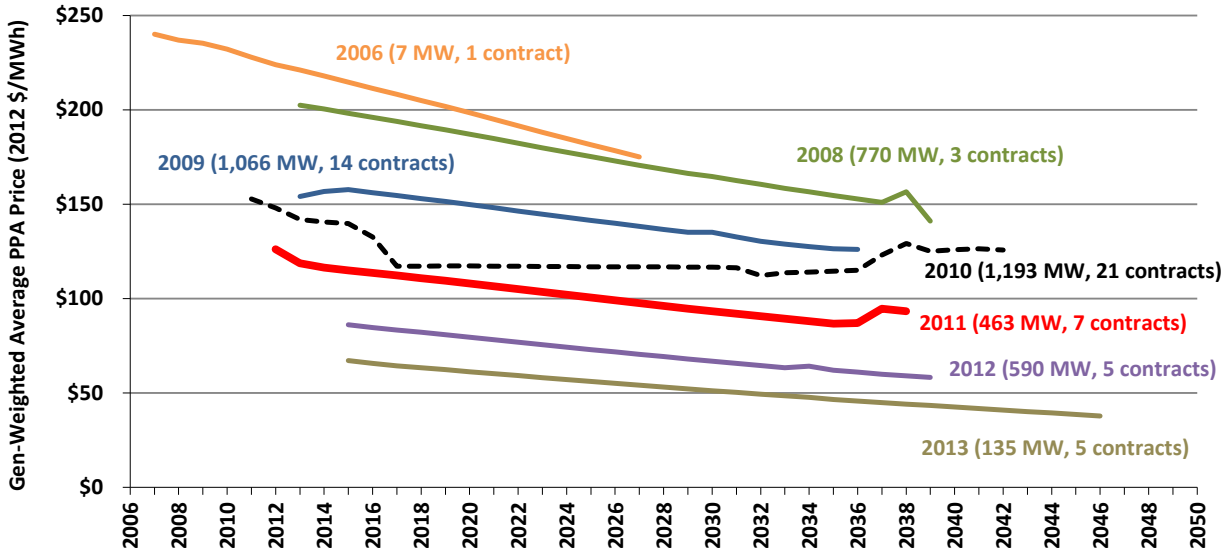
Levelized PPA Prices Have Fallen By More Than Two-Thirds in the Past Five Years

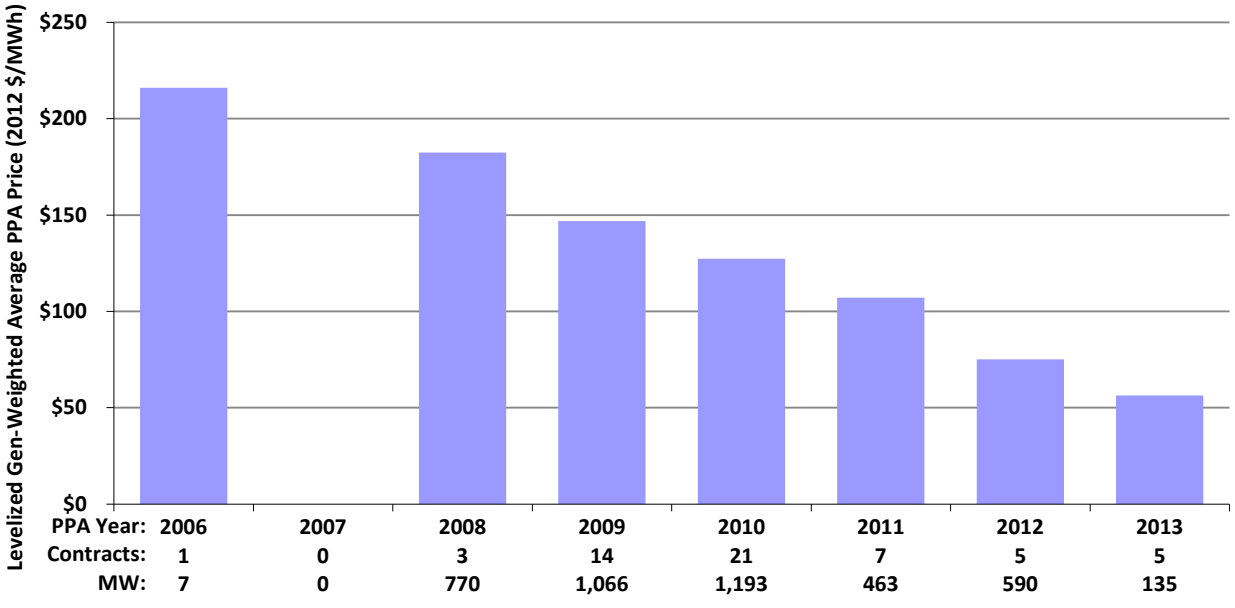




- PPA prices are levelized over the full term of the contract, after accounting for any escalation rates and/or time-of-delivery ("TOD") factors
- Strong downward price trend since 2007
- Smaller projects (e.g., 20 MW) no less competitive
- CPV and CSP largely competitive ***at the time***, but little visibility recently
- Only about 60% of the sample is currently operational (or at least partly operational) – bottom graph

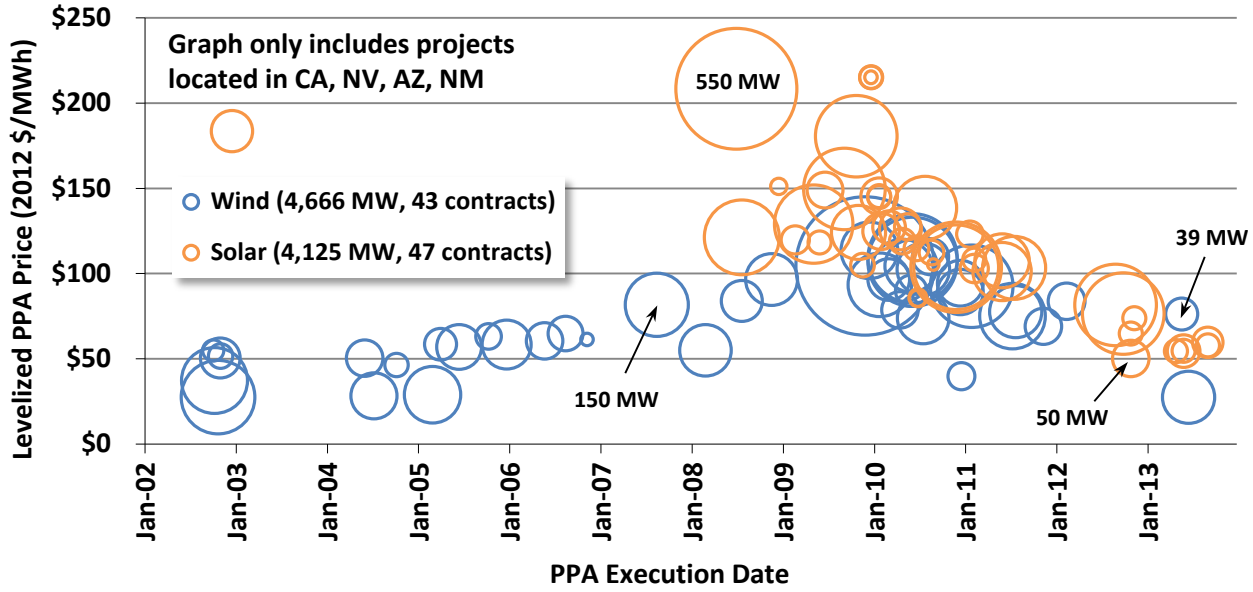
Levelized PPA Prices Have Fallen By Roughly $25/MWh per Year

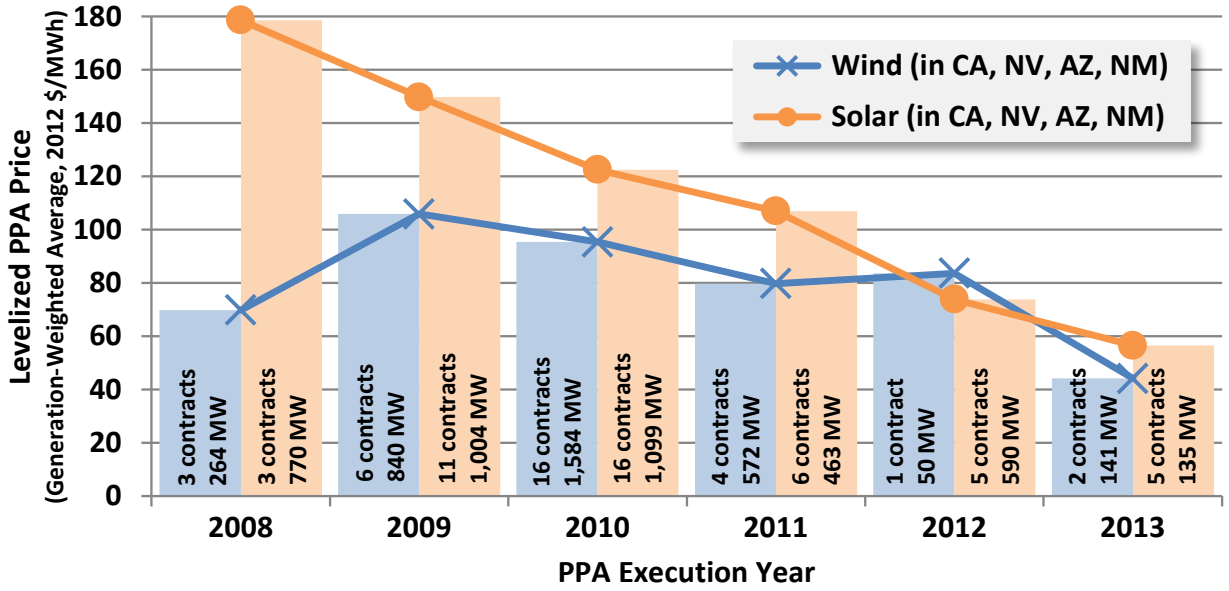




- 60% of sample has flat annual PPA pricing (in nominal dollars), while the rest escalate mostly at low rates intended to keep pace with inflation – this means that average sample PPA prices ***decline*** over time in real dollars (top graph)
- Top graph also shows the steady march downward by PPA vintage
- Bottom graph simply levelizes each line in the top graph, to provide a clearer picture of the time trend

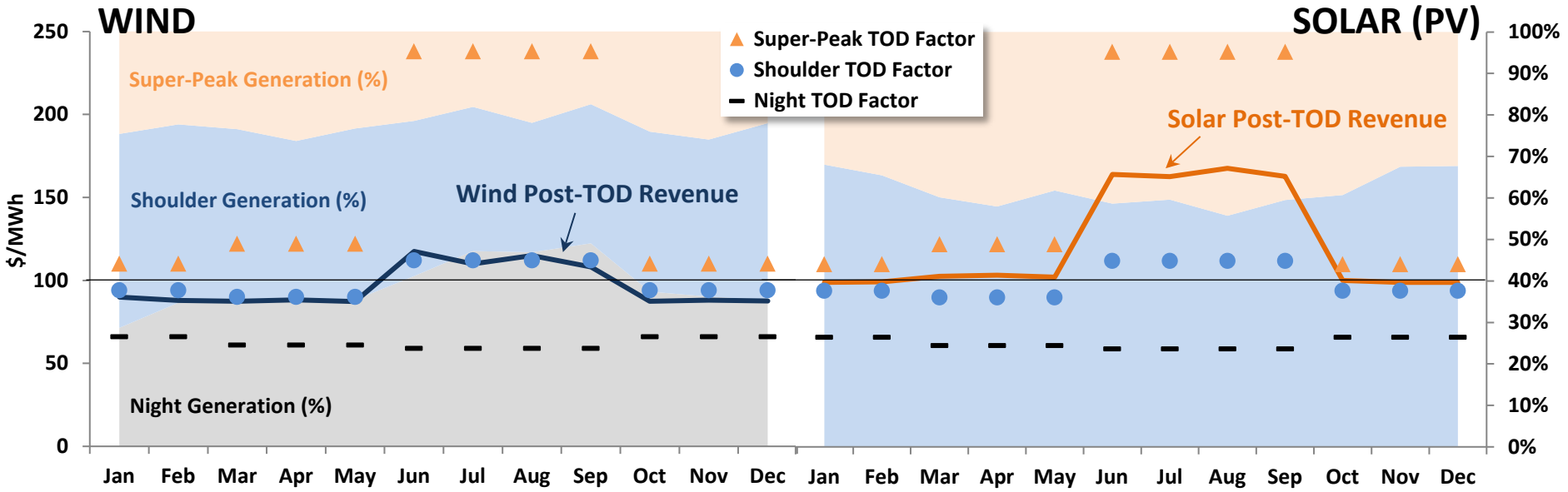
Solar and Wind: Neck-and-Neck in the Southwest





- 96% of our solar PPA sample (in MW) is in CA, NV, AZ, and NM
- These two graphs compare levelized PPA prices from solar and wind projects in these four states
- In 2012 and 2013, solar has given wind a run for its money
- This is particularly true given solar's greater time-of-delivery value to utilities (see next slide)

Time of Delivery ("TOD") Factors Favor Solar Over Wind



- Graphs show PG&E's 2011 TOD factors applied to a hypothetical $100/MWh base PPA price for both wind (left graph) and solar PV (right graph)
- Wind & solar generation profiles are from real projects selling to PG&E under TOD prices
- Over the course of a year, solar earns ***~$25/MWh more*** post-TOD revenue than wind
  - The vast majority of solar's TOD advantage over wind comes from differences in diurnal generation profiles (e.g., no night generation for solar), but seasonal profiles do help a little
  - This is a PG&E example, but results are similar for other investor-owned utilities in California
- As solar penetration increases, causing "net peak load" to shift later into the afternoon or evening, solar's (or at least PV's) TOD advantage will likely diminish

Questions?

Report and slide deck available at:
http://emp.lbl.gov/reports/re

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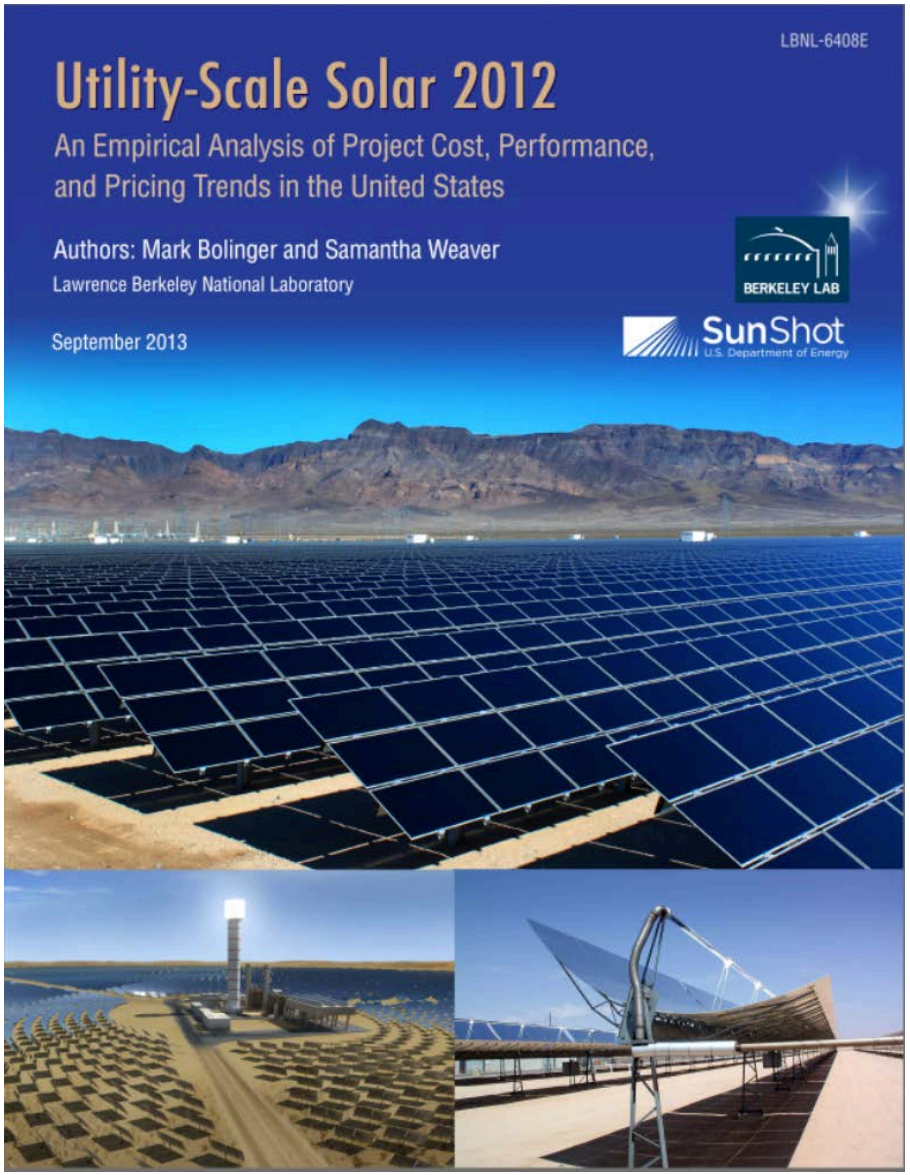

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