Utility-Scale Solar 2013

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

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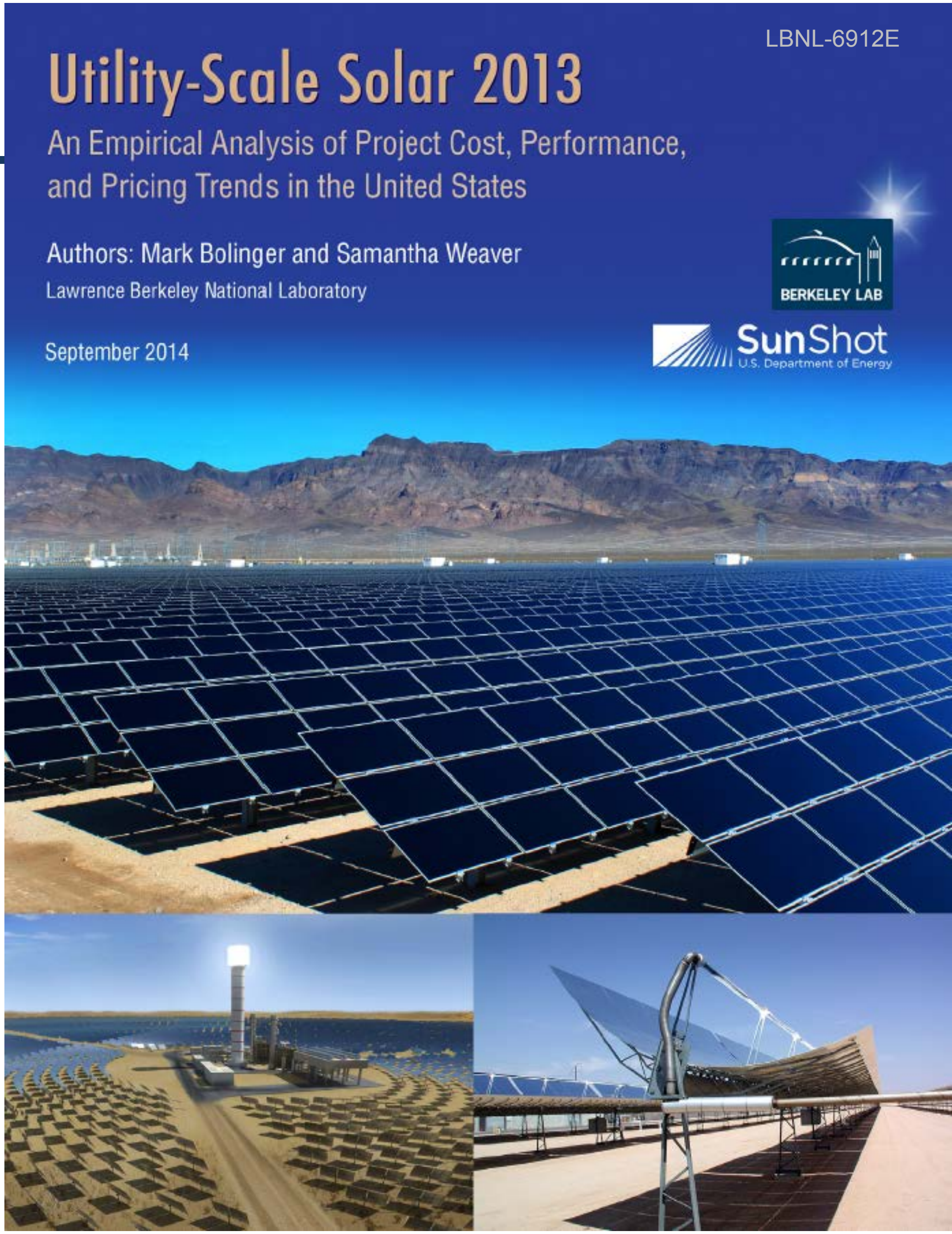

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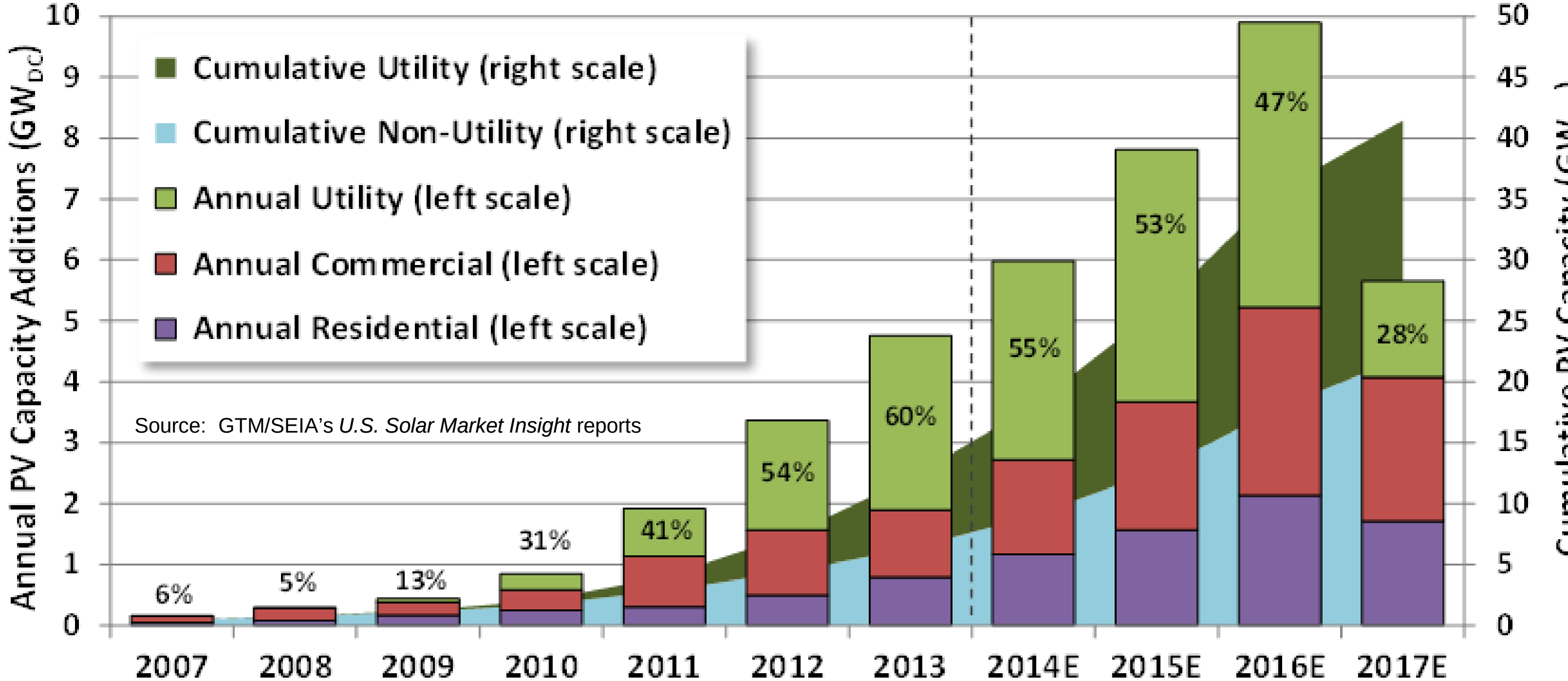
Presentation Outline

- Strong growth has resulted in a critical mass of project-level data ripe for analysis
- Describe and characterize the population of photovoltaic (“PV”), concentrating photovoltaic (“CPV”), and concentrating solar power (“CSP” or solar thermal) projects from which data samples are drawn
- Key findings from analysis of the data samples:
  - Installed Costs/Prices
  - Operating (O&M) Costs
  - Performance (Capacity Factors)
  - Power Purchase Agreement (“PPA”) Prices
- Future outlook

A few notes about this second edition:

- In this second edition, we define “utility-scale” as **any ground-mounted project that is larger than 5 MW_{AC}** (up from 2 MW_{AC} in the first edition). This definition differs from how others define it, and is driven by the four types of data analyzed in this report.
- Certain data (e.g., O&M costs) are still rather limited, but are expected to become more widely available in future years.

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 **60%** in 2013
- Utility-scale has been the largest sector of the overall U.S. PV market since 2012, and is projected to remain so through 2016 (at which point ***half*** of the cumulative installed PV capacity in the United States is projected to be utility-scale)
- Though it has a longer history, CSP is also in the midst of a renaissance in the U.S., with significant new capacity additions (featuring new technology) in 2013/2014

Total LBNL Project Population Dominated by PV

PV: 126 projects totaling 3,023 MW_{AC}

- The next three slides describe and characterize trends in the utility-scale PV project population

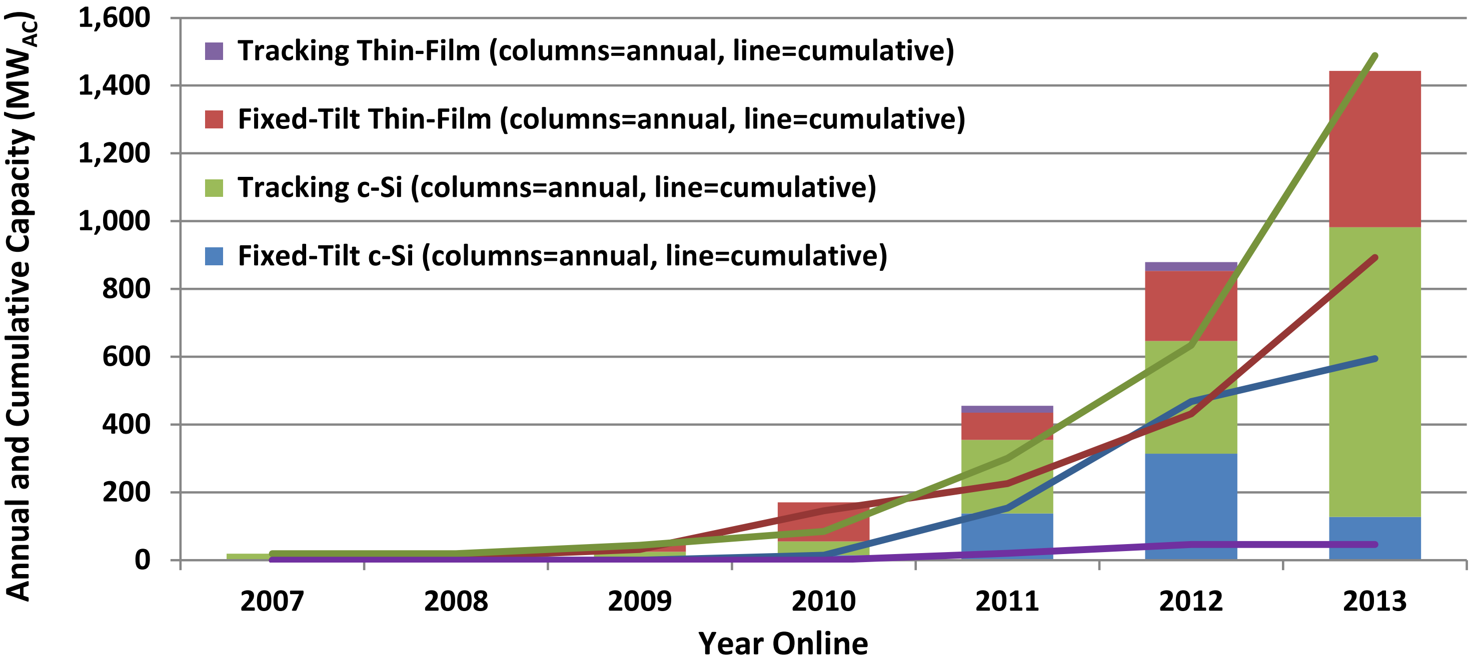
CPV: 2 projects totaling 35 MW_{AC}

- Both use Amonix high-concentration technology, are sited in high solar resource locations (~7.6-7.7 kWh/m^2/day DNI), and have inverter loading ratios of ~1.17

CSP: 16 projects totaling 1,848 MW_{AC}

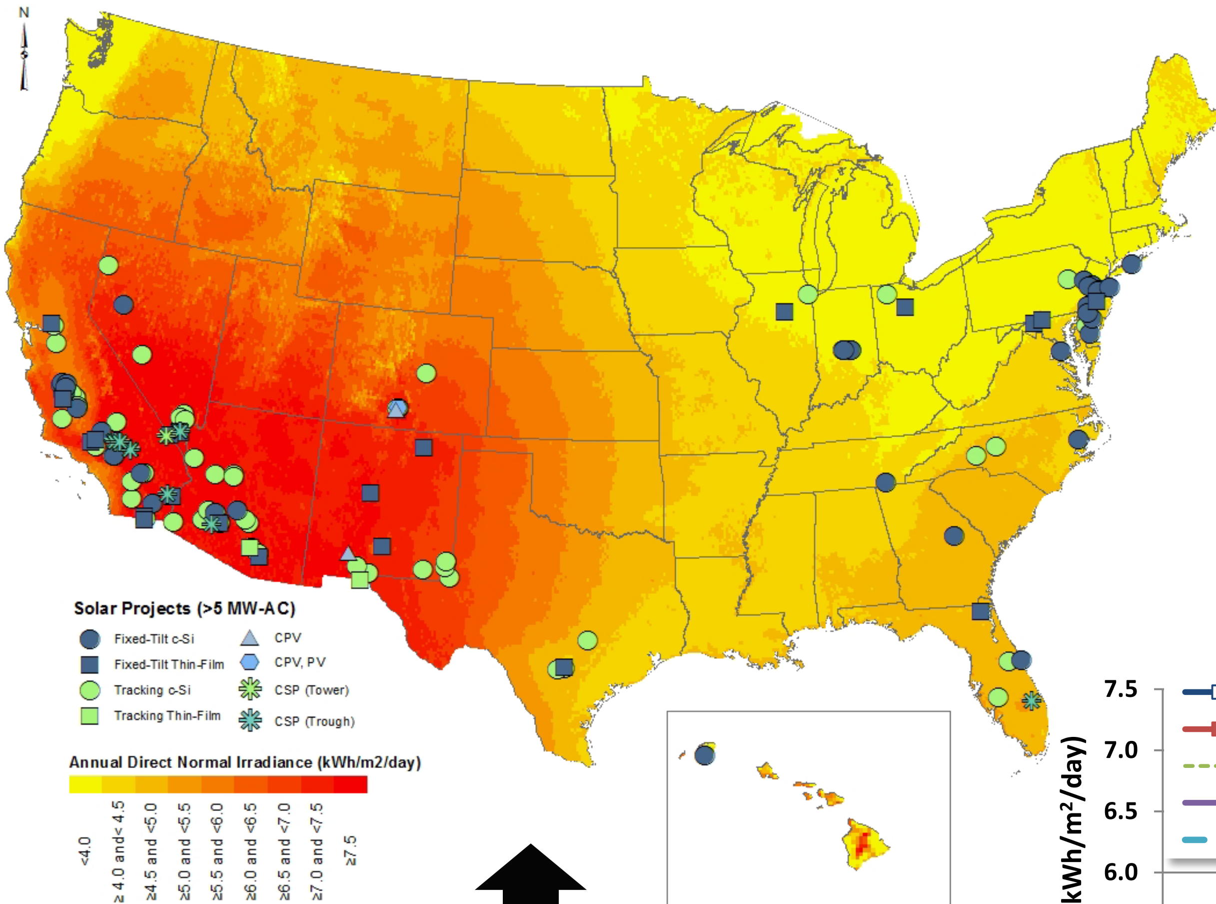
- After nearly 400 MW_{AC} built in the late-1980s/early-1990s, no new CSP was built in the U.S. until 2007 (~68 MW_{AC}), 2010 (~75 MW_{AC}), and 2013/2014 (~1,300 MW_{AC})
- Prior to 2013/14 build-out, all utility-scale CSP projects in the U.S. used parabolic trough collectors
- The five 2013/2014 projects include 3 parabolic troughs (one with 6 hours of storage) totaling ~800 MW_{AC} and two "power tower" projects (one with 10 hours of storage) totaling ~500 MW_{AC}.

PV Project Population Broken Out By Module Type, Tracking vs. Fixed-Tilt, and COD



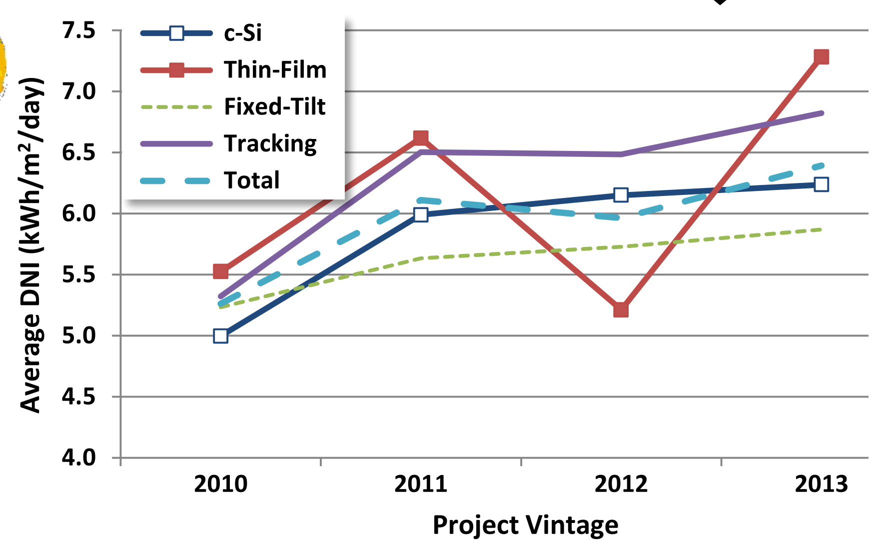
- 92% of total capacity in PV population was built from 2011-13 (98% from 2010-13)
- Though projects using thin-film modules (primarily cadmium telluride or CdTe) were as or more common than projects using crystalline silicon ("c-Si") modules in early years, the market shifted in favor of c-Si starting in 2011
- Projects using tracking systems have gained in popularity (over fixed-tilt projects), and accounted for nearly 60% of all capacity installed in 2013
- Cumulative rank at the end of 2013: tracking c-Si (1,489 MW_{AC}), fixed-tilt thin-film (893 MW_{AC}), fixed-tilt c-Si (595 MW_{AC}), and tracking thin-film (47 MW_{AC})

Project Location & Solar Resource
(resource map based on Direct Normal Irradiance or “DNI”)

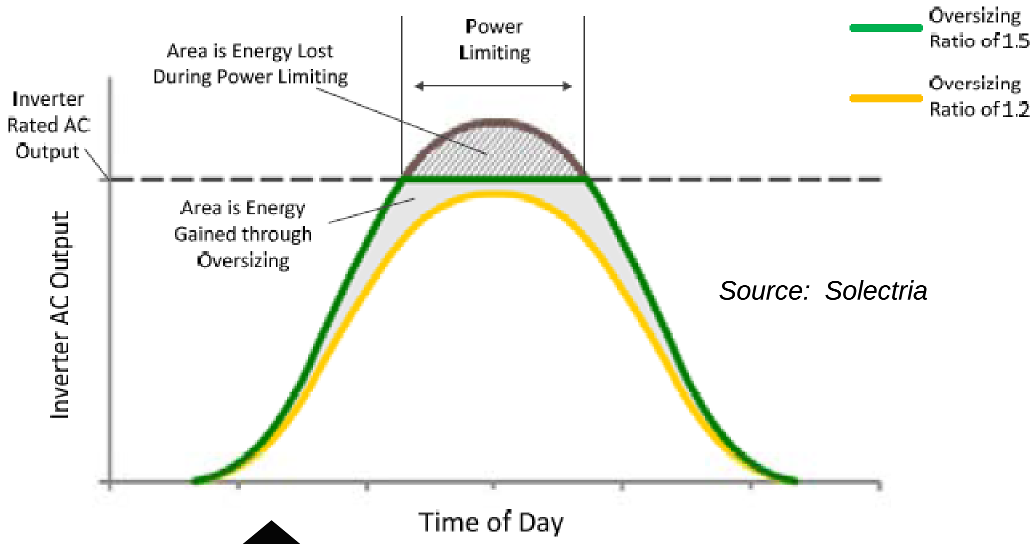


Among PV population, the average DNI has increased by project vintage, has been higher for tracking than for fixed-tilt projects, and (except for 2012) has been higher for projects using thin-film than c-Si modules

86% of PV population capacity is located in CA (48%), AZ (19%), NV (10%), NM (5%), CO (2%), and TX (2%)



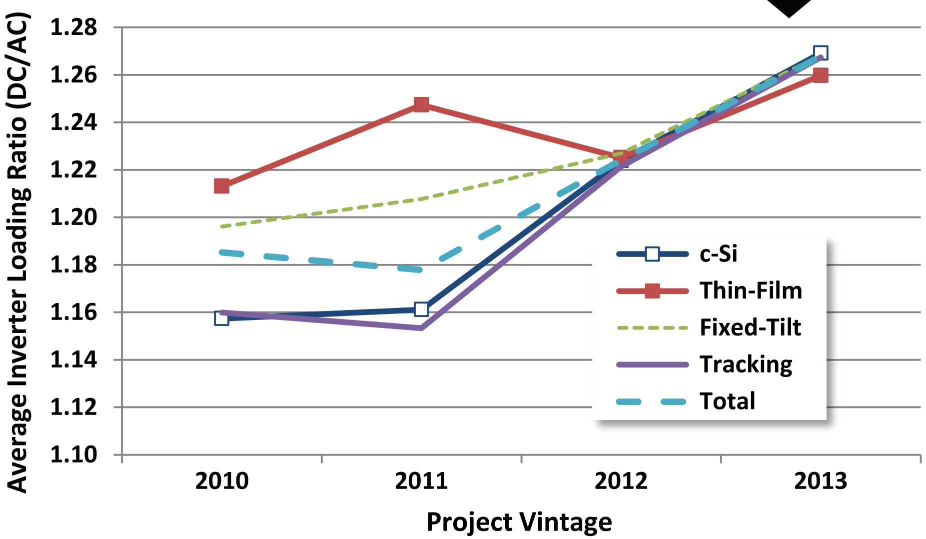
Trend Towards Higher Inverter Loading Ratios



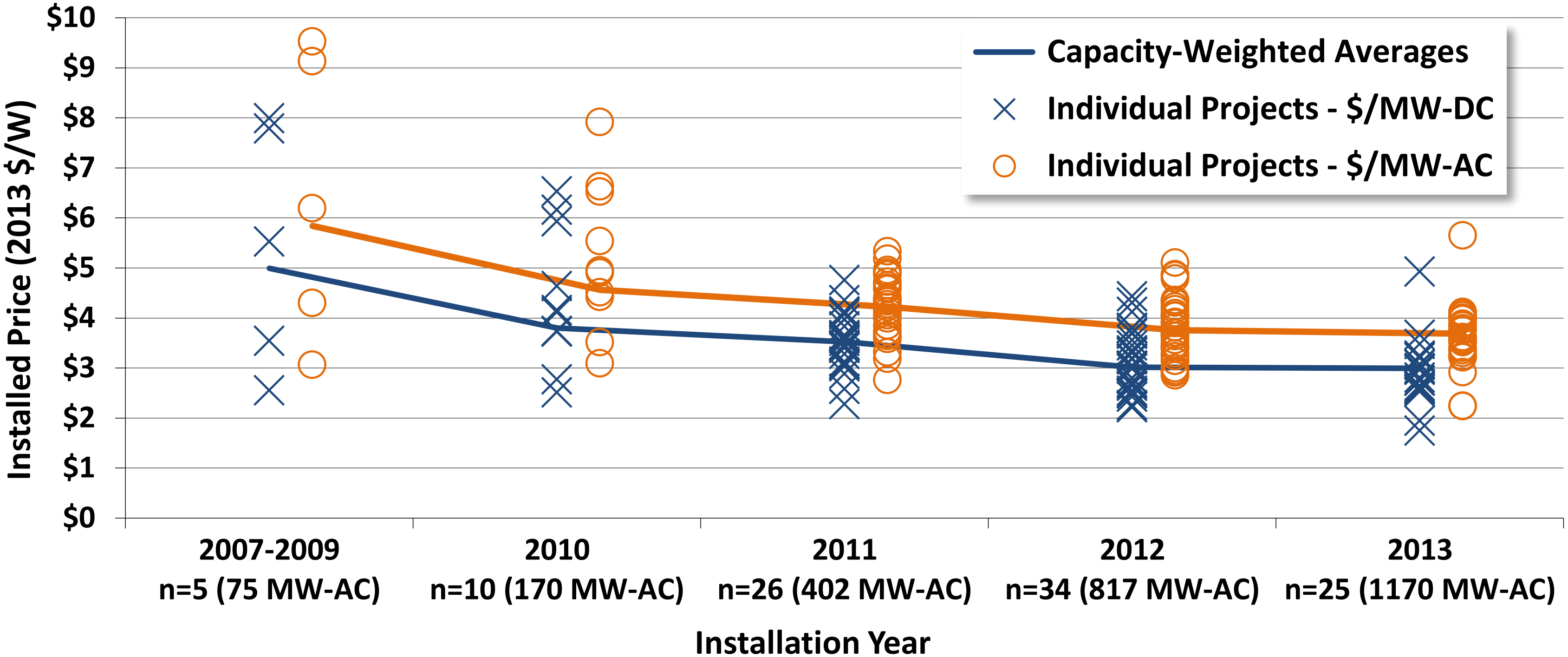
Source: Solectria

- Among the PV population, the average ILR has increased by project vintage, and pre-2012 was higher for fixed-tilt than tracking projects, and higher for thin-film than c-Si projects
- The 2012/2013 convergence in average ILR suggests increasing recognition of the economic benefits of a higher ILR

- As module costs have fallen, projects have increasingly oversized the DC array relative to the AC inverter rating (boosting the "inverter loading ratio" or "ILR") as a way to enhance project economics (particularly with time-of-delivery pricing)
- Extra output/revenue in shoulder periods outweighs losses from power limiting

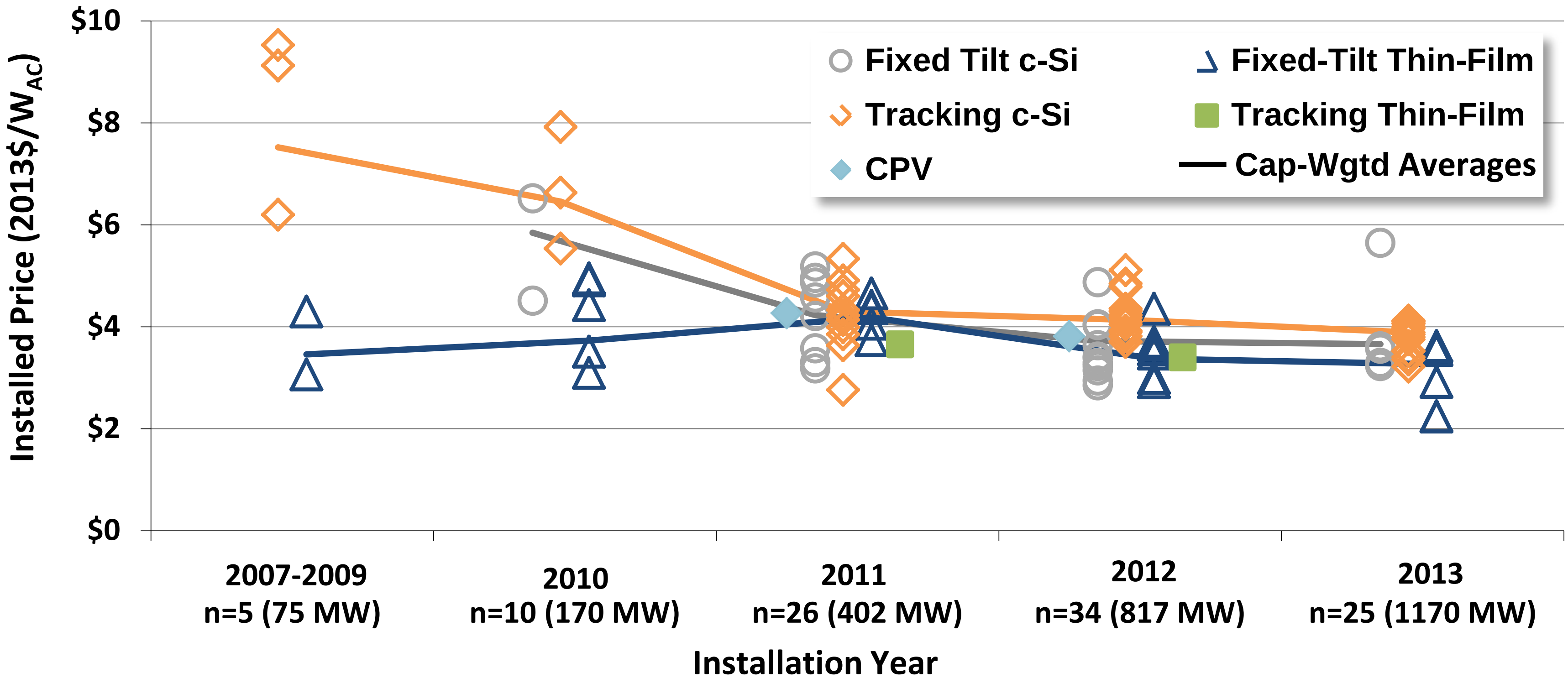


Installed Prices Have Fallen Since 2007-2009, But 2013 Prices Little Changed from 2012



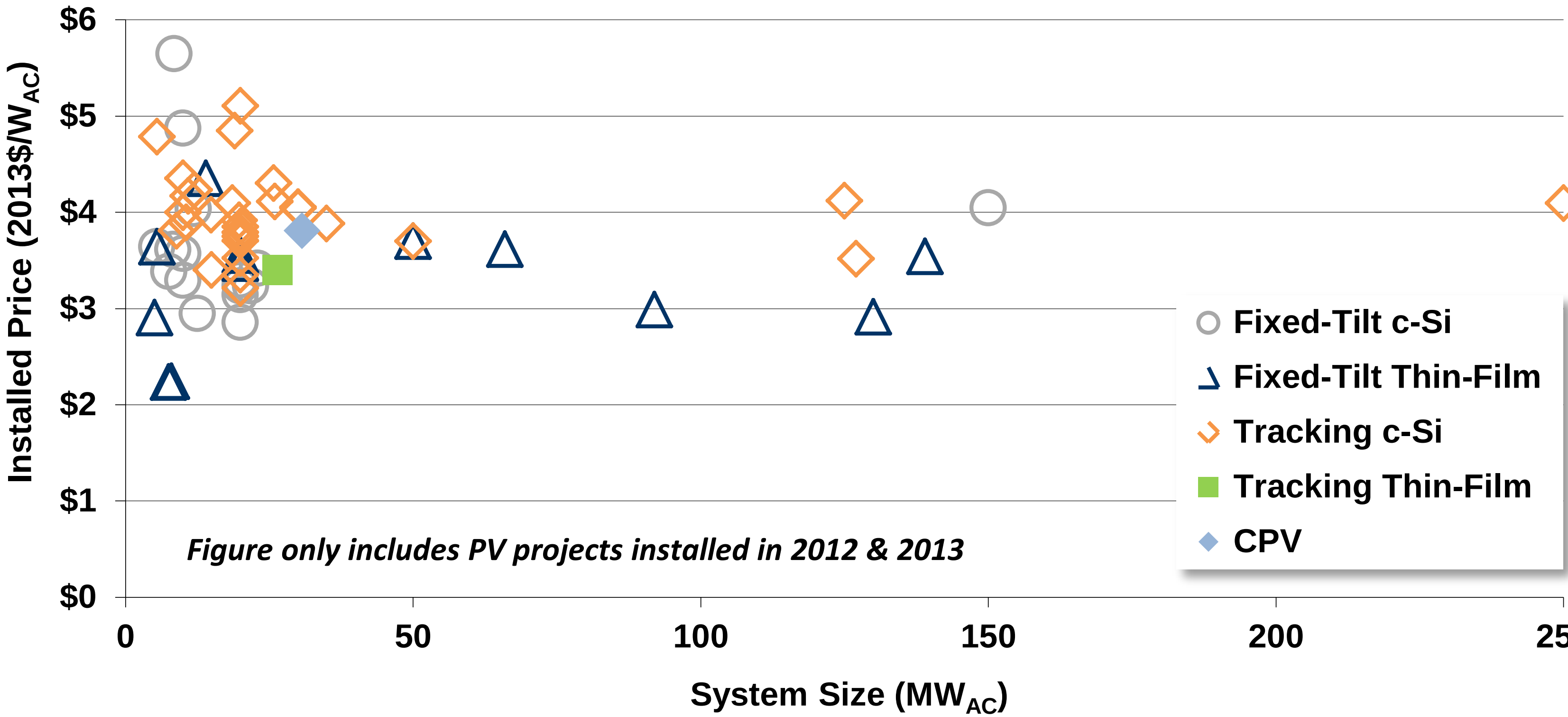
- Installed prices are shown here in both DC and AC terms, but because AC is more relevant to the utility sector, all metrics used in the rest of this slide deck are expressed solely in AC terms
- This sample is backward-looking and may not reflect the price of projects built in 2014/2015
- That said, other anecdotes also suggest that installed prices may be leveling off:
  - **Example:** PNM recently filed for regulatory approval of 40 MW_{AC} to be built in 2015 at a contracted price of just $1.98/$W_{AC}$, down only slightly from the $2.03/$W_{AC}$ it is paying for 23 MW_{AC} being built in 2014 (and compared to $2.25/$W_{AC}$ in 2013 and $3.99/$W_{AC}$ in 2011)

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



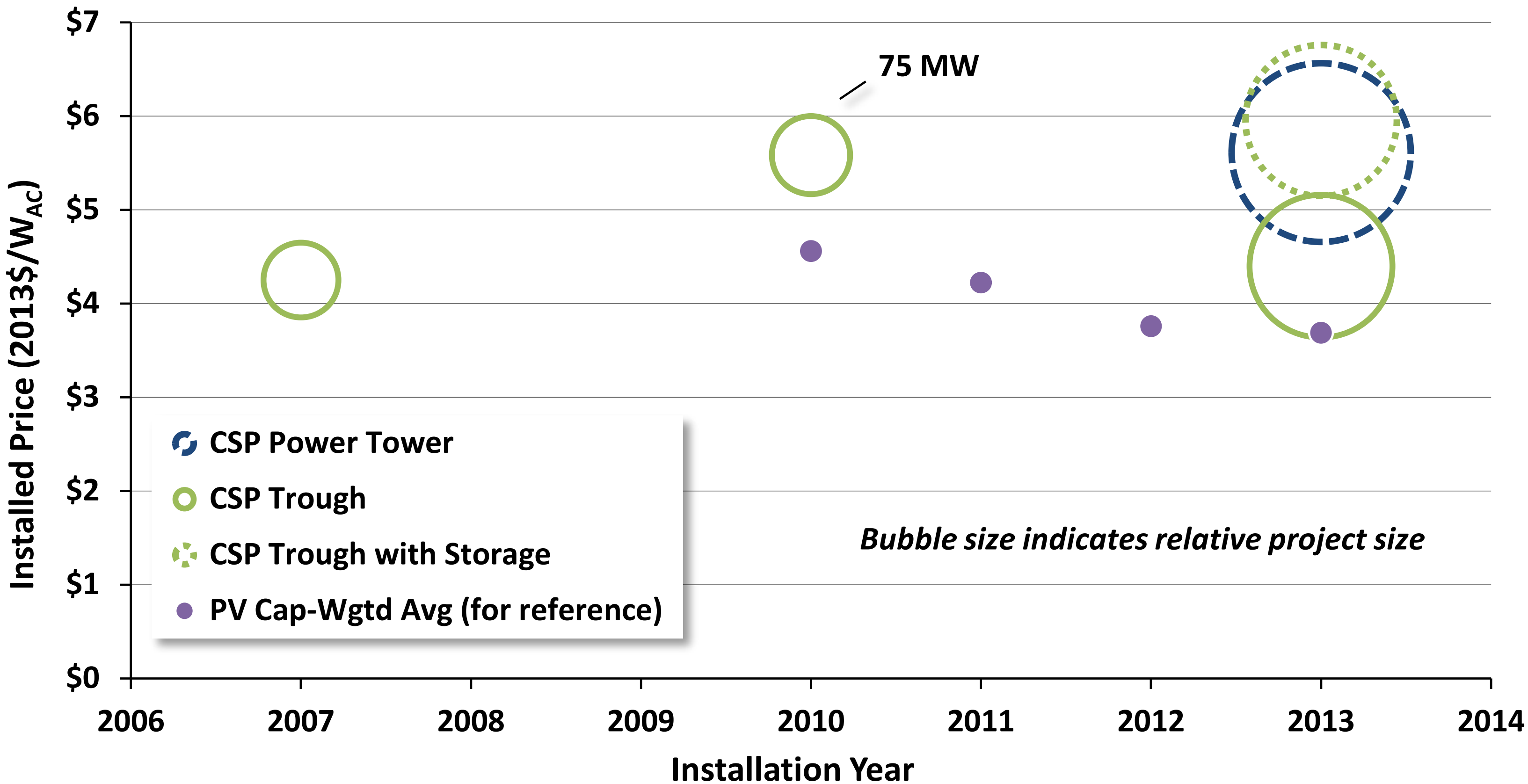
- Price of c-Si projects largely converged with thin-film in 2011 (coincides with growth of c-Si projects in the overall population); little price difference since
- Small (~$0.20/W_{AC}$) premium for tracking over fixed-tilt in 2013
- Two CPV projects priced similar to PV in 2011/2012

Evidence of Scale Economies is Elusive



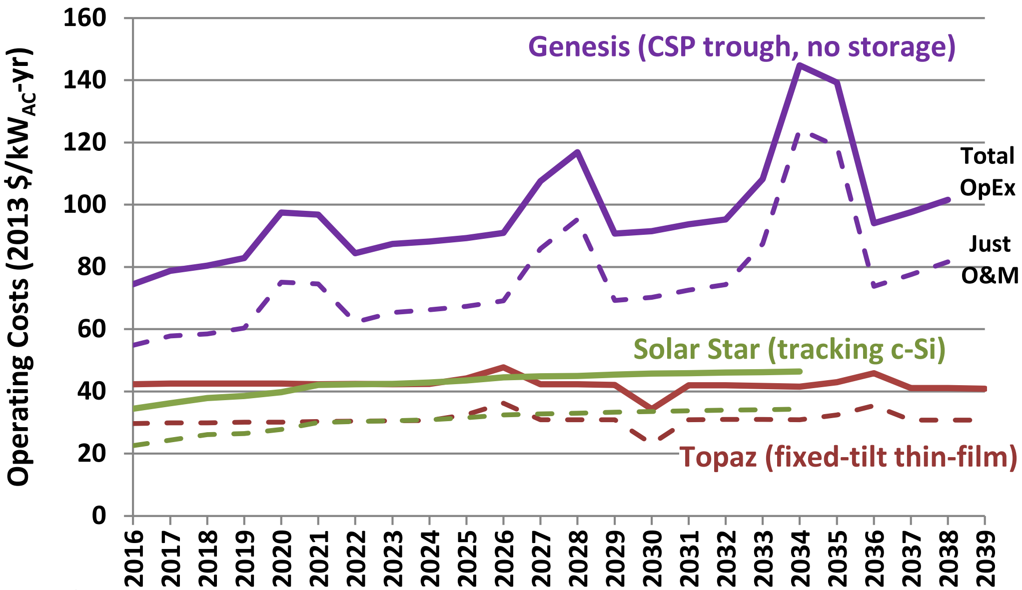
- Overall variation in installed prices does seem to narrow as size increases, but average price level in the sample does not decline (either across the full sample or broken out)
- Perhaps economies of scale are most readily seen at project sizes under 5 MW_{AC}?
  - ➢ Modular/scalable “power block” solutions from manufacturers like SunPower and First Solar may have already wrung out most of the scale economies otherwise available to larger projects
  - ➢ Larger projects may face greater (and more expensive) development barriers, which could offset any scale economies

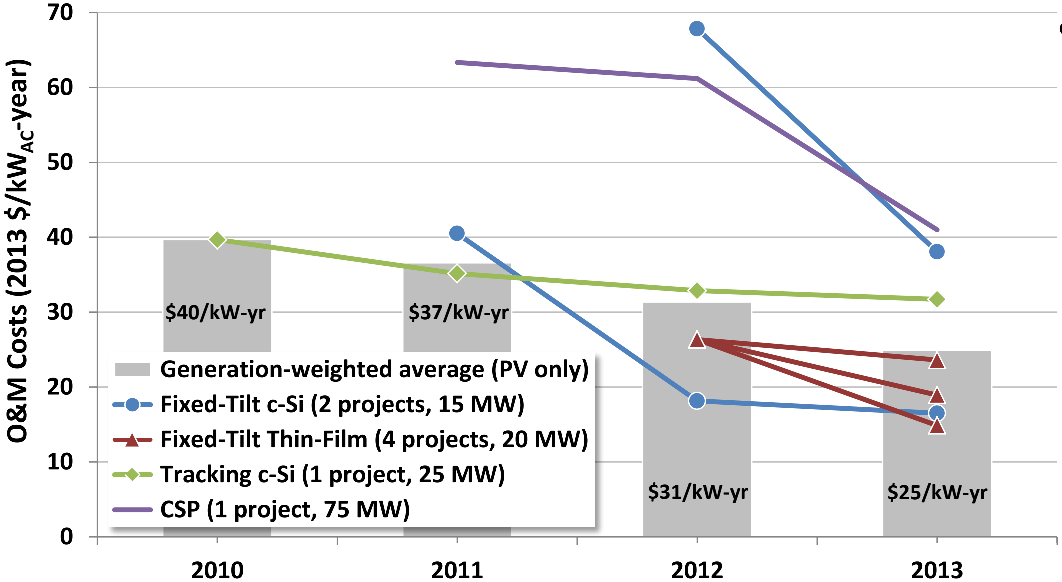
Installed Price of CSP Exceeds PV On Average



- Small sample of 5 projects (3 built in 2013) makes it hard to identify trends
- In 2013, power tower project (without storage) falls in between trough projects with and without storage
  - ➢ $1.55/W$_{AC}$ difference between similar-sized trough projects with and without storage

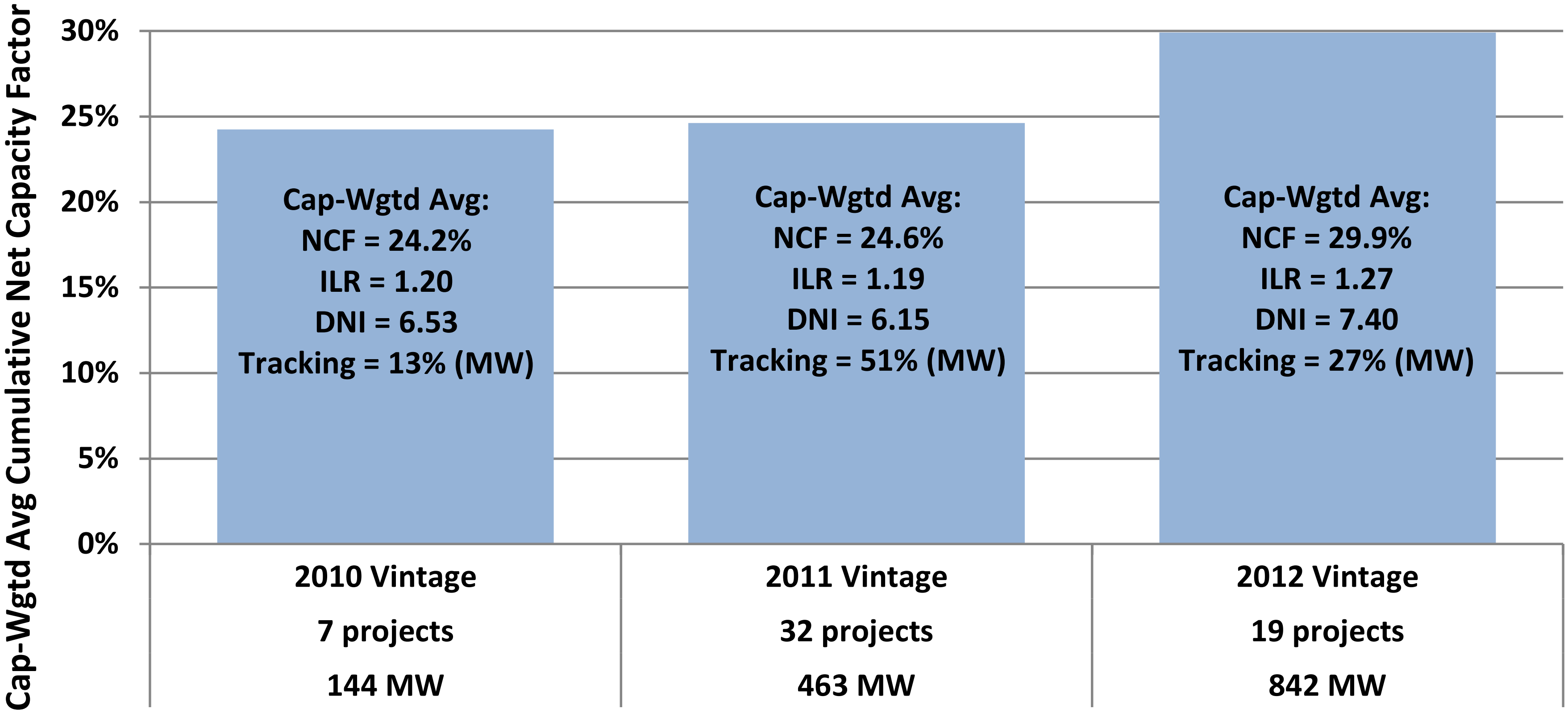
O&M Cost Data Still Very Thin, But Largely Consistent With Early Years of Cost Projections





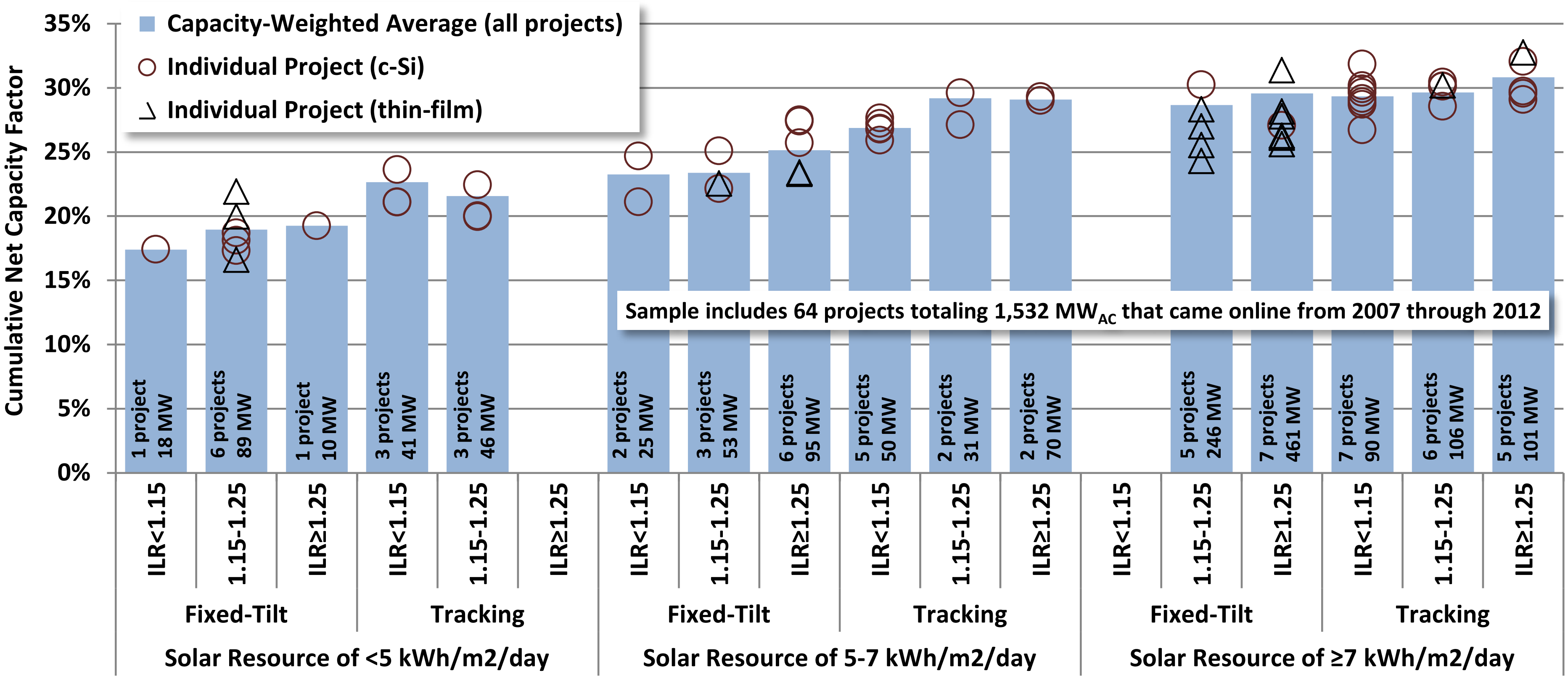
- Due to limited empirical data (due to under-reporting), the report compares ***projected*** project-level O&M costs pulled from bond rating agency research (top graph) to what limited empirical data are available so far (bottom graph)
- Results suggest that actual operating costs (from a VERY limited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

PV Capacity Factor Driven By Underlying Project Characteristics (DNI, ILR, Tracking)



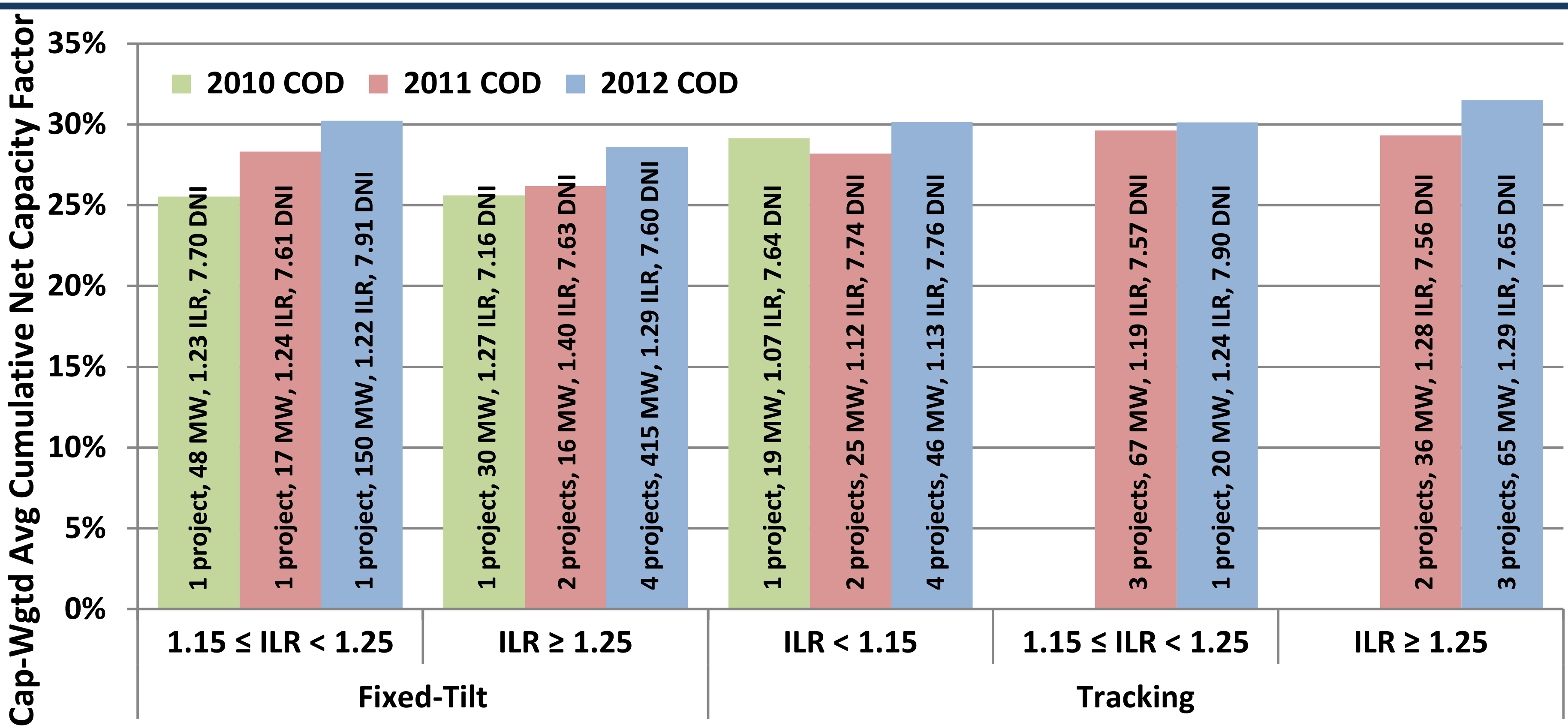
- 2010/2011 vintages have similar average capacity factors: driven by similar ILR, in combination with offsetting DNI/tracking differences
- Significant jump in 2012 vintage driven by substantially higher ILR and DNI (despite less tracking)
- The next slide focuses in on these drivers

27.5% Sample-Wide Capacity Factor, But With Large Project-Level Range (driven by DNI, fixed vs. tracking, ILR)



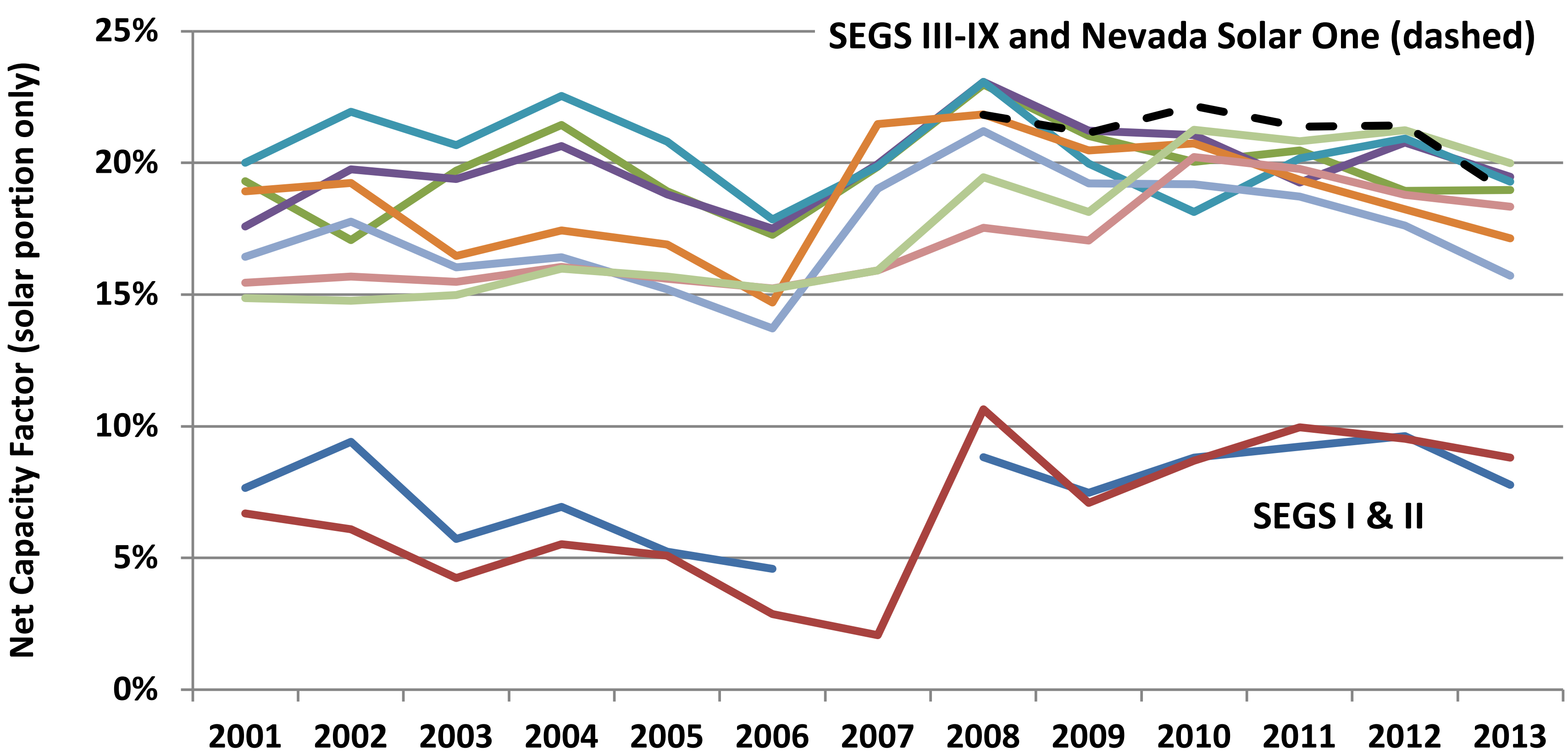
- **Solar Resource (DNI):** highest resource bin 30-50% higher capacity factor than lowest
- **Tracking:** Provides ~20% boost on average in lowest resource bins, less in highest
- **ILR:** 5-10% difference between highest and lowest ILR bins
- **Module type:** No discernible pattern between c-Si and thin-film

Further Investigation of a Time Trend
(based on ILR and DNI)



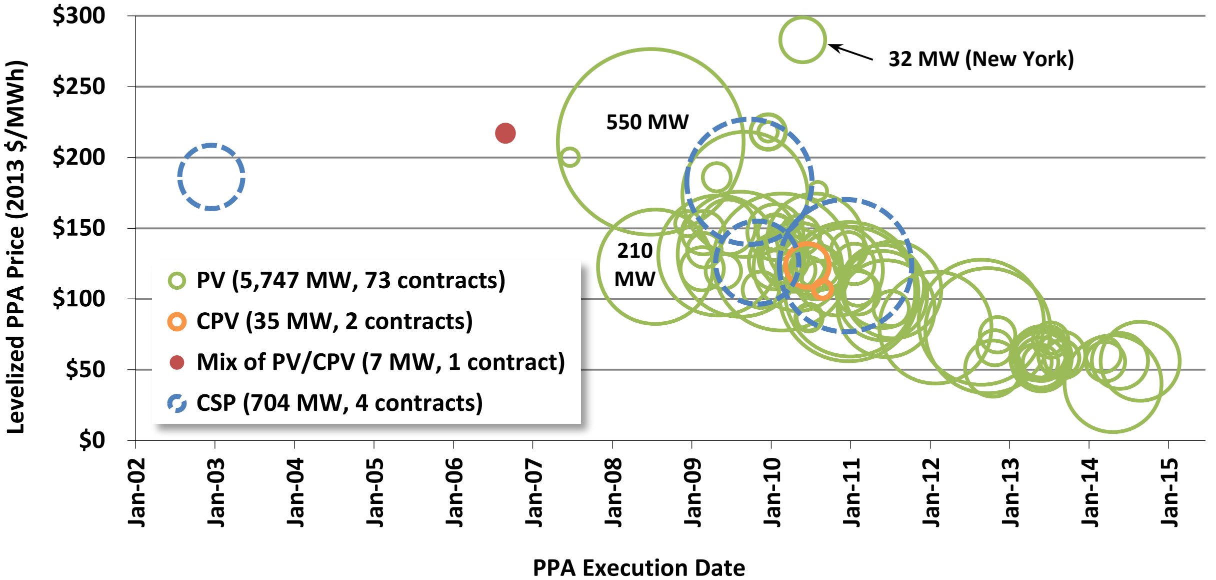
- Graph shows only the highest solar resource bin from previous figure, and 2010-2012 vintage projects only
- In general, later vintages have higher ILR and DNI supporting a higher capacity factor
- Were they included, the two CPV projects would fall into the second bin from the right – with capacity factors of 19.7% and 24.7%, they appear to be underperforming PV

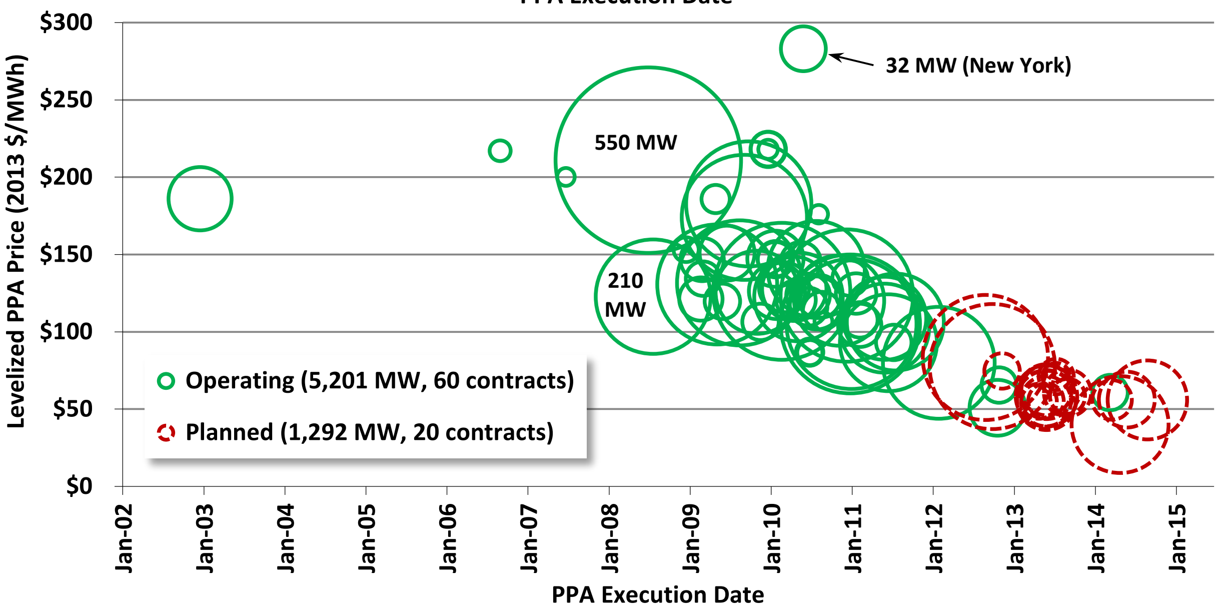
CSP Trough Solar-Only Capacity Factors Below PV (at similar DNI sites)



- SEGS III-IX from the 1980s still going strong (not far below 2007's Nevada Solar One)
- SEGS I and II have lower capacity factors due to a combination of operational practices, smaller collector fields, and less-efficient turbines
- All of these CSP projects have lower capacity factors than PV sited in a similar resource
- 2013/14 CSP build-out is not reflected here – need a full year of operating history

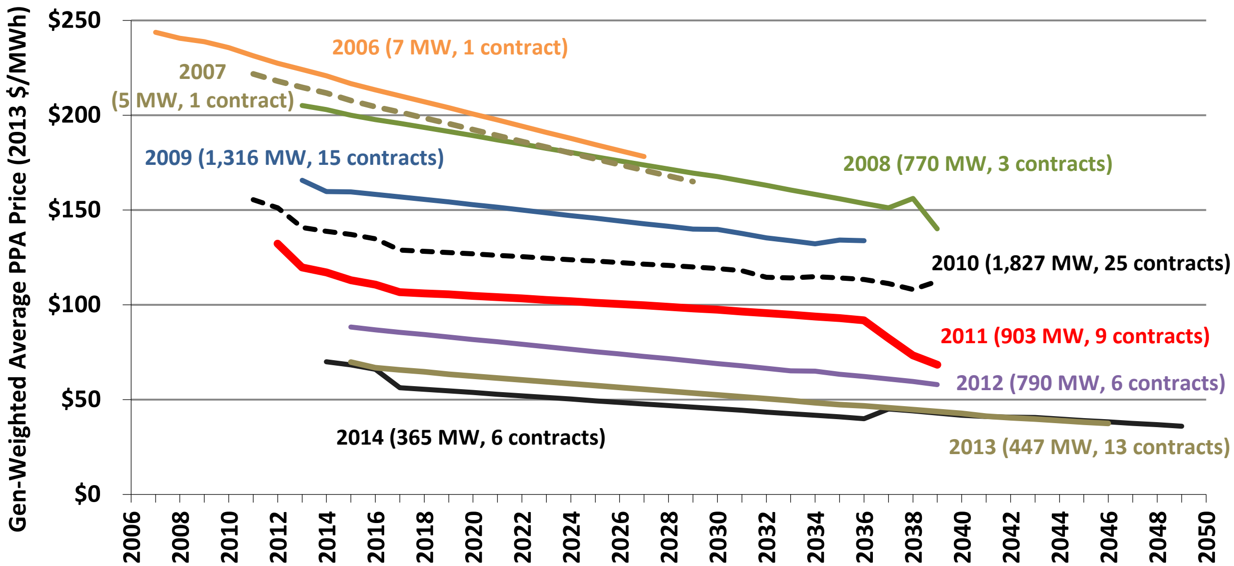
Levelized PPA Prices Have Fallen By More Than Two-Thirds Since 2009

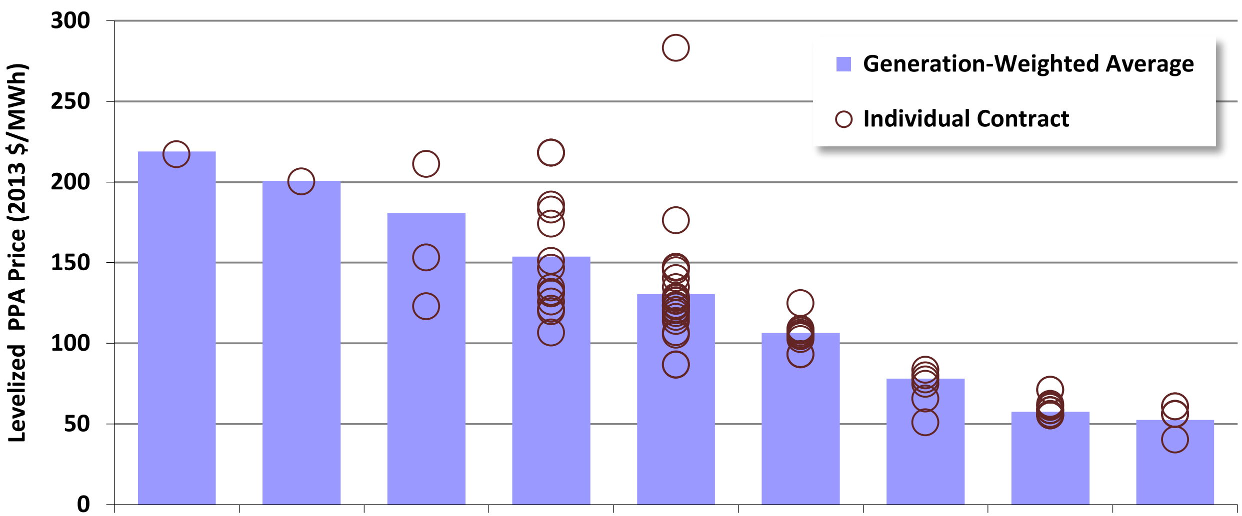




- PPA prices are levelized over the full term of the contract, after accounting for any escalation rates and/or time-of-delivery ("TOD") factors
- Strong downward price trend since 2007
- Smaller projects (e.g., 20 MW) no less competitive
- CPV and CSP largely competitive ***at the time***, but little visibility recently
- 82% of the sample is currently operational (or at least partly operational) – see bottom graph

Levelized PPA Prices Fell By ~$25/MWh per Year Through 2013, Less in 2014





PPA Year:	2006	2007	2008	2009	2010	2011	2012	2013	2014
Contracts:	1	1	3	15	25	9	6	13	6
MW:	7	5	770	1,316	1,827	903	790	447	365

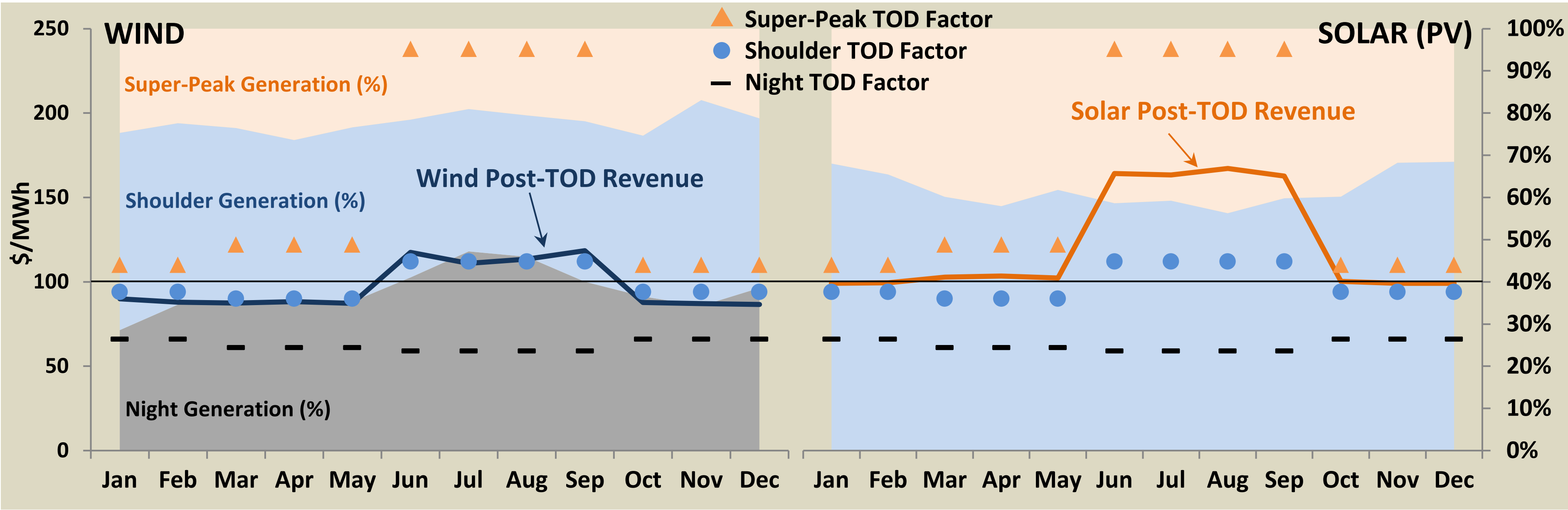
- Two-thirds of sample has flat annual PPA pricing (in nominal dollars), while the rest escalate mostly at low rates intended to keep pace with inflation – this means that average sample PPA prices ***decline*** over time in real dollars (top graph)
- Top graph also shows the steady march downward by PPA vintage
- Bottom graph levelizes each line in the top graph, to provide a clearer picture of the time trend
- Levelized PPA prices now down around $50/MWh

What Does it Take to Break $50/MWh?

Modeling Parameter	Value	Notes
Installed Cost ($/$W_{AC}$)	1.85	***below slide 8 range!***
Capacity Factor (AC)	33%	upper end of slide 14 range
Annual Degradation	0.5%	standard assumption
Total Operating Expenses ($/$kW_{AC}$-year)	27	within slide 12 range
Sponsor After-Tax Internal Rate of Return (IRR)	10%	current market-based financing terms
Term Debt Interest Rate	5.5%	
Debt Term (years)	17	
Debt Service Coverage Ratio (P50)	1.35	
Capital Structure (%Equity/%Debt)	53%/47%	determined by model
Resulting 20-Year PPA Price (flat, no escalation)	**$49.8/MWh**	**sub-$50/MWh PPA price!**

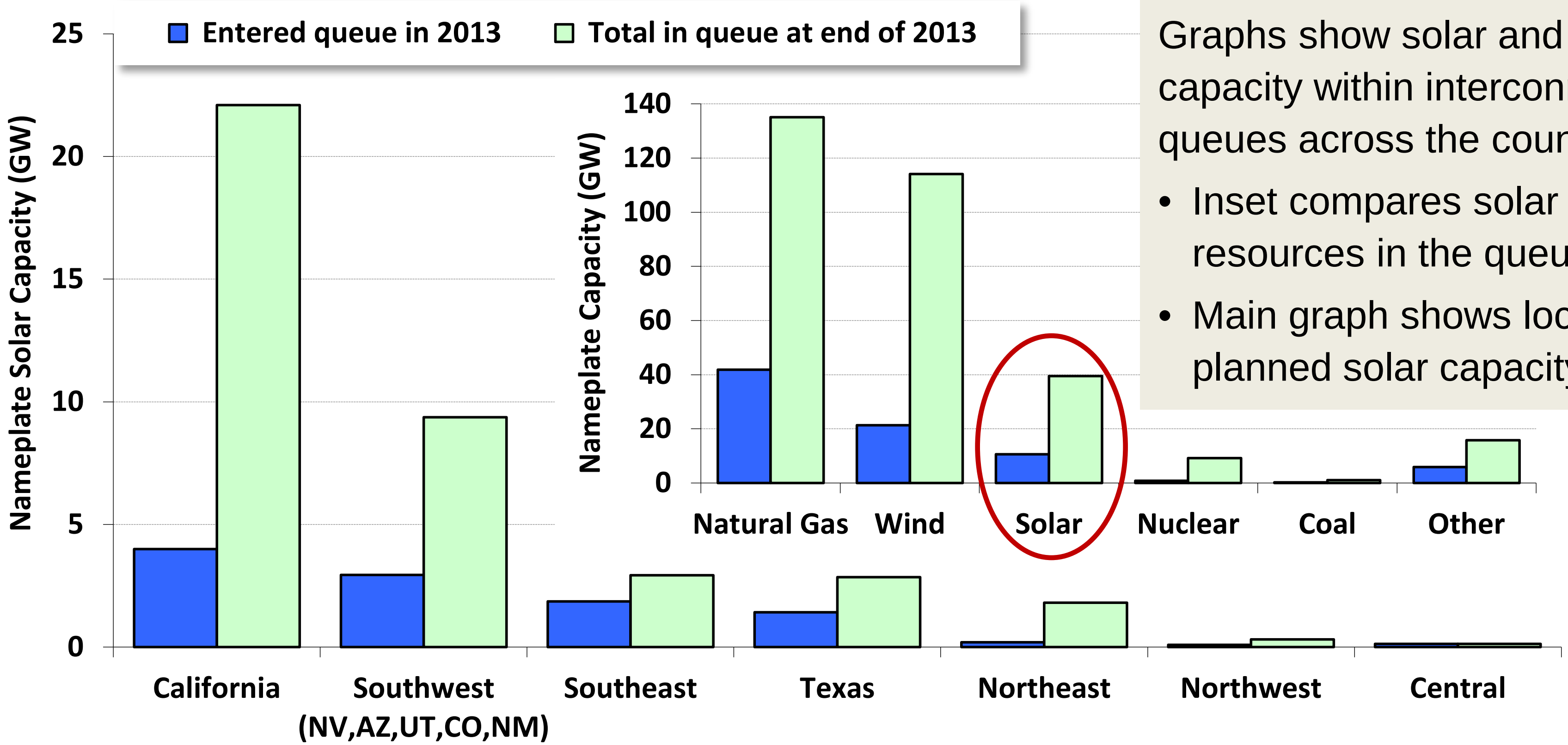
- Simple pro forma financial model assumes project sponsor has sufficient tax appetite to use all tax benefits (ITC, MACRS) efficiently – i.e., no third-party tax equity
- Using modeling inputs (other than installed cost) that fall within currently observed ranges, an installed cost of $1.85/$W_{AC}$ is needed to break $50/MWh
  - $1.85/$W_{AC}$ is below the observed range in slide 8, but may be attainable in 2014/2015/2016
- Other input combinations (e.g., higher installed cost and lower operating cost) can also break $50/MWh, and state-level incentives can also sweeten the deal

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 & PV generation profiles are from real projects selling to PG&E under TOD prices
- Over the course of a year, PV earns ***~$25/MWh more*** post-TOD revenue than wind
- Compared to a "flat block" of wholesale power (not shown), PV's TOD benefit is smaller, more like $20/MWh
- This is a PG&E example, but results are similar for other 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

Looking Ahead: Strong Solar Pipeline



Graphs show solar and other capacity within interconnection queues across the country:

- Inset compares solar to other resources in the queues
- Main graph shows location of planned solar capacity

- 39.5 GW of solar capacity was in the queues at the end of 2013 – *roughly **8 times** the installed utility-scale solar capacity in our project population at that time*
- Solar was in third place, behind natural gas and wind
- 80% is within California (56%) and the Southwest region (24%), followed by 7% each in the Southeast and Texas (ERCOT), and 5% in the Northeast
- ***Not all of this capacity will be built!*** (but much of what is will likely be built prior to 2017)

Questions?

Full report, slide deck, and recorded webinar available at:

http://emp.lbl.gov/reports/re

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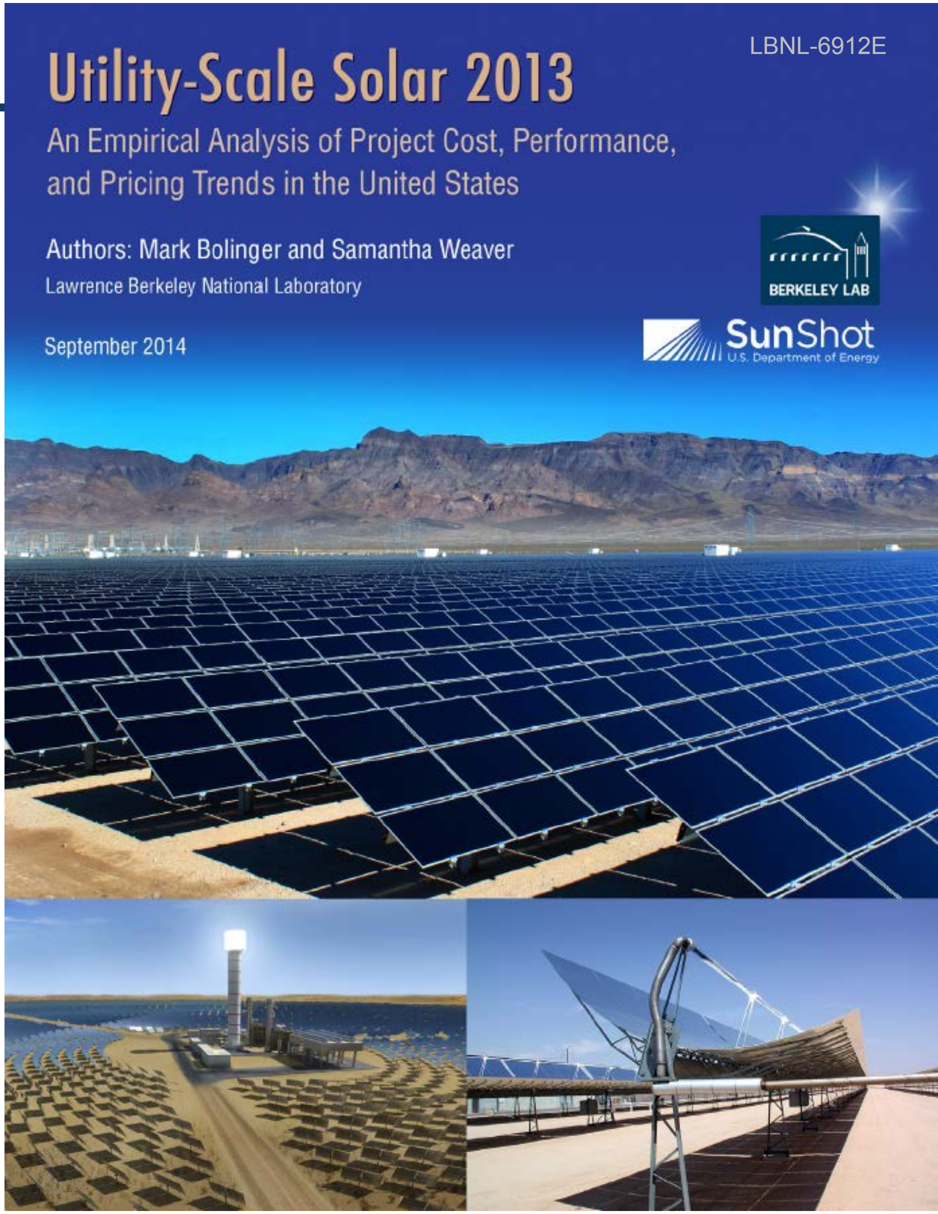

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