



Photovoltaics: Technology Trends and Future Perspectives

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Innovation Scout for Photovoltaics

Presentation to SPREE / UNSW

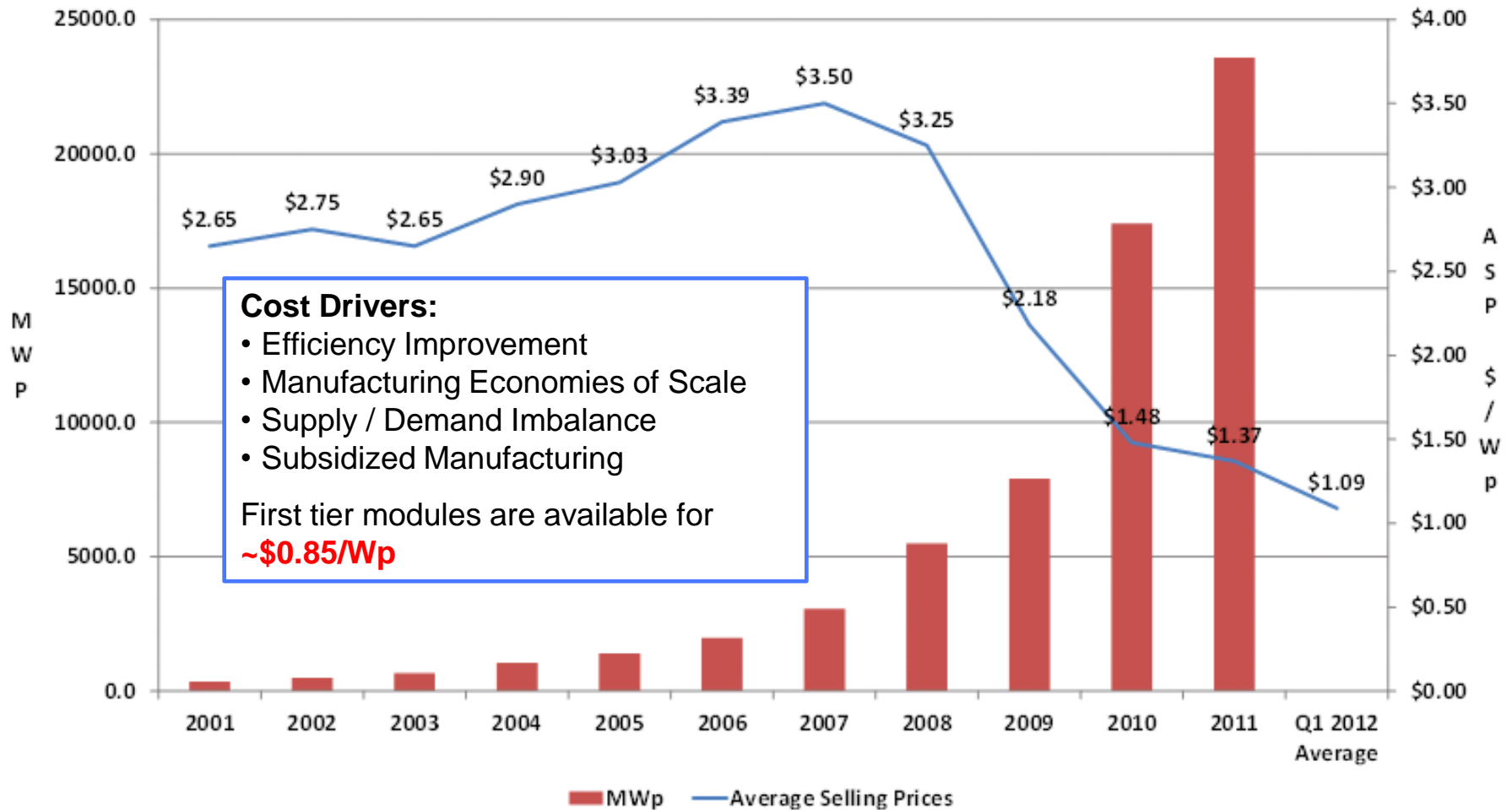
Sydney, Australia

July 26, 2012

Key Takeaways

- **Industry growth around conventional photovoltaics will make it difficult to unseat incumbent technologies in traditional markets**
 - Crystalline Silicon PV will remain the dominant technology while other products are developed for specific markets
- **Power electronics will be smarter, module integrated, higher efficiency, and enable improved grid support and functionality**
 - This will lead to higher efficiency systems combined with easier installation, ultimately yielding improved system economics.
- **Improvements across the value chain will result in continuous downward system pricing trends**

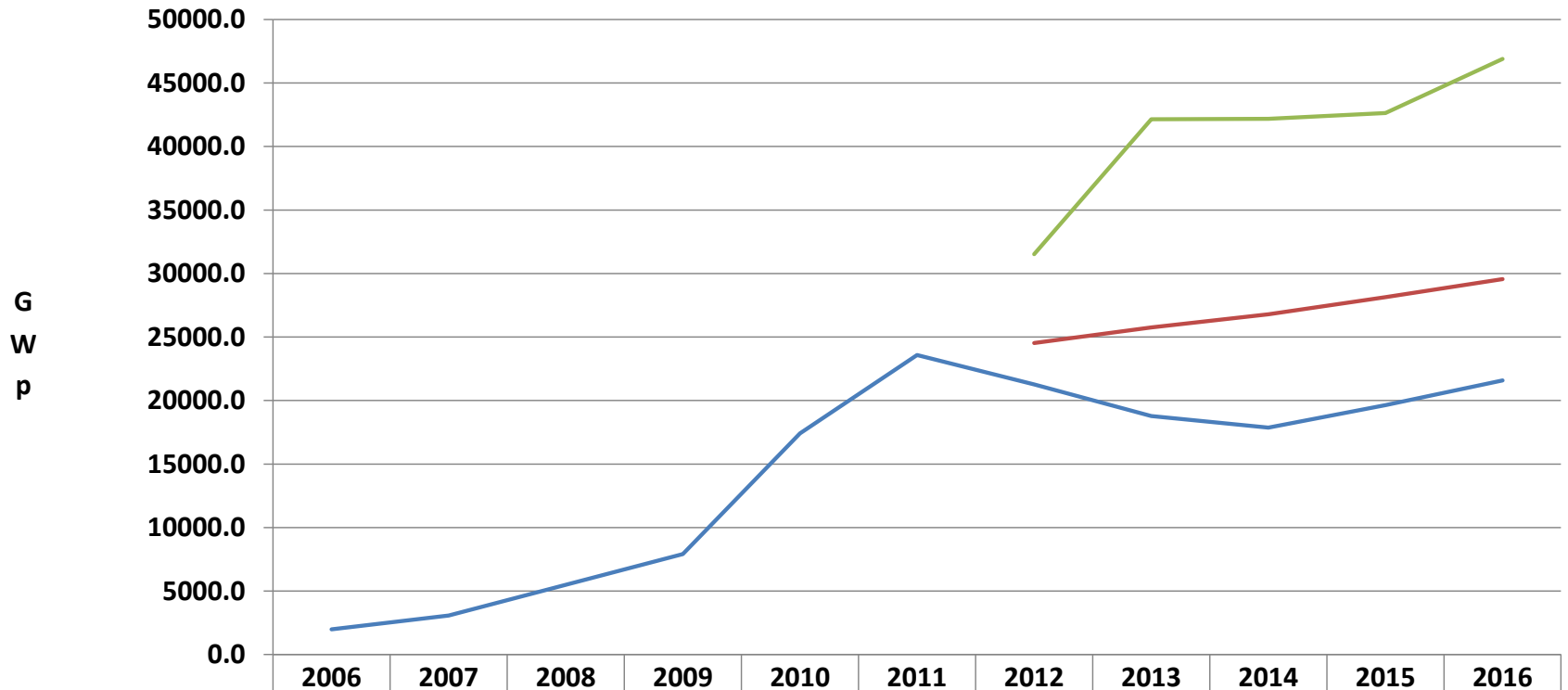
Historic and Current PV Industry Pricing



Source: Paula Mints – Navigant PV Services Program

Global PV Market Forecast

RECESSION, CONSERVATIVE, ACCELERATED FORECAST 2006-2016 (MWp)

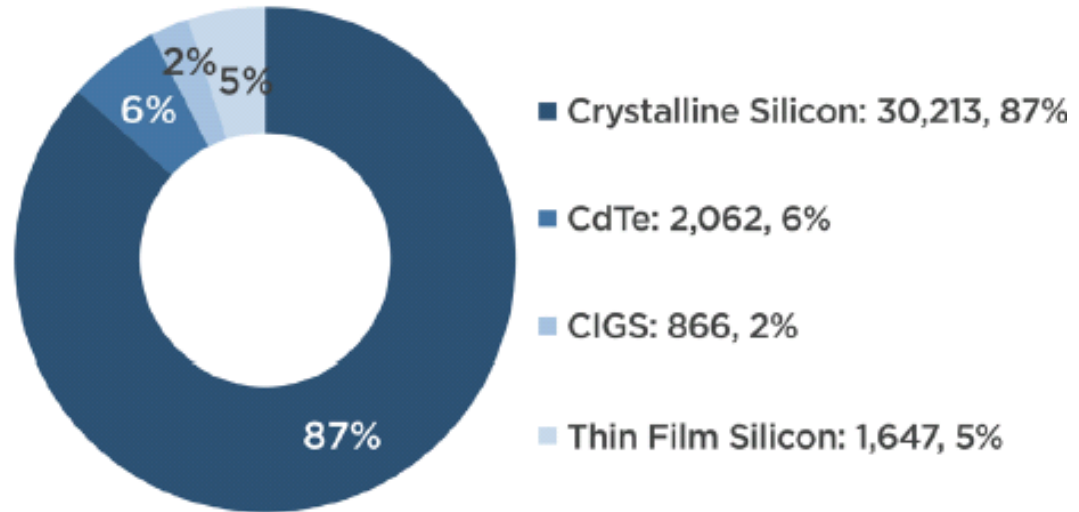


	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
History/Reduced Incentives	1984.2	3073.0	5491.8	7913.3	17402.7	23579.3	21269.5	18770.0	17863.7	19629.9	21586.3
Conservative							24528.4	25759.0	26798.1	28145.9	29562.5
Accelerated							31518.4	42151.3	42181.7	42633.0	46894.8

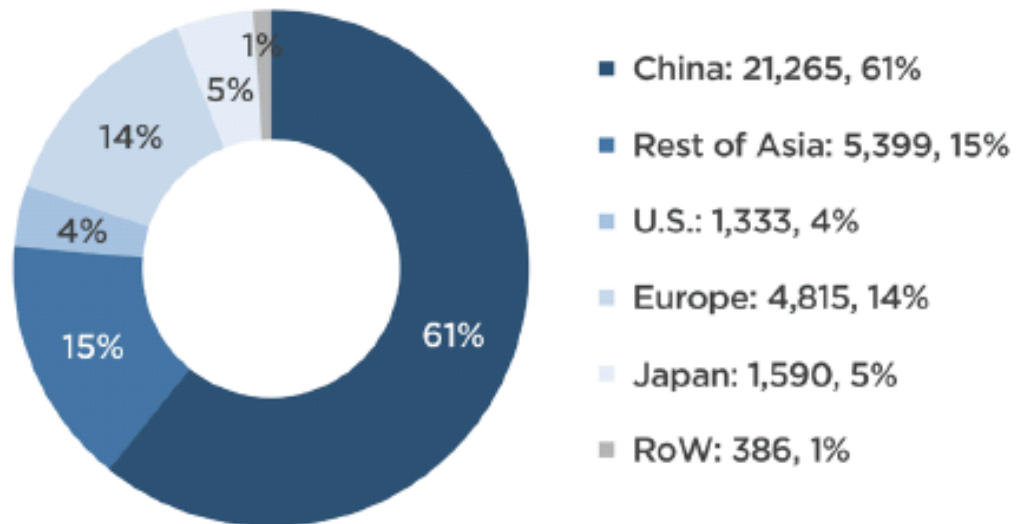
Source: Paula Mints – Navigant PV Services Program

Module Production in 2011

- By Technology



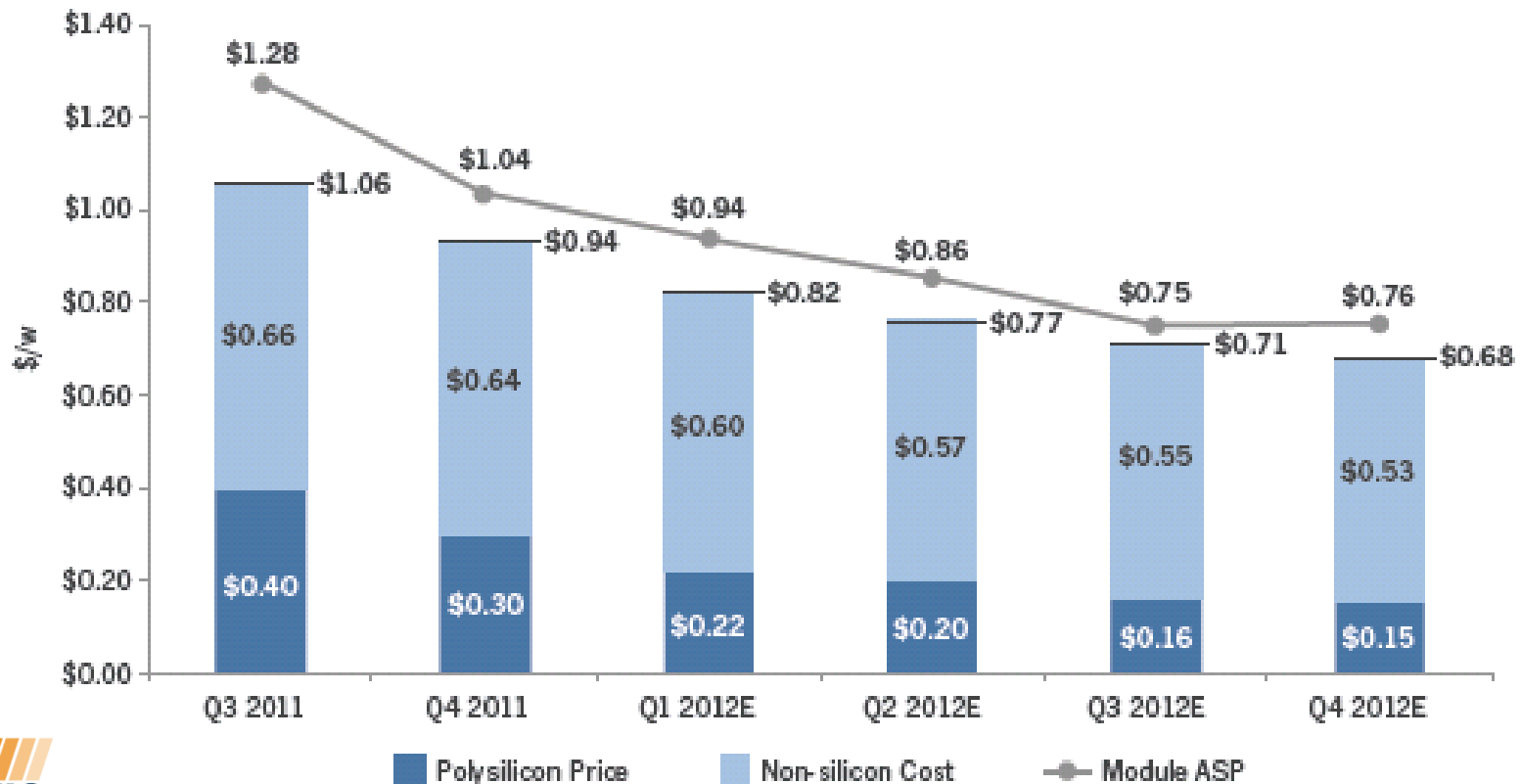
- By Region



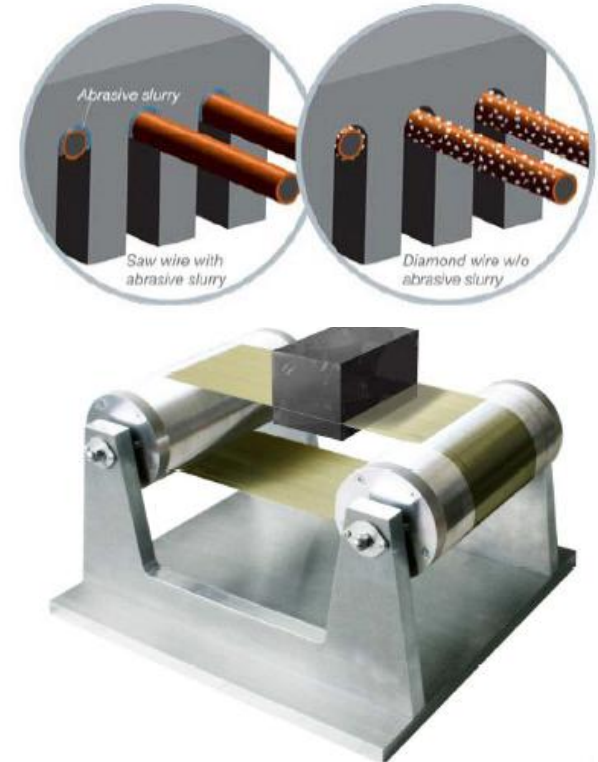
Source: GTM, PV News, May 2012

Production Costs are Coming Down

MANUFACTURING COST STRUCTURE - TIER 1 CHINESE WAFER/CELL/ MODULE PRODUCER, Q3 2011-Q4 2012E

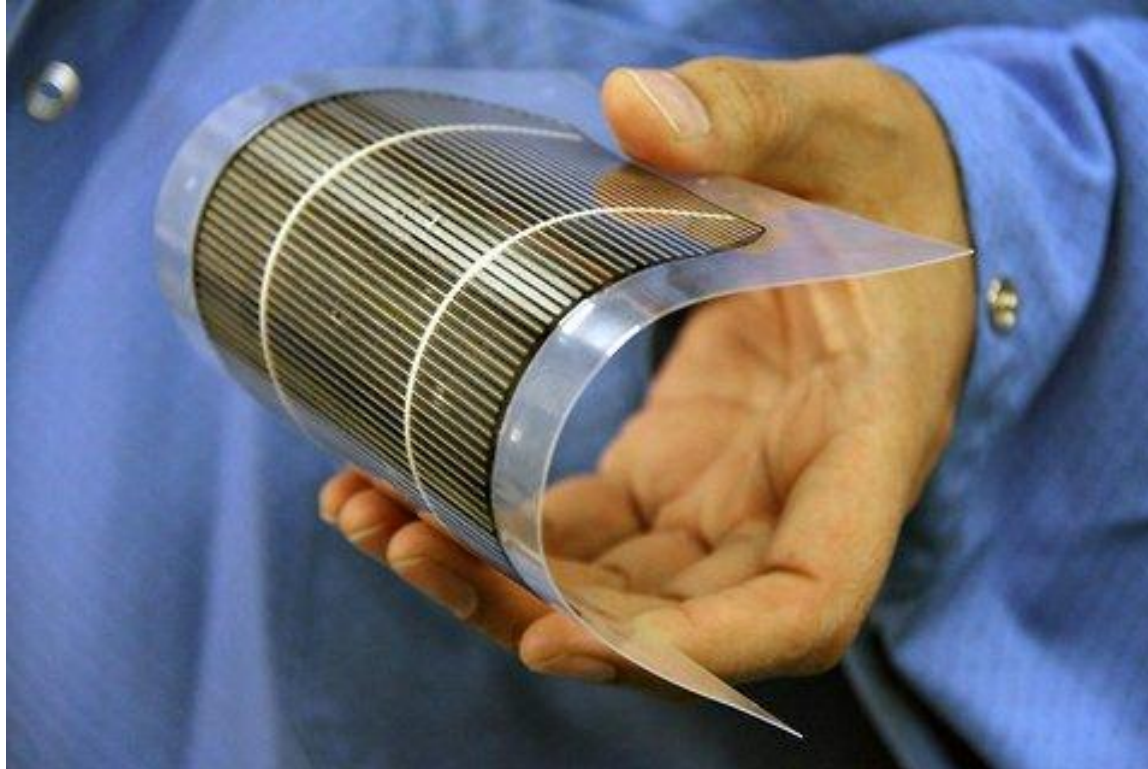


Thinner Wafers = Reduced Material Cost



- **Twin Creeks Technologies unveils the Hyperion “Ion Cannon” to create thinner silicon wafers.**
- **Wire saw technology transitioning from traditional wire / abrasive slurry mix to diamond wire cutting, reducing “kerf” losses while improving wafer yield.**

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Rooftop Specific Technologies for Weight Constrained Projects



AC Modules Will Be Here Shortly



- **Streamlined design will lead to inverters on the module, leading to higher efficiency, faster installation, and improved economics.**

The Onset of the Smart Inverter

- **Improving Grid Reliability**

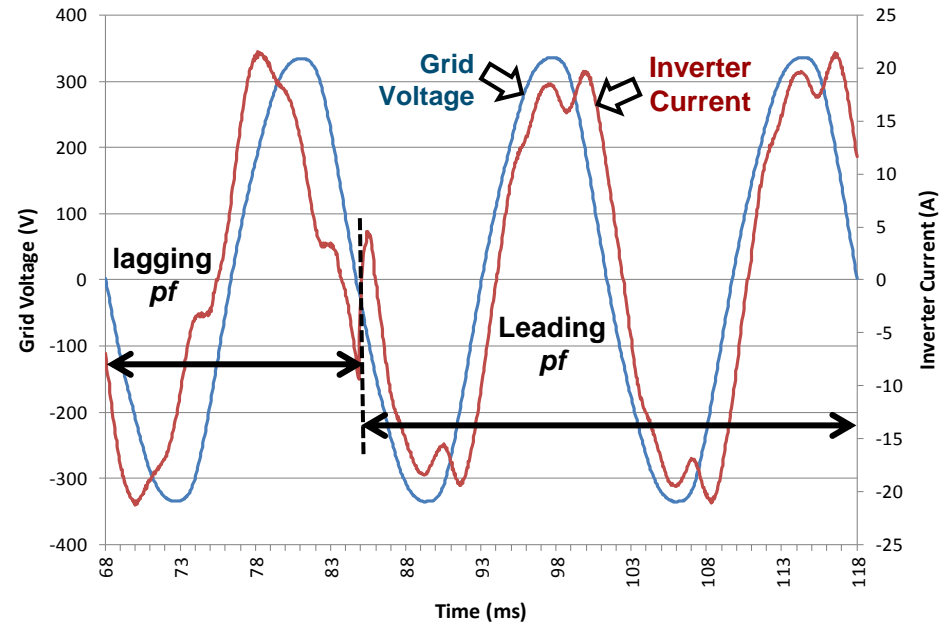
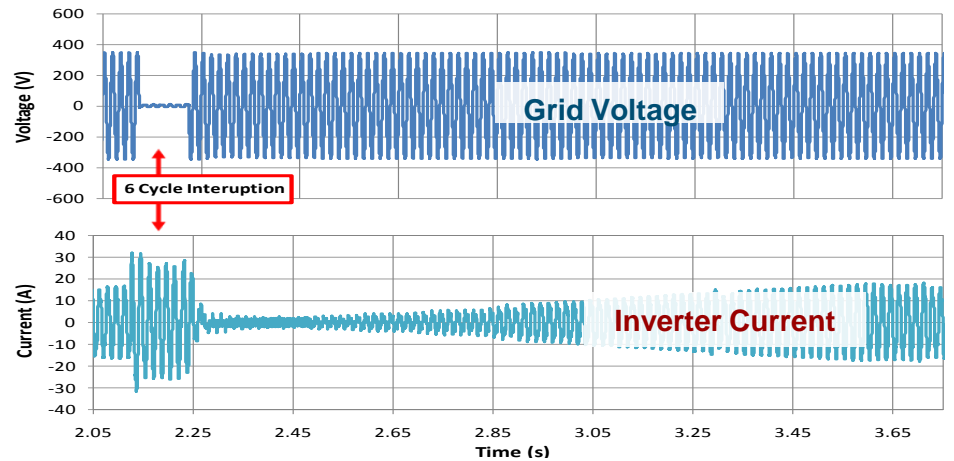
- Inverter able to ride through momentary interruptions

- **Providing VAR Support**

- Finer steps and faster response compared to capacitor banks

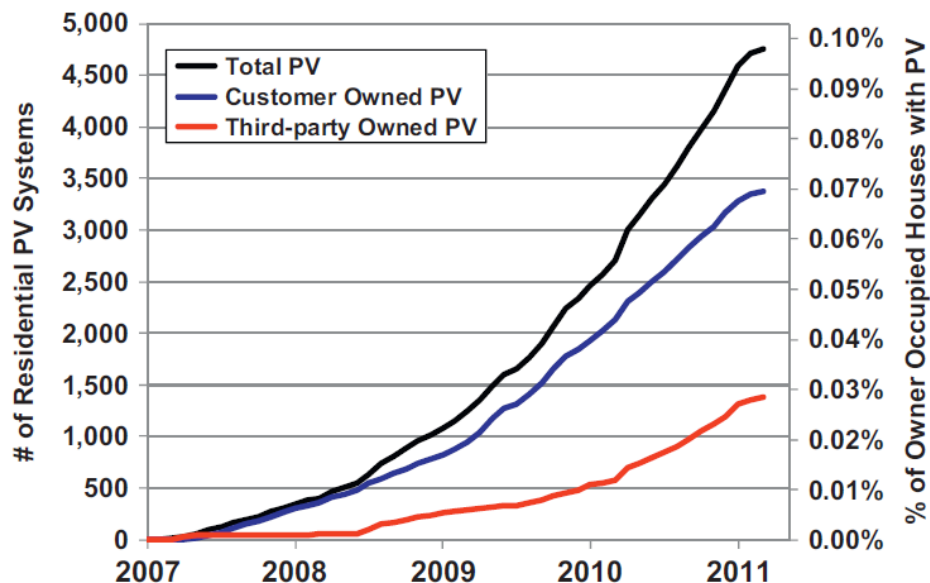
- **Power Curtailment**

- Faster Response for power curtailment



Distributed PV Ownership Also Growing

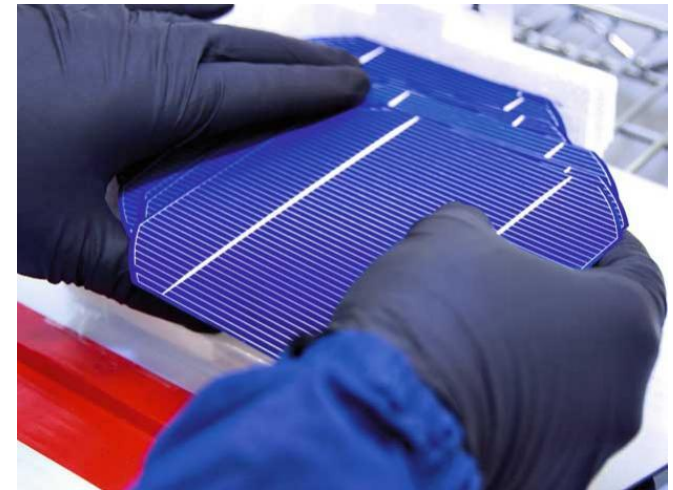
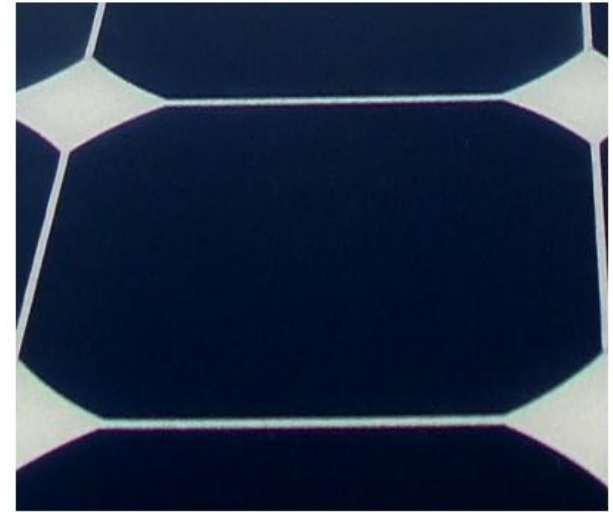
- **Third-party owned PV gaining market share in multiple markets**
- Distributed PV economics depend on incentives, retail rates and rate design, e.g., net metering
- Third party residential PV markets growing rapidly, > 60% market share in CA in 2012
- PV leasing products appear to be enticing new demographics to adopt PV in LA
- Third-party adoption trends likely to extend to other states



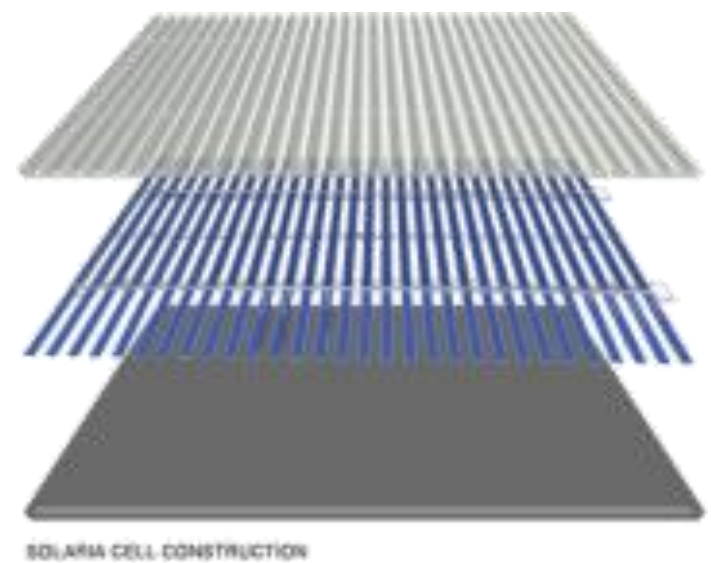
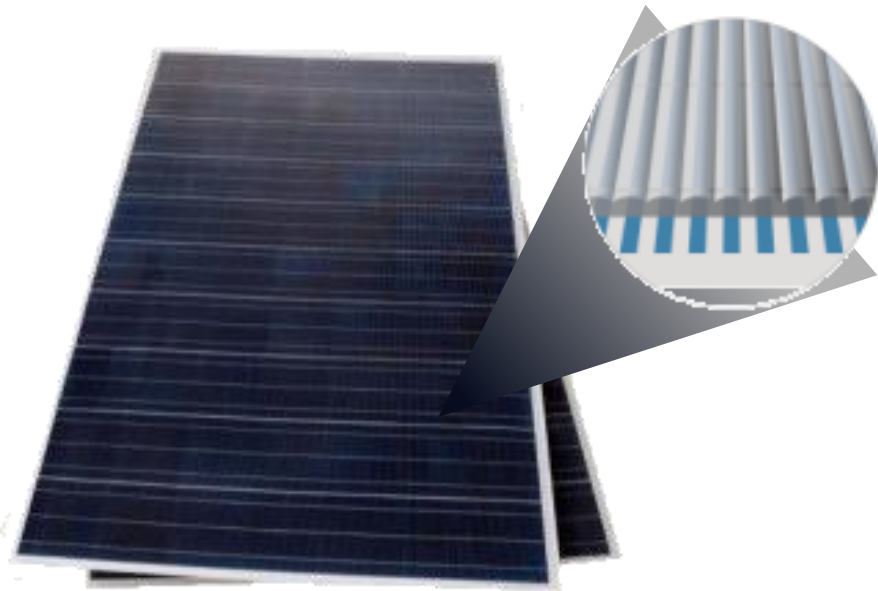
Source: Drury et al. 2012 (NREL)

Performance Improvements and Market Enablers for Conventional PV

- Transition to rear contact cells (reduced front shading)
- Copper metallization in lieu of silver
- Cheap tandem cell architecture based on crystalline – Silicon cell foundation
- Selective emitters (improved blue response, better able to absorb high energy photons)
- Gen 110 (*Startup designed to identify high rate customers for third party installations*)
- Third Party leasing via no upfront costs
- Breakthrough technologies exist... but constrained to lab development through 2020



Low Concentration PV

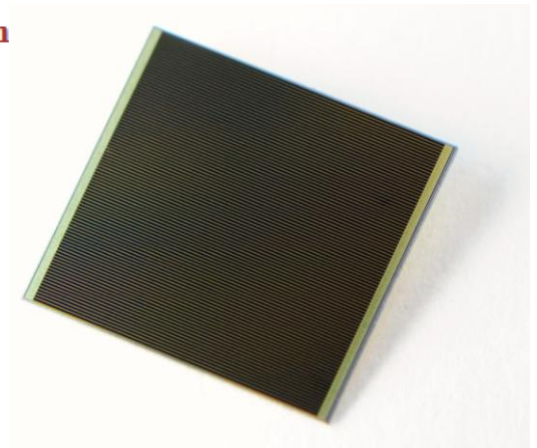
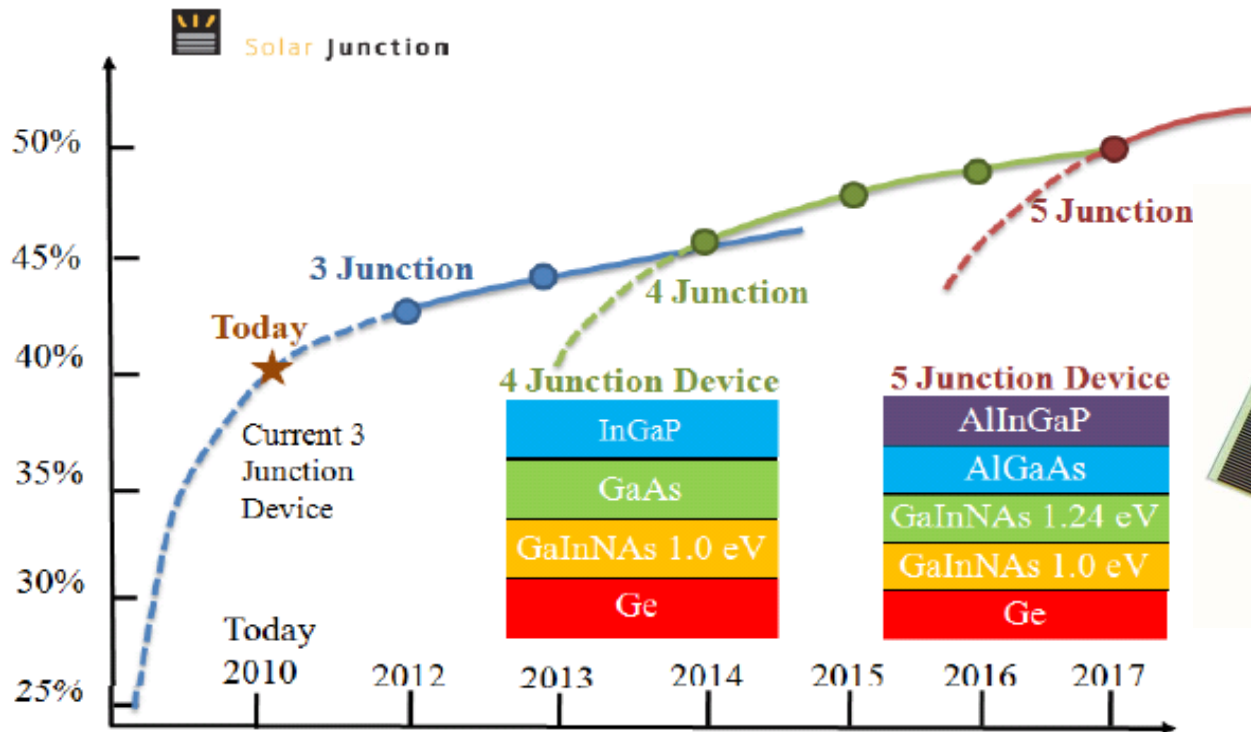


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Third Generation PV

- **Third Generation (High Efficiency, Multi-junction, Multi-exciton, Hot Carrier Cells)**

- More involved cell architecture, primarily research based currently with the exception of multi-junction (MJ), significantly higher efficiencies



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Together...Shaping the Future of Electricity