

A New Era for Solar



Sarah Kurtz



UC Solar Symposium

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San Francisco, CA

Outline

- Solar is coming of age! A new era for solar!
 - Is there a ceiling?
- PV technology
 - The success
 - The challenge(s)
 - The opportunities

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A new era for solar

[Sarah Kurtz](#), [Nancy Haegel](#), [Ronald Sinton](#) and [Robert Margolis](#)

The field of photovoltaics has grown tremendously over the past decade and in 2015 solar cell deployments accounted for 20% of the expansion of global electricity capacity.

IEA agrees: It's a New Era for Solar

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New era of solar power is now upon us, IEA says

      341 SHARES

- "What we are witnessing is the birth of a new era in solar PV," Birol said.
- According to the IEA's report on Wednesday, renewables accounted for nearly two-thirds of net new power capacity in 2016.

Anmar Frangoul
Published 3:02 AM ET Wed, 4 Oct 2017 | Updated 7:52 AM ET Wed, 4 Oct 2017



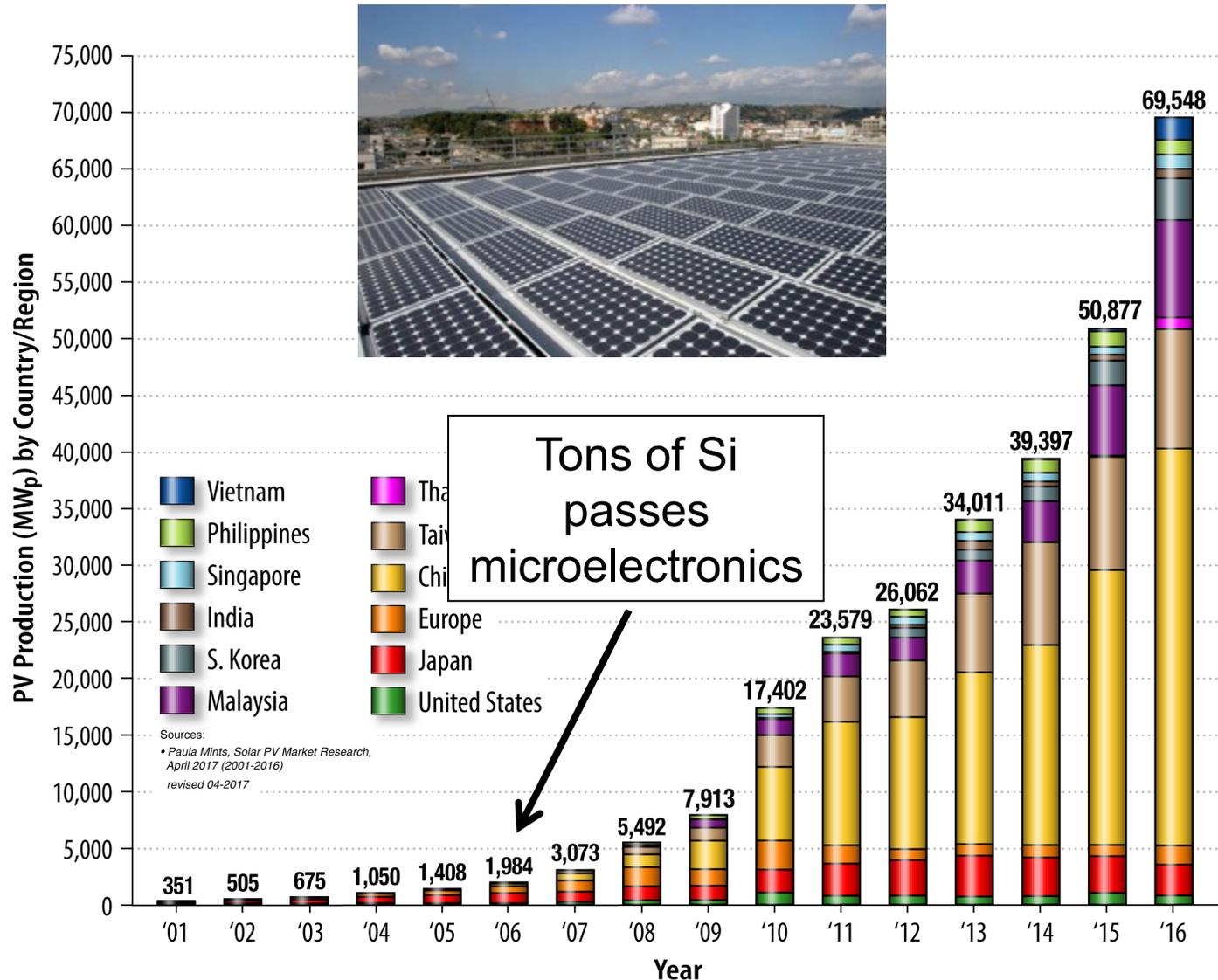

LATEST STORY FROM TOTAL

A \$300 billion energy efficiency market

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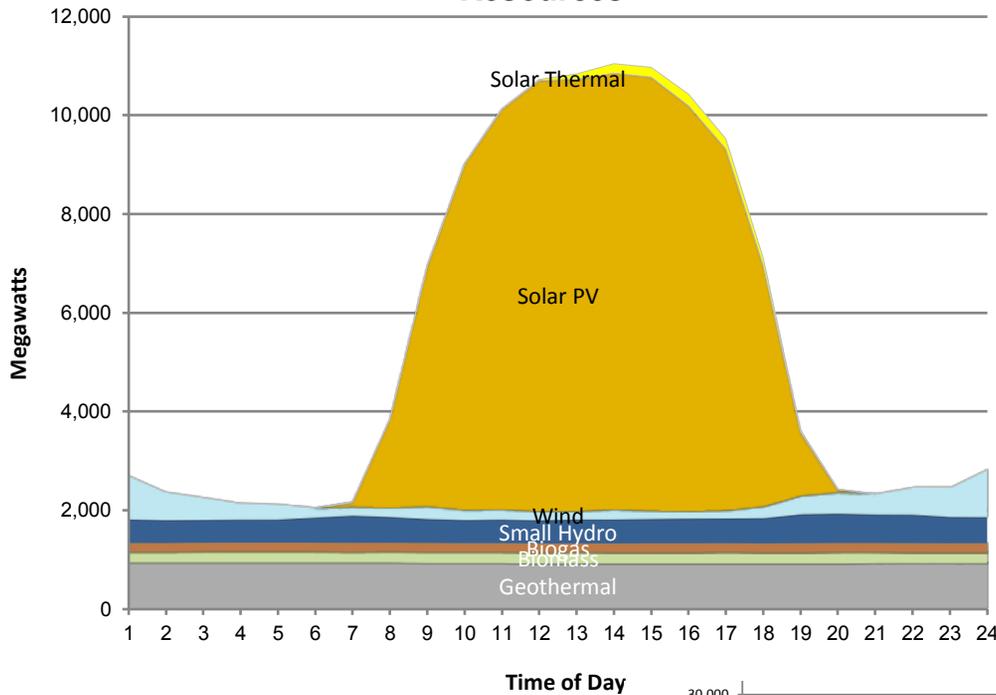


PV Industry has Grown to be Huge!



California solar electricity: 13% in 2016

Hourly Average Breakdown of Renewable Resources



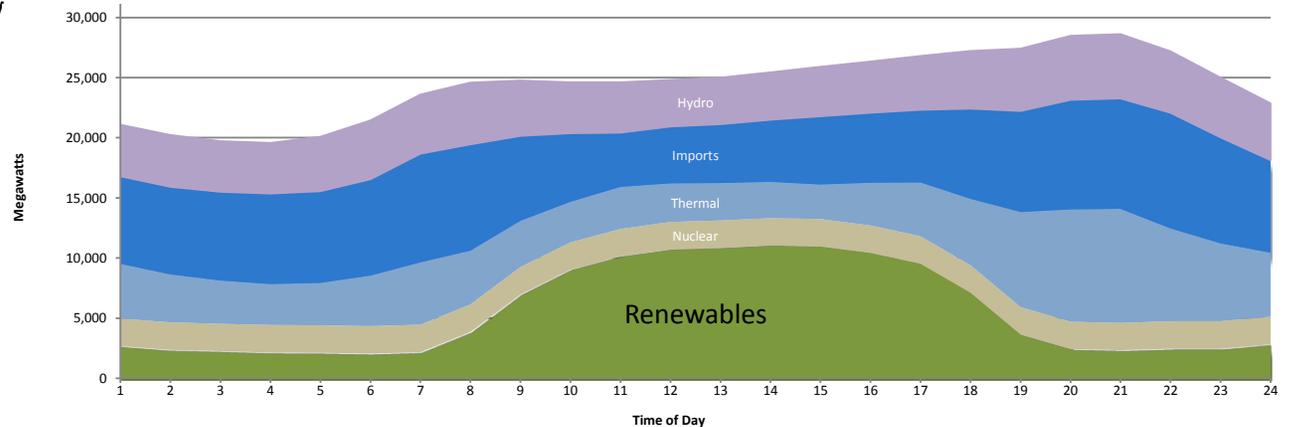
In California:
On April 5, 2017

At noon,
~ 9 GW solar electricity
~ 11 GW renewable electricity
~ 25 GW total demand

What happens on a windy, sunny day?

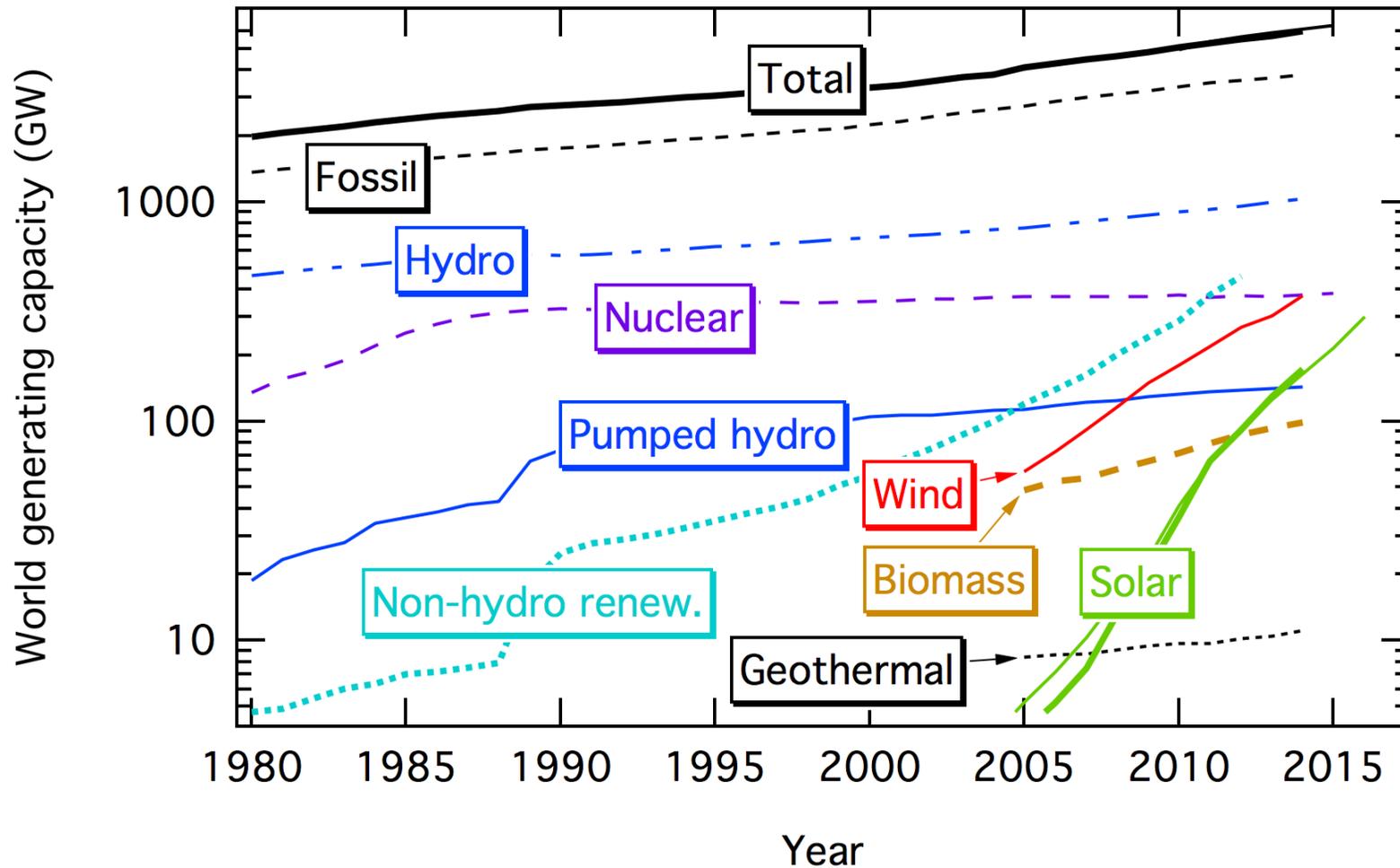
What if solar is tripled?

Time of Day

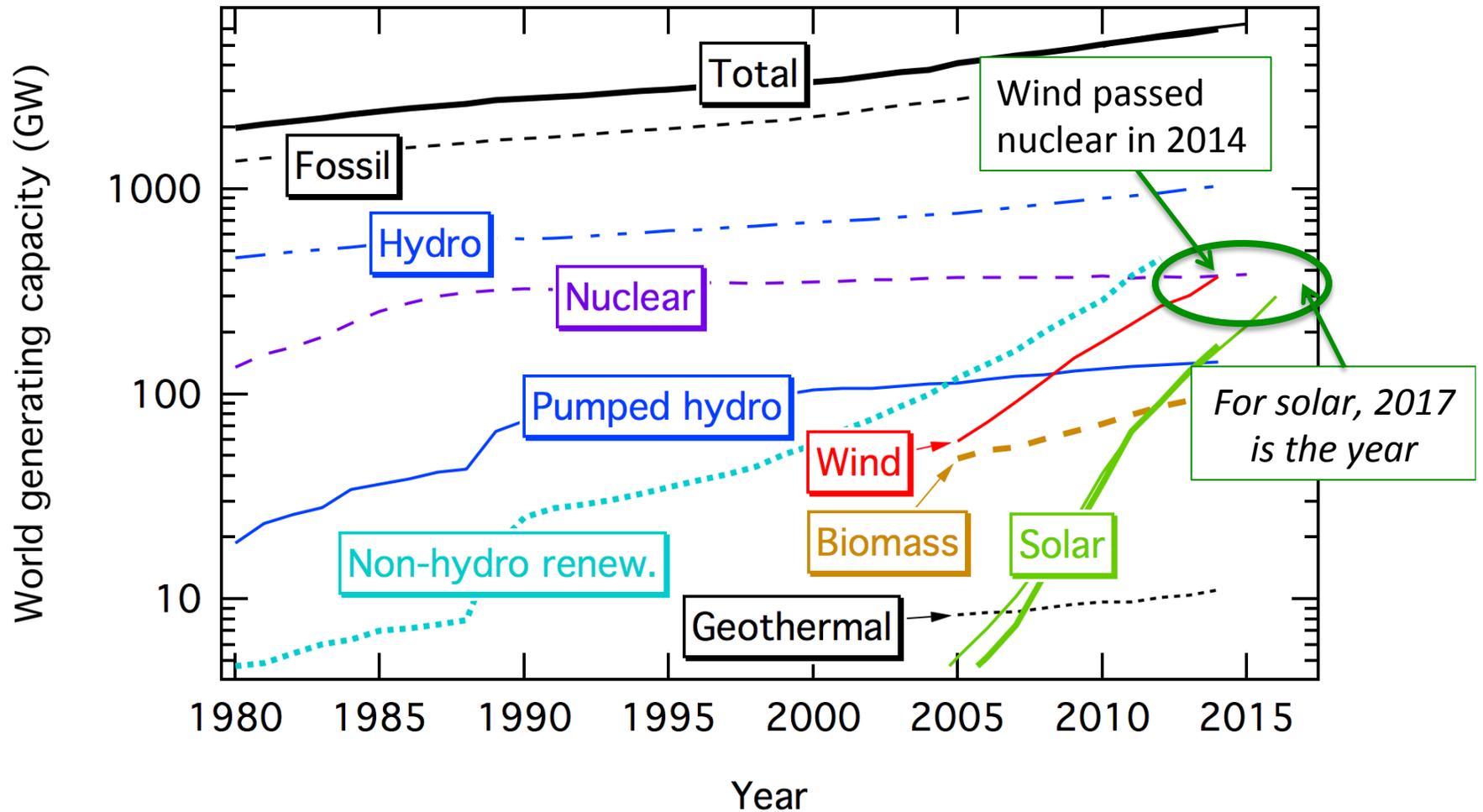


<http://www.caiso.com/market/Pages/ReportsBulletins/DailyRenewablesWatch.aspx>

Solar (electricity) is growing rapidly



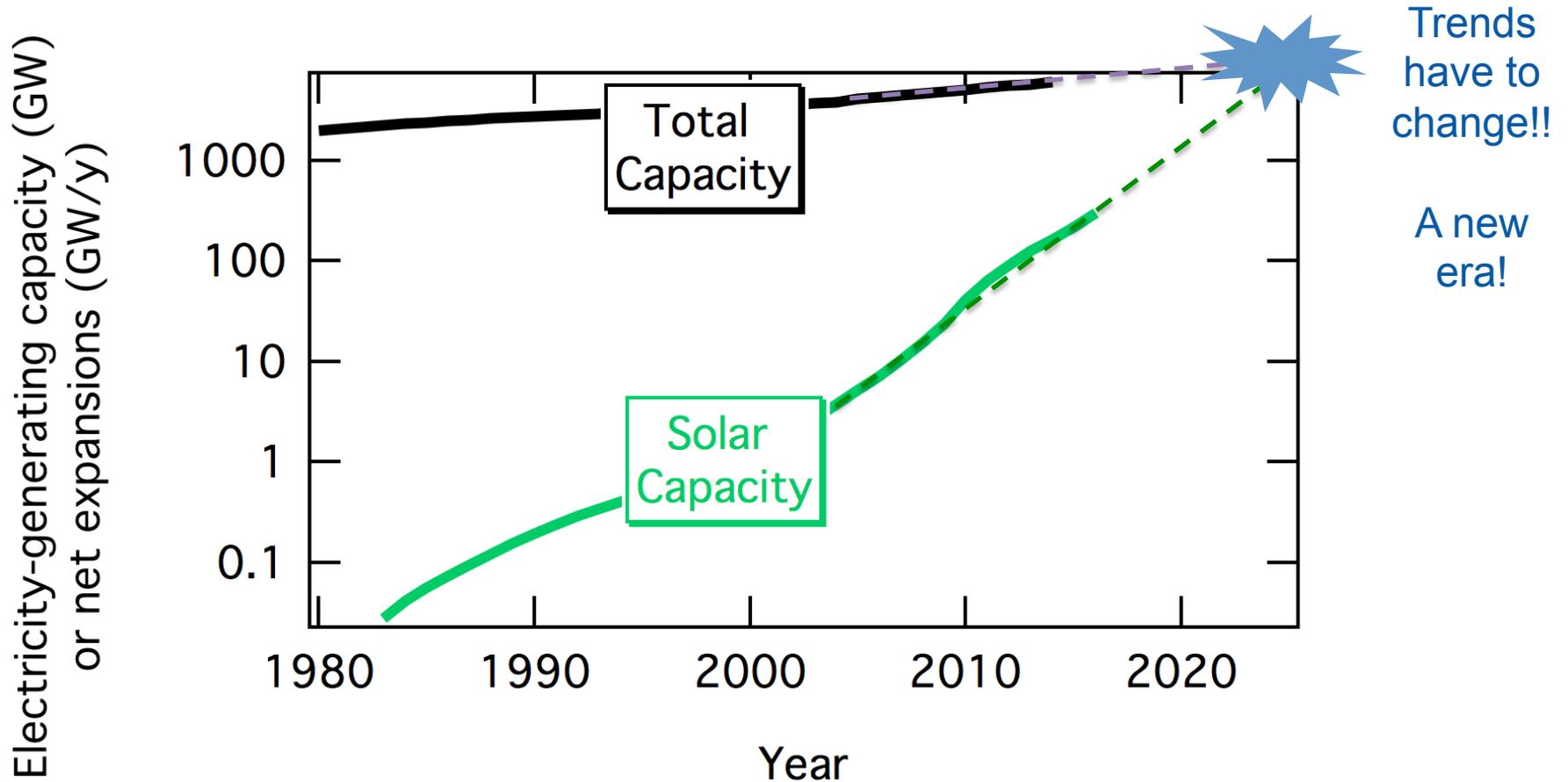
Solar (electricity) is growing rapidly



This is amazing success! What next?

Historical data from EIA

What happens when PV approaches the total?



Can renewable energy continue to grow at the historical rates?

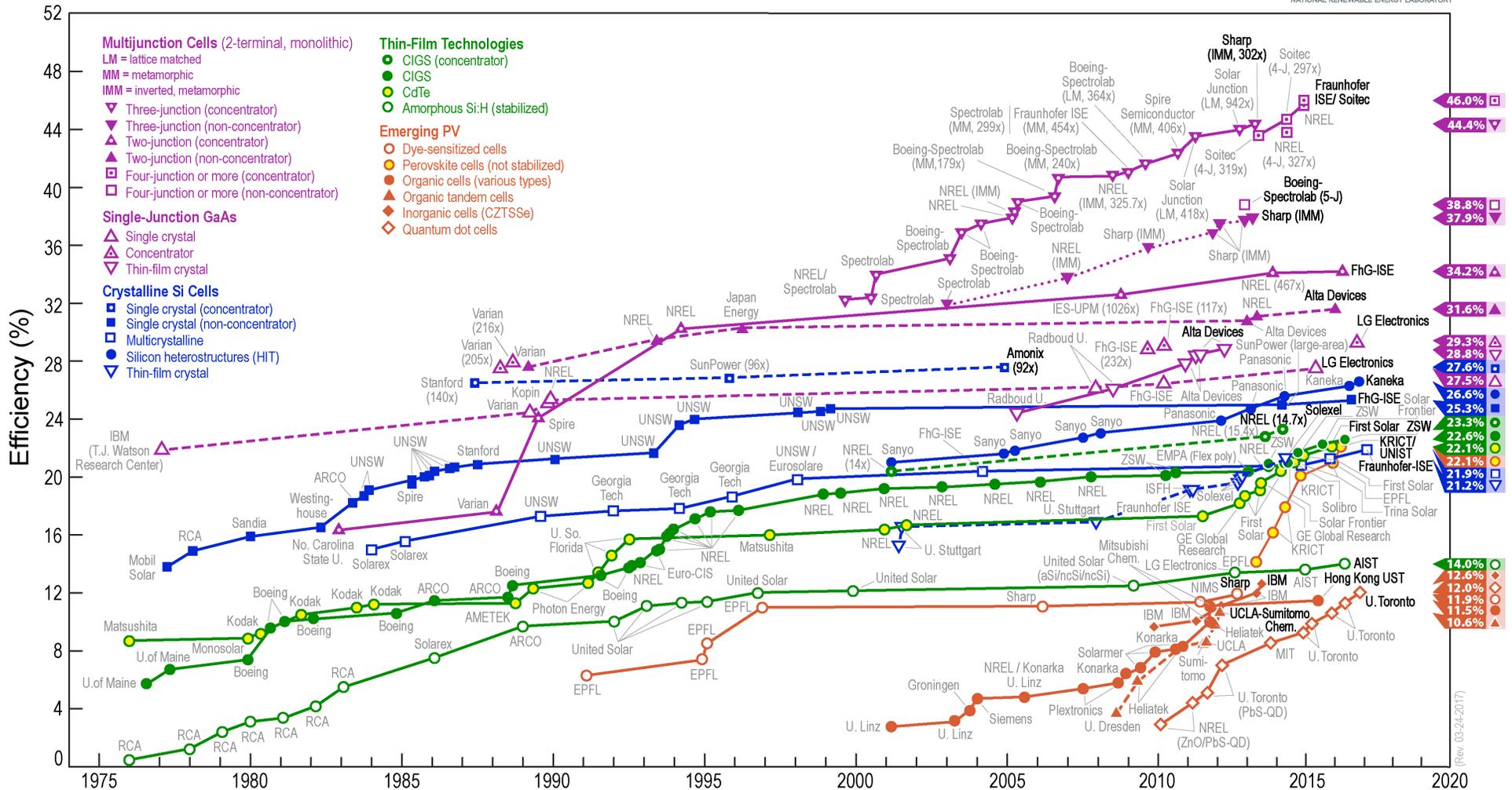
Electrification may be key (worldwide) to continued growth of renewable energy!

Replacing fossil fuels (transportation, heating) with electrification can reduce energy demand!

Our R&D explores many PV technologies



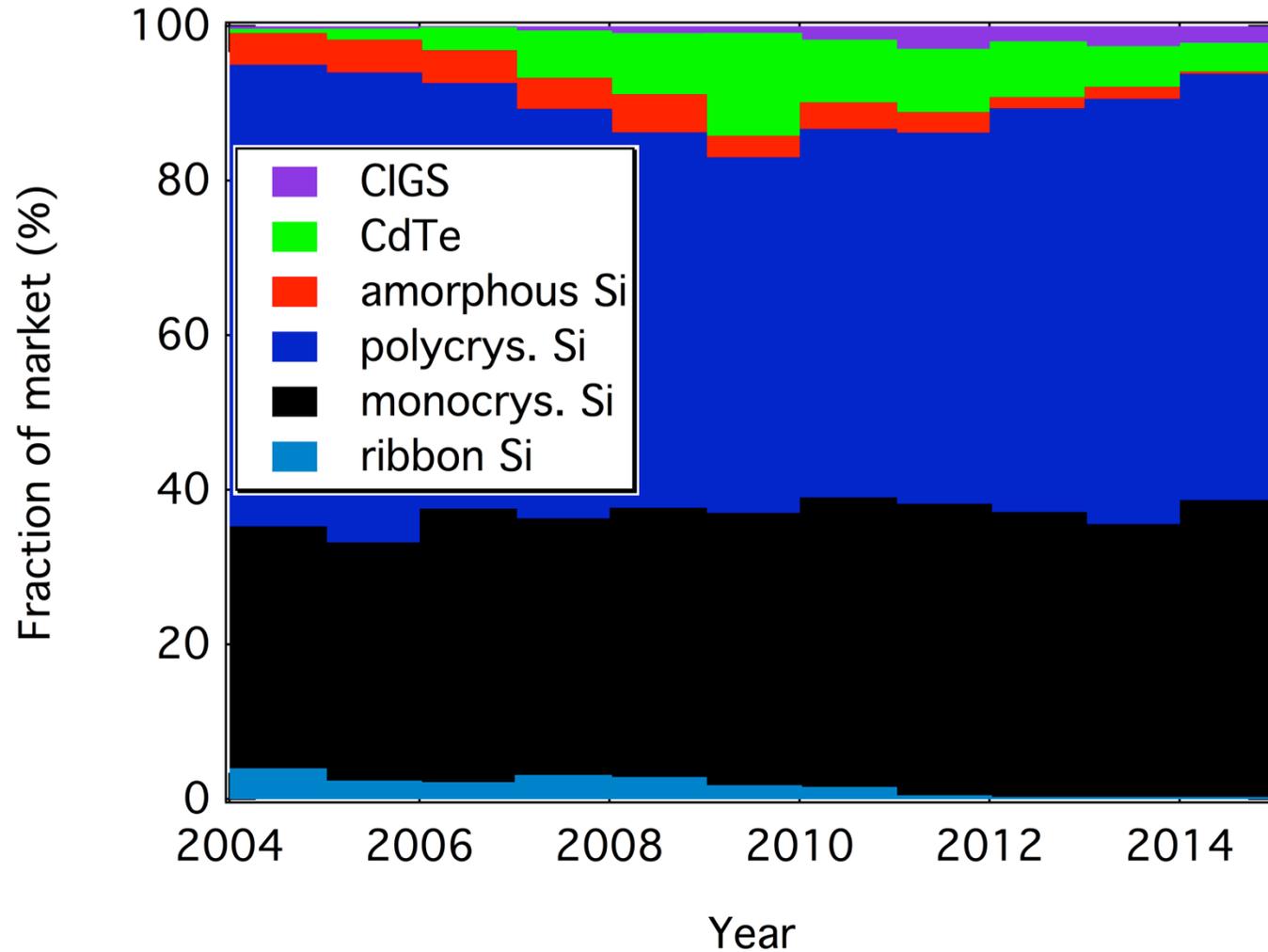
Best Research-Cell Efficiencies



(Rev. 03-24-2017)

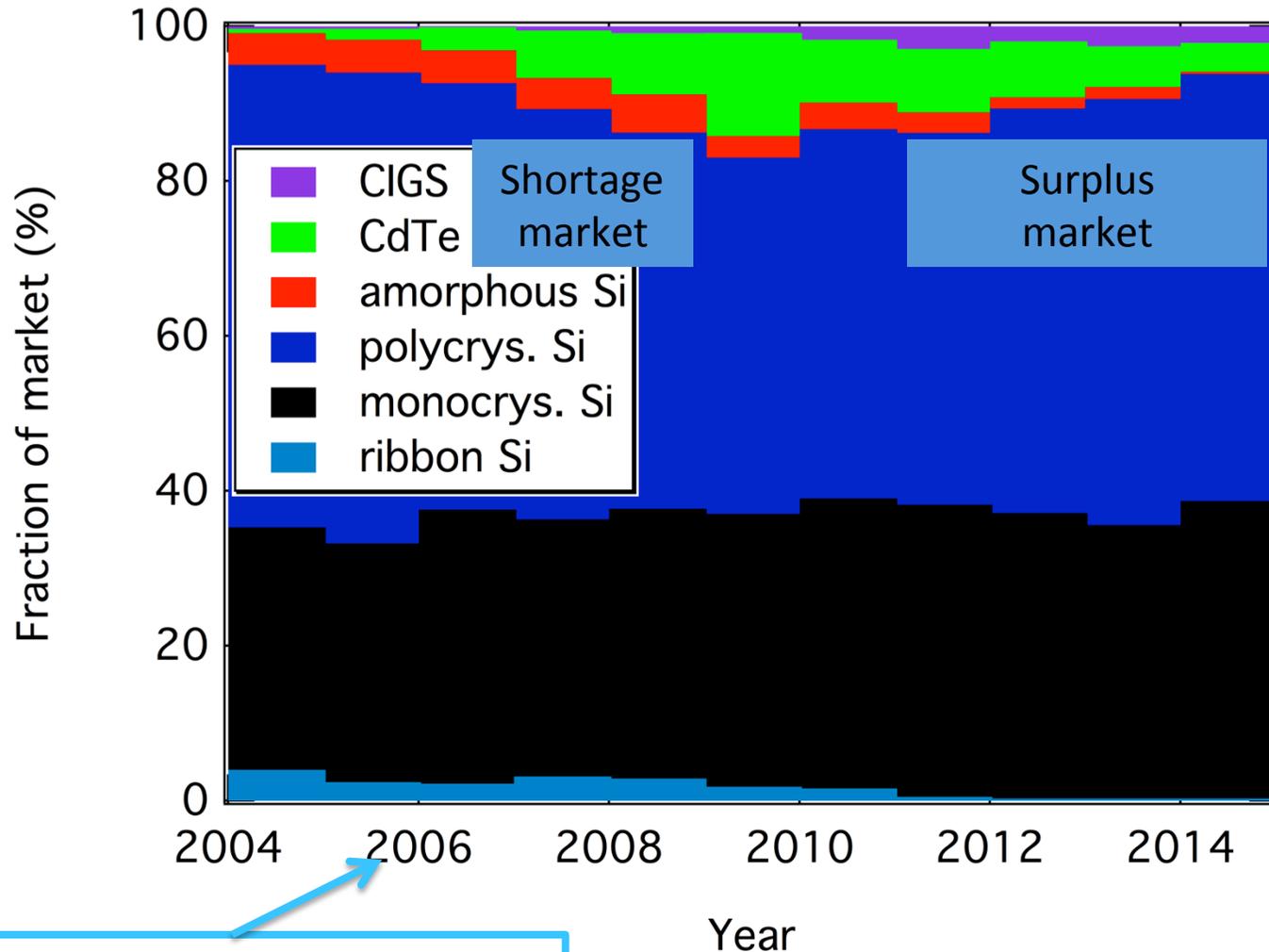
National Renewable Energy
Laboratory
Innovation for Our Energy
Future

Evolution of PV market by technology



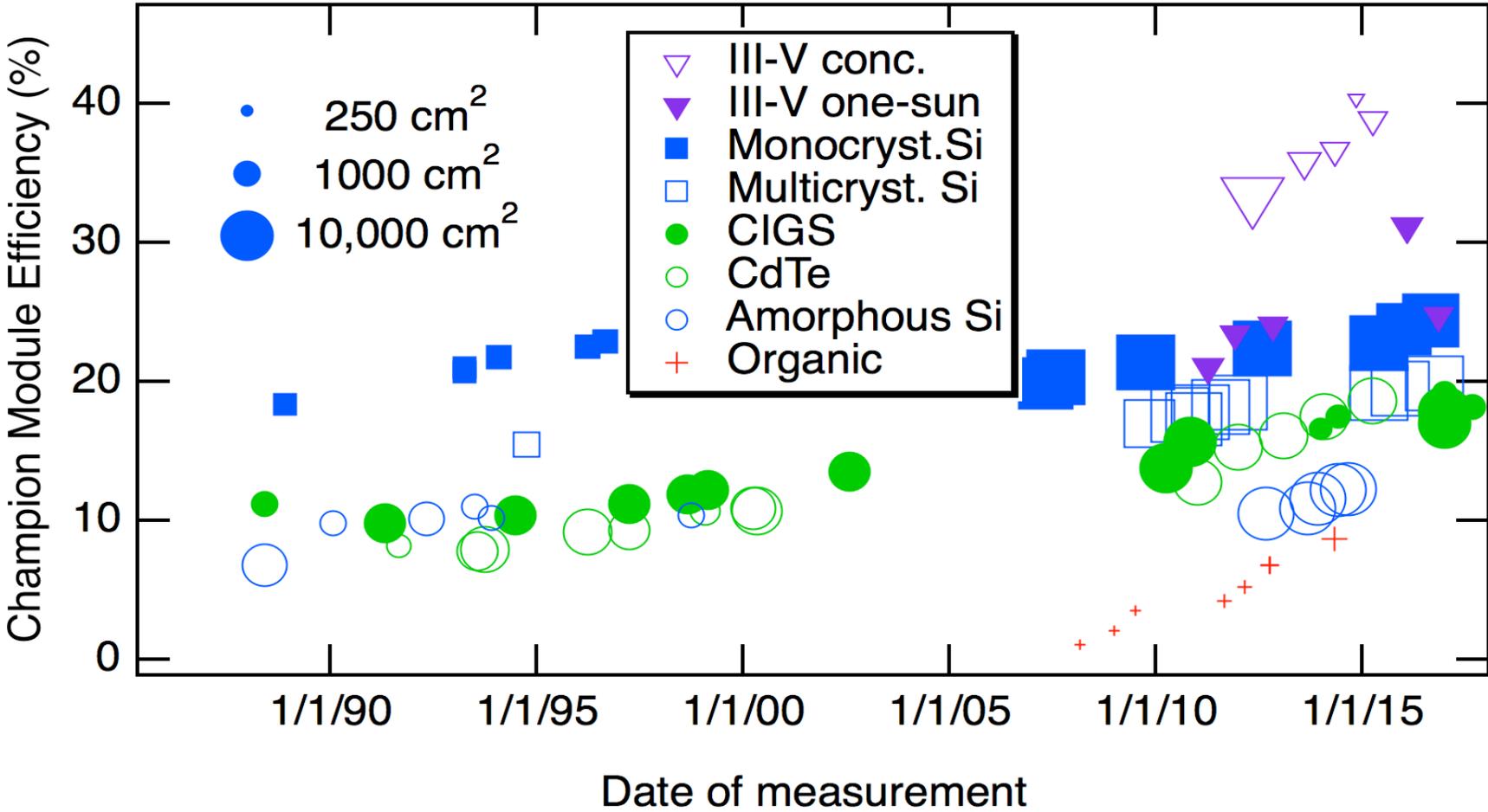
Silicon has been and is currently king!

Evolution of PV market by technology

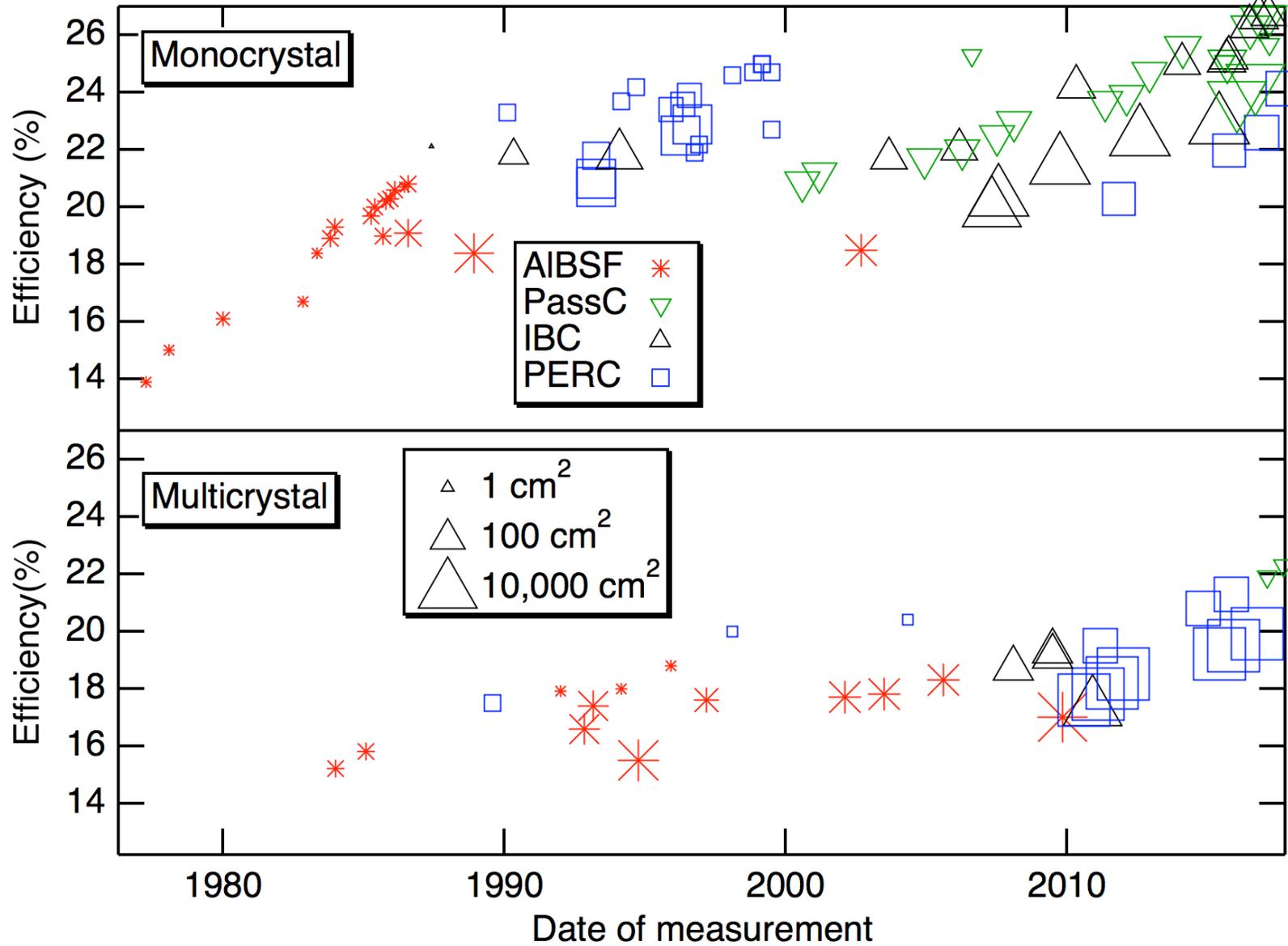


PV passed microelectronics industry in use of tons of Si

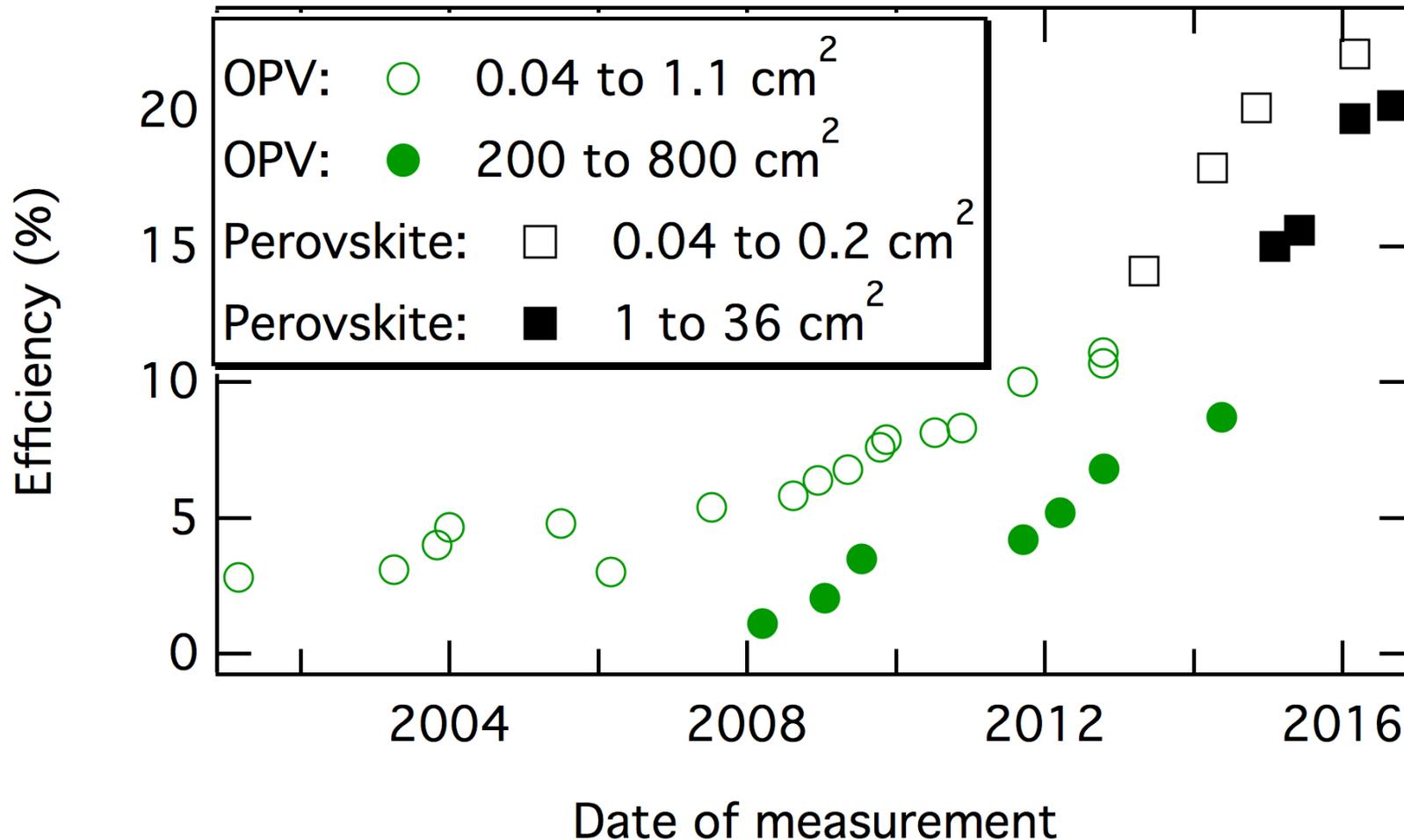
Champion Module efficiencies



Silicon efficiencies



OPV & Perovskite (unstabilized) efficiencies

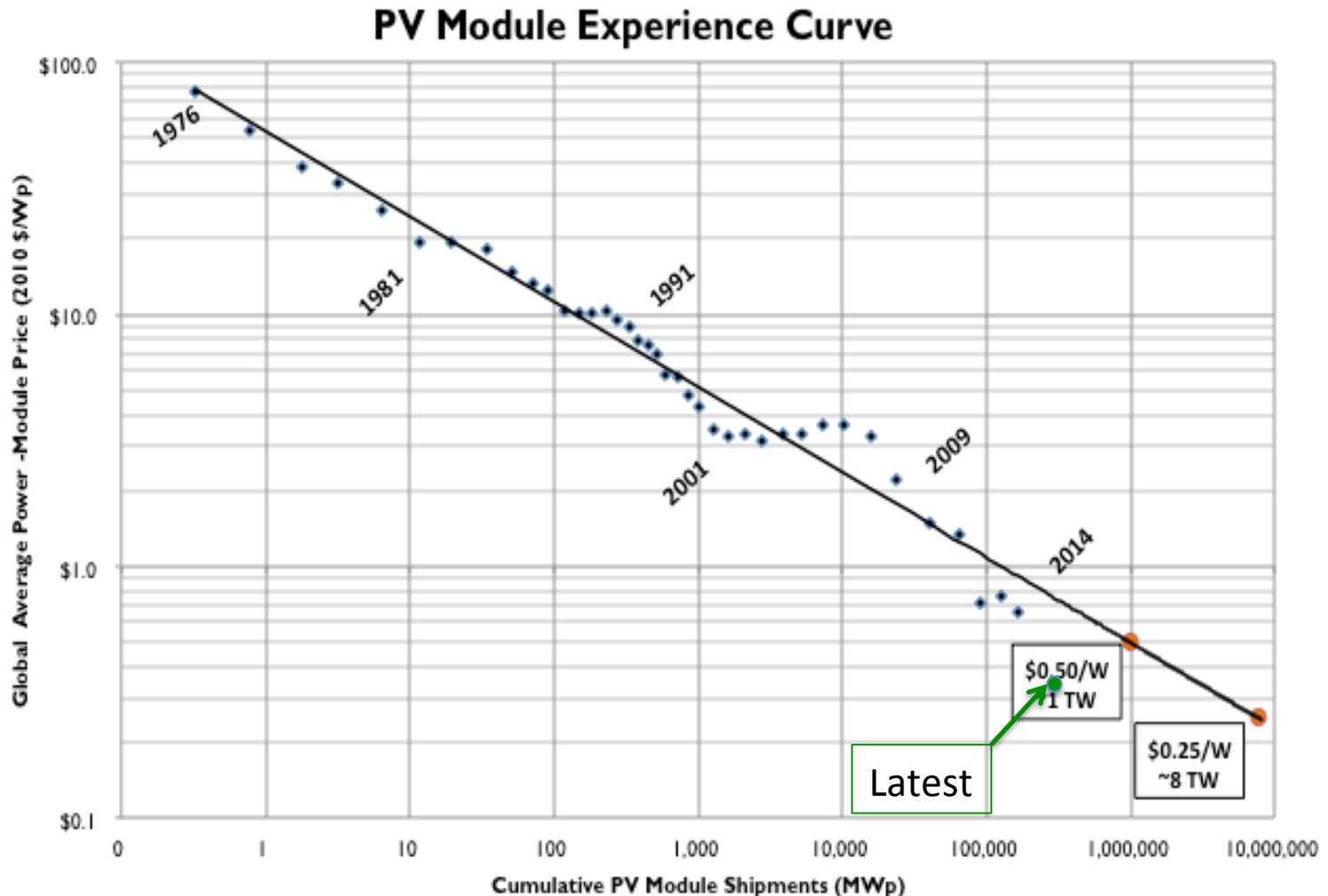


Perovskite efficiencies have been spectacular – need larger areas and good stability
Where can this technology go?

PV technology development

- Revolutionary vs Evolutionary
 - For years, people have said that “silicon can’t make it, so we need a breakthrough”
 - But, silicon is now quite cheap and dominates the market
 - Will a different technology grow in the long term?
 - Or, will silicon continue to evolve and remain dominant?

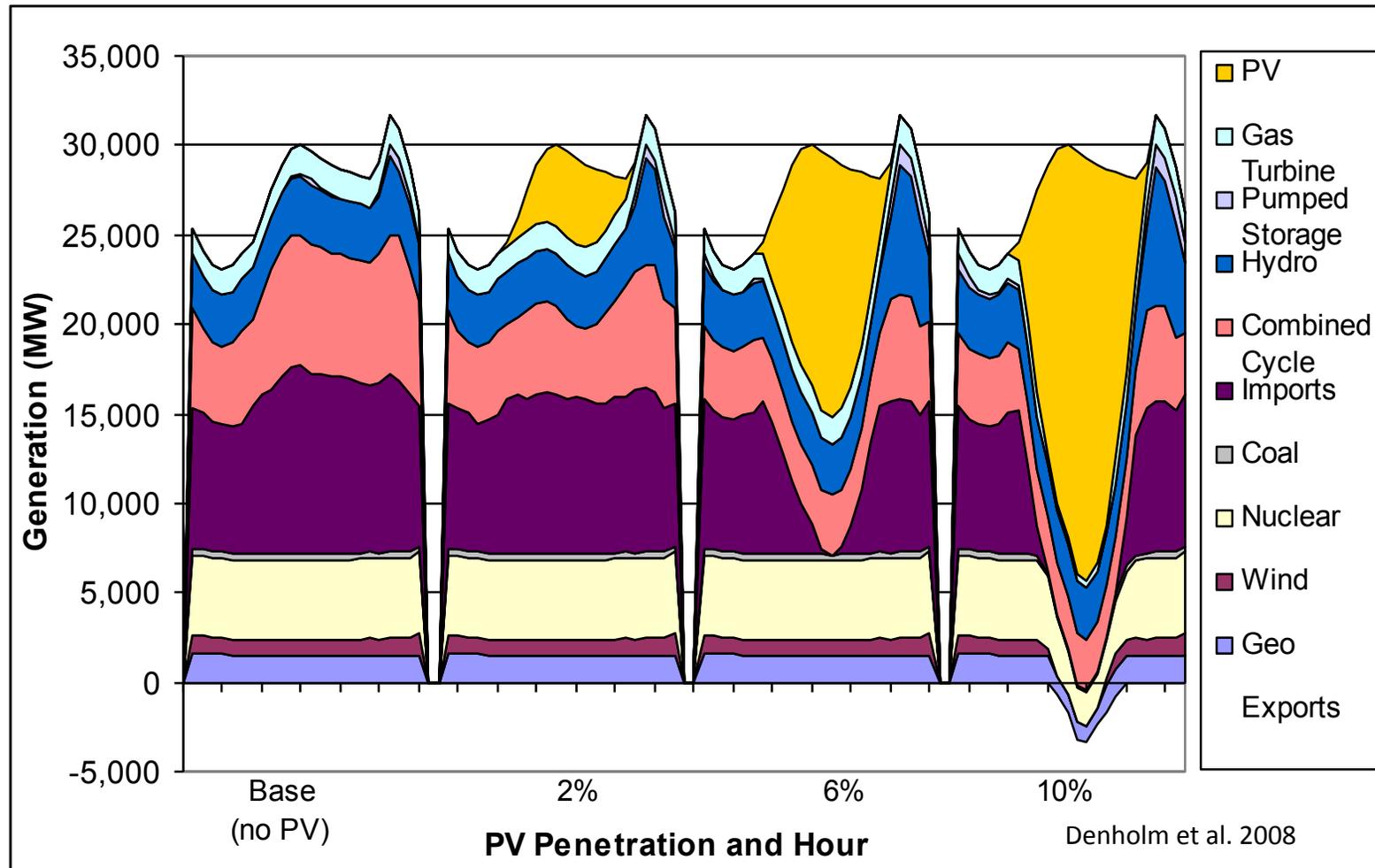
Cost reductions have been impressive



Is this enough? What about system cost?

Sources: For 1999-2014: SPV Market Research, Photovoltaic Manufacturer Shipments: Capacity, Price & Revenues 2014/2015, Report SPV-Supply2. For 1984-1998: Navigant Consulting (2010), Photovoltaic Manufacturer Shipments, Capacity & Competitive Analysis 2009/2010, Report NPS-Supply5 (April 2010). For 1980-1984: Navigant Consulting (2006), Photovoltaic Manufacturer Shipments 2005/2006, Report NPS-Supply1 (August 2006). For 1976-1980: Strategies Unlimited (2003), Photovoltaic Manufacture Shipments and Profiles, 2001-2003, Report SUMPM 53 (September 2003).

PV value depends on the level of penetration



Simulated Dispatch in California for a Spring Day with PV Penetration from 0-10%

The Duck Curve shows “ramp” problem

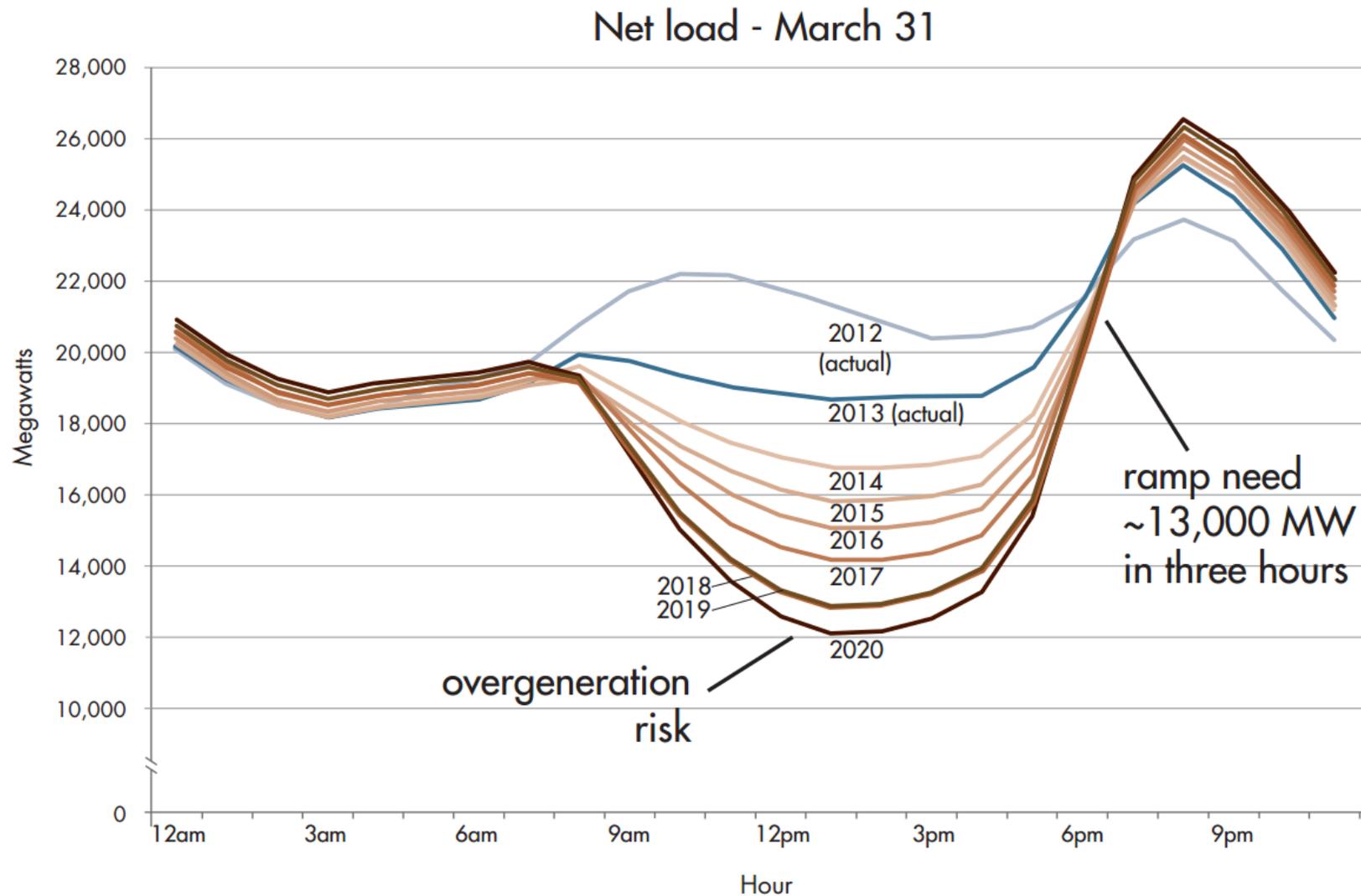


Figure 1. The CAISO duck chart

The Duck Curve shows “ramp” problem

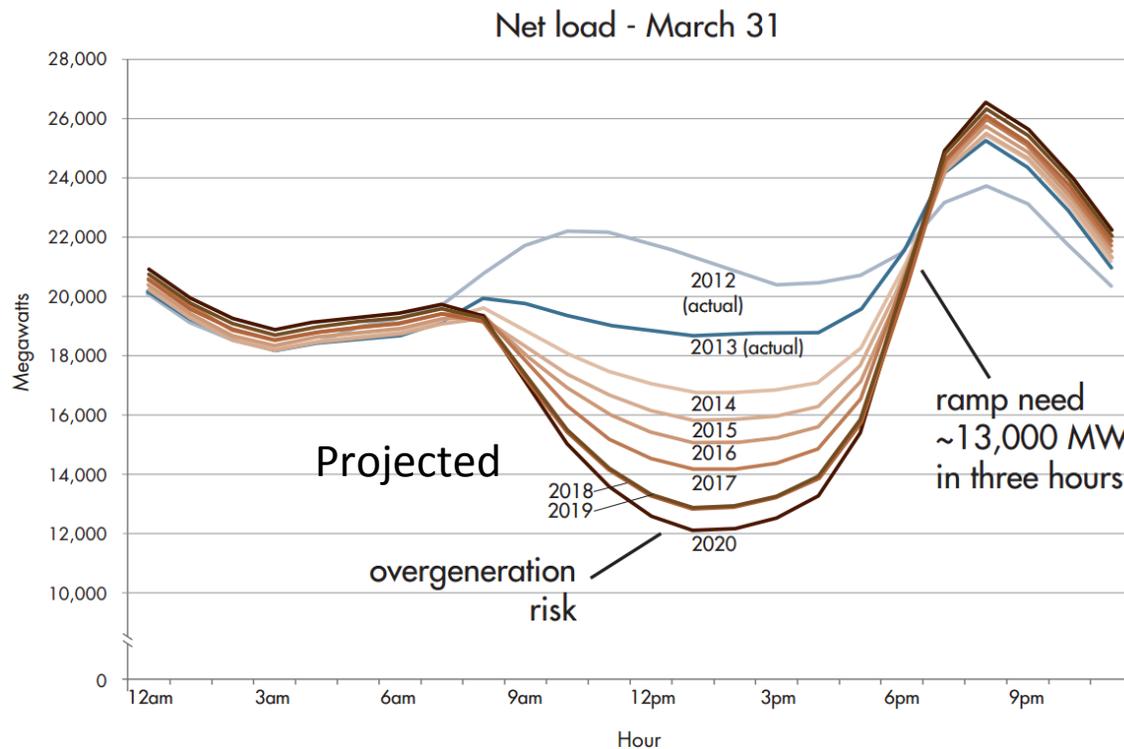
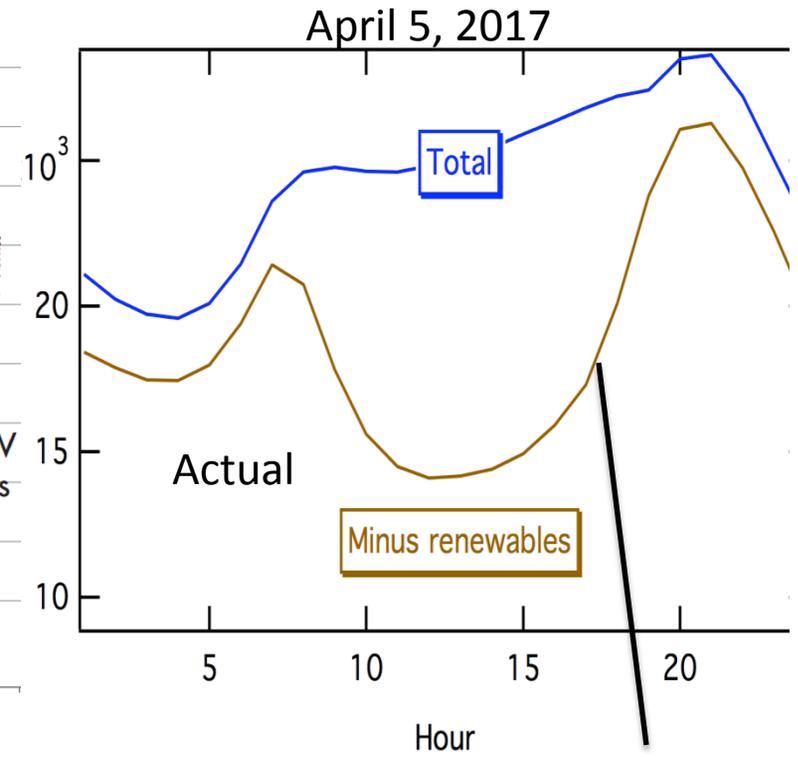


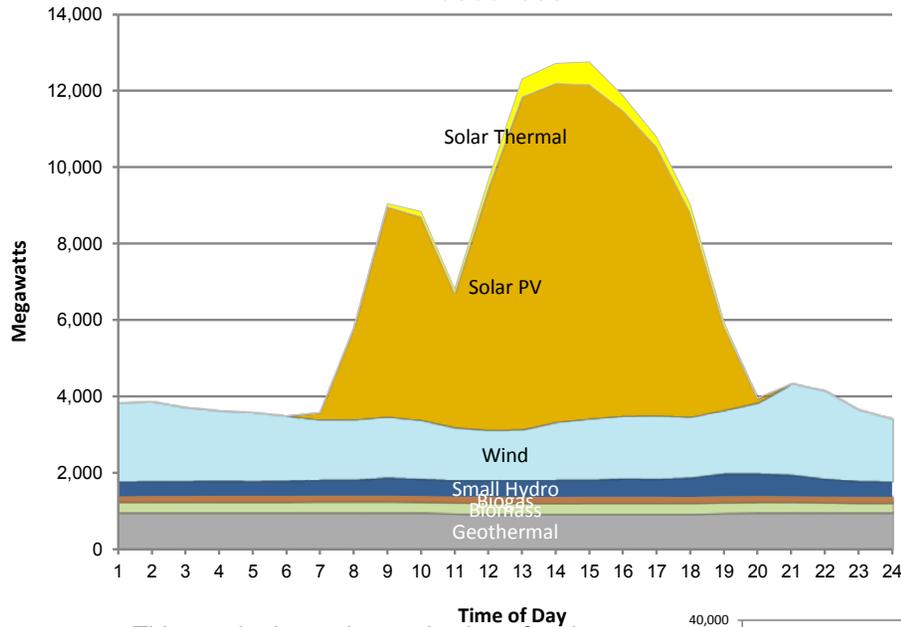
Figure 1. The CAISO duck chart



Challenge: Dealing with variable generation

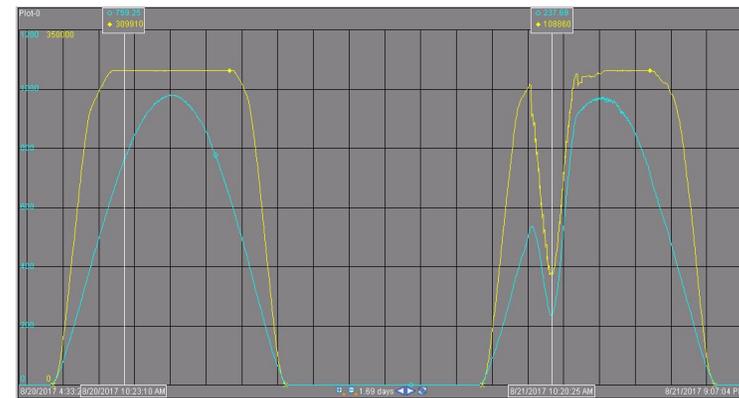
California can deal with variable generation, even with an eclipse!

Hourly Average Breakdown of Renewable Resources

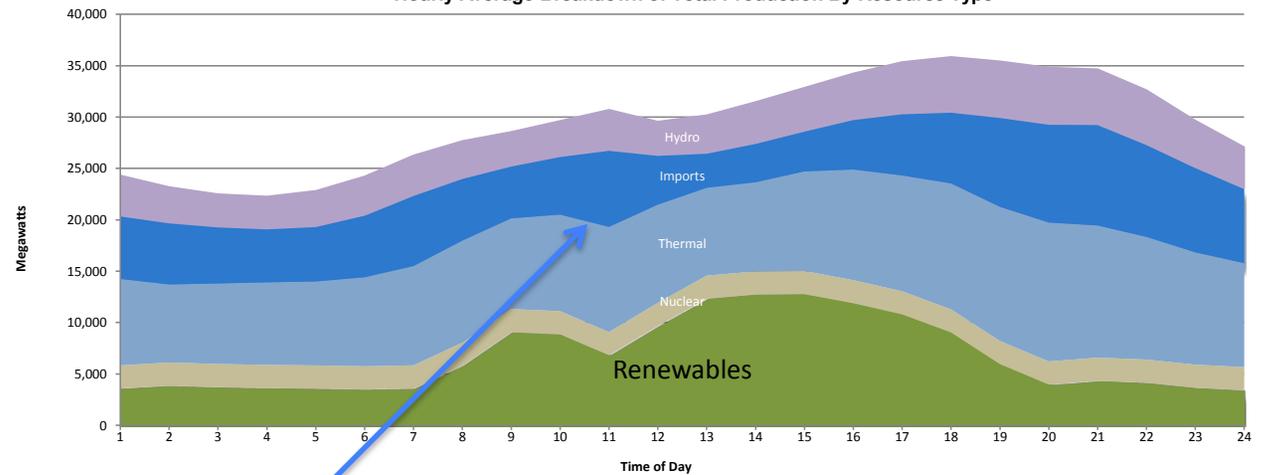


In California:
On August 21, 2017

Eclipse takes a notch



Hourly Average Breakdown of Total Production By Resource Type



This graph depicts the production of various generating resources across the day.

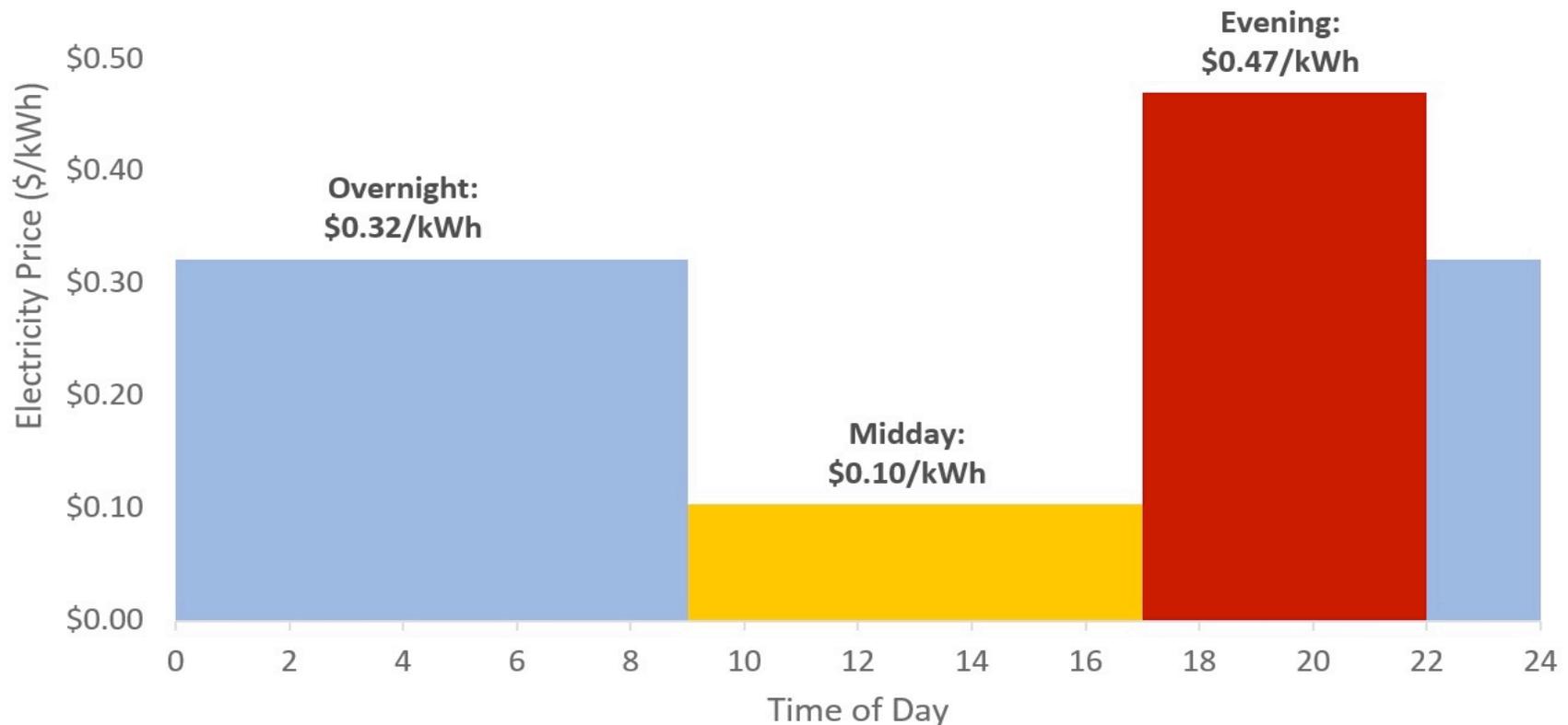
Imports help!

<http://www.caiso.com/market/Pages/ReportsBulletins/DailyRenewablesWatch.aspx>

Thanks to Tim Dierauf for graph

Hawaii solar electricity pricing changes

Big Island Time-Varying Electricity Rates



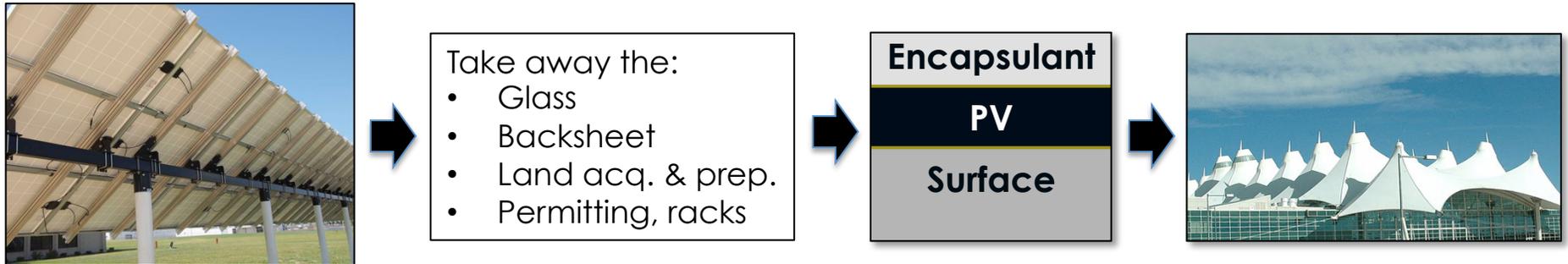
Clean Energy Group, 2017

<http://www.cleanelectricity.org/hawaii-tou-solar-storage/>

Hawaii can't use imports – will California always be able to? Challenge: need lower cost!

Here's an approach to much lower cost

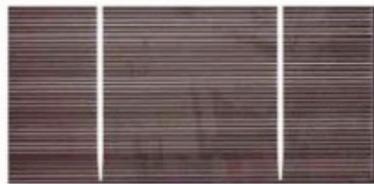
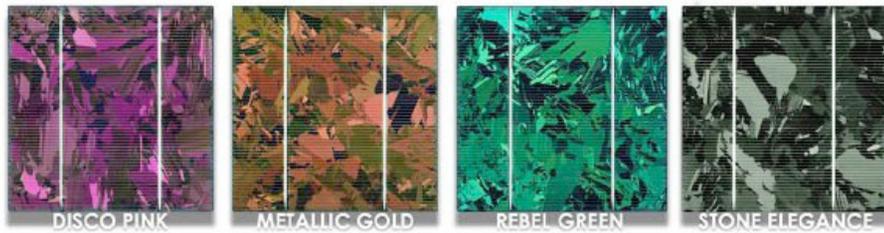
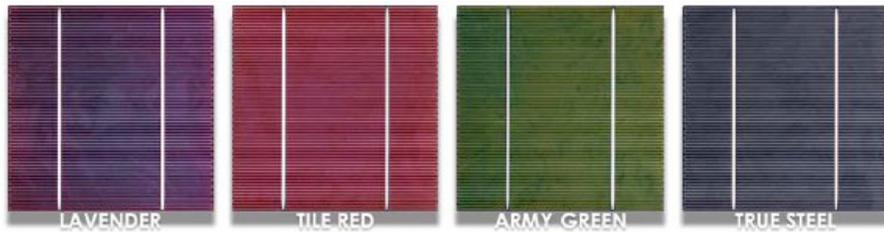
What if PV didn't need its own package and mounting, creating "solar surfaces" on any surface?



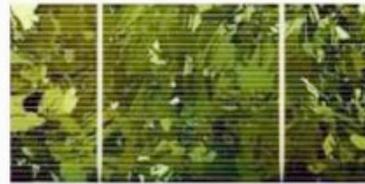
Item	Utility	Solar surface
Balance-of-module materials	\$0.20/W	No glass or back sheet; still need isolation
Cell and other costs	\$0.20/W	\$0.20/W
Power electronics	\$0.10/W	\$0.10/W
BOS-Hardware	\$0.35/W	No racking and long wires
BOS-Soft Costs	\$0.25/W	Reduced permitting, land acquisition & preparation
Total	\$1.10/W	\$0.30/W

Research opportunity to create tomorrow's technology – dream a little!

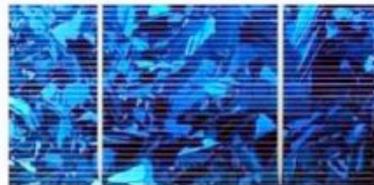
Aesthetics provide opportunity



Grey/Brown



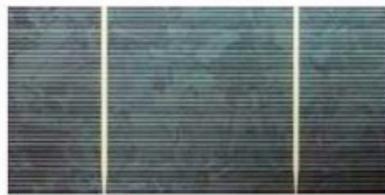
Green



Blue



Red



Grey/Green



Purple

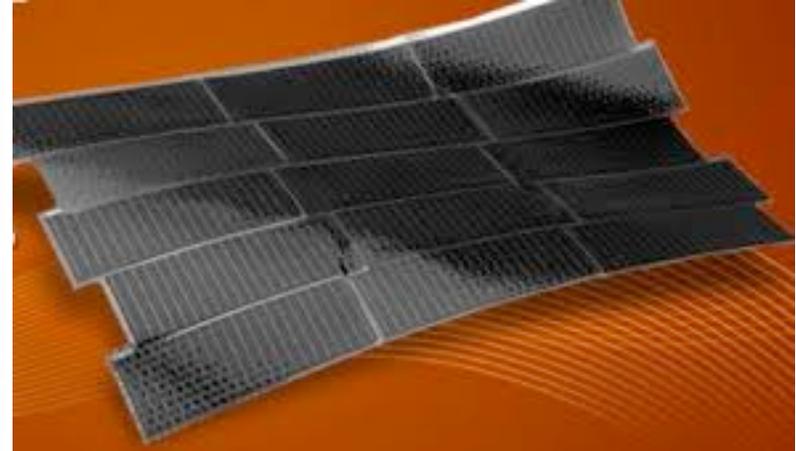


Weight reduction provide opportunity

- Silicon panels use glass for rigidity to prevent cracking of solar cells
- CdTe and CIGS often achieve higher efficiencies when deposited on glass
- Can all of these be light weight?



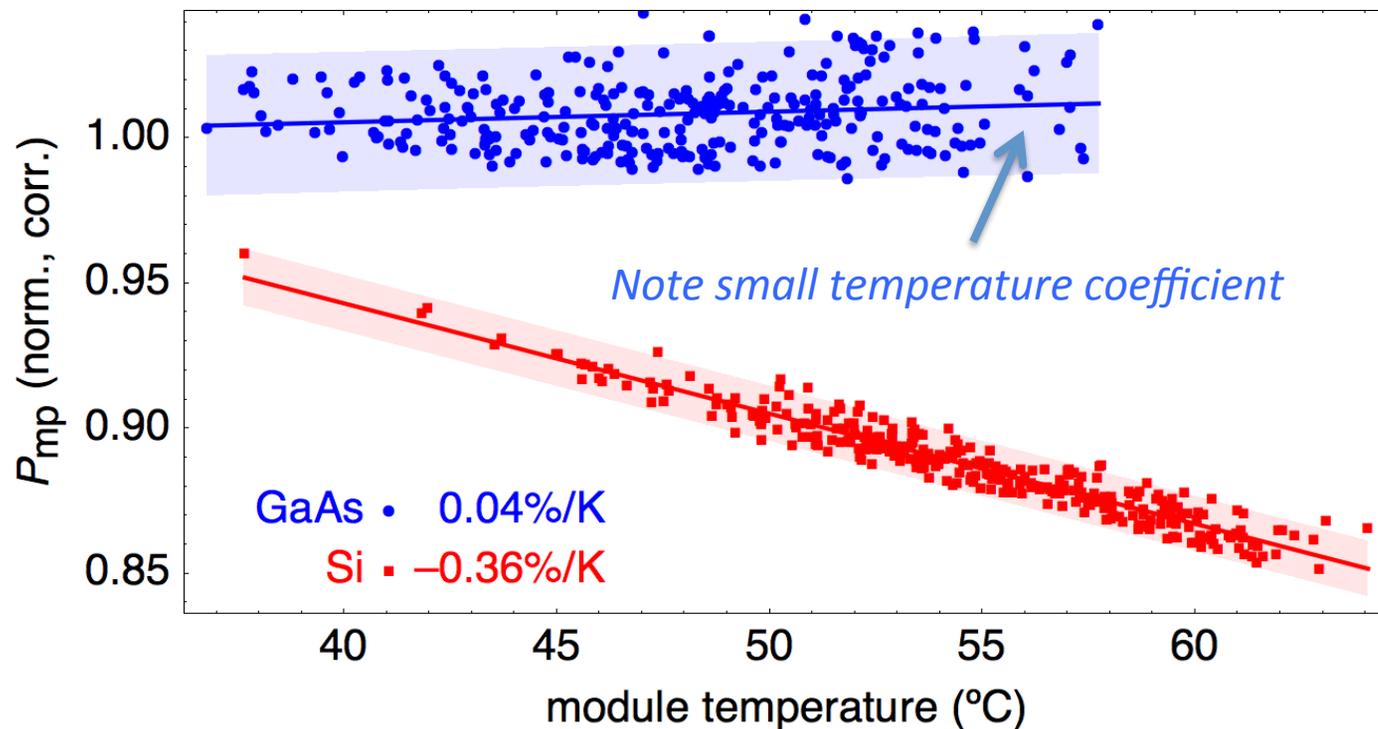
Ascent Solar – Flexible CIGS



Alta – Flexible GaAs

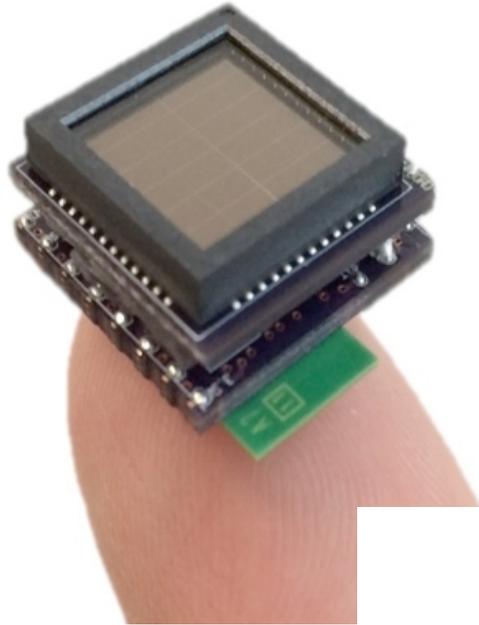
Lower operating temperature is opportunity

- Solar panels heat up in the sun, reducing efficiency
- GaAs modules retain their efficiency better at high temperature and don't heat as much!



Silverman, et al, "Outdoor performance of a thin-film gallium-arsenide PV module" 39th PVSC

PVoT (PV on Things) to drive the IoT



PVoT can drive more than IoT!

Where can our research take us?

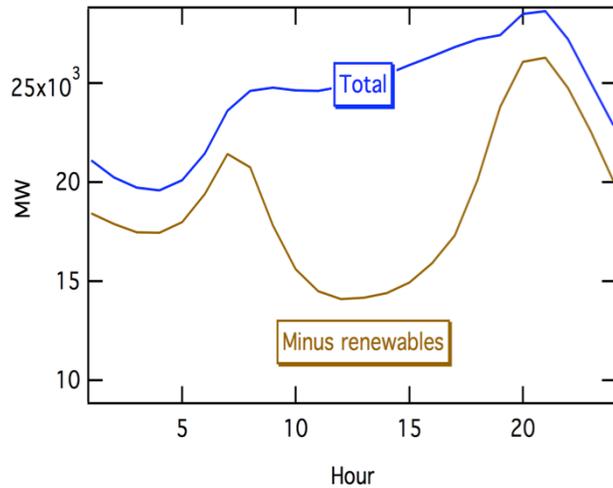


What will the future look like? Will PV be everywhere?



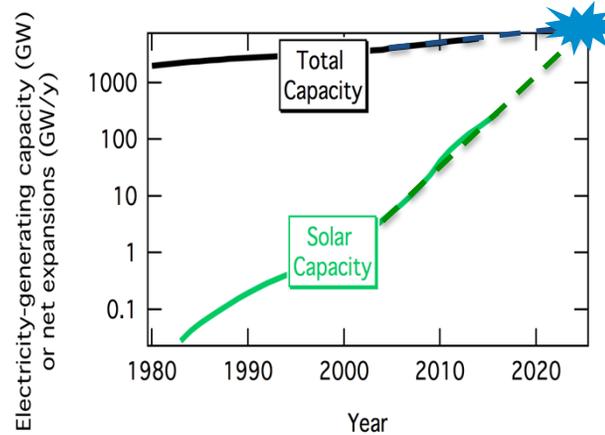
Government roles in the new era

Near term

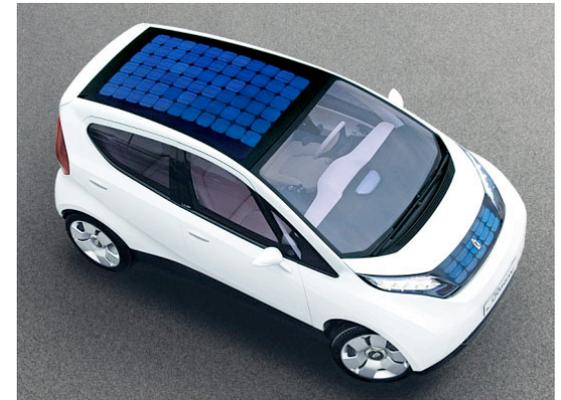


Grid integration challenges are here today!

Long term



Need for electrification is upon us!

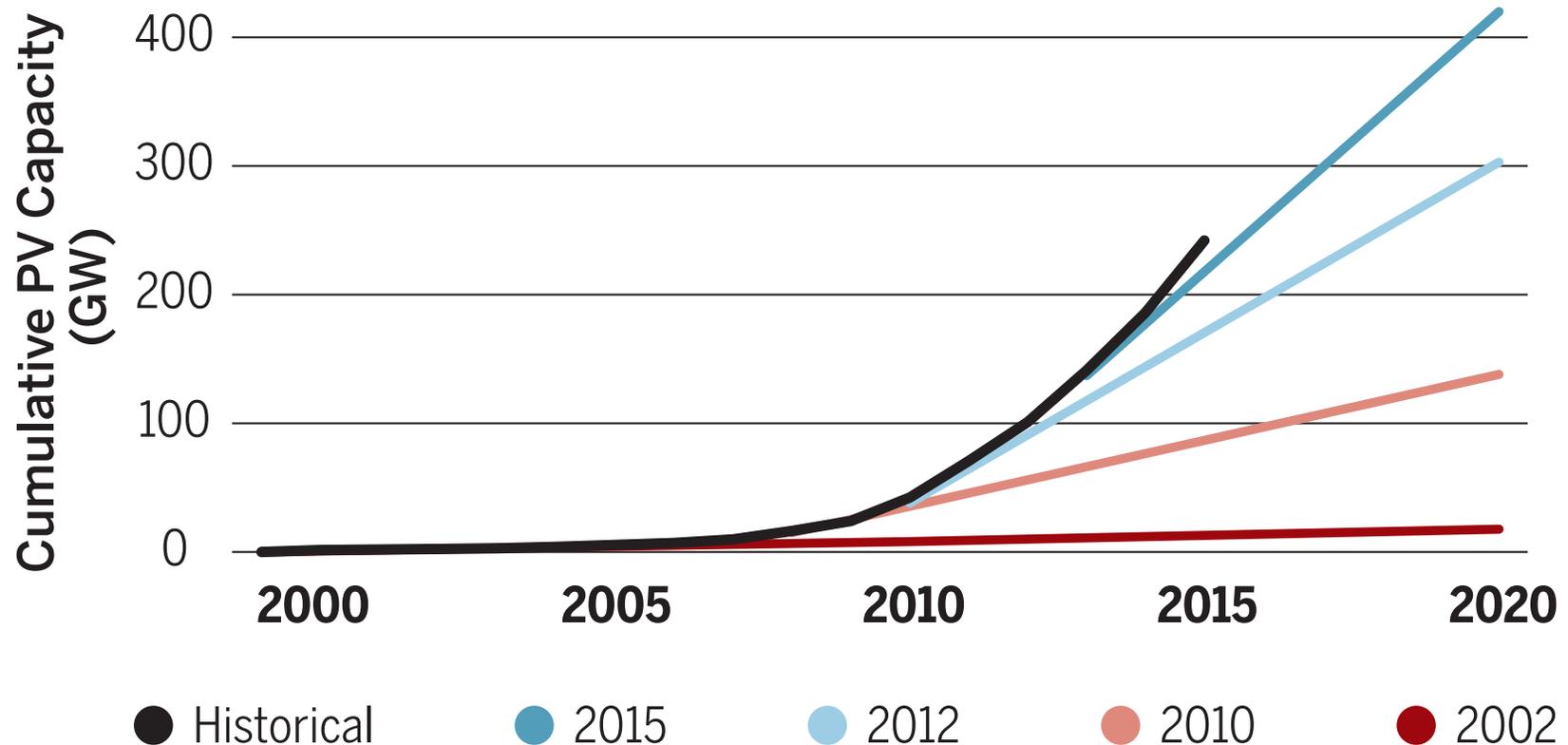


PV materials research can transform how we use PV!

Historically, we underestimated solar

Cumulative PV installations

Projected (labeled by year of IEA publication) versus actual (labeled as “historical”). See supplementary materials for data sources and discussion.

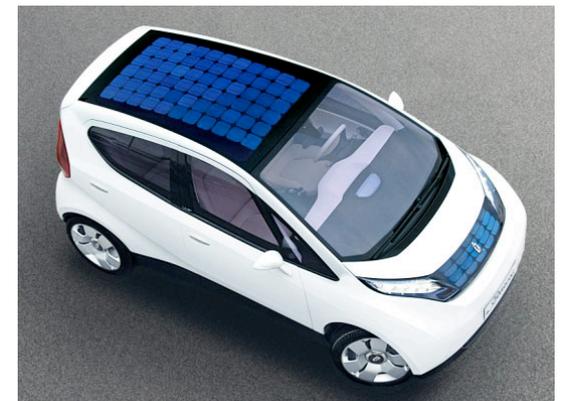
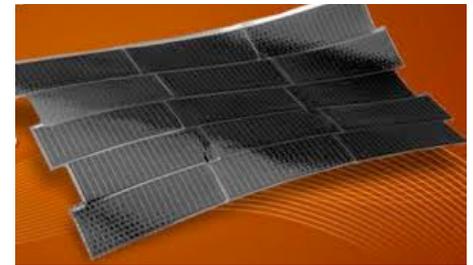
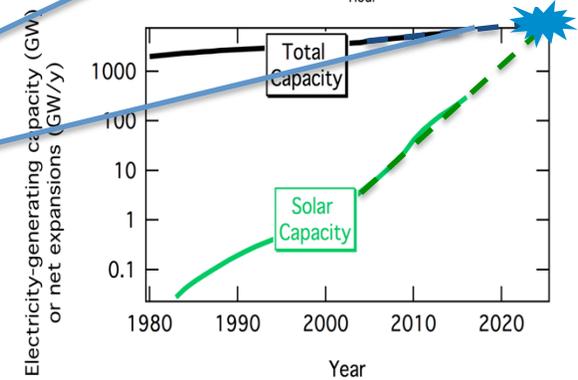
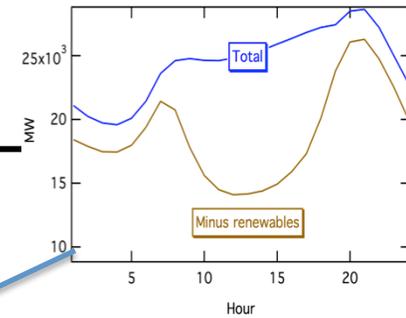


See Science Vol. 356, April 2017

Predictions are now increasing
In the new era, will we get it right?

Conclusions

- Solar has “grown up,” and is entering a new era
 - Need to deal with grid integration
 - Need increased electrification
 - PV research is not done! Lower costs are still needed/desired! Can we reduce the system-level costs dramatically?
 - R&D for batteries, electrolyzers, and others are needed for storage, demand management, and transmission



Thank you for your attention

Sarah Kurtz

skurtz@ucmerced.edu

Sarah.kurtz@nrel.gov