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Observations for “Building a PV roadmap” panel

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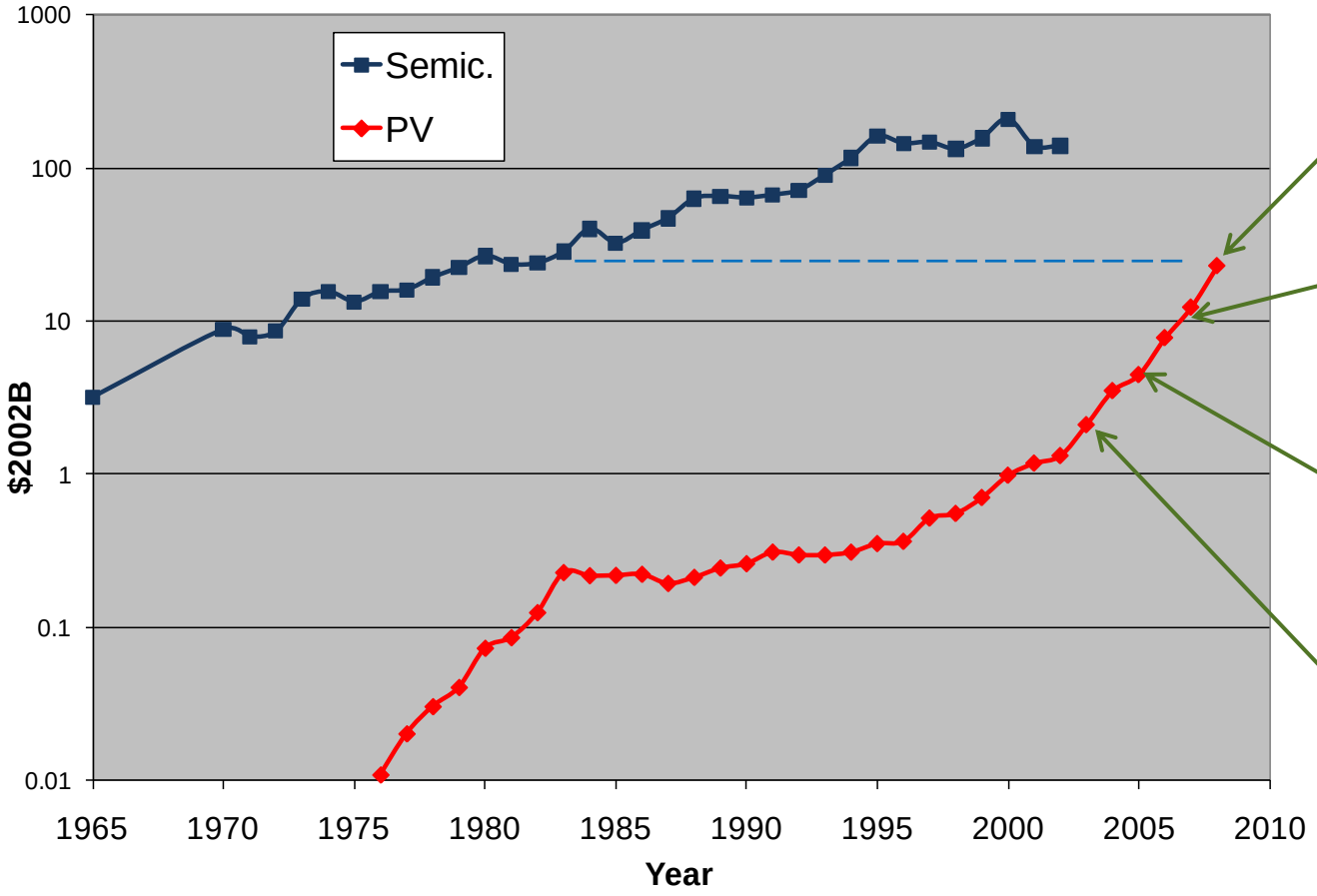
Overview

- Observations:
  - PV is poised to become a significant source of cost-effective renewable energy
  - A “Semi-like” equipment/technology roadmap is not appropriate for PV
  - DOE has been instrumental to the progress of PV in the U.S.
  - There are many ways that the DOE/Federal Government can accelerate PV industry growth, and thereby help the U.S. in the near and long term

Historical Semiconductor and PV Module Annual Sales



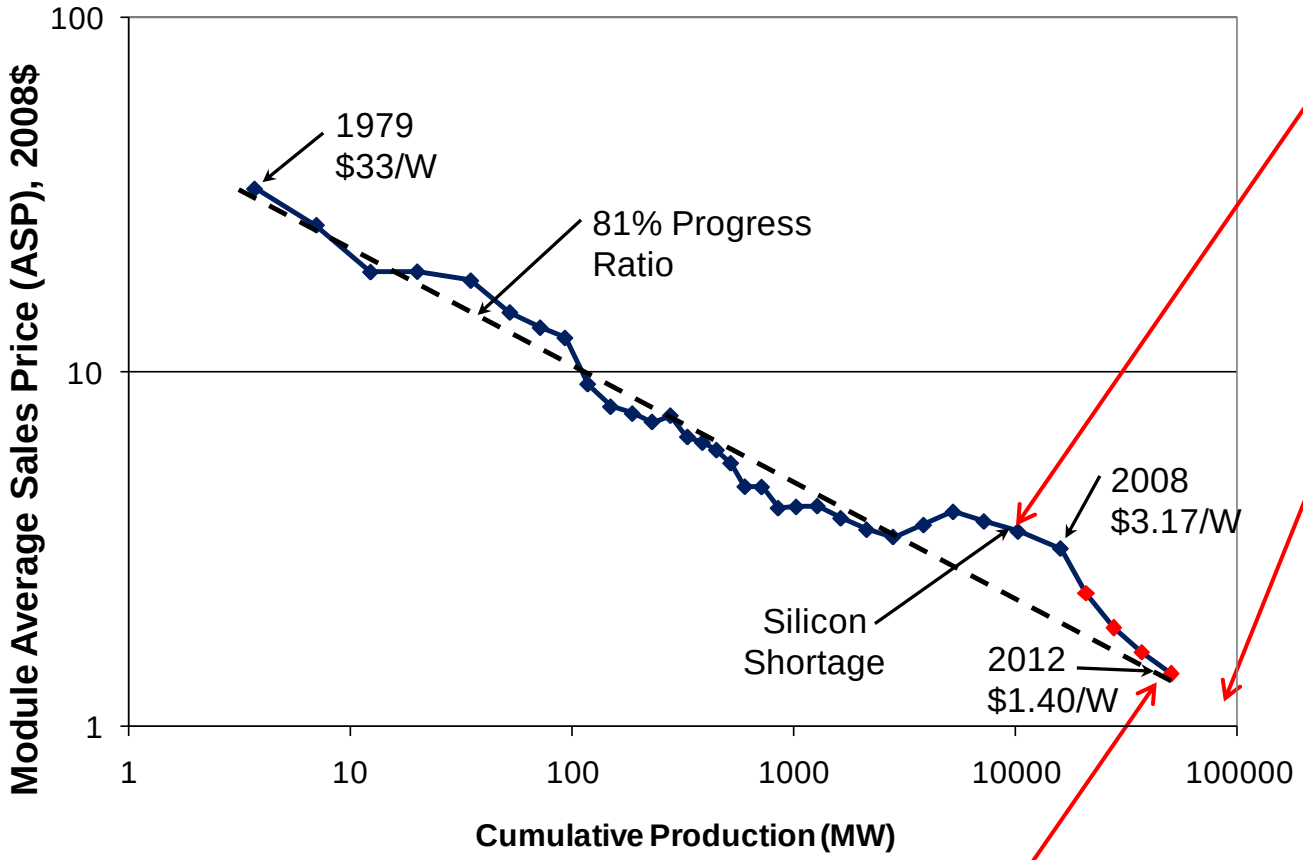
6- 7 GW installed in 2008 worldwide

PV uses more silicon than the IC industry

PV processes more area of wafers than the IC industry

Dedicated PV tools with automation

c-Si PV industry back on cost learning-curve



Large decreases in balance of system cost during this time period

Here, PV is competing for baseload (in the 7 to 10 years it takes to build a nuclear plant, PV installed over that same time frame will be lower cost)

By most estimates, PV LCOE without incentives using these modules will be lower than peaking natural gas LCOE. Best-in class thin film and high efficiency PV power plants will give even lower LCOE .

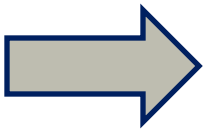
Last 4 data points are forecast by the Prometheus Institute

Technology/Equipment Roadmaps

- There is much we can learn from the successes of the IC roadmaps and consortia, but..
- There are significant problems/risks of implementing technology/ equipment roadmaps in PV like those used to drive the IC industry
  - IC industry had split of IP in processing and chip design, with shared interest of geometry shrinks on predictable schedule -- not analogous to PV
  - Most of the PV value chain is not similar to the IC industry (closer to construction, building materials, automotive, consumer electronics)
  - IC-industry-derived standards would increase equipment costs
  - Could undercut the existing collaboration infrastructure in PV
  - Could undercut guidance from organizations more familiar with PV
  - Could lead to delay in needed US market development
  - Could pull funding and resources from the needed diversity of architectures and application solutions

Technology / Equipment roadmap?

- Which one(s)? (with a tiny sampling of the current variation within each one)
  - c-Si:
    - Back contact?, HIT?, 5”, 6”, 8”?, Legacy architecture?, others
    - Polycrystalline or crystalline? N-type or P-type? Cleaved or advanced saw? Film? …
    - Focus on variations on legacy architecture at expense of others likely counterproductive
  - CIGS:
    - Sputtering (1 step or 2 step?)?, Co-Evaporation?, Electrodeposition?, Nanoparticle ink printing? FASST reaction process? Ion-beam assisted?
    - Multi-junction? Up or down conversion layers?
    - Flexible or rigid?, large for ground mount?, small for rooftiles?, cylinders for roof mount?
  - CdTe: VTD? CSS? Nanoparticle print? Sputtering? Flexible? Small or large?
  - Amorphous Si: Tandem or 3j? a or µc? Giant for ground mount, flexible roof mount, bipv?
  - High concentration: Mirror with dense array, off-axis small mirrors, lens, plastic, IMM, …
  - III-V based thin films? New materials? Organics? Dye sensitized?



So, even having 10 different technology roadmaps would still discourage competition and innovation

And there is important innovation in the rest of the value chain, for example for c-Si:

Polysilicon → **Ingot** → **Wafer** → **Solar Cell** → **Solar Panel** → **System**

Rough percentages for conventional c-Si* (and a sampling of innovation efforts)

10% → **6%** → **7%** → **11%** → **20%** → **46%**

- Lower-cost
- UMG
- Lower g/W via down-stream work

- Continuous growth, etc.

- Diamond wire, etc.
- New wafering:

- A variety of methods to increase cell efficiency, which decreases all the upstream & down-stream $/W costs.
- Cost reduction via thinner cells, reduced materials, etc.

- Higher performance or reduced cost through new materials, new interconnection, …
- Increased value via aesthetics, on-module intelligence, …
- Reduced system costs via customization to application

- New tracking approaches
- Increase value via higher performance, aesthetics, monitoring and control, …
- Productized, easy-mount solutions
- Integration of module and end application system

* Value chain distribution percentages are for new Centrotherm 347MW plant as reported in Dec. 2008 Photon International, with 30% GM added to all steps and system costs of $1.69/W (including margin), using average of U.S. and China locations and $1.32/euro exchange rate.

Diversity is needed for maximum success

- Energy market > 1 trillion $ / yr
- Competition drives cost reduction
  - Innovations and private funding for many different approaches
- Multiple approaches will give greater total volume (reduced impacts from material limits, exponential scaling limits, etc.)
- Diverse applications require diverse product characteristics
  - Next 3 slides: Some of the diversity of systems from SunPower alone, using only all-back-contact high-efficiency silicon cells

Residential

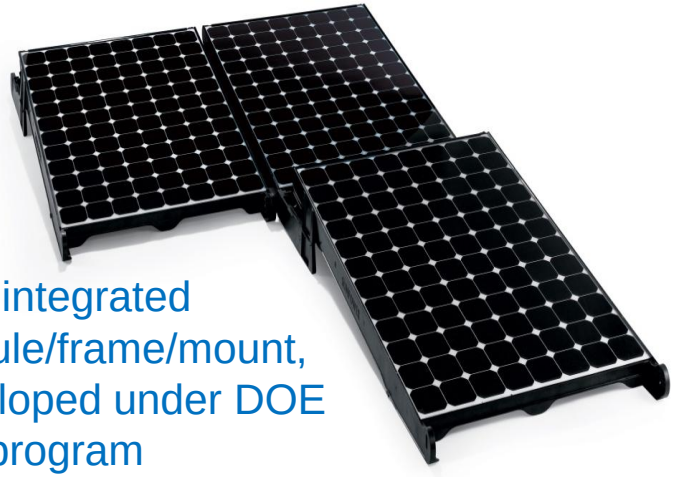
Building integrated

Building applied

- Plus: Smart-mount system, monitoring, packaged systems …

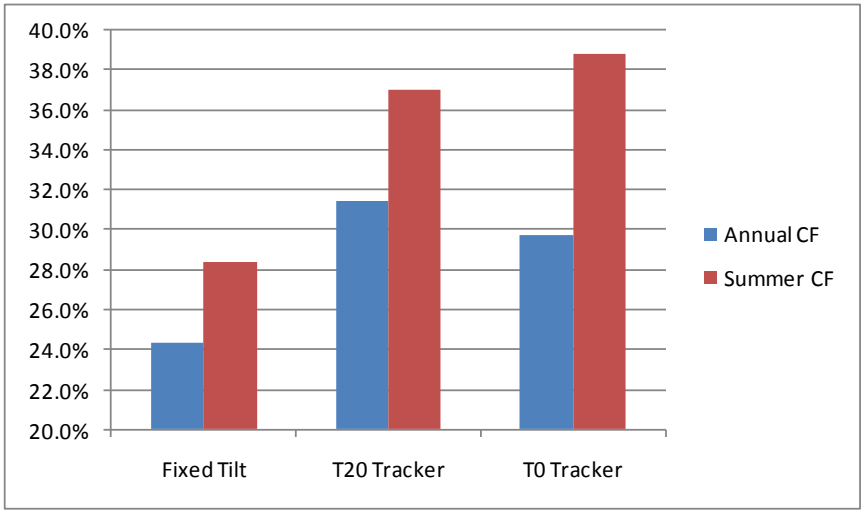
Commercial

No roof penetrations;
easy to install



New integrated module/frame/mount, developed under DOE SAI program

Power plants



Summertime capacity factor with SunPower modules and T0 tracker in Las Vegas is 39%

Recommended public/private partnerships (1 of 2)

- **Downstream areas would have biggest positive impact**
  - Local markets with multi-year demand drive local manufacturing
    - Majority of jobs in value chain are in module manufacture and system manufacture/assembly – and these are the steps best done locally
    - Downstream infrastructure (new approaches, sales channels, personnel, installation knowledge, local companies) has lasting benefit because it will be local and will be in place for further scaling with future technologies.
    - Long-term commitments for PV for Federal building and state grants
    - Carbon tax (with refund to Americans on per-capita basis)?
  - End-project financing is the key constraint now, so Green Bank, ITC grants, and other similar programs will have big impact
  - Bringing down other barriers for PV penetration (grid, permitting, local ordinances, educating customers about value of no energy cost risk for 25 years, etc.)

Recommended public/private partnerships (2 of 2)

- Programs that directly encourage development and manufacturing
  - Funding for diverse constituents
    - Federal labs such as NREL and Sandia, Centers of Excellence, large and small companies, Universities, technology development centers
  - Manufacturing tax credit
  - Technology partnerships in select areas
    - For example, the Thin Film Partnership which funded universities and companies with collaboration on areas of common interest was very helpful
- Module Energy Ratings
- Cost / volume roadmaps to help guide policy and industry investment

Key take-aways

- PV is now poised to become a large source of clean energy
- Approaches for Equipment/Technology Roadmaps that were helpful for the IC industry are not appropriate for the PV industry
- DOE has been a key part of the progress of the US PV industry, and can continue to drive progress and more manufacturing through:
  - Downstream programs such as Green Bank that drive increased scale and local infrastructure
  - Programs that encourage development and US manufacturing
  - Education that PV can deliver lower cost and higher volumes than commonly believed

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