DOE Solar Energy Technologies Program
Accelerating the U.S. Solar Industry

International Photovoltaic Reliability Workshop II

Removing Barriers to Photovoltaic Technology Adoption:
Reliability, Codes/Standards, and Market Acceptance
July 29–31, 2009 – Tempe Mission Palms Hotel, Tempe, AZ, USA

Chris Cameron

Sandia National Laboratories

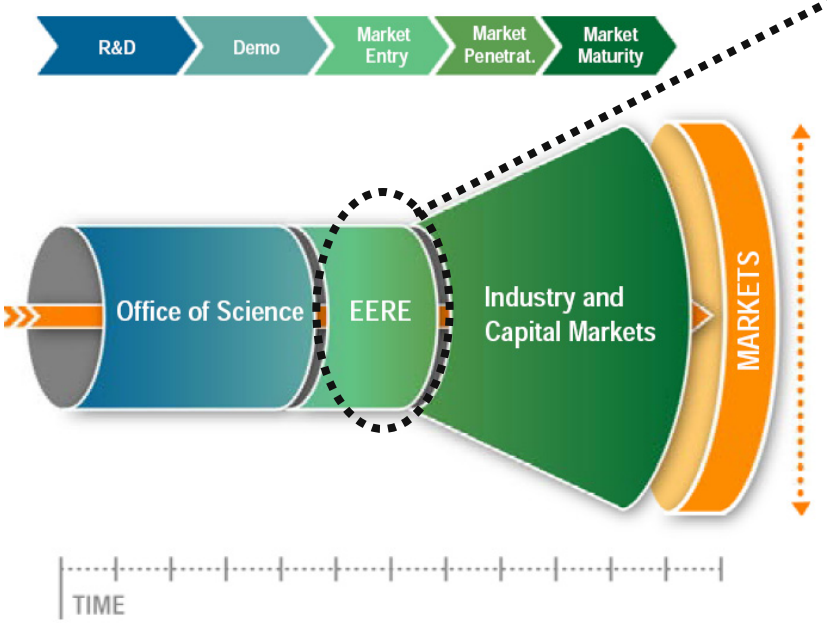
On Assignment to the DOE Solar Energy Technologies Program

Organizational Structure

U.S. DEPARTMENT OF ENERGY

U.S. Department of Energy

Annual Budget: $27 Billion (FY09)



Energy Efficiency, Renewable Energy (EERE)

Annual Budget: $1.9 Billion (FY09)

10 Programs

Energy Efficiency

- Building Technologies
- Weatherization & Intergovernmental
- Industrial Technologies
- Federal Energy Management
- Vehicles

Renewable Energy

- Wind & Hydropower
- Biomass
- Geothermal
- Hydrogen, Fuel Cells & Infrastructure
- and ….

Solar Energy Technologies Program (SETP)

Annual Budget: $175 Million (FY09)

~20 Staff (incl. contractors)

The SETP is executing four critical subprograms to reduce solar technology cost and achieve high penetration

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The Solar Energy Technologies Program Budget

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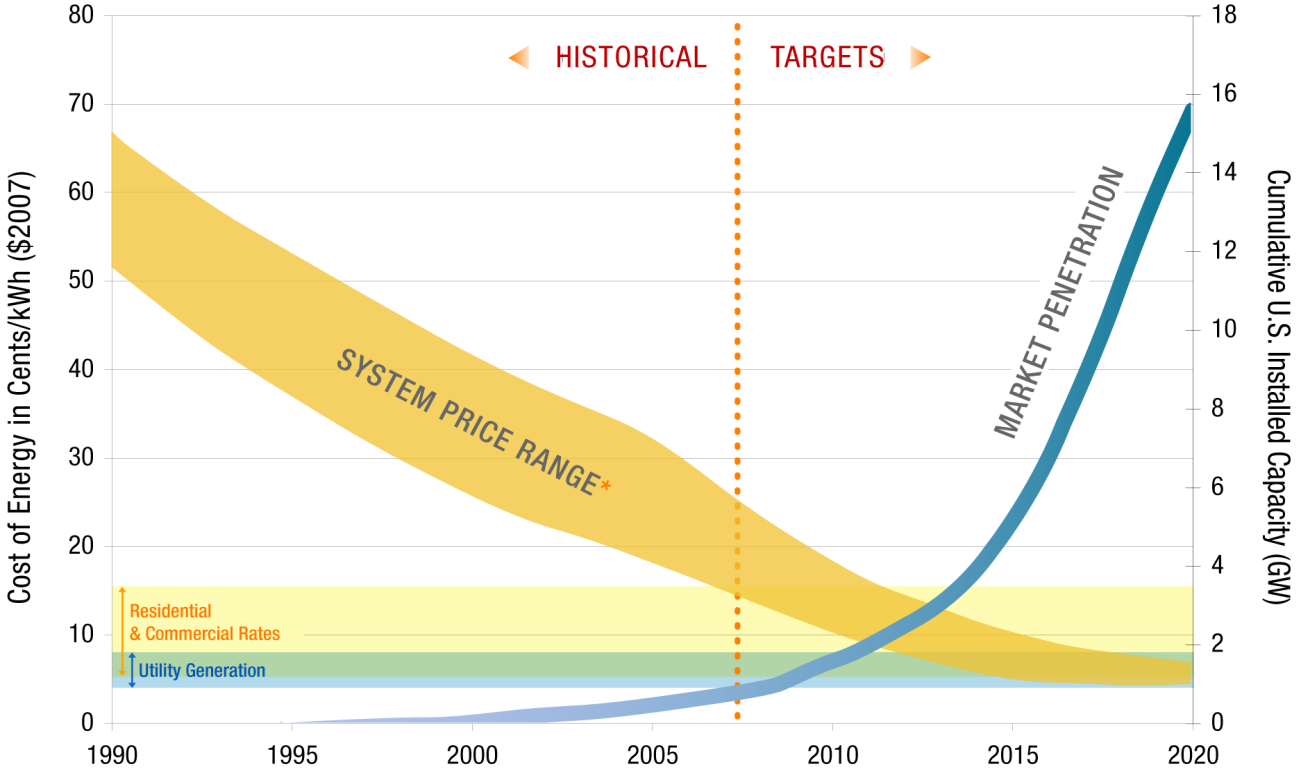
Subprogram	FY 09 Appropriations	FY 09 Recovery	FY 10 Request
PV Applied Research and Systems Development	$ 124.54 m	$51.5 m	$149.47 m
Concentrating Solar Power	$24.31m	$25.6 m	$78.42 m
Systems Integration	$12.12m	$25.5 m	$29.66 m
Market Transformation	$14.03 m	$15 m	$27.45 m
Solar Energy Hub	---	---	$35 m
TOTAL	$175 m	$117.6 m	$320 m

The SETP is focused on enabling high penetration of solar energy technologies and achieving grid parity by 2015



Market Sector	Current U.S. Market Price Range (¢/kWh)	Cost (¢/kWh) Benchmark 2005	Cost (¢/kWh) Target 2010	Cost (¢/kWh) Target 2015
Residential	5.8 - 16.7	23 - 32	13 - 18	8 - 10
Commercial	5.4 - 15.0	16 - 22	9 - 12	6 - 8
Utility	4.0 - 7.6	13 - 22	10 - 15	5 - 7

Historical DOE Role:
R&D Focus for Advancing Solar Energy

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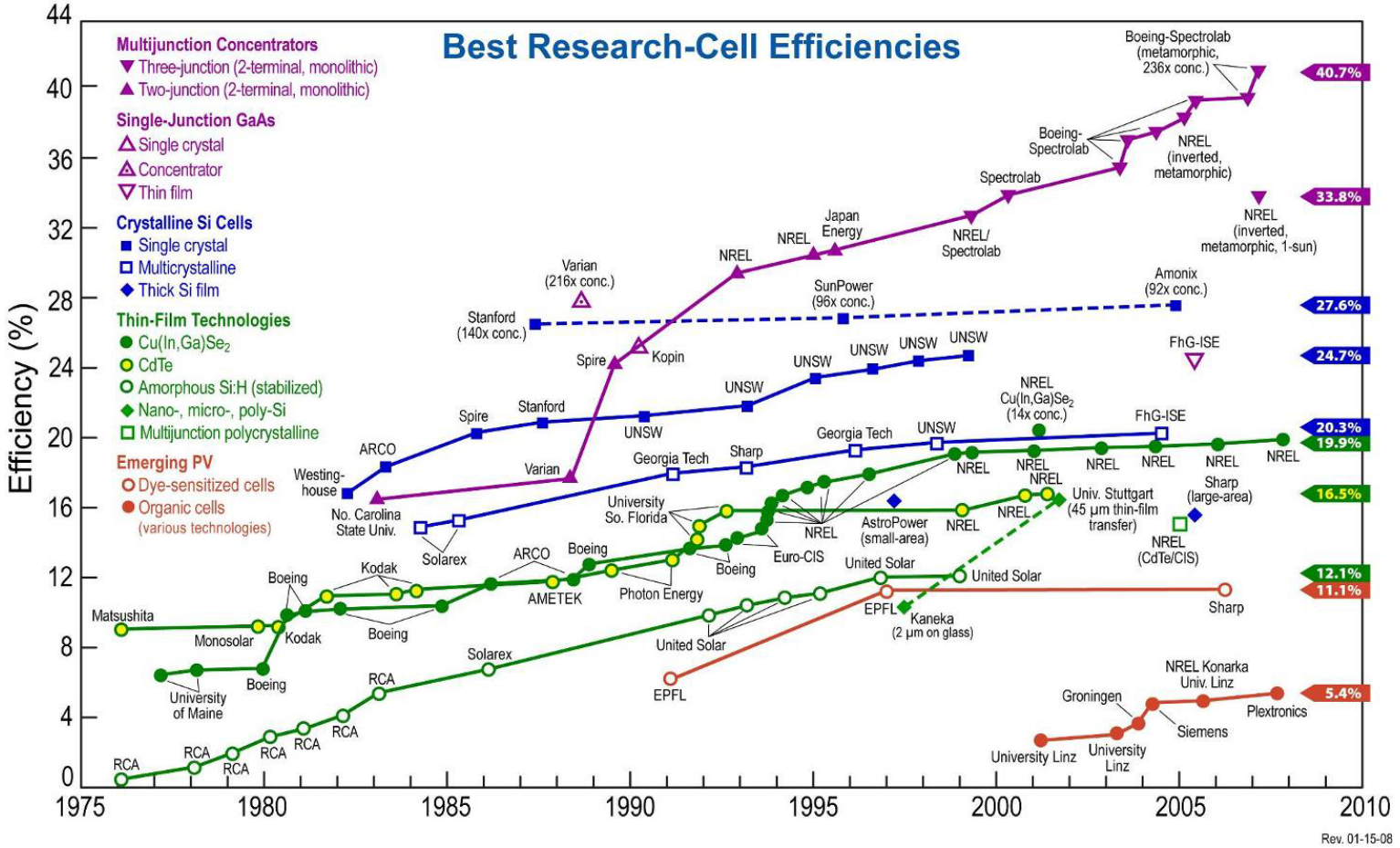

- Focus on narrow and quantifiable metrics: $/W, cell efficiency, g/W, etc.
- Fund risky technologies: advanced materials, designs, processes, products
- Provide support for new and emerging industries

Current DOE Role: Solar Energy Technologies Program works along the whole RD&D pipeline

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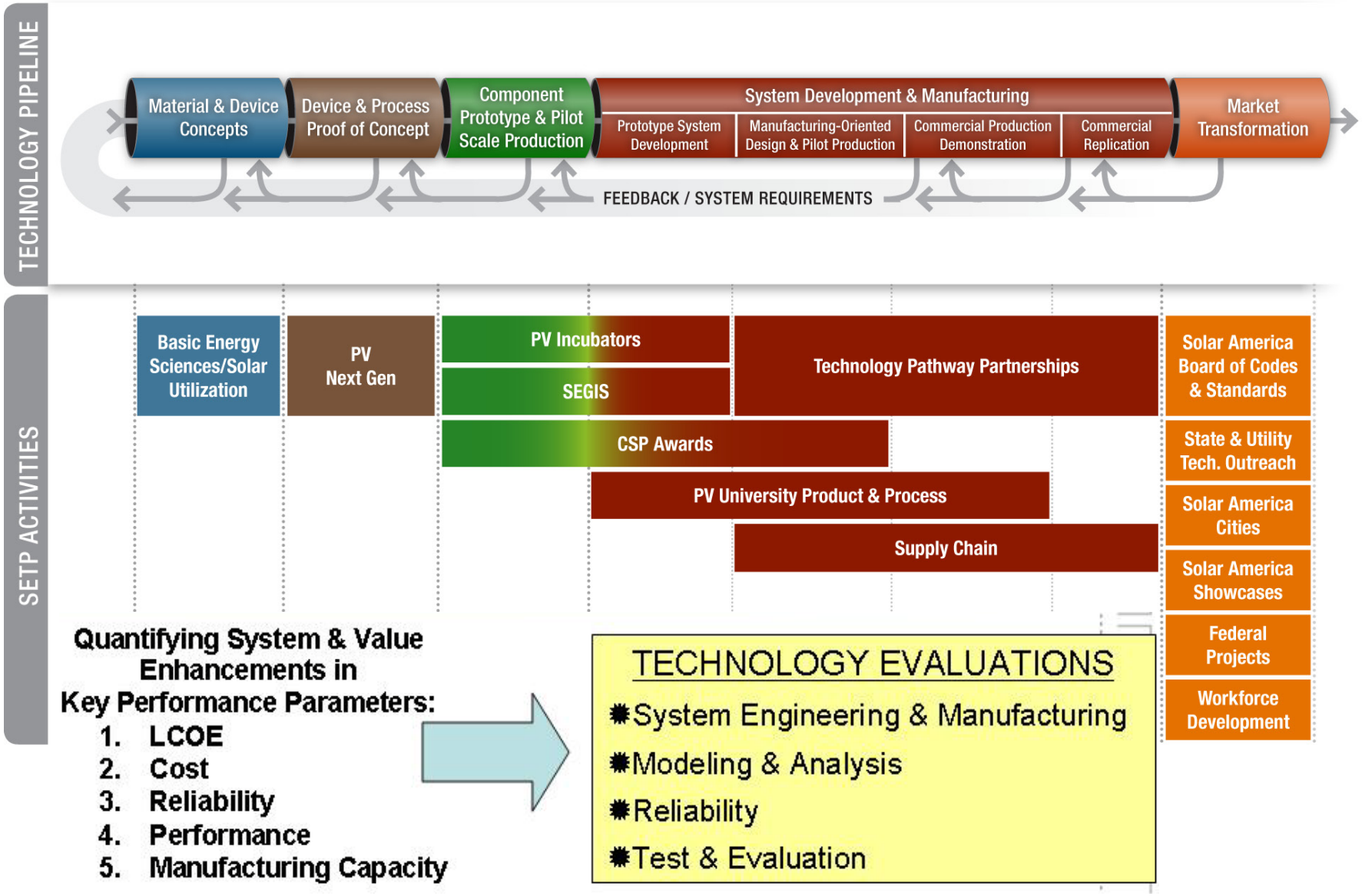

The SETP works with a number of stakeholders to grow and accelerate the U.S. the Solar Industry

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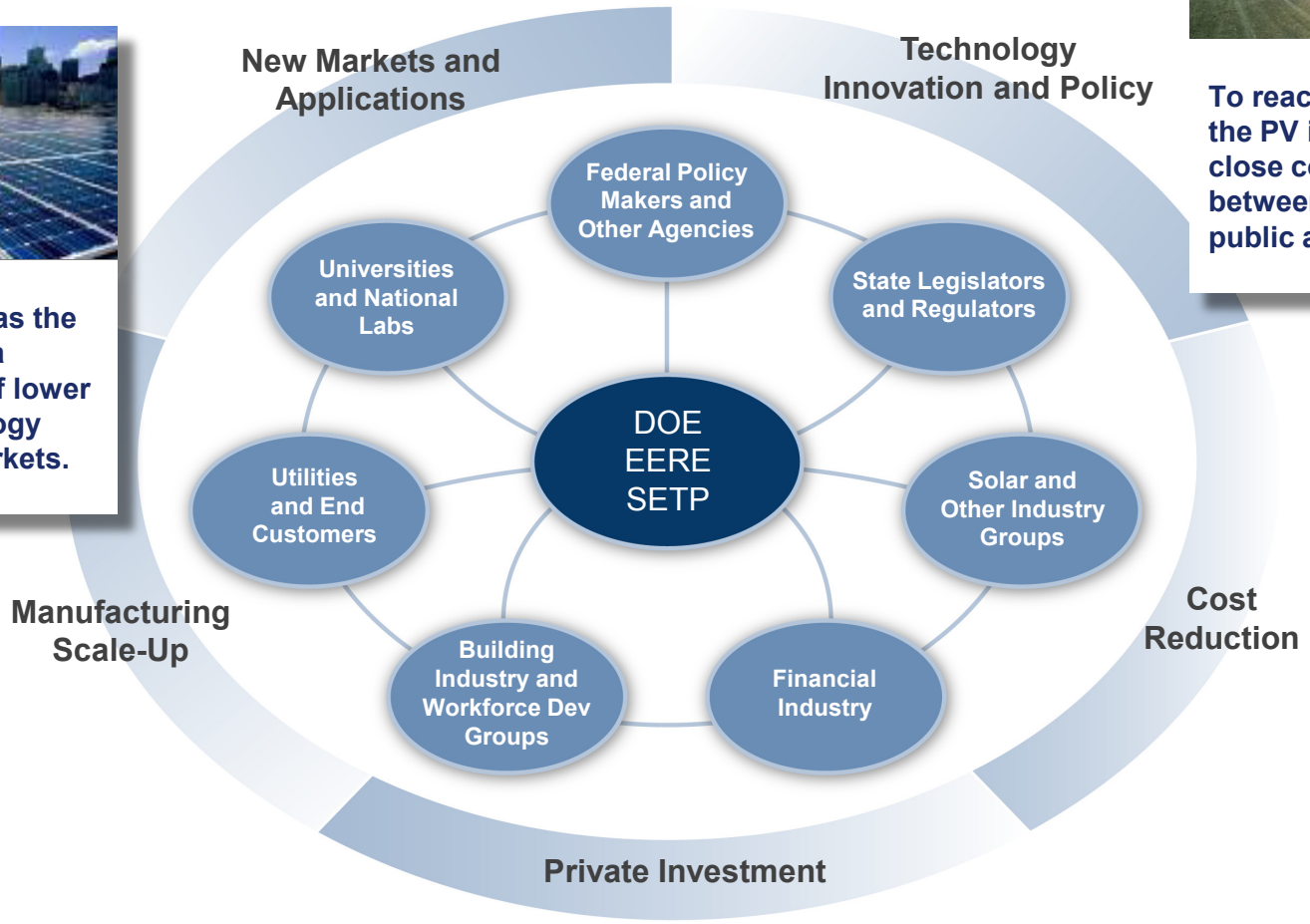
The PV industry has the potential to enter a *"virtuous cycle"* of lower cost, new technology and expanded markets.

To reach it's full potential, the PV industry requires close coordination between a number of public and private entities.



The solar program will need to be continually rebalanced to adjust to dynamic industry conditions

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Challenges: Photovoltaics

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- Continue to drive down costs and develop sufficient product diversity to address and maximize all market segments
- Ensure adequate supply chain for a large and rapidly growing industry
- Continue to provide reliable products with 30 yr lifetimes (both actual and perceived)

DOE's industry R&D programs include diverse technologies for potentially diverse PV markets

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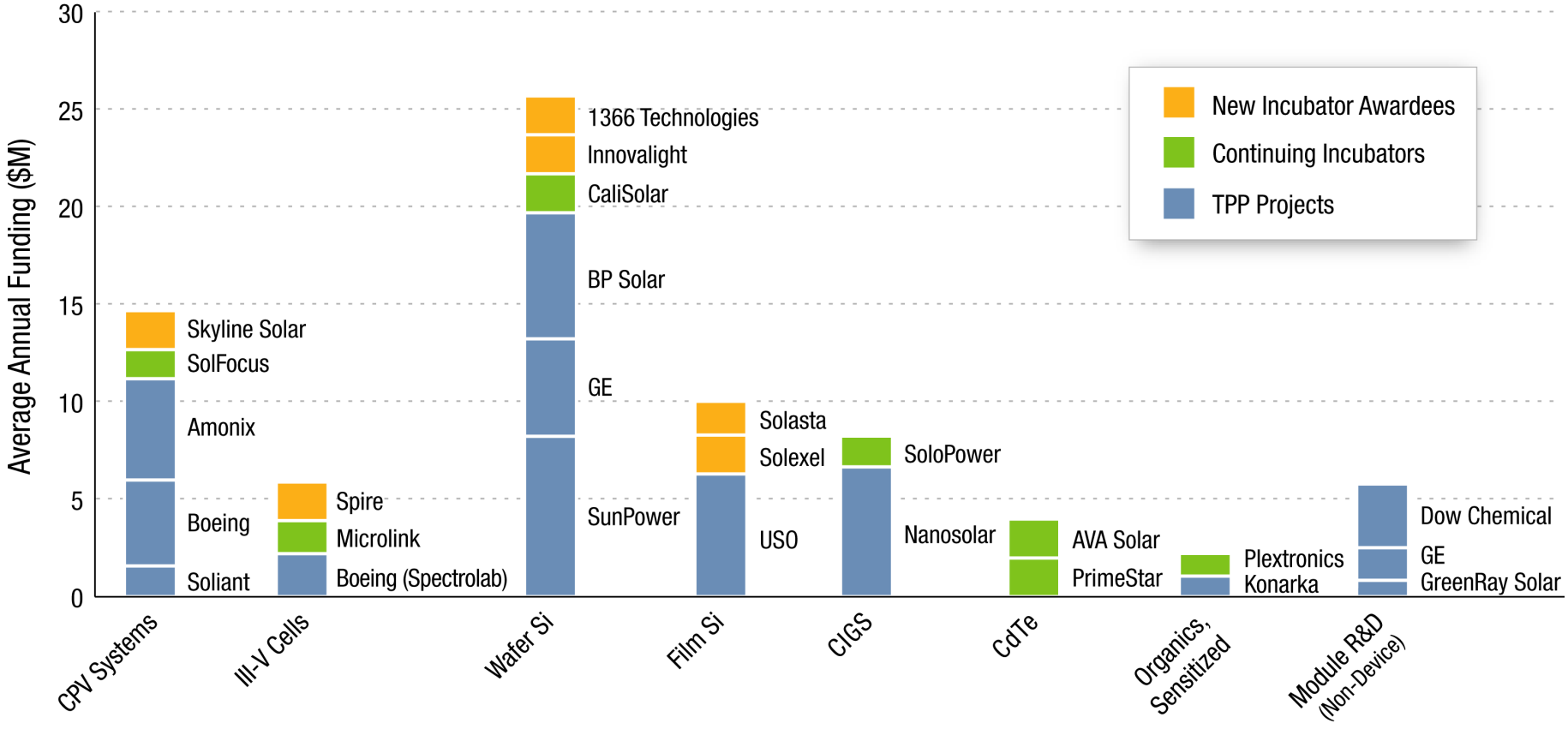

- **Technology Pathway Partnerships focus on minimizing total system cost**
- **Incubator program focuses on scaling up innovative new solar technologies**

DOE's Next Generation PV seeds the beginning of the pipeline with high risk/ high payoff projects

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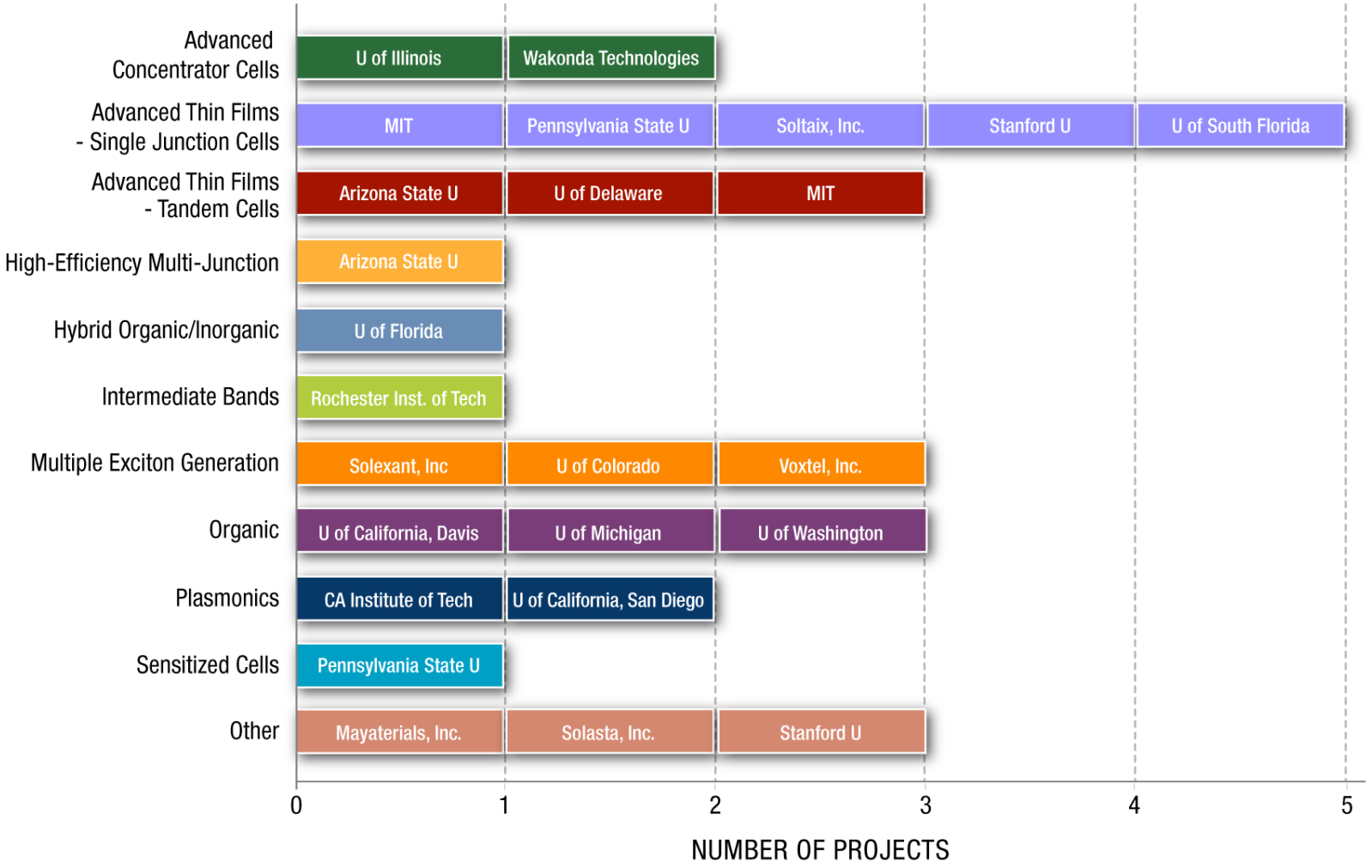

Challenges: Grid Integration

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- Ensure safe and reliable two-way electricity flow
- Develop smart grid interoperability
- Create models for renewable systems that allow them to be included in planning and analysis tools
- Integrate energy storage for short-term load balancing and long-duration peak shifting
- Integrate solar with time-of-use pricing and demand response
- Develop more reliable inverters (>10 yrs)
- Understand how a multitude of large megawatt systems affect grid stability
- Understand how various climates and conditions affect system reliability

Addressing Grid Integration Barriers

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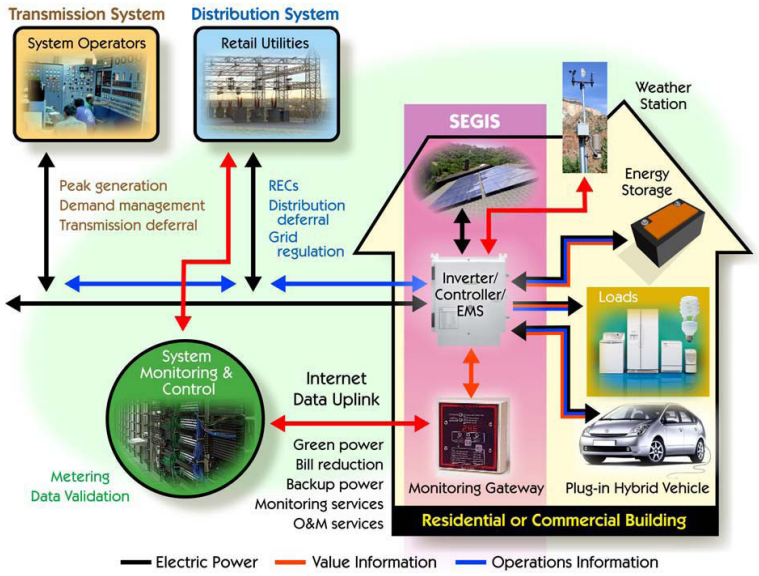
- Solar Energy Grid Integration Systems (SEGIS) is an industry partnership collaborative program
  - Will allow customer-generated electricity to be better allocated
  - Defines requirements for energy storage
  - The SEGIS "brain" is expected to be a combination of the inverter, controller and energy management system

- The PV Community Project focuses on the testing and evaluation of fielded PV systems to develop a database of field data



SEGIS Program Phase I Awards for Advanced Inverters/Controllers/Energy Management Systems

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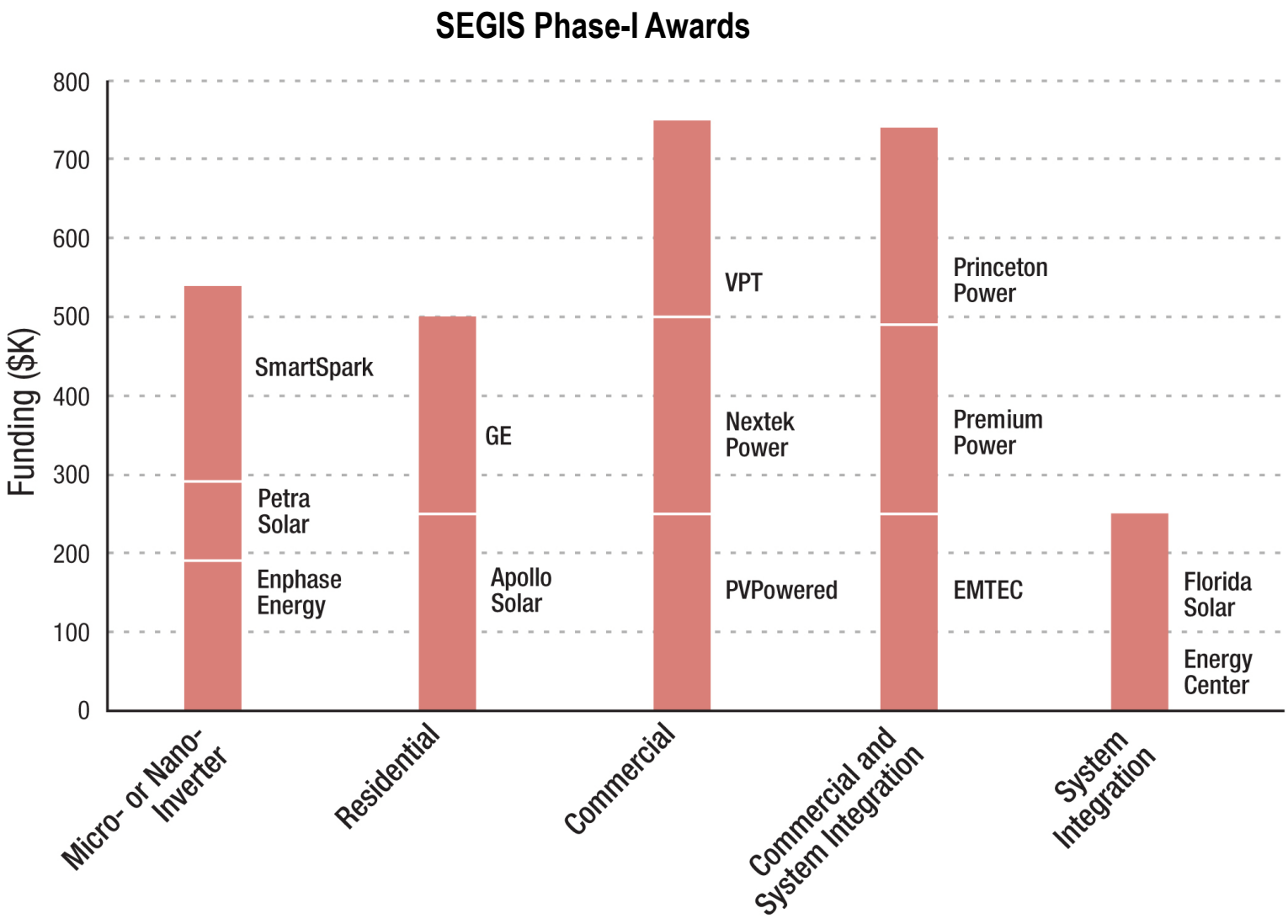

Challenges: Market Transformation

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- Shortage of information about solar technologies and little consumer awareness
- Insufficient product standards
- Inconsistent interconnection, net metering, and utility rate structures and practices for solar systems
- Inadequate codes and complex and expensive permitting procedures
- Inconsistent and insufficient state and local financial incentives and other market drivers
- Lack of flexible, sophisticated, and proven financing mechanisms
- Limited education for and insufficient numbers of trained and experienced personnel and services

Addressing Market Transformation Barriers

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- State Technical Outreach
  - Working with regulators and policy makers to ensure proper policy framework
- Utility Technical Outreach
  - Working with utilities to foster their acceptance and use of solar
- Codes and Standards
  - Collaborating with code officials to create uniform practices in solar code development
- Education, Training and Workforce Development
  - Working with training centers and certifying bodies to foster a robust qualified workforce
- Solar America Cities Partnership
  - Partnering with 25 cities to assist with city-wide solar energy adoption
- Solar America Showcases
  - Providing technical assistance for large scale, highly visible PV installations

Global PV market projections

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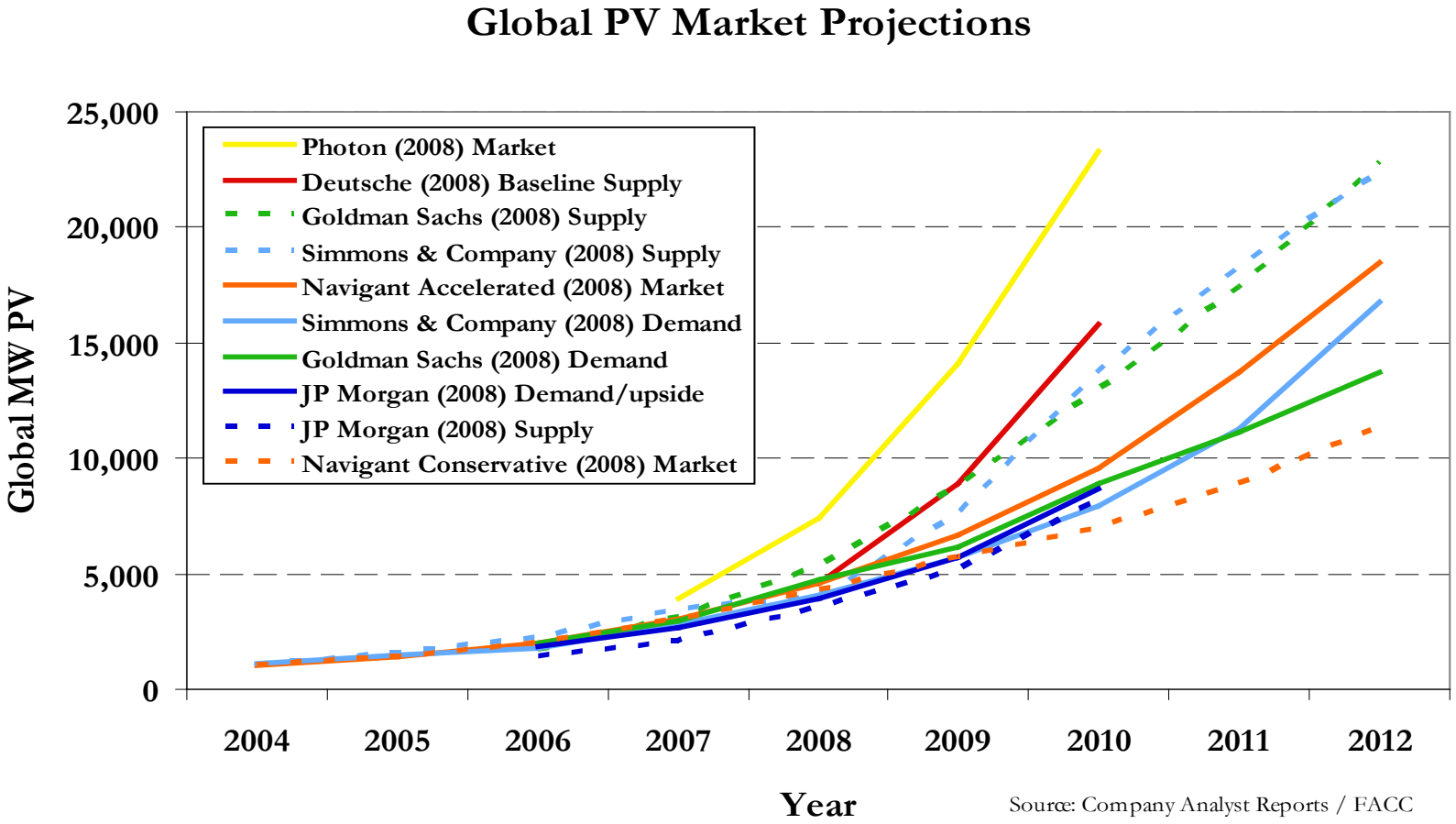
Projections made before the current financial crisis predict significant growth, with even the most conservative forecast shows over 25% compound annual growth from 2008 to 2012.



In a program-funded review of recent global module demand forecasts, not yet published, the *median* estimate of growth is a four-year CAGR of 34%, with little change to the most conservative predictions.

PV Module and System Reliability

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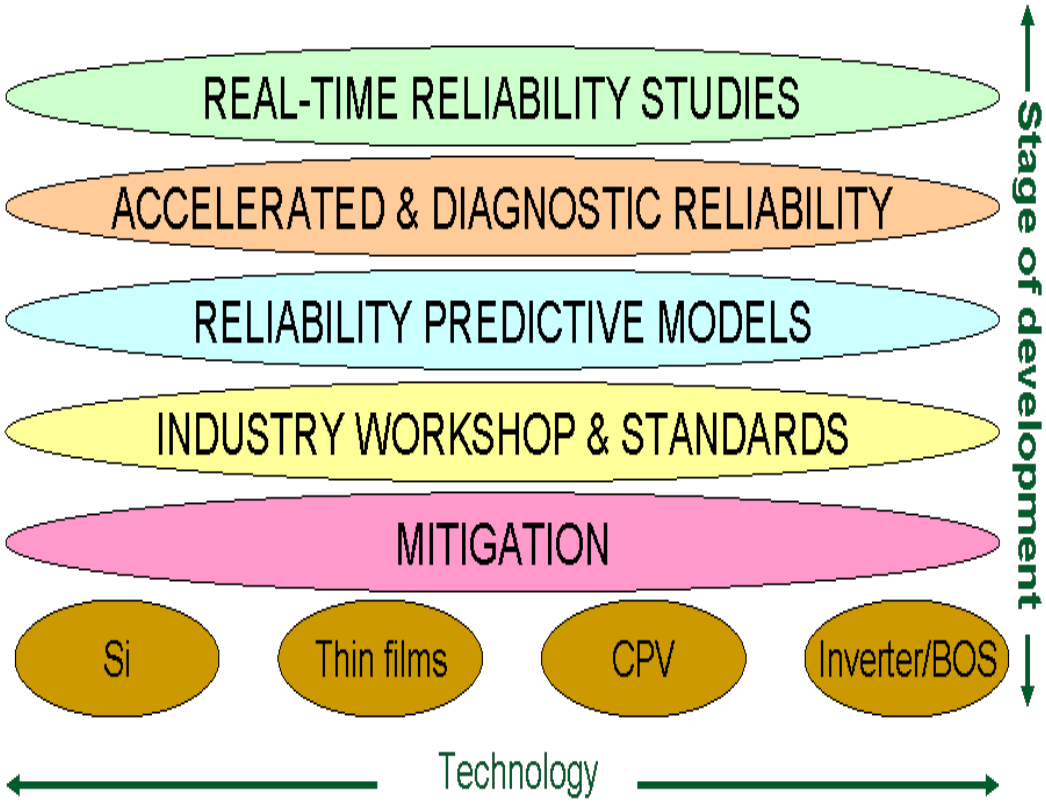
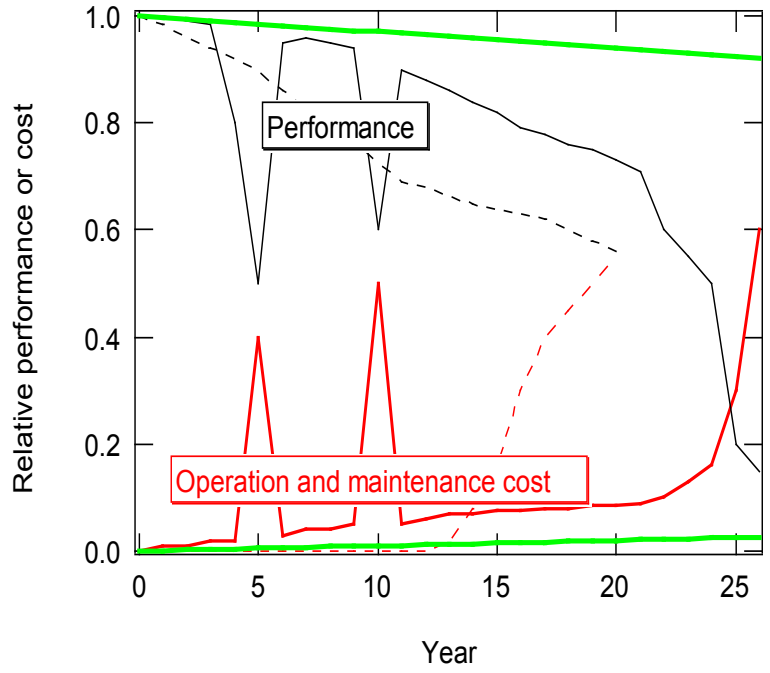
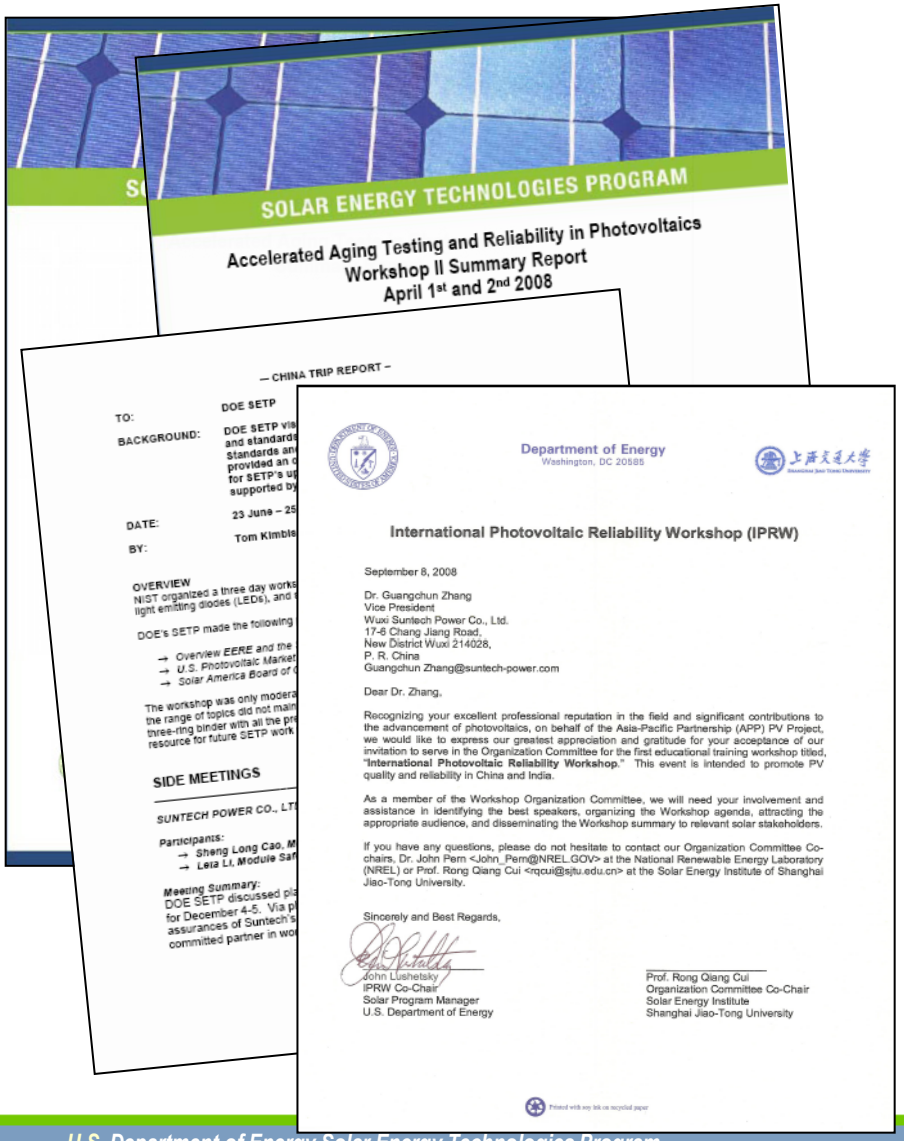
Rapid production scale-up and new PV technologies and system designs, driven by increasing private investment, are making "reliability" a growing priority





Detect failures, in order to *predict* performance & lifetime;
Mitigate failures to achieve excellent performance & low cost

Industry Workshops Conducted Domestically and Internationally to Address Reliability Issues



In the U.S., *Accelerated Aging Workshops* have provided a platform for high-level technical discussion on reliability, quality, and safety issues.

International Photovoltaic Reliability Workshops promote technical standards and raise awareness about important reliability issues affecting the global industry.

Why focus on PV reliability?

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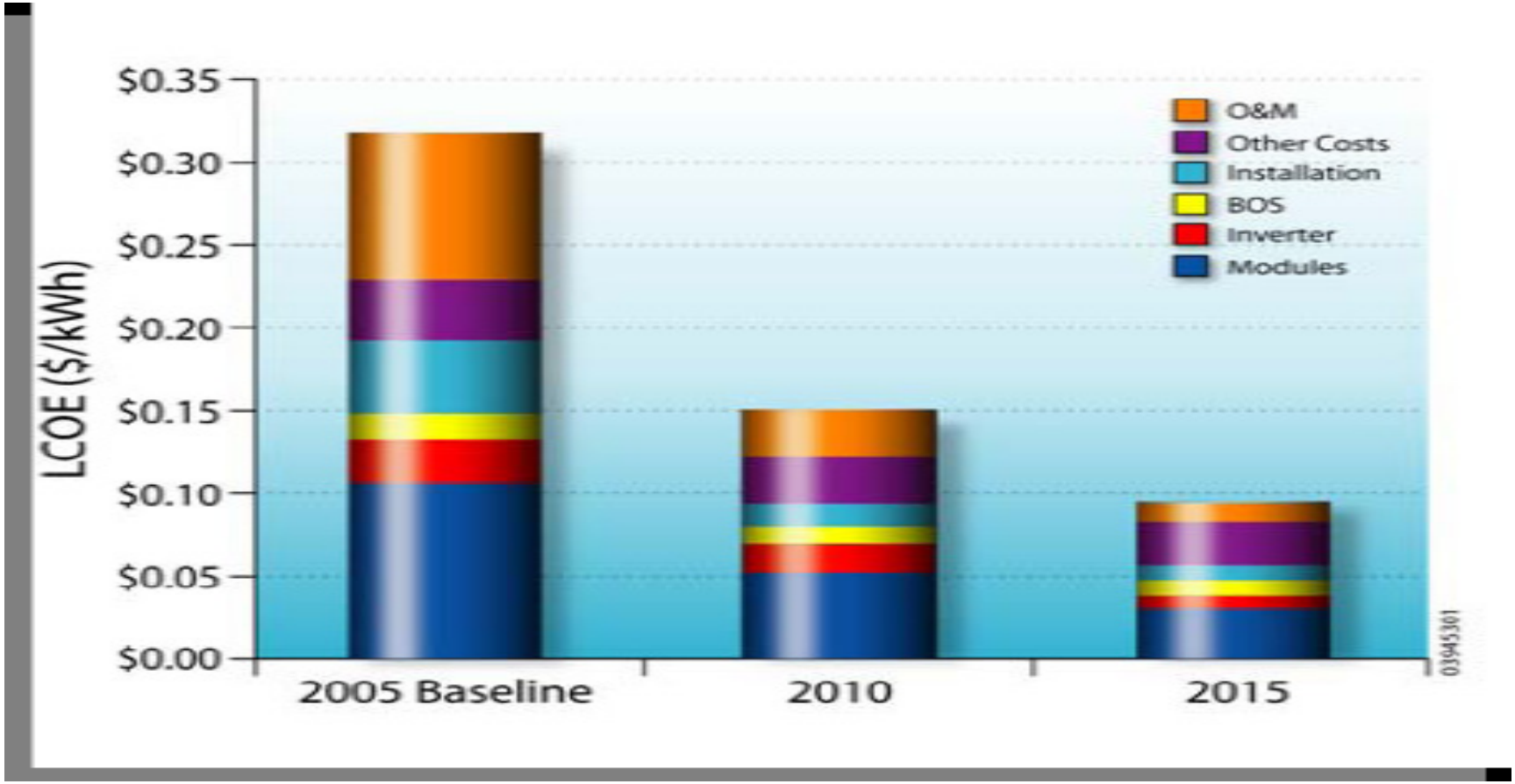
1) Long-term Reliable Performance of Modules & Systems Critical to Cost Parity .

- More than 20 years required for most components and systems.



Why focus on PV reliability?

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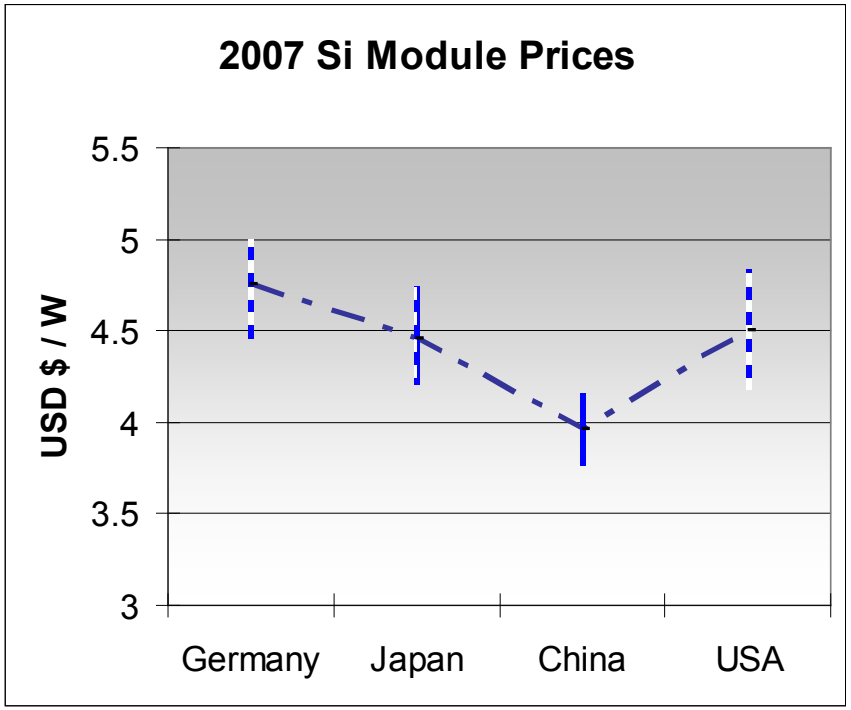
2) Long-term success of the industry depends on it.

- The incentive-driven global market along with non-discriminating buyers will change. Major product failures could disrupt growth.
  - Passage of 30% ITC and State RPS's has created strong demand in the US
- The expected growth trend also created a wide range of new companies with unknown quality and reliability of product performance.
  - Even within the solar industry, disconnects about "reliability" exist among manufacturers / installers / consumers.
- Perceptions of reliability risk (with or without a technical basis) are driving discounts into module prices.



Solarbuzz and PHOTON International, Aug. 2007

Corporate reputation, reliability history, and consumer perception affect pricing.

Proven reliability can lead to positive market differentiation.

For example- note resale value of Toyota is comparably higher than Chevy in the US.

Why focus on PV reliability?

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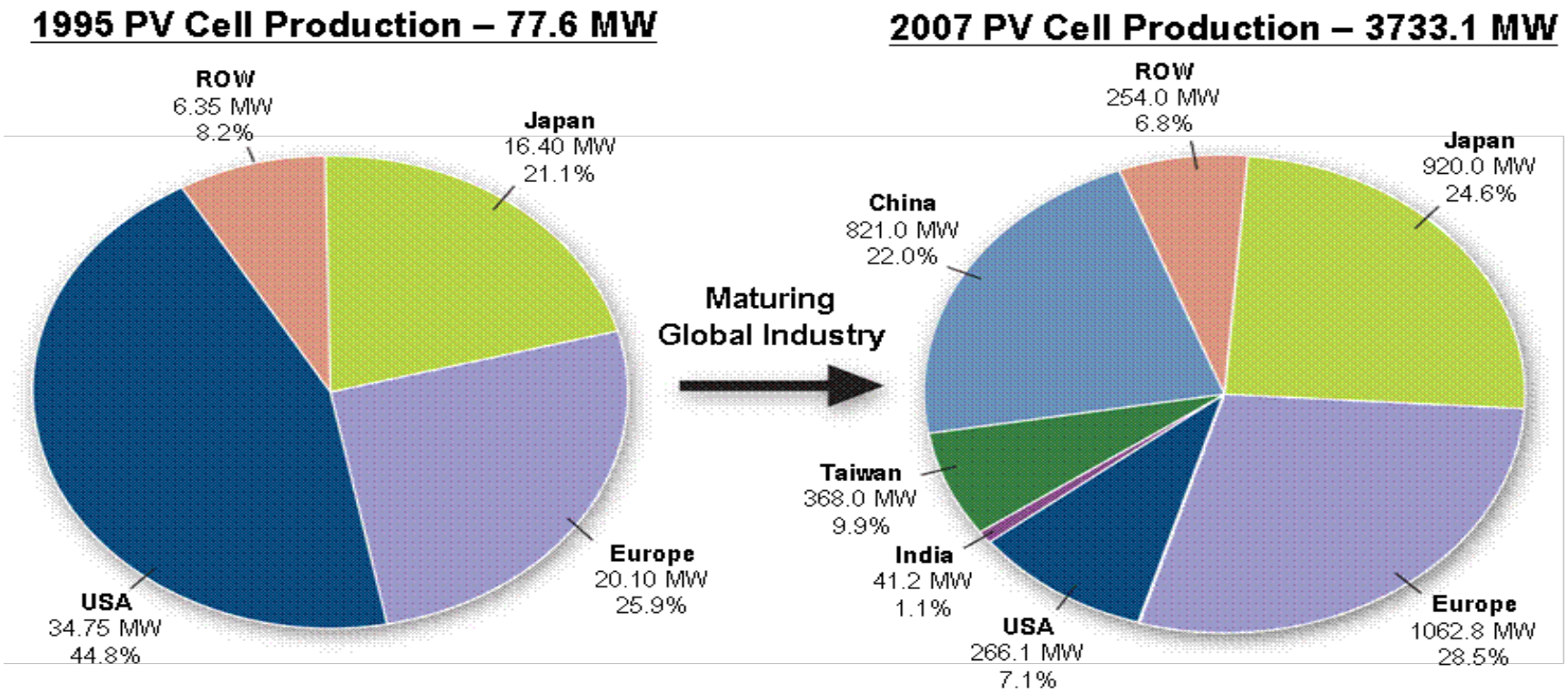
3) Growing Significance of Asian PV Module Production.

- In 2007, China accounted for more than 22% of global PV production in 2007 (PV News). Approx. 98% of PV is exported.



Data From PV News – Prometheus Institute (March 2001)

Data From PV News – Prometheus Institute (March 2008)

Poor System Quality and Reliability Adversely Impacted U.S. Solar Water Heater Market Growth

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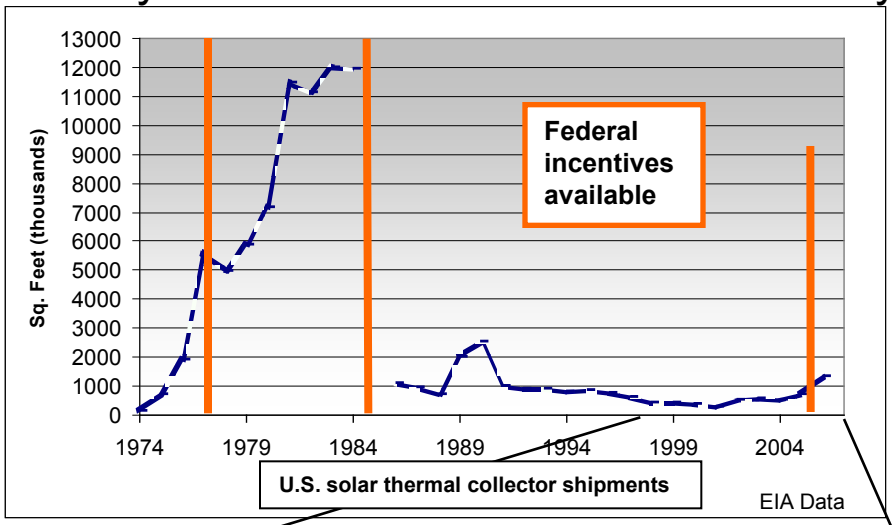
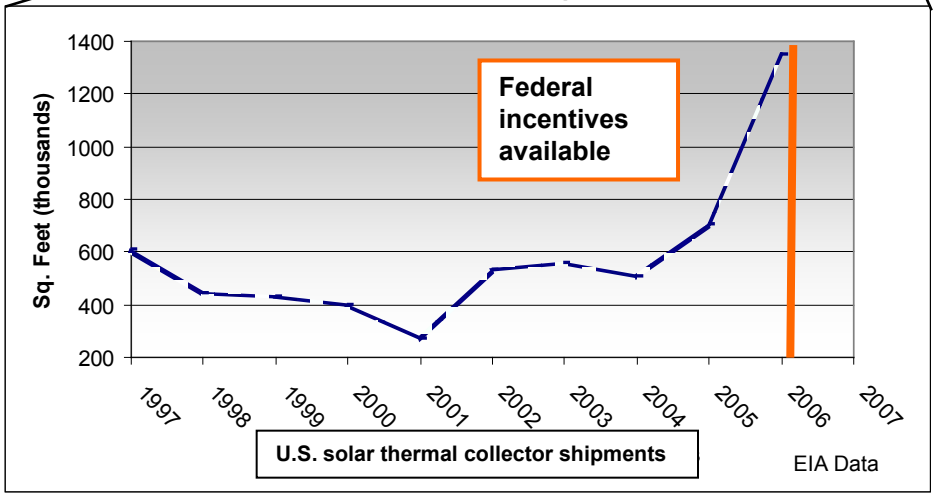
History of U.S. solar water heater industry



Solar water heater shipments '97-'06



→ Product failed at early stage of production ramp.

→ Primary problems affecting the technology's success: short-term tax incentive, poor system reliability, inefficient technology, and aesthetic appearance.

→ Key recommendation from survey results: communications on solar water heaters should be primarily focused on a message of low maintenance and strong warranties (NREL 1999).

Known Failure Modes Affecting PV Reliability

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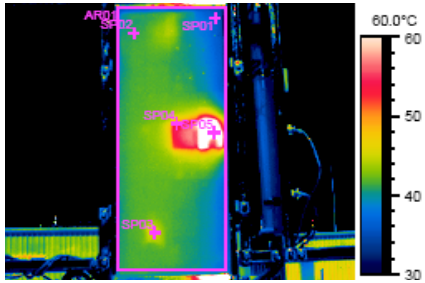
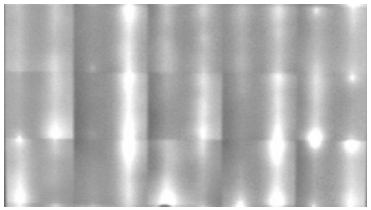
COMMON RELIABILITY PROBLEMS

Tracking	Interconnects	De-lamination
Soiling / Dirt	Junction Box Seals	Glass Breakage
Overheating / Heat Sinks		Corrosion

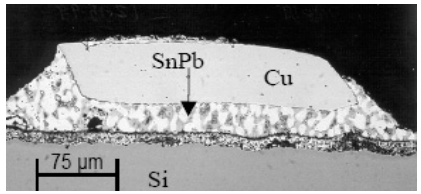
Glass breakage can present high-voltage safety problems



De-lamination causes poor heat transfer in addition to optical decoupling



Broken interconnects



Corrosion of soldering joints

Risks- REC Solar recalls 420,000 panels @ $56MK.

http://www.solarfeeds.com/greentech-media/7596-rec-to-recall-all-of-its-solar-panels-from-2008.html

Fires:

Standards, certifications, and appropriate testing can reduce the prevalence of commonly known failure modes.

U.S. Solar Energy Technologies Program
Reliability Programs and Activities

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U.S. Department of Energy

Develop Web-Based Photovoltaic (PV) Database (Funding $1.5M over five years)

eere.energy.gov/solar/upcoming_opportunities.html

National Renewable Energy Laboratory

Accelerated Aging Testing Centers

Real-Time Reliability Studies

Predictive Model Development

(Funding- $4.2 Million in FY09)

The Atlas 260 is one of several accelerated-testing chambers in the high-bay laboratory at OTF. (NREL)

Sandia National Laboratories

Accelerated & Diagnostic Reliability Testing

Center for System Reliability

(Funding- $1.6 Million in FY09)

Regional Experiment Stations

System Long-Term Exposure Tests

Southwest Technical Development Institute

Florida Solar Energy Center

Joint Events Leading to this Workshop

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- December 2007: Participated in a Suntech-organized conference in Wuxi, China.
- February 2008: Coordinated with the Asia Pacific Partnership (APP) to expand U.S. – China engagement on reliability.
- June 2008: Participated in a NIST-organized codes and standards workshop.
- *December 2008: International PV Reliability Workshop* in Shanghai, China.

Collaborative Workshop & Follow-up Activities

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December 4-5, 2008: **International PV Reliability Workshop in Shanghai.**

- Information-sharing with a focus on PV module qualification standards and methodologies currently being used in the U.S., Japan, and the EU. Most of this information is based on IEC procedures.
- *U.S. Co-organizers:* U.S. Dept. of Energy, Asia-Pacific Partnership, National Renewable Energy Laboratory, Sandia National Laboratories, Underwriters Laboratories.
- *Chinese Co-organizers:* Solar Energy Institute of Shanghai, Jiao-Tong University, Suntech Power, China General Certification Center, China Quality Certification Center, Wuxi National PV Test Center.
- *Sponsors:* Suntech Power, LDK Solar, Trina Solar, Jolywood (SuZhou) Solar Material Technology, Underwriters Limited.

July 29-31 2009: **International Photovoltaic Reliability Workshop II**

- A reciprocal U.S.-based technical training workshop with solar stakeholders from China and elsewhere and SNL, NREL, RESs, FSEC, ASU, TUV-Rheinland, APS and associated partners.
- Removing Barriers to Photovoltaic Technology Adoption: Reliability, Codes/Standards, and Market Acceptance

Winter 2009: Summary Report.

Thank You

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Sign up for SETP quarterly newsletter by emailing: solar@ee.doe.gov

Back-up Slides

Funding for the SETP has been increased in response to the Solar America Initiative

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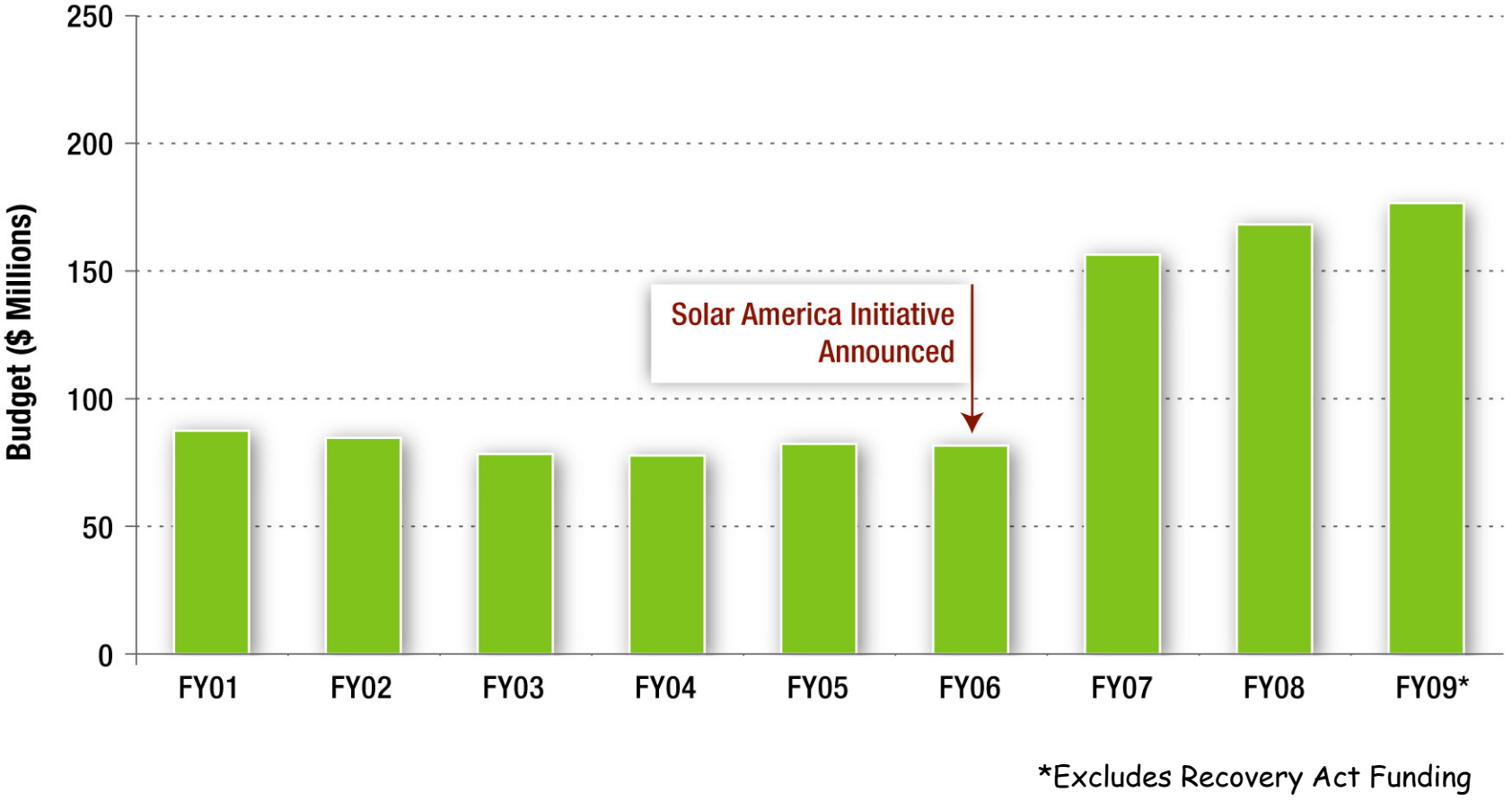

*Excludes Recovery Act Funding

Program Budget Breakdown

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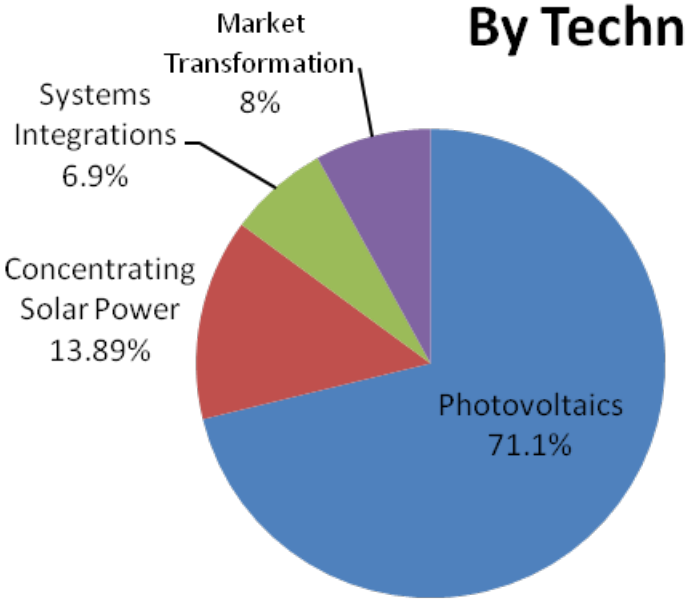
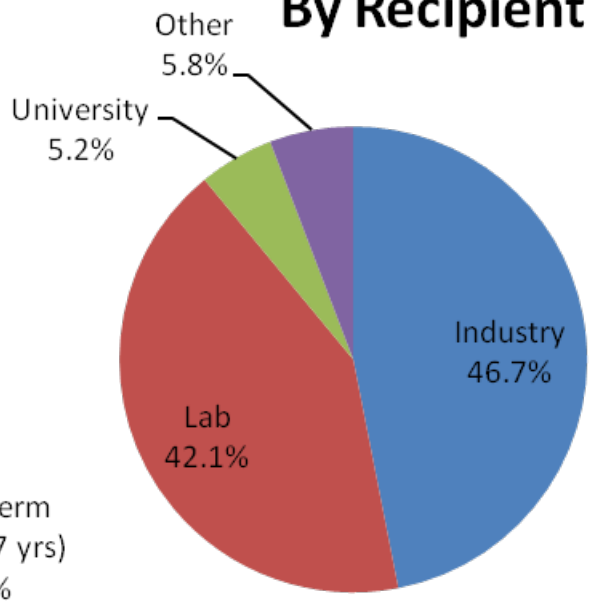
By Technology



By Recipient



By Term