Manufacturing challenges facing CdTe and CIGS

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Our Mission

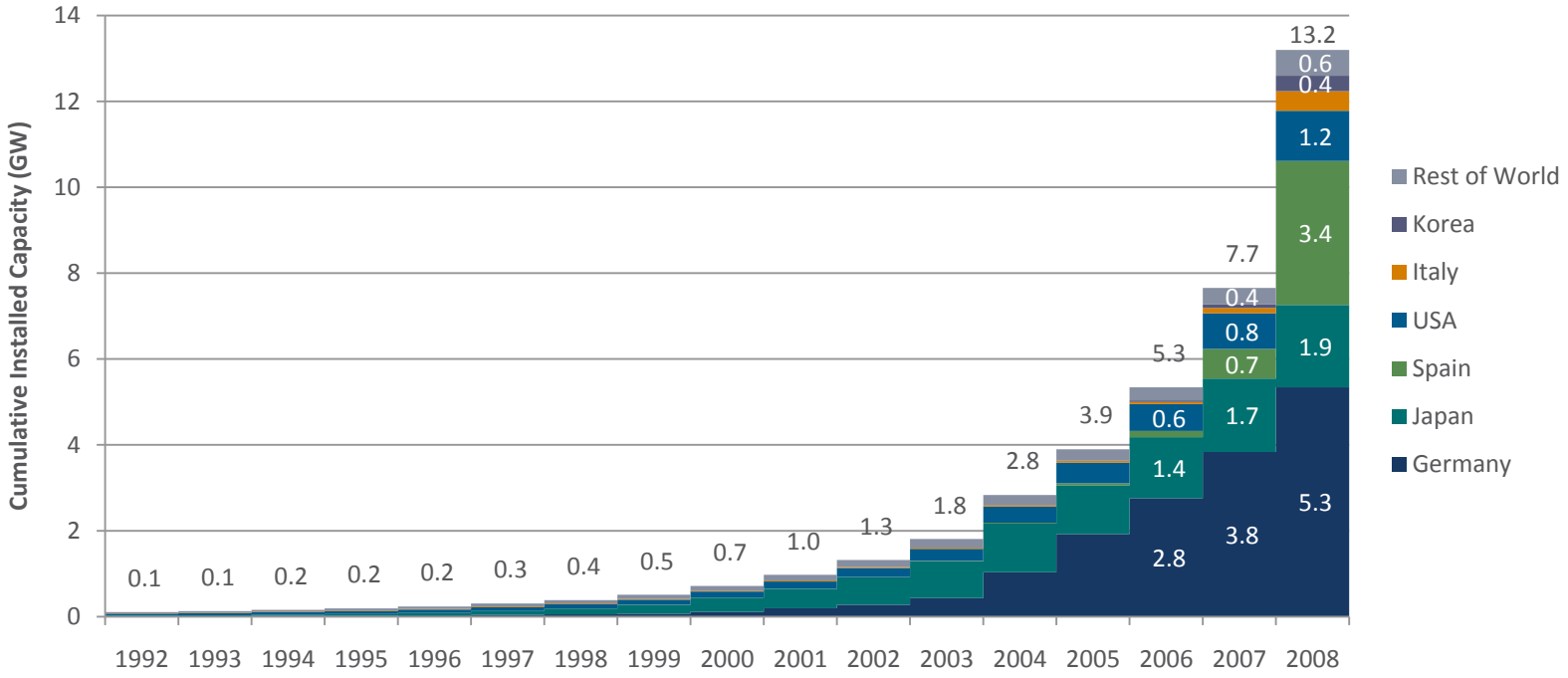
To create enduring value by enabling a world powered by clean, affordable solar electricity.

Outline

- Brief market overview
- Current status
- Opportunities in TF PV manufacturing
  - Technological Improvements
  - Labor force characteristics
- Conclusions

Global Cumulative Installed Capacity of PV

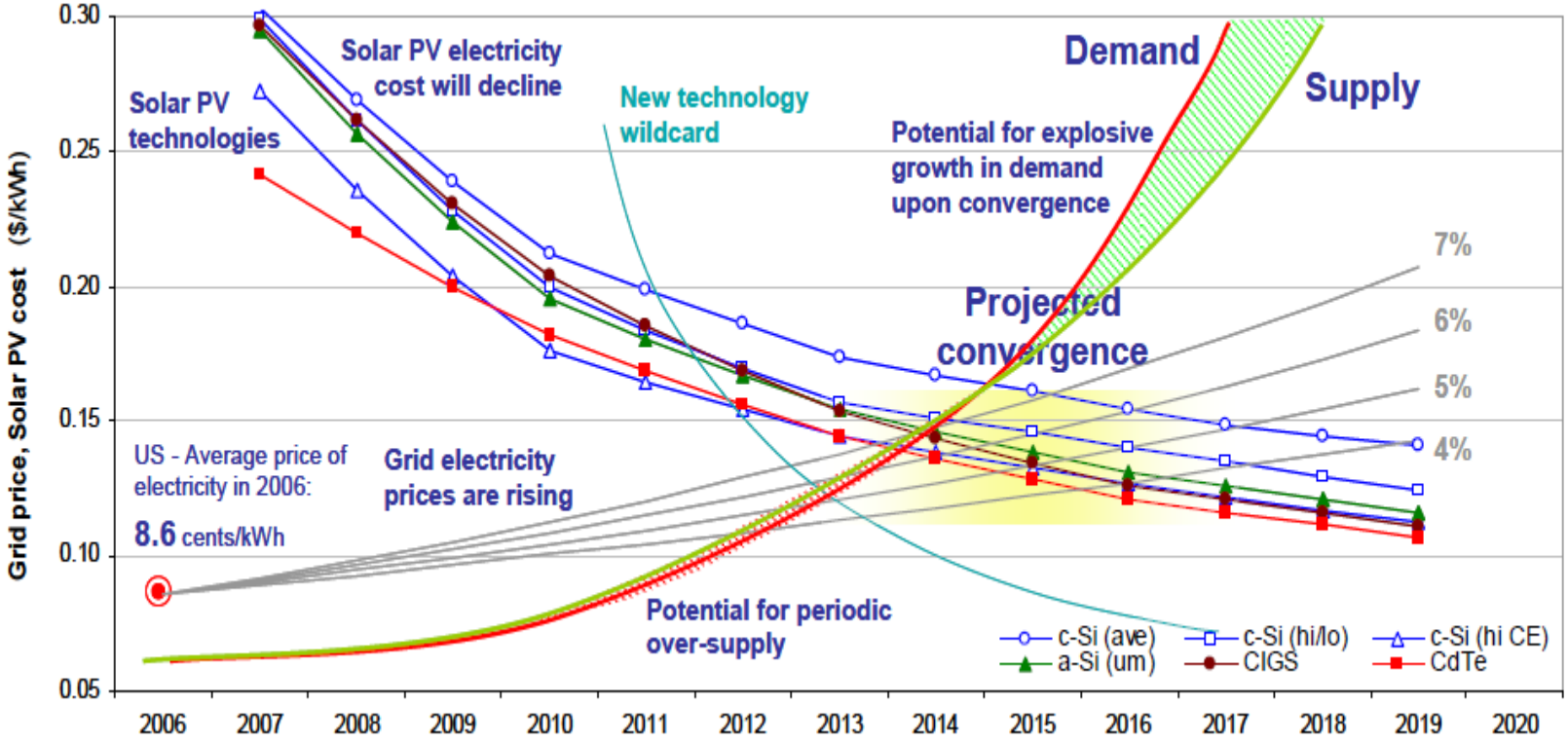
Selected IEA countries



Source: "Trends in photovoltaic applications". IEA PVPS. September 2009.

Long-term View of the Solar PV Industry

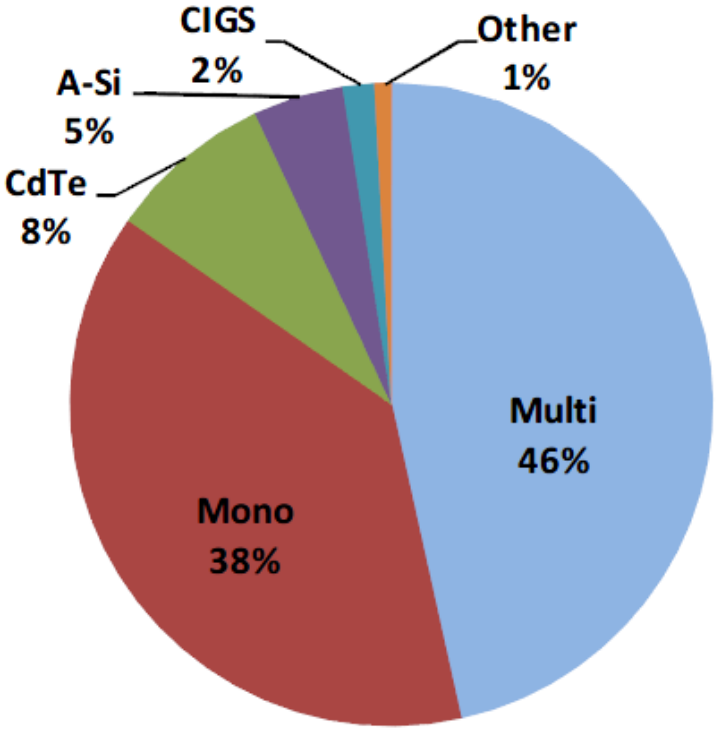
A complex marketplace



Source: "Solar Photovoltaic Industry", Deutsche Bank, May 2008

PV Technologies

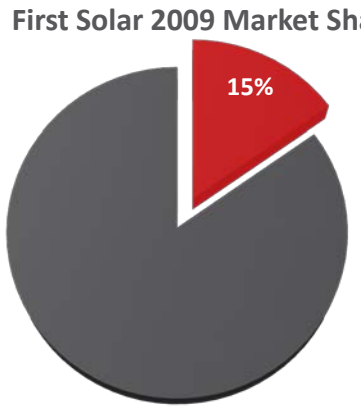
2008 Technology mix



Source: "Clean Technology Primer", Jeffries Research, March 2

"Copy Smart" Production Capacity Growth

Driven by increasing efficiency, run rate, and yields

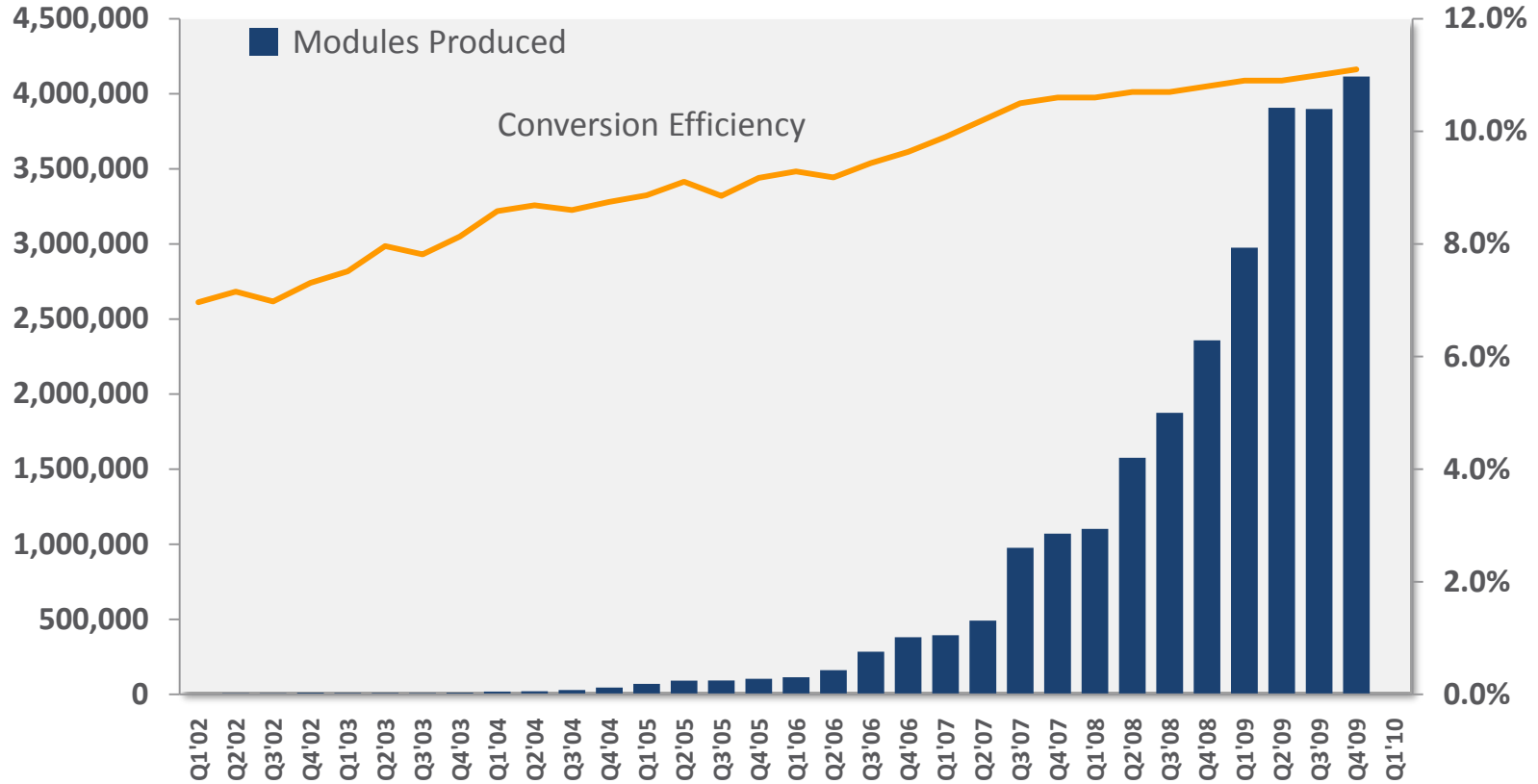


* - based on Analyst estimated 7.3 GW global installs in 2009

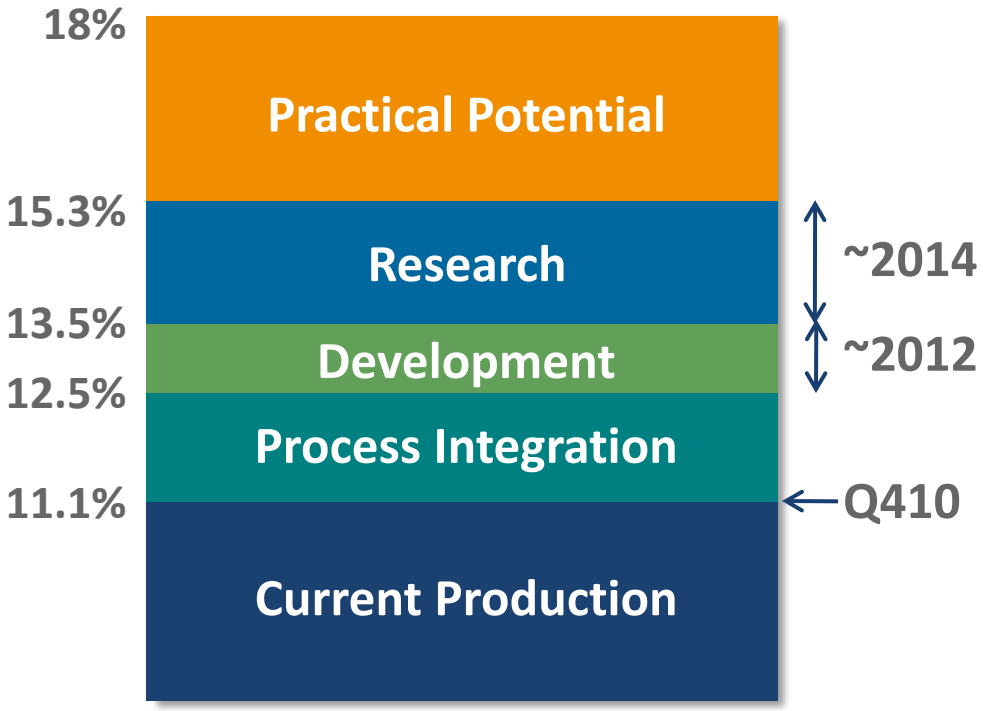
2005 & 2006 based on Q406 run rate; 2007 based on Q407 run rate; 2008 based on Q408 run rate; 2009 – 2012 based on Q409 run rate

Products & Performance

Proven Record of Increasing Module Conversion Efficiencies



Conversion Efficiency Potential



High-Confidence Roadmap to >12.5%

- **12.5% requires closing the gap between CdTe product and lab record performance**
  - NREL “hero” CdTe Cell is 16.5%
  - Best module is 80% of "hero" cell
  - Production average is 90% of best module
  - 16.5% hero-cell corresponds to ~13% production
- **Pathway is mostly improved light transmission into existing device**
  - NREL Jsc demonstrates upside of 1.3% absolute
  - Many opportunities for improvements in current
  - Technology challenge is to make these improvements manufacturable
    - Reducing thickness of CdS
    - Proprietary improvements to TCO
    - Proprietary improvements to glass transmission
- **FSLR Leveraging current leadership for sustained competitive differentiation**

1,000 Pathways to >16% and Beyond

- Multiple approaches to driving performance
- Renewed excitement in the technical field
- Fundamental device physics and materials science
- TF-CdTe still has enormous headroom

Optical Engineering

Contact Engineering

Grain-boundary Engineering

Band-Engineering

Dopant Engineering

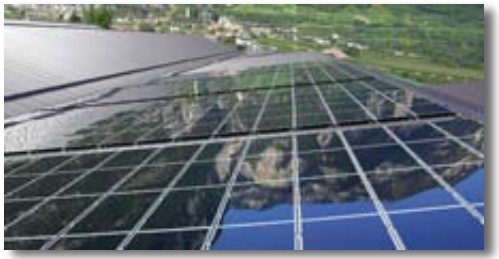
Opportunities in TF PV Manufacturing

1. Technological Improvements
2. Labor Force Characteristics

Key Criteria

i. R&D needs to be compatible to HVM – i.e. takt times, CapEx, OpEx, environmental impact (toxicity, CO_2 footprint)

ii. No need to fix what isn't broken/reinvent the wheel



Technological Improvements

- Increased fundamental understanding of semiconductor system and interfaces
- Novel in-situ, on-line, and off-line metrology
  - compositional control
  - key opto-electronic properties
  - module scale solar simulators and QE
- Equipment engineering
  - P1 through P3 laser scribing for CIGS
  - thermal processing
- Reliability
  - fundamental understanding of device & material degradation mechanisms
  - new packaging materials
  - energy rating standards, methods and algorithms
  - accelerated stress test protocols representative of multiple climatic regions

Technological Improvements cont.

- Novel materials for encapsulation and device stack
  - ohmic back contact
  - TCO
- Recycling methods for CIGS
- BOS optimization
  - inverters optimized for TF PV
  - NEC revision enabling > 600V system voltage

Labor Force Characteristics

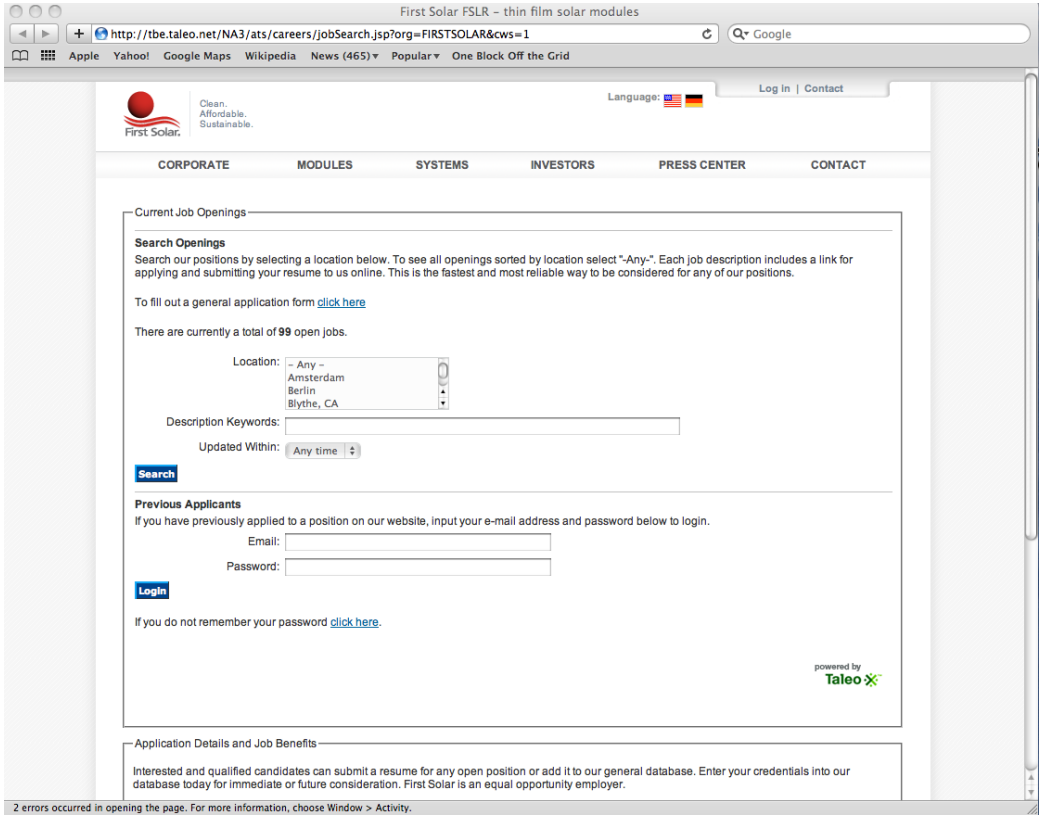
- Solid state and theoretical physicists trained in polycrystalline compound semiconductor systems
- Analytical and physical chemists as well as process engineers understanding TF deposition technologies
- Materials Scientists skilled in materials characterization and failure analysis
- Electrical engineers and physicists trained in device characterization and instrumentation
- Mechanical engineers with focus on large area, HVM deposition and automation equipment
- Computer scientists
- Sound understanding of basic principles in physics, chemistry, and engineering

Conclusions

- PV historically too expensive; conventional electricity rising in price; PV reducing cost
- Grid parity leading to inflection in price elastic demand; exponential demand leading to continued growth of PV
- CdTe clear leader in LCOE from PV; c-Si will continue to play a major role; CIGS, if commercial scale will prove viable, can emerge as competitive on cost to c-Si
- Better understanding of fundamentals for CdTe and CIGS required
- Technology/engineering challenge is to make R&D improvements manufacturable
- Need for a wide array of experts – mechanical as well as electrical engineering, physics, chemistry, materials science, and computer science

Career Opportunities at First Solar

http://www.firstsolar.com/en/careers.php



First Solar Locations

Global Headquarters	Tempe, Arizona, USA
Europe	Amsterdam, Netherlands Berlin, Germany Brussels, Belgium Madrid, Spain Mainz, Germany Paris, France
Manufacturing	Frankfurt (Oder), Germany Kulim, Malaysia Perrysburg, Ohio, USA
North America	Bridgewater, New Jersey, USA Oakland, California, USA New York, New York, USA Sarnia, Ontario, Canada
Asia/Pacific	Sydney, Australia