iNEMI

International Electronics Manufacturing Initiative

Emerging Energy Efficient Technologies

Solid State Illumination

Photovoltaics

Advancing manufacturing technology

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International Electronics Manufacturing Initiative

Solid State Illumination Highlights

Speaker: Bob Pfahl, iNEMI
Chair: Marc Chason, Consultant
APEX 2009/Las Vegas, NV
March 31, 2009

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Roadmap for Solid State Illumination(SSI)

The Lighting Challenge

"According to the Department of Energy (DOE), lighting accounts for 8% of all energy consumption in the United States and 22% of electricity nationwide. LEDs have the potential to reach 200 lm/W, compared to the efficacies of incandescent lamps at 15 lm/W and fluorescent tubes at 90 lm/W. If solid-state lighting replaced all existing lights, the DOE estimates customer savings of $115 billion by 2025 and a 10% reduction in greenhouse emission gases

NGLIA
NEXT GENERATION LIGHTING INDUSTRY ALLIANCE

"The Solid State Illumination (SSI) chapter addresses technologies specific to inorganic and organic LED assembly (i.e., materials, assembly, packaging, manufacturing), test and measurement, devices and circuits, reliability and standards."

2009 iNEMI SSI Roadmap

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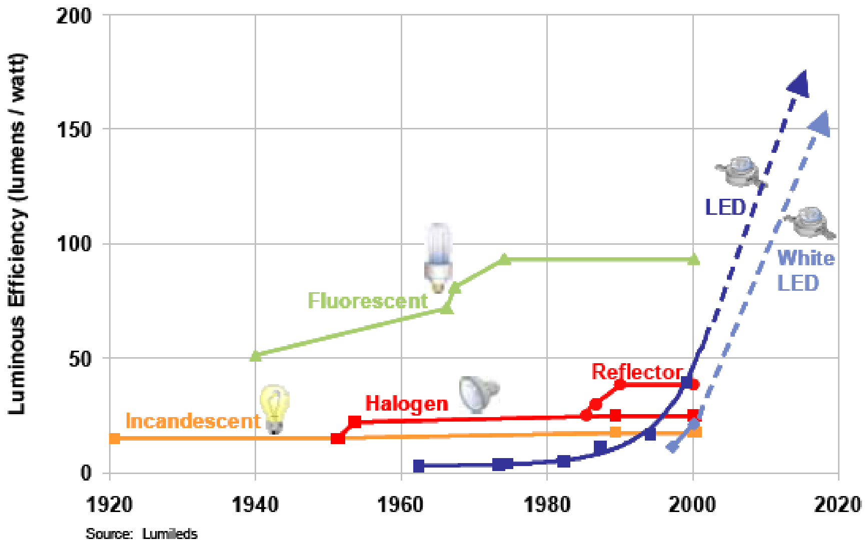
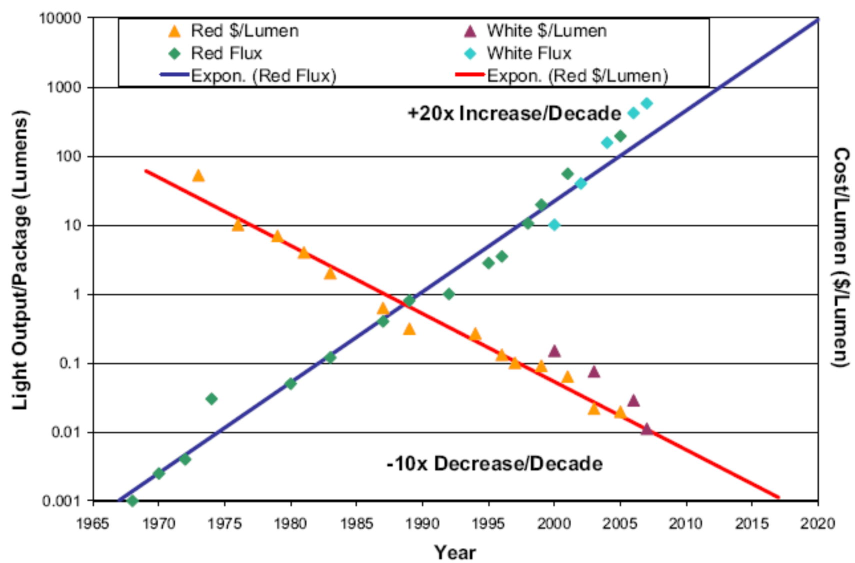
2009 is the Initial iNEMI SSI Roadmap

- **This roadmap is the first of its kind in the SSI field that:**
  - **Seeks to bring a supply chain focus**
  - **Seeks industry needs assessment**
  - **Broader than conventional materials and device roadmaps identified by government, trade organizations and university research communities**
- **Strong Environmental Driver**
  - **Increased energy efficiency yields a smaller carbon footprint**
  - **No mercury in consumer product**
- **Roadmap Perspectives**
  - **Incandescent lighting is based on technology that is over 100 years old, and fluorescent lamp technology is over 80 years old.**
  - **Since its invention in 1962, LED technology has progressed to the point where it has the potential to enter mainstream lighting markets and revolutionize the lighting industry.**
  - **Semiconductor technology, which changed the electronic industry the last half of the 20th Century, is poised to affect the lighting industry in the beginning of the 21st Century.**

The Solid State Illumination Promise





- **Traditional light sources have reached a plateau with respect to luminous efficiency**
- **LED lumens/watt is increasing**
- **High lumens/watt reduces overall lighting carbon footprint**

- **Haitz's Law drives LED cost reduction**
- **Analogous to Moore's Law for the semiconductor industry**
- **The cost per lumen produced via SSI sources is dropping, enabling new products and markets**

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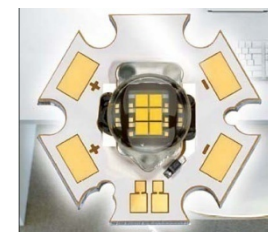
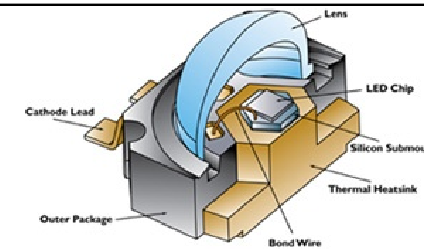
Solid State Illumination Assembly Hierarchy

Assembly Level	Definition	Comments	Examples
3	System level assembly (Total system)	Assembly of light engine into luminaire. Product is sold to customers.	 
2	Second level assembly (Package on board)	Assembly typically accomplished with SMT and solder reflow according to established processes.	
1	First level assembly (LED & OLED in package)	Assembly process technologies such as solder reflow, gold wire bond, lens mounting, phosphor coating, clear encapsulation, etc.	
0	Device (LED & OLED)	Focuses on the fabrication of the light emitting structure, which can be from inorganic or organic materials.	 

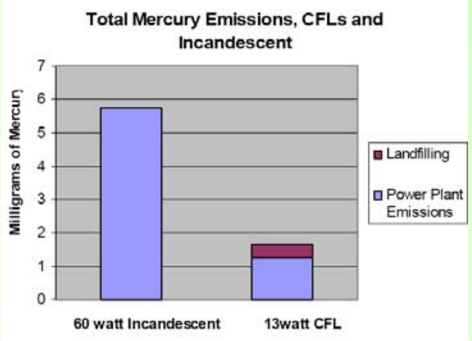
SSI is Part of a Sustainable Future

SSI Light Source is Environmentally Friendly

LED & OLED do not present any known environmental risk

Clearly a consumer benefit over Compact Fluorescent lamps (CFL)

SSI technologies have reduced carbon footprint



Future Challenges for the SSI Industry

Assembly	• Design tools required for new assembly processes & to assess product life cycle issues • Package designs must address high thermal loads for ultra-bright LEDs • SMT assembly not readily amenable with LED & OLED structures
Inspection & Measurement	• May need different focus for new markets.
Materials	• Need more efficient inorganic materials • Need functional inks to enable low cost OLEDs • Need improved phosphor materials
Standards	• WEEE, RHoS, Energy Star, EuP, etc., need to be watched for impact on industry direction
Supply Chain	• Need alignment of supply chains for cost reduction to drive consumer acceptance • Supply chains for distribution from non-traditional luminaire suppliers

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Photovoltaics Highlights

Speaker: Bob Pfahl, iNEMI
Chair: Alain Harrus, Crosslink
Co-Chair: Jim Handy, Objective-Analysis
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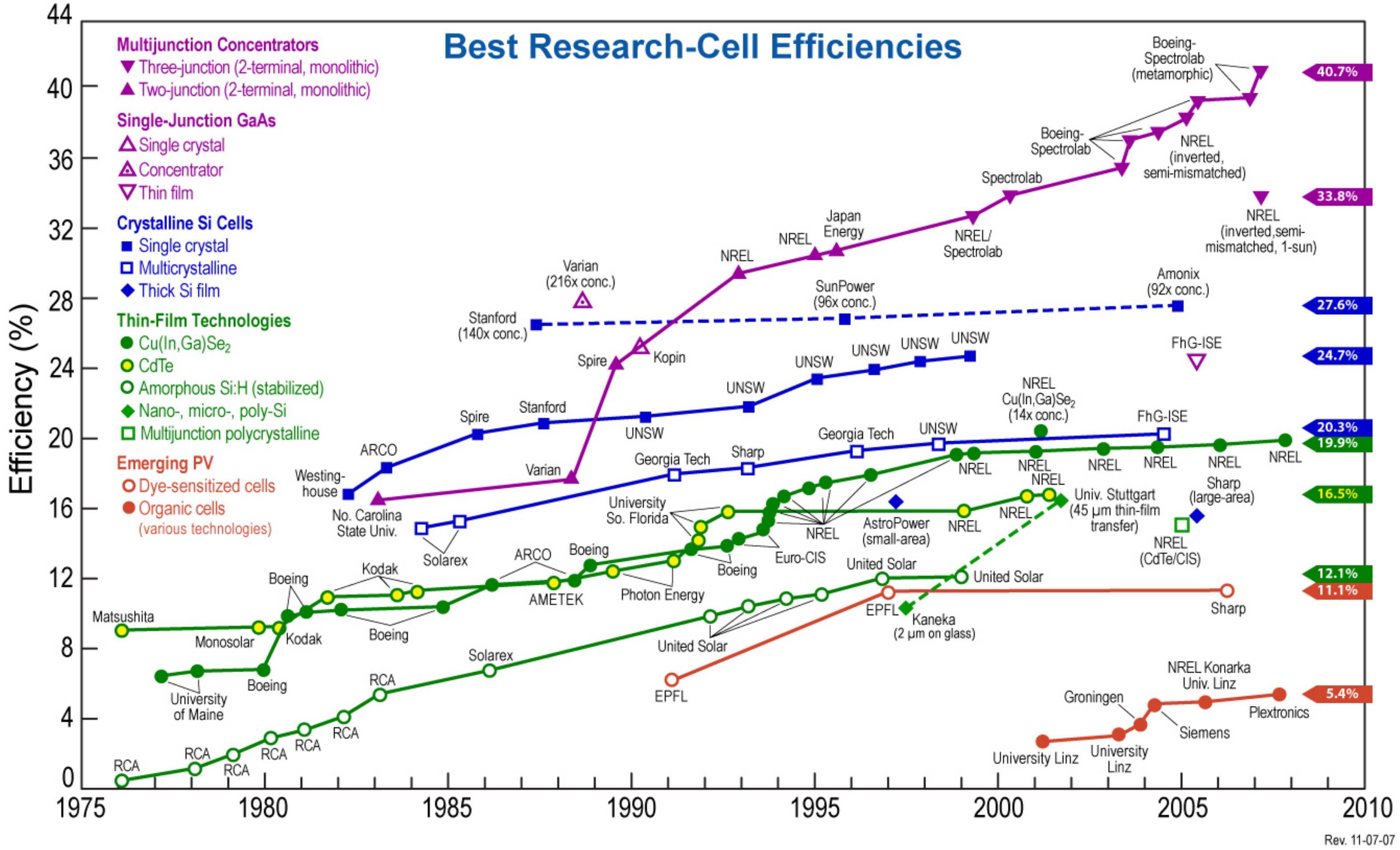
The Issues

- Cell Efficiency
- Cost
  - Return
- Material availability
- Manufacturability

Cell Efficiency

National Renewable Energy Lab Efficiency Chart
Best Research Cells Today

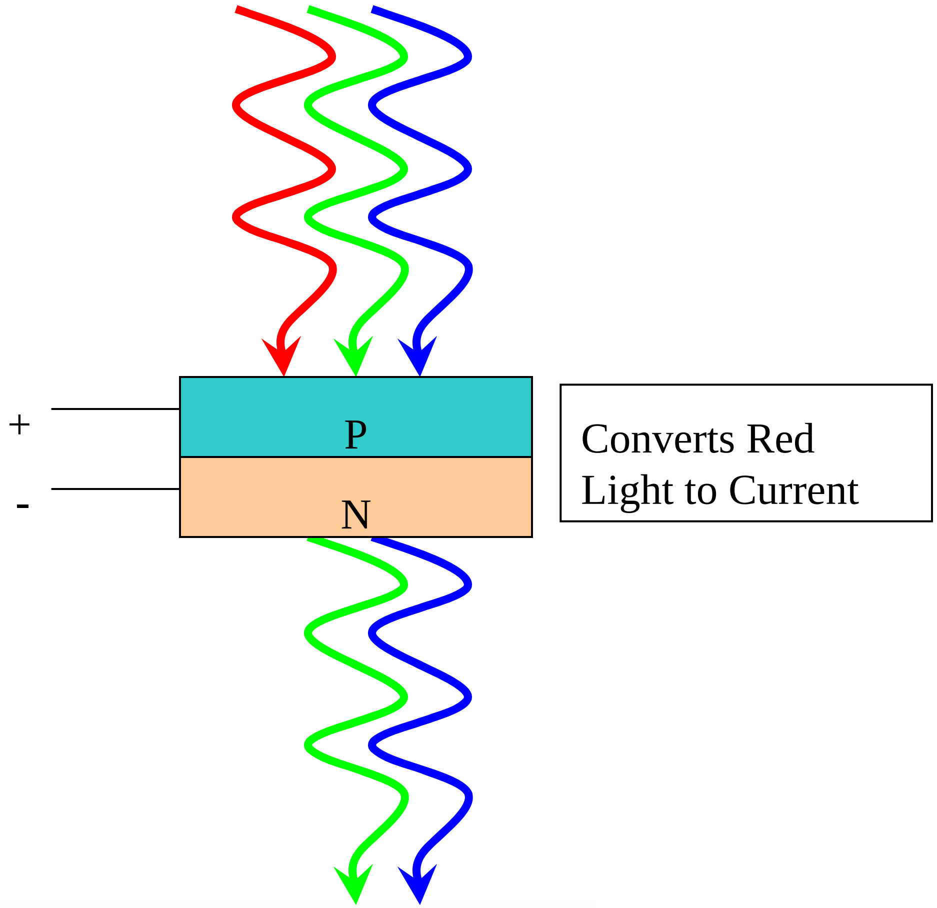


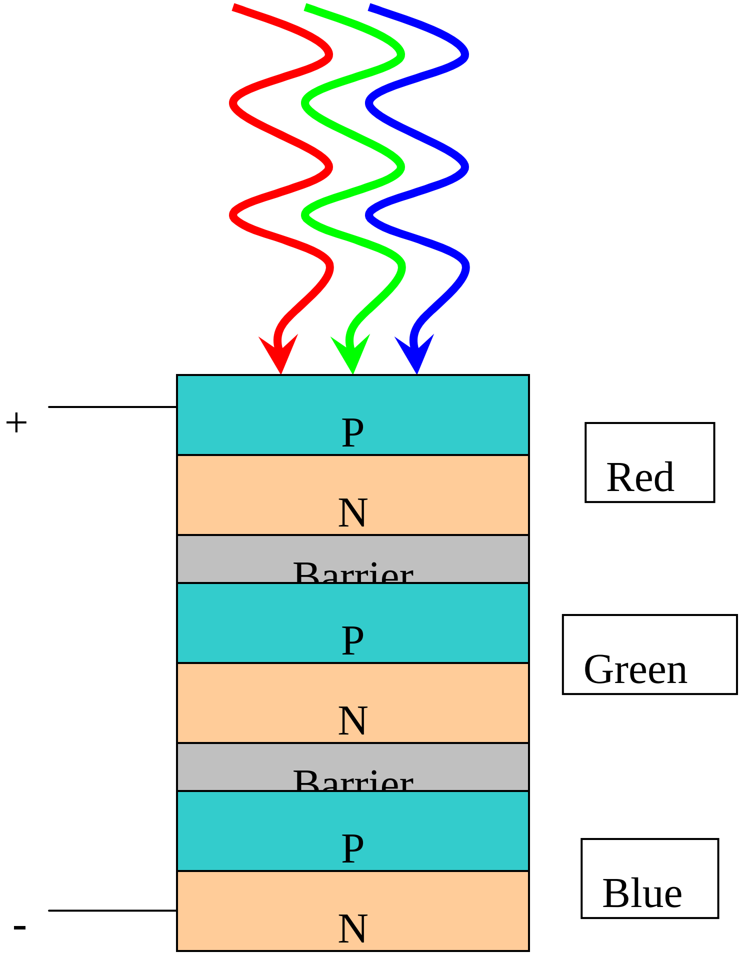
Source: US DOE NREL Nov 2007

Some Cells Trickier than Others

- Bulk Si well understood: ~15-20% efficient
  - Thin-film silicon:
    - Uses semiconductor industry thin-film Si experience
    - Efficiency ~10%
- Other thin films show promise
  - CdTe inexpensive, ~12%
  - CIGS promising, ~14%
- Best efficiencies from multijunction
  - Higher than 40%
  - Use costly materials

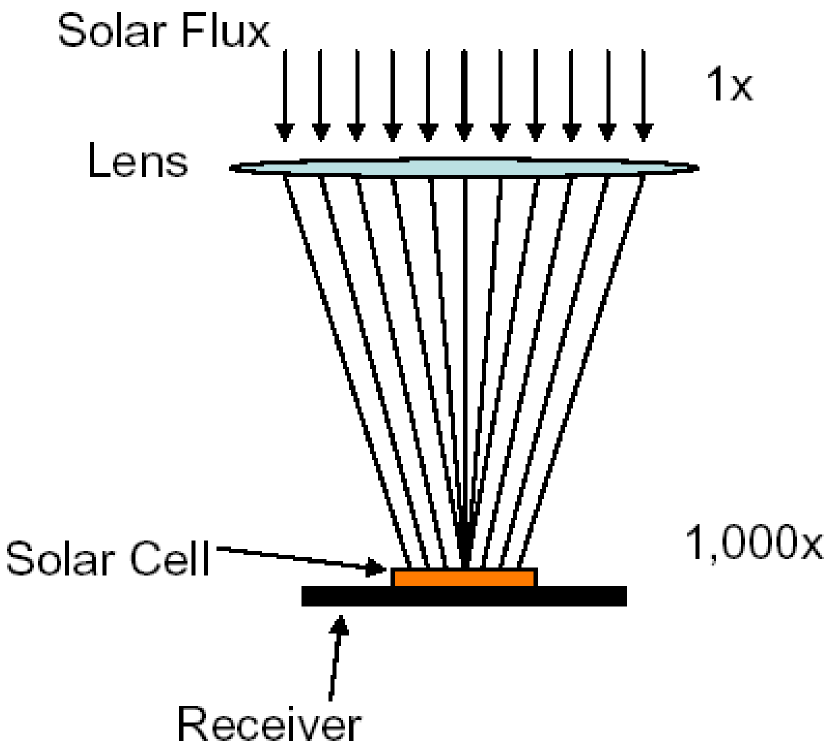
Single-Junction vs. Multijunction



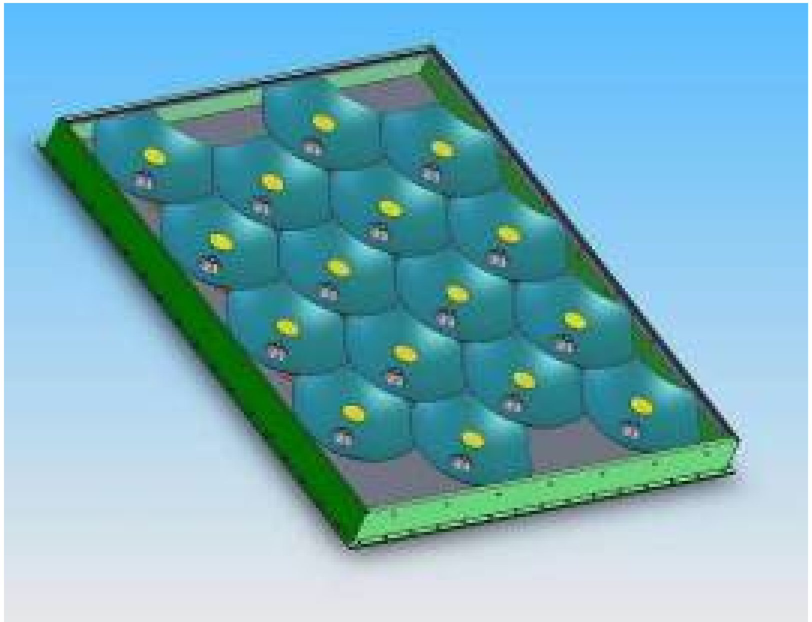


One Approach: Concentrators

Lens Type



Reflector Type



Use less material by concentrating the sunlight

Cost

Elements of Solar Cell Cost

- **Material usage**
  - **Bulk silicon has caused problems**
- **Learning curve**
  - **Silicon better understood/managed than other materials**
- **Scale**
  - **How many are in current production?**

Active elements are the bulk of the cost

Material Consumption

- Silicon is cheap, but demand outstripped production
  - Spot prices soared starting in 2005
  - New polysilicon production is coming on-line
  - PV makers are experimenting with thinner wafers
  - Thin-film silicon uses very little material
- Most other technologies are thin-film
  - Low material consumption
  - CIGS: Some concern of an indium shortage
  - CdTe very inexpensive today
    - Some environmental concerns with cadmium

Learning Curve

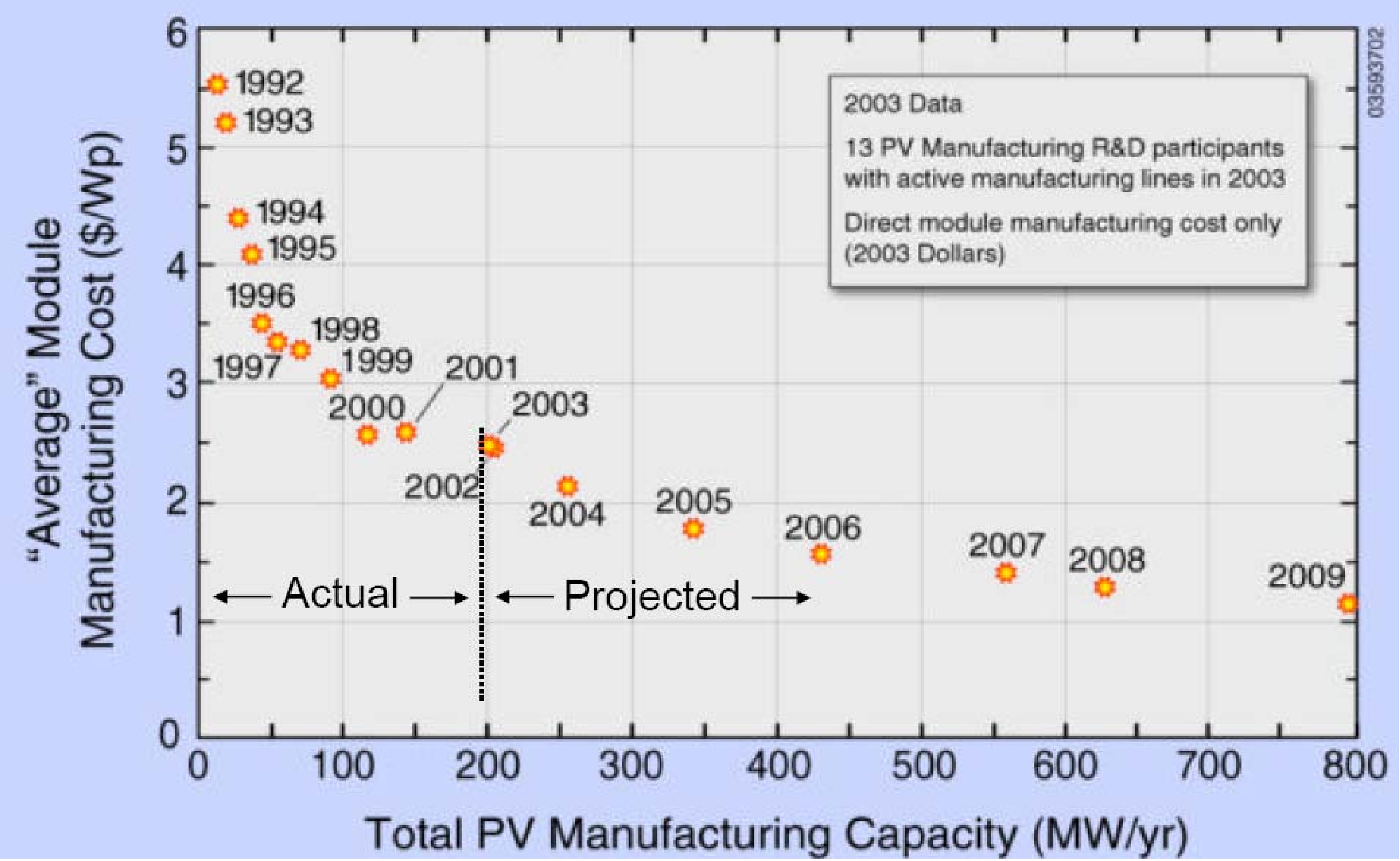
- **Silicon used for semiconductor production since mid-1960s**
  - **GaAs in use since early 1970s**
    - **Costly, not widely used**
  - **CdTe & CIGS evolved this decade**
- **R&D budgets can't compare:**
  - **Silicon: $200B+ to date**
  - **GaAs: $10B**
  - **CdTe & CIGS combined: <$1B**

Process engineers *<u>really understand</u>* how to make Silicon do their bidding!

Scale

- Si has advantage over other technologies
  - Si PV production outstrips others 20-1
  - Economies throughout the supply chain
  - Equipment is all mature
- GaAs is a boutique semiconductor
  - LED is largest user – needs very little material
- CdTe and CIGS are new
  - Problems remain to be worked out

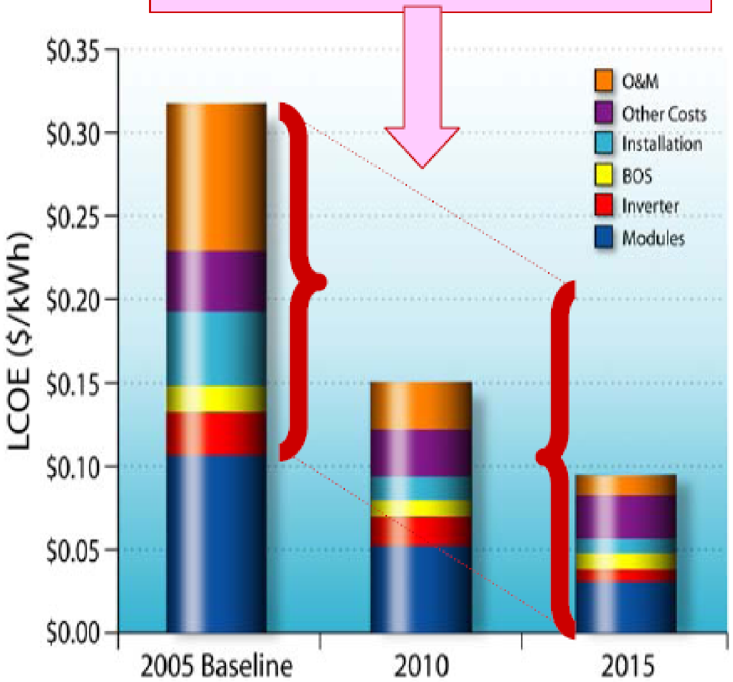
National Renewable Energy Lab Module Cost Projections



BOS
(Balance of System)
Costs

PV Modules are Just Half the Cost

All Non-module costs must be reduced.
Brackets show needed improvement



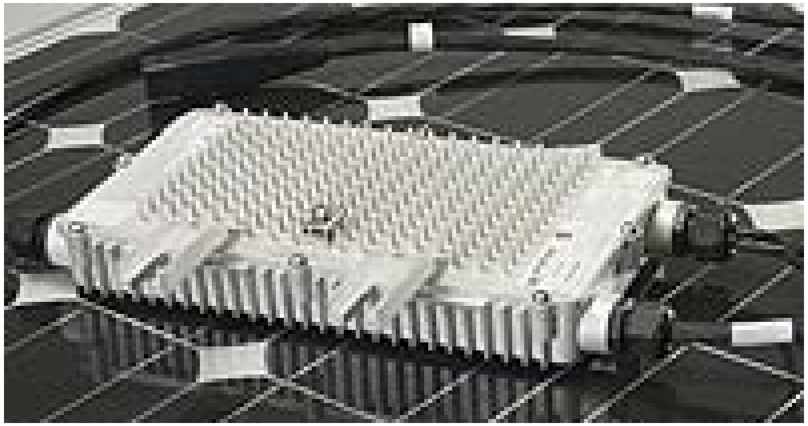
Source: DOE Solar America Initiative

BOS costs include:

- Inverter
- Connectors
- Wiring
- Mounts
- Installation labor
- Operation & maintenance
- Financing

Inverters: A Weak Link

- **Warranty short:**
  - **Module warranty: 20-25 years**
  - **Inverter warranty: 5 years**
    - **Electrolytic capacitors a problem**



Replacement costs an important factor

Installation, Operation & Maintenance

- All labor-related
- Focus of future cost-reduction efforts
- Lack glamour
  - Don't attract large investments

Potential of a good pay-back

Incentives

PV Adoption Requires Incentives

- Japan was first to try this
  - Widespread adoption during incentives
  - Dead halt after incentives stopped
  - Insolation (sunshine) very low compared to US southwest
    - Power output very low
- Germany & Spain current hotbeds
  - Feed-in tariffs causing fast adoption
  - German insolation ~1/3 of US southwest

Material Availability

Silicon Spot Prices

Source: MetalPrices.com, March 2009

Silicon Shortage Drove Development

- **Alternative methods:**
  - **Thinner wafers**
  - **Amorphous silicon cells**
- **Alternative materials**
  - **CdTe: First Solar**
  - **CIGS**
  - **GaAs**

Other Elements Readily Available

- Some concern about indium for CIGS
  - Could drive need for more refineries
- Some of the multijunction materials tricky
  - Elements & compounds not rare, just hard to control
  - This is typical of any new technology
    - Once it is well understood, ramp to volume is very fast

Manufacturability

Silicon Far Ahead of Other Materials

- Long history of semiconductor mass production
  - Even silicon PV has been around since 1960s
  - Well down learning curve
  - Volumes are significantly higher
    - Efficiencies of scale very good
- GaAs has long history
  - Well down learning curve
  - Volumes are low
- CdTe & CIGS are new

Glass Panels Offer Promise

- All PV materials are batch-processed
  - The bigger the batch, the cheaper the process
  - Amorphous silicon borrows from LCD TVs
    - Large glass panels cut processing costs
- Some thin films are flexible
  - Offer promise of roll-to-roll processing
  - Would cut production costs significantly
  - Organic materials being investigated

Summary

- Modules attract the most attention
  - Efficiency improvements
  - Cost reduction
  - Materials availability
- Balance of system (BOS) needs more focus
  - How to cut this large share of costs
- Incentives are imperative

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FF02: iNEMI Technology Roadmap: Concluding Thoughts

Session Chair:
Bob Pfahl
Apex
April 1, 2009

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Strategic Infrastructural Changes

- The restructuring of the electronics industry over the last decade from vertically integrated OEMs to a multi-firm supply chain has resulted in a disparity in R&D needs versus available resources.
- Restructuring has created skill gaps at various nodes of supply chain.
- Critical needs for research and development exist in the middle part of the supply chain (IC assembly services, passive components and EMS assembly) and yet these are the firms least capable of providing the resources.
- A partial solution has been the development of vertical teams to develop critical new technology while sharing the costs.

Concluding Thoughts
Impact of the Recession

- Strengthening of vertical development teams (across design / supply chain)
- Will delay new technologies requiring significant investments (both capital and R&D)
- Increased consortial activity on environmental efforts (reduce total industry investments)
- Industry must work together to determine their priorities for closing Technology Gaps

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