National Renewable Energy Laboratory
Innovation for Our Energy Future

Material Needs for Thin-Film and Concentrator Photovoltaic Modules

NREL

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CDMA Conference: Opportunities for Chemicals and Materials in Wind and Solar Energy

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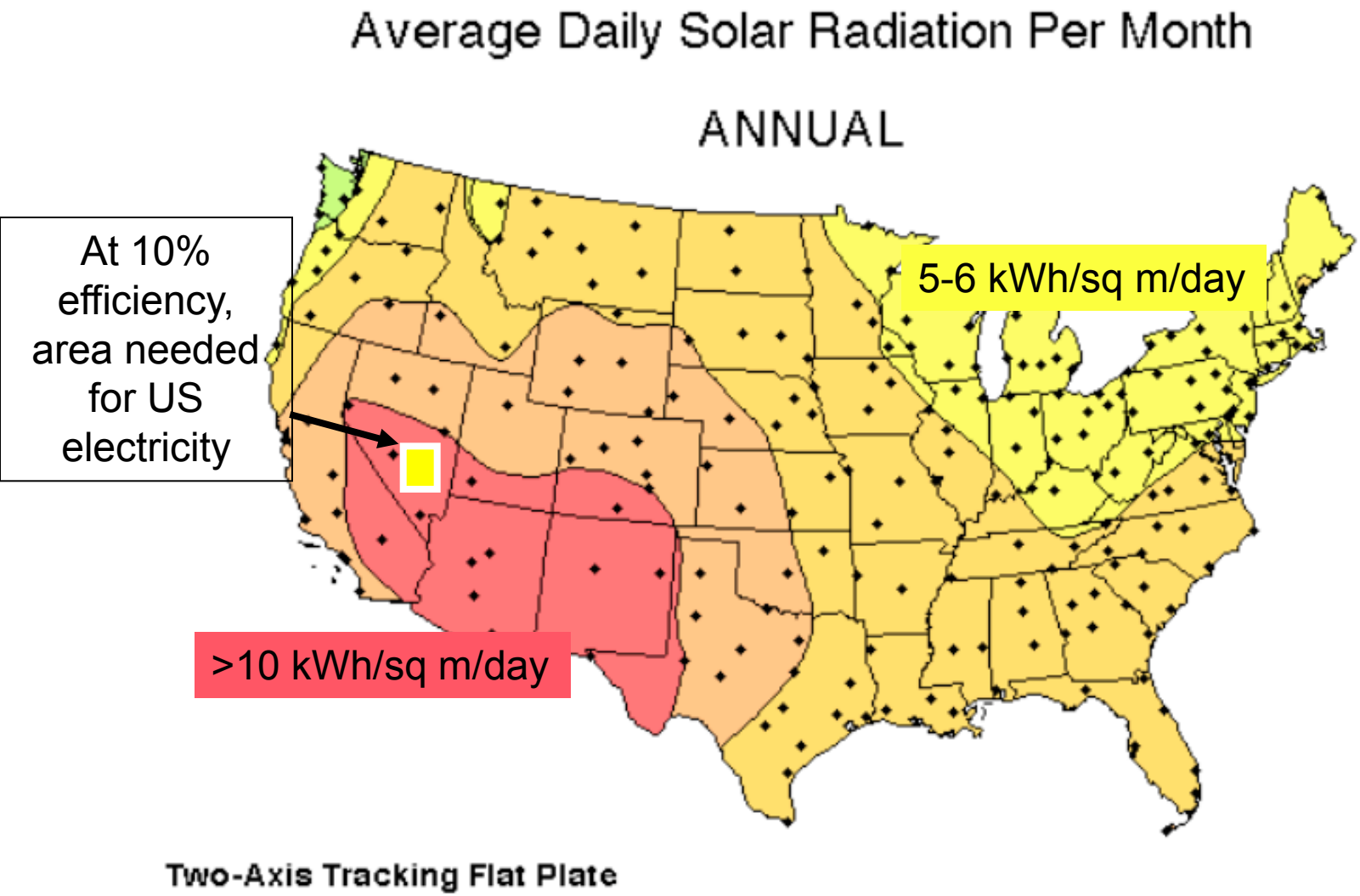
Outline

- Solar – a huge success, but still a long way to go
- Material requirements:
  - Low cost
  - High performance
  - Excellent reliability
- Materials for thin-film and concentrator PV
  - Support (substrate, superstrate)
  - Encapsulation
  - Electrical connections (inside and out)
  - CPV – optics, heat sinking, etc.

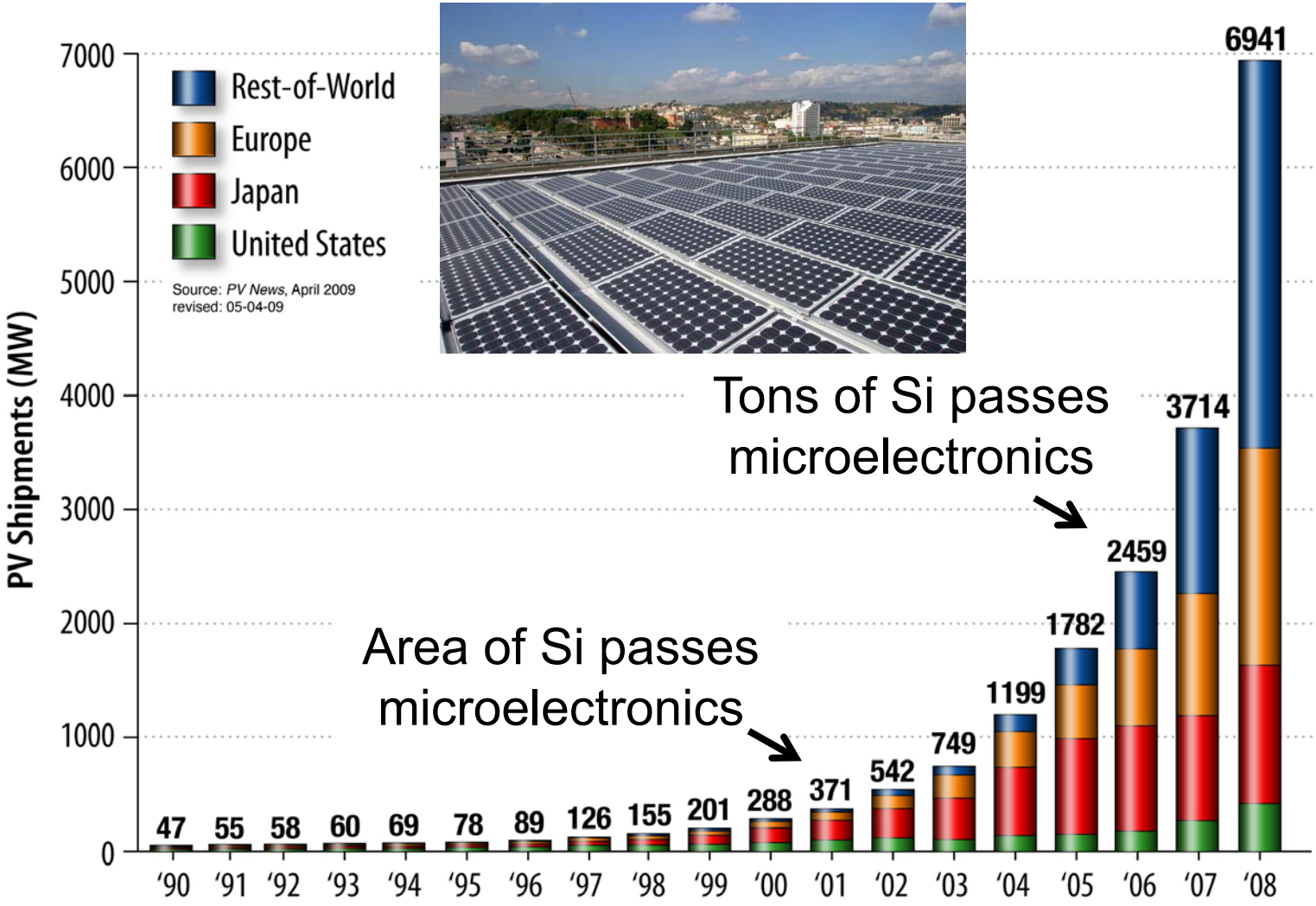
Solar energy is abundant

Convenient truth: small area can supply our energy needs



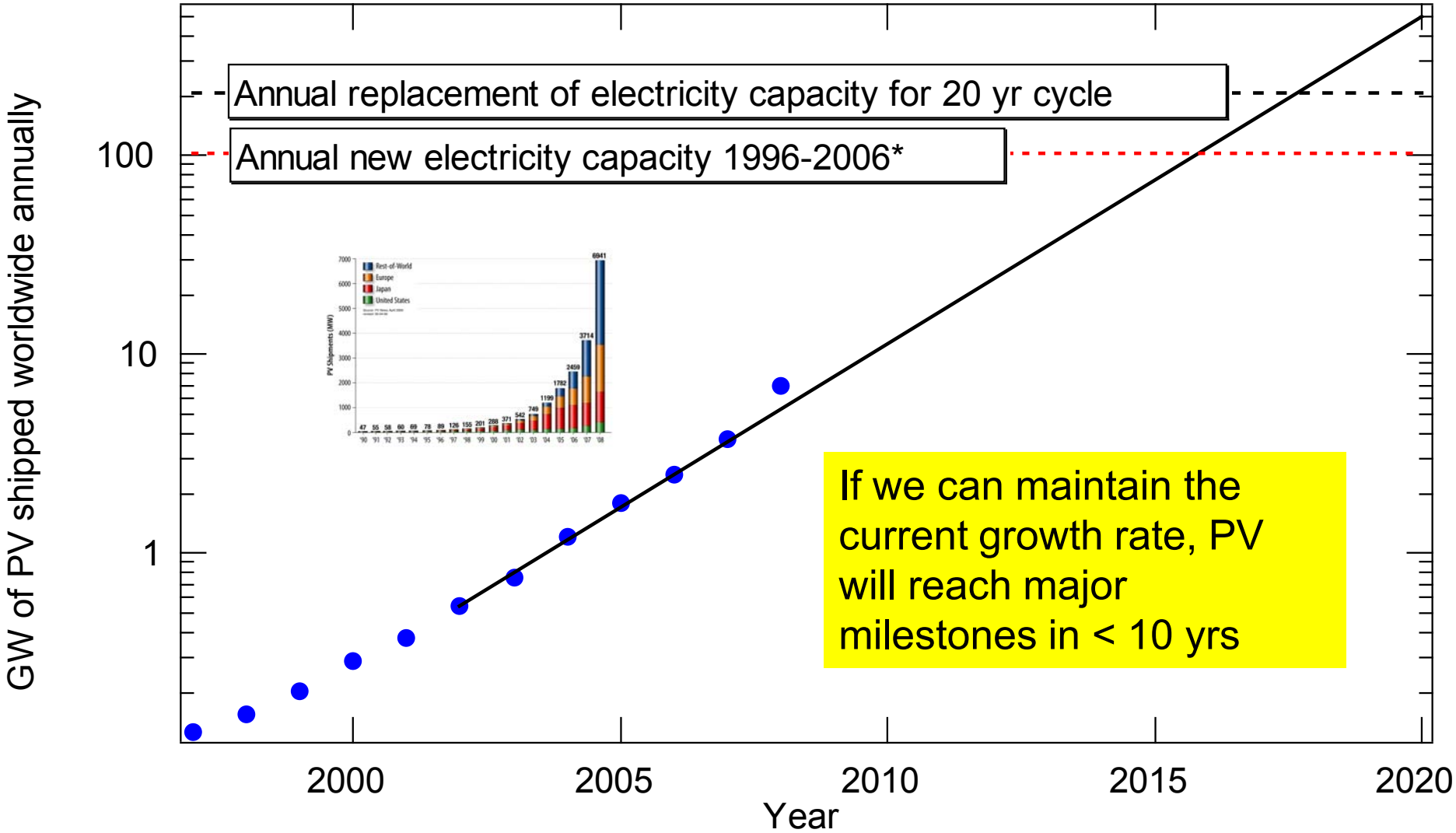
Sunlight reaching earth in 1 hour is enough to power the world for 1 year

Growth of photovoltaic (PV) industry



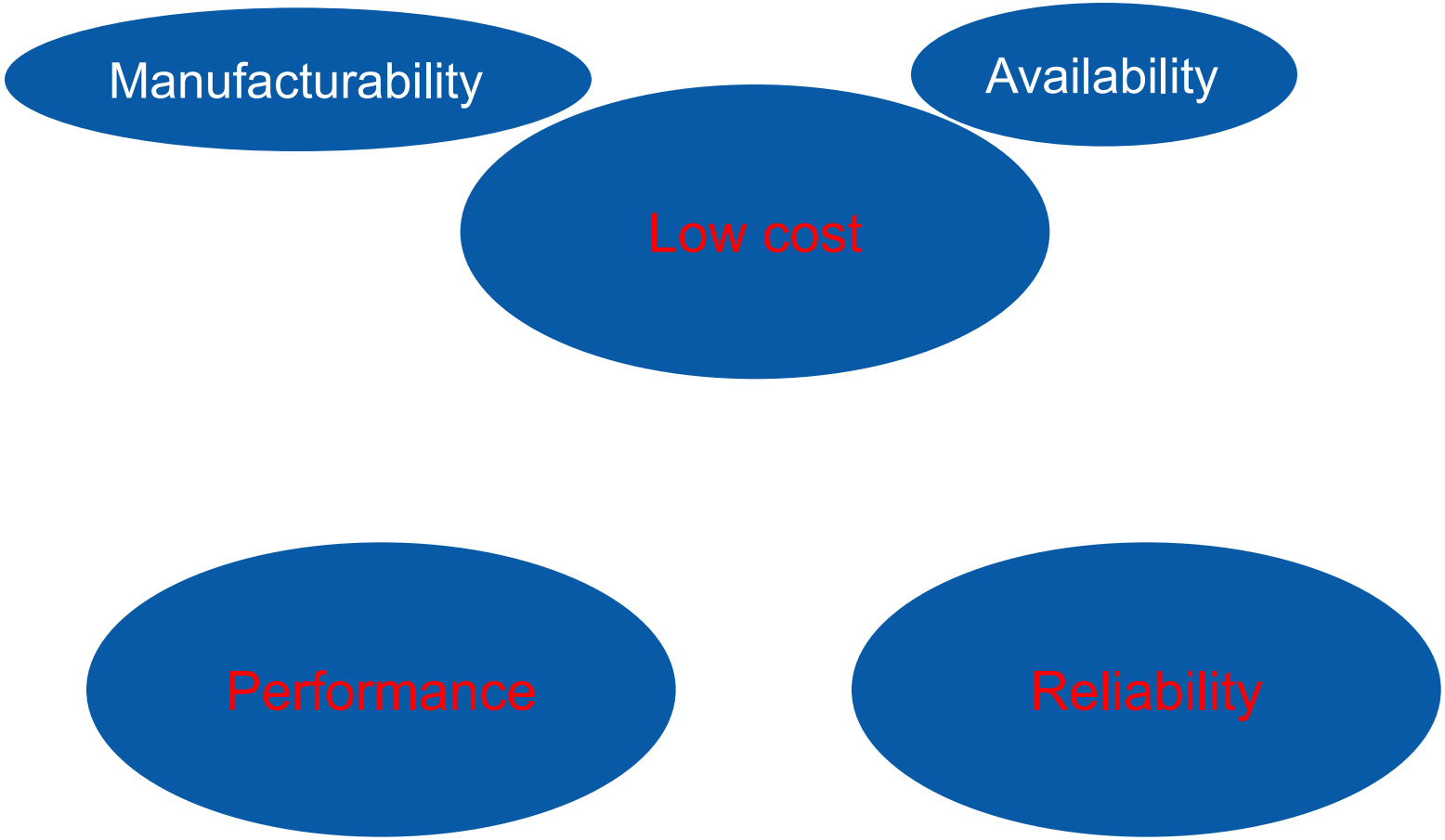
Maintaining growth rate requires reduction in cost & adequate availability

Growth of PV industry



*www.eia.doe.gov/emeu/international/electricitycapacity.html (4012-2981 GW)/10 yr

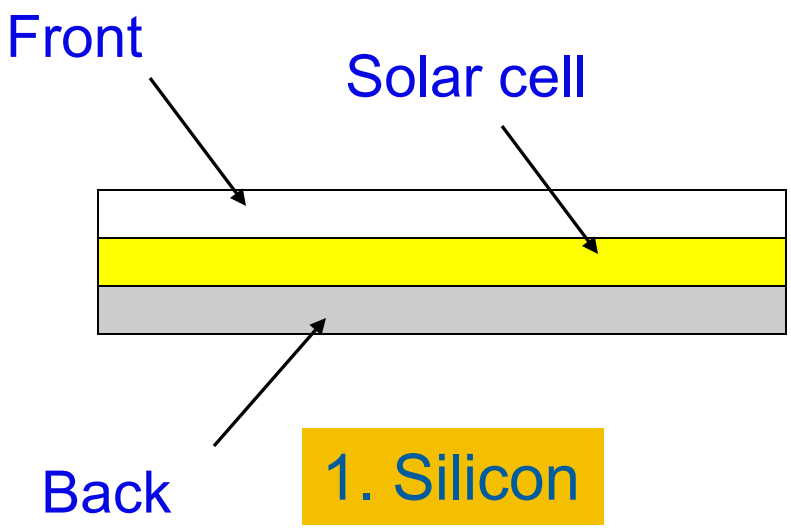
Ongoing needs motivate use of new materials

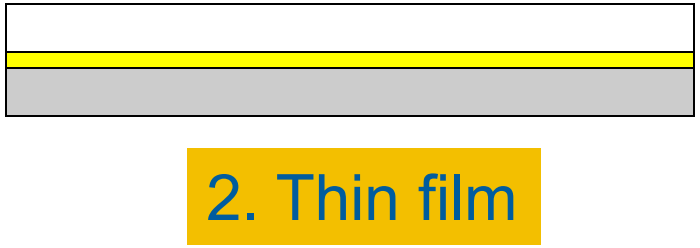


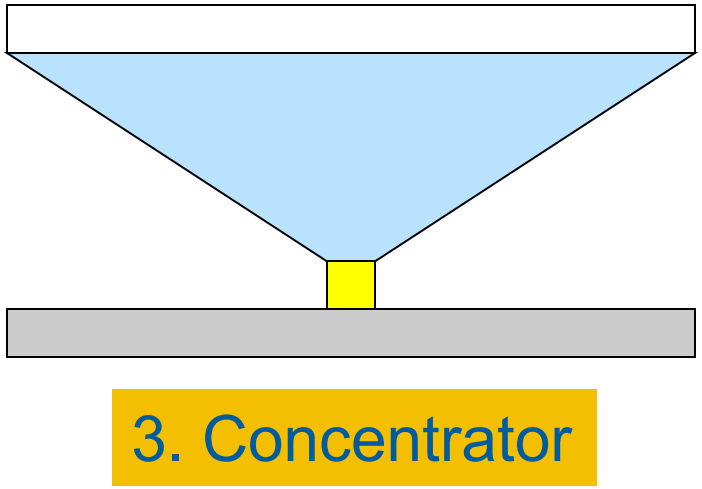
Three key approaches to photovoltaic (PV) panels

Conventional approach

Two strategies to reduce semiconductor material

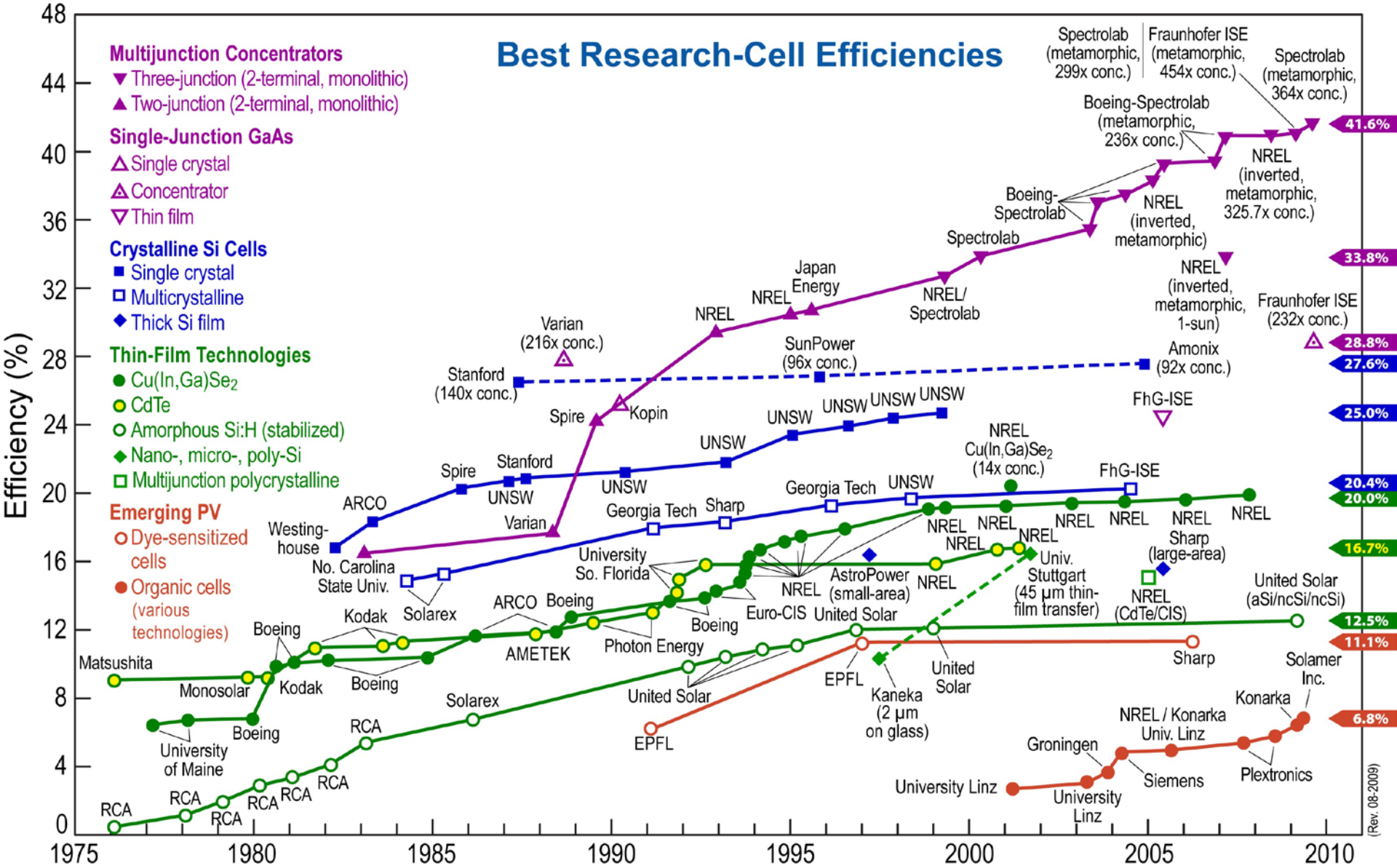






Reduce cost by reducing use of semiconductor

Many technology choices



One “winner” or many technologies?

Alkaline

Nickel cadmium

Nickel metal hydride

Lead acid

Lithium ion

Lithium

Different technologies for different applications

Thin-film approaches on the market

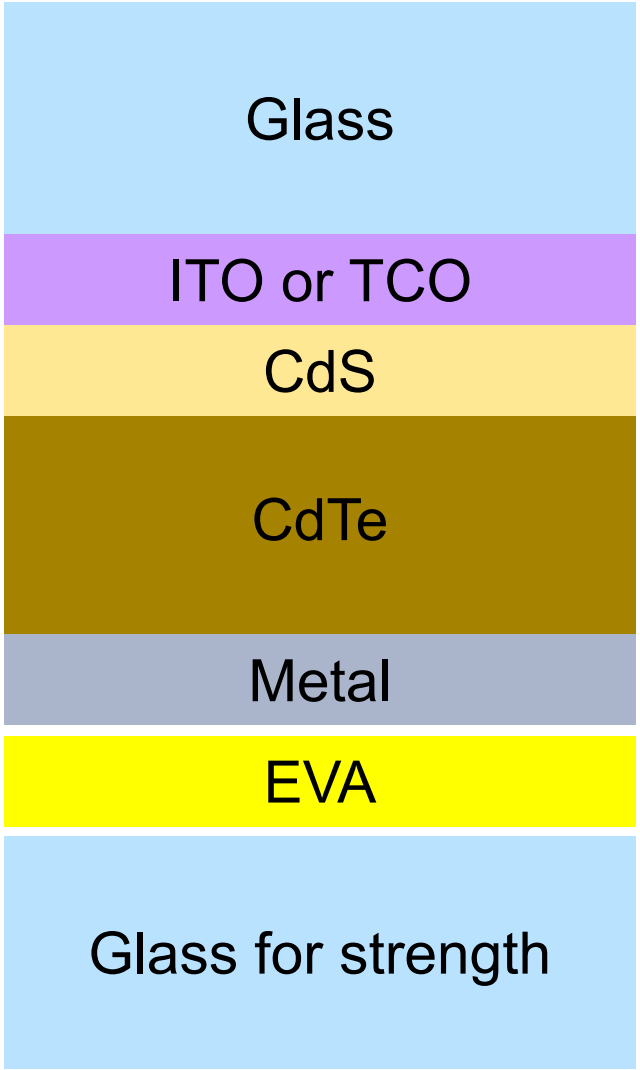
CuIn(Ga)Se

CdTe

Amorphous silicon

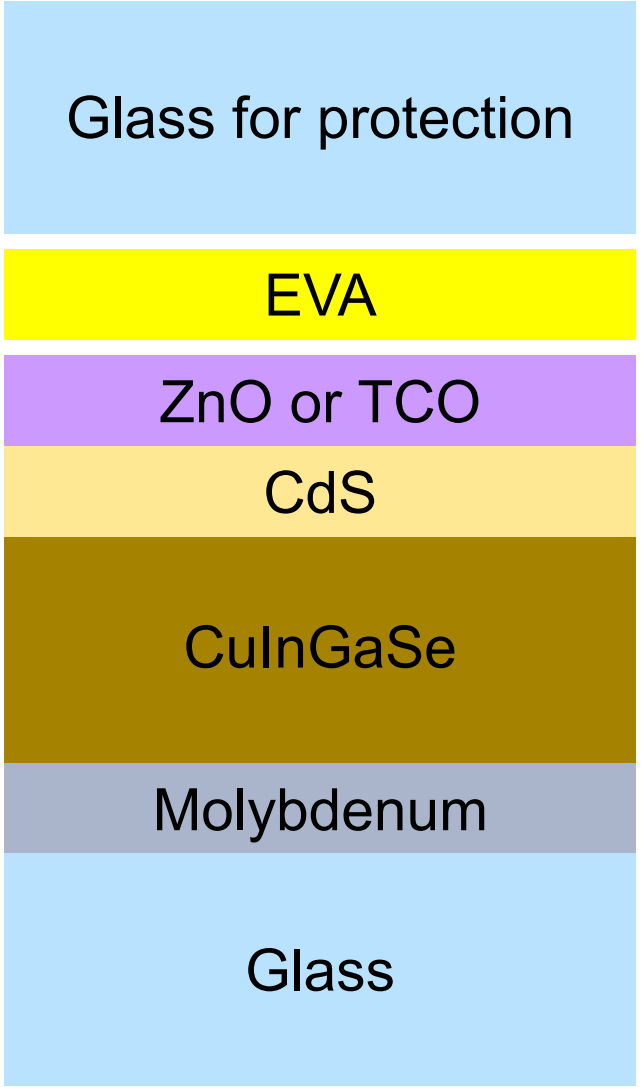
Typical thin-film structures require many materials

CdTe uses superstrate

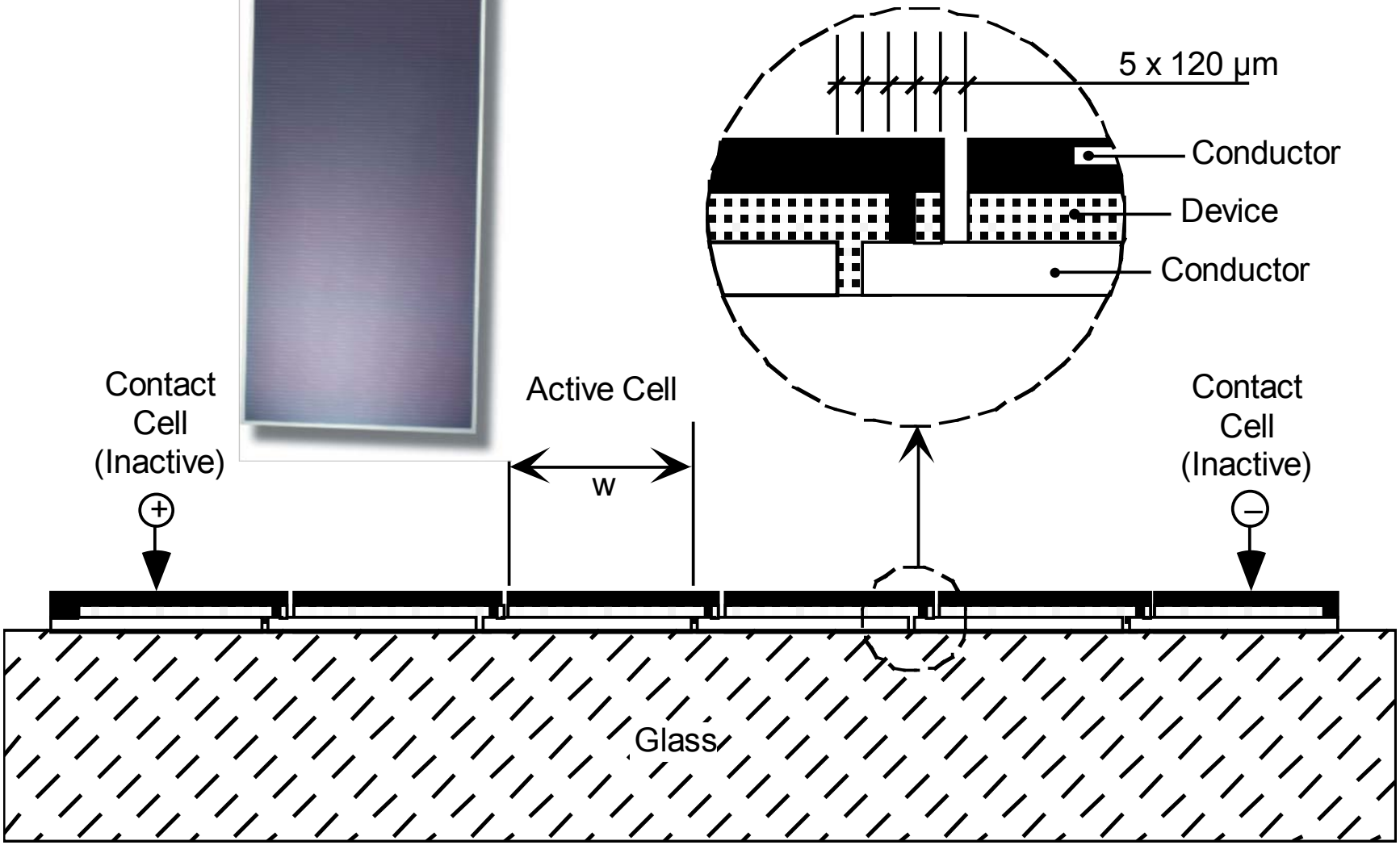


Not to scale

CuInGaSe uses substrate



Monolithic module integration



Substrate/superstrate

Glass is transparent, strong, inert, and relatively cheap

Glass is relatively heavy, breakable, and more expensive than desired

Light-weight, flexible substrates are desired, especially for building-integrated applications

- strong (mechanically, durable to UV, moisture, etc.)
- withstand processing of solar cells
- inexpensive

Packaging is essential to PV reliability

Packaging needs:

- Keep water out
- Resistant to UV
- Resistant to temperature cycling and high temperatures
- Inexpensive
- Front packaging must be transparent (~ 300-1100 nm)
- Adequate adhesion
- Easily processed

Flexible CIGS requires reduced sensitivity to moisture

ZnO (and other transparent conductors) react with moisture, causing increase in series resistance

Two strategies:

- Harden the cell (e.g. Sundaramoorthy, et al 34th PVSC)
- Harden the packaging (barrier coatings)

Electrical connections

Monolithic interconnections avoids need to tab every ‘cell’

Need two wires coming out:

- Connect to end cells
- Bring contacts to junction box
- Junction box (and mounting) has similar requirements to silicon modules

- Pressure-sensitive adhesives are controversial

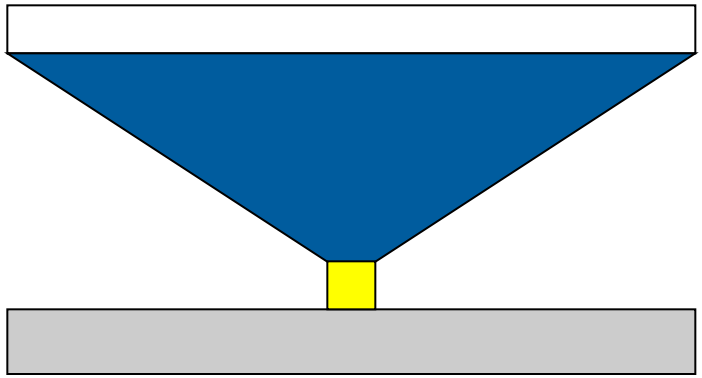
Variety of material needs for thin-film PV

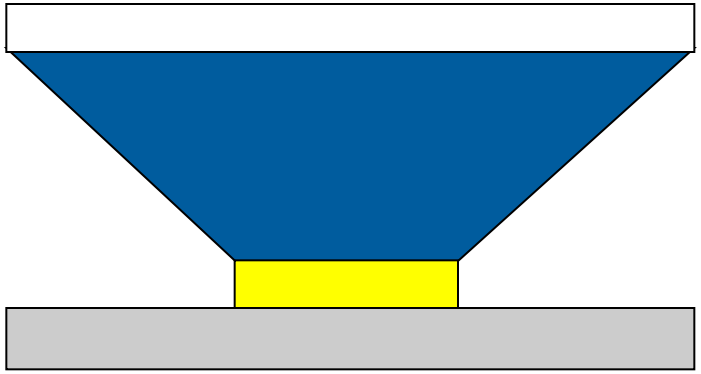
- Edge seal may allow water into glass/glass module
- Desiccant may be useful
- Adhesion to glass can be problem – add materials/coatings to improve adhesion
- Role of sodium is important in CuInGaSe modules, but sodium can move; may intentionally add sodium
- Currently, the biggest effort with CuInGaSe is to try to put it on a flexible substrate – requires excellent barrier coating unless cell can be hardened to moisture
- Organic PV uses mostly low-temperature processes

Range of concentrator approaches

Amonix

JX Crystals

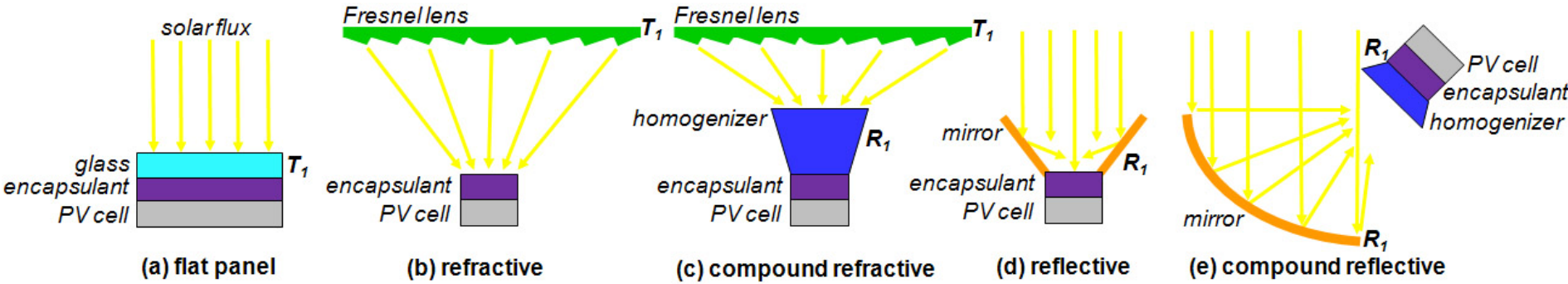




High concentration
- 35% - 40% cells
- 400X – 1500 X

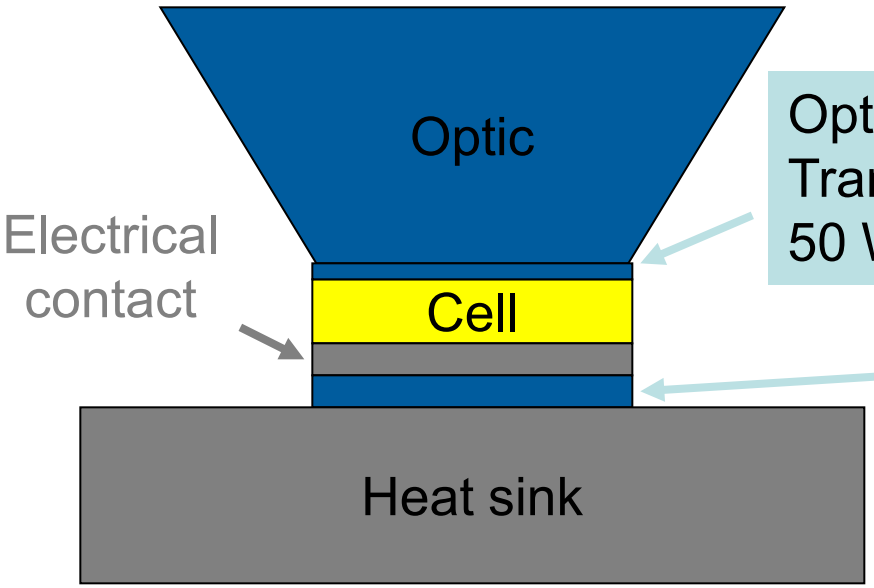
Low concentration
- 15% - 25% cells
- 2X – 100 X

UV transmission depends on design



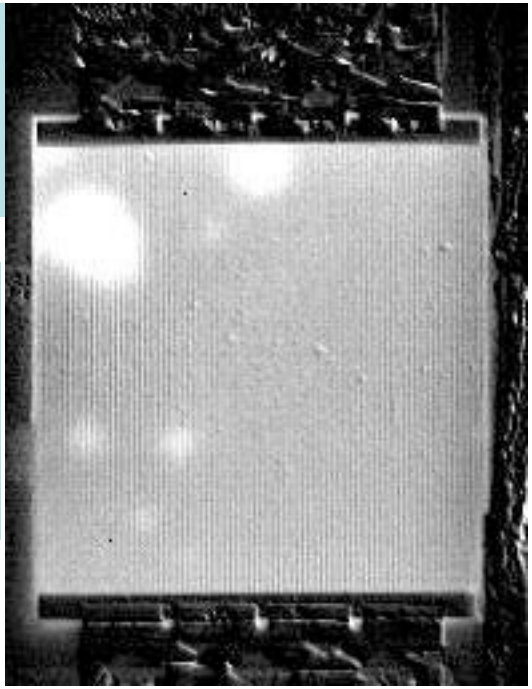
Analysis of transmitted optical spectrum enabling accelerated testing of CPV designs
SPIE 2009 David Miller, et al

Bonds to heat sink and optics



Optical bond with 100% Transmission
50 W/sq cm

Small ΔT (<10°C)
Electrical isolation
No voids
T cycle OK



IR image of void in die attach
Bosco, et al 34th PVSC

- DBC (direct bonded copper) performs well, but is expensive
- Intense UV may be a substantial problem, but optics may not transmit UV

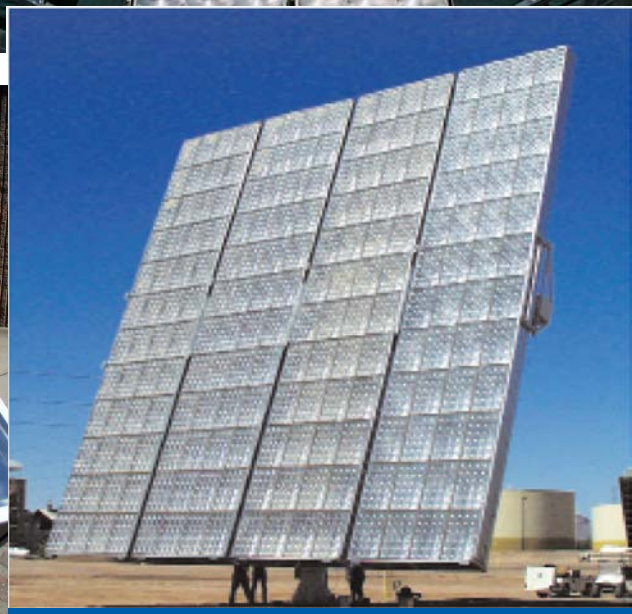
CPV – many parts

CPV has many parts

- Optics – lens, mirrors, (primary & secondary); glass, plastic, metal, film, etc.
- Cell encapsulation – water out, resistant to UV
- Thermal contact – low cost; electrical isolation
- Heat sink – must be electrically isolated, but excellent thermal contact
- Strategy for letting air in, while keeping dirt out (filters?)

Concentrator technology

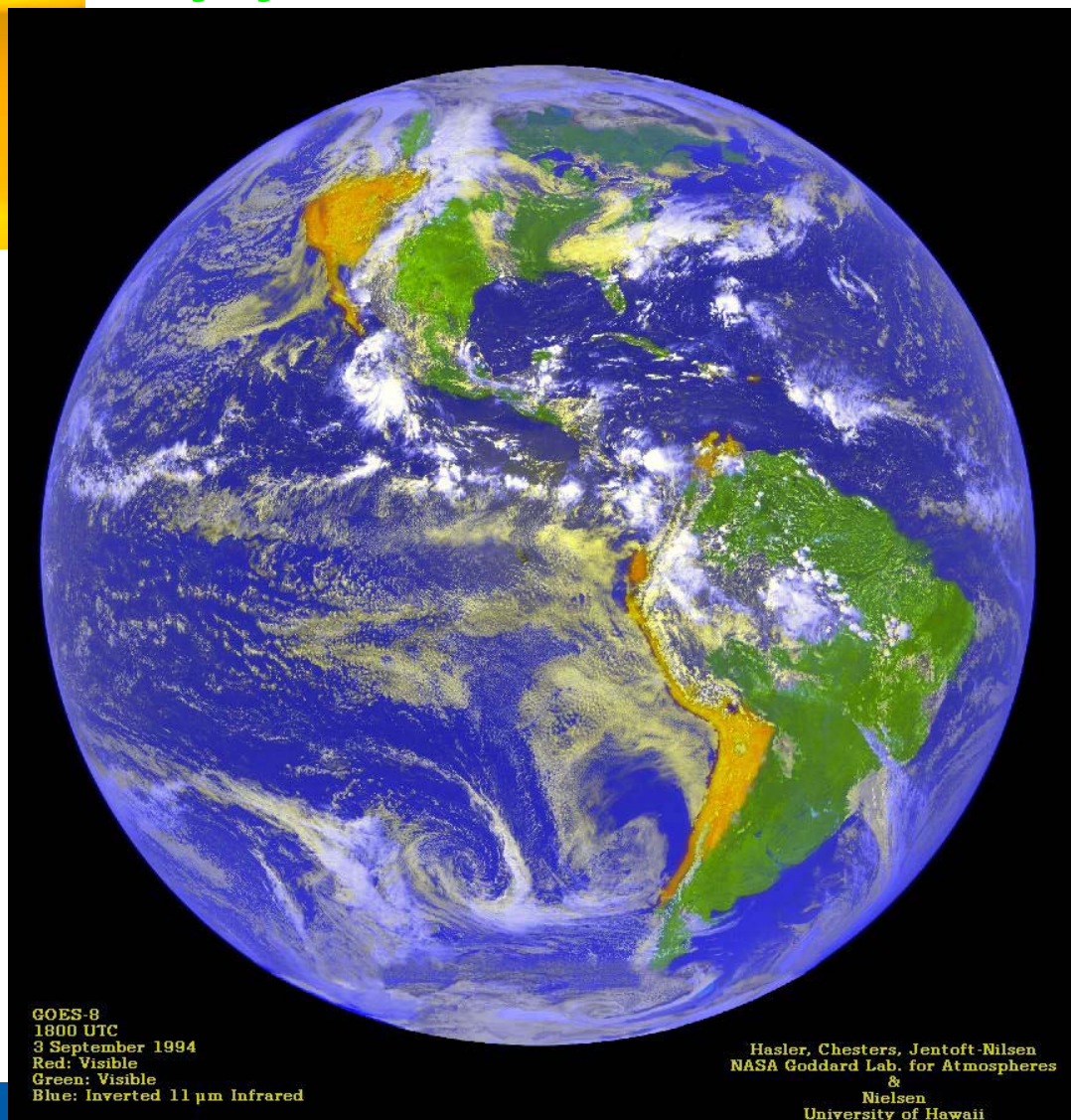
Creative designs?



Summary

- Solar is growing rapidly and could become a significant source of electricity within our lifetimes
- Packaging is essential to success of PV
- Key material needs for thin-film and CPV include:
  - Structural support (substrate/superstrate, frames, etc.)
  - Electrical connections to cells
  - Electrical connections to outside world
  - Packaging to keep water out
    - Encapsulants
    - Barrier coats
    - Edge seals (maybe even desiccant)
  - Thermal contacts for CPV
  - Optical materials for CPV

Planet powered by renewable energy By year 2100 or before?



Thank you for your attention!