

Renewable Energy Laboratories at the Colorado School of Mines



Colorado Energy Research Institute

Colorado School of Mines



Second Generation Panels for Solar Power

P. Craig Taylor

Associate Director

Colorado Energy Research Institute

Renewable Energy in the San Luis Valley

Adams State College

December 2, 2006





(Gerald Pearson, Daryl Chapin, Calvin Fuller)



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Long-term Energy Future: Solar

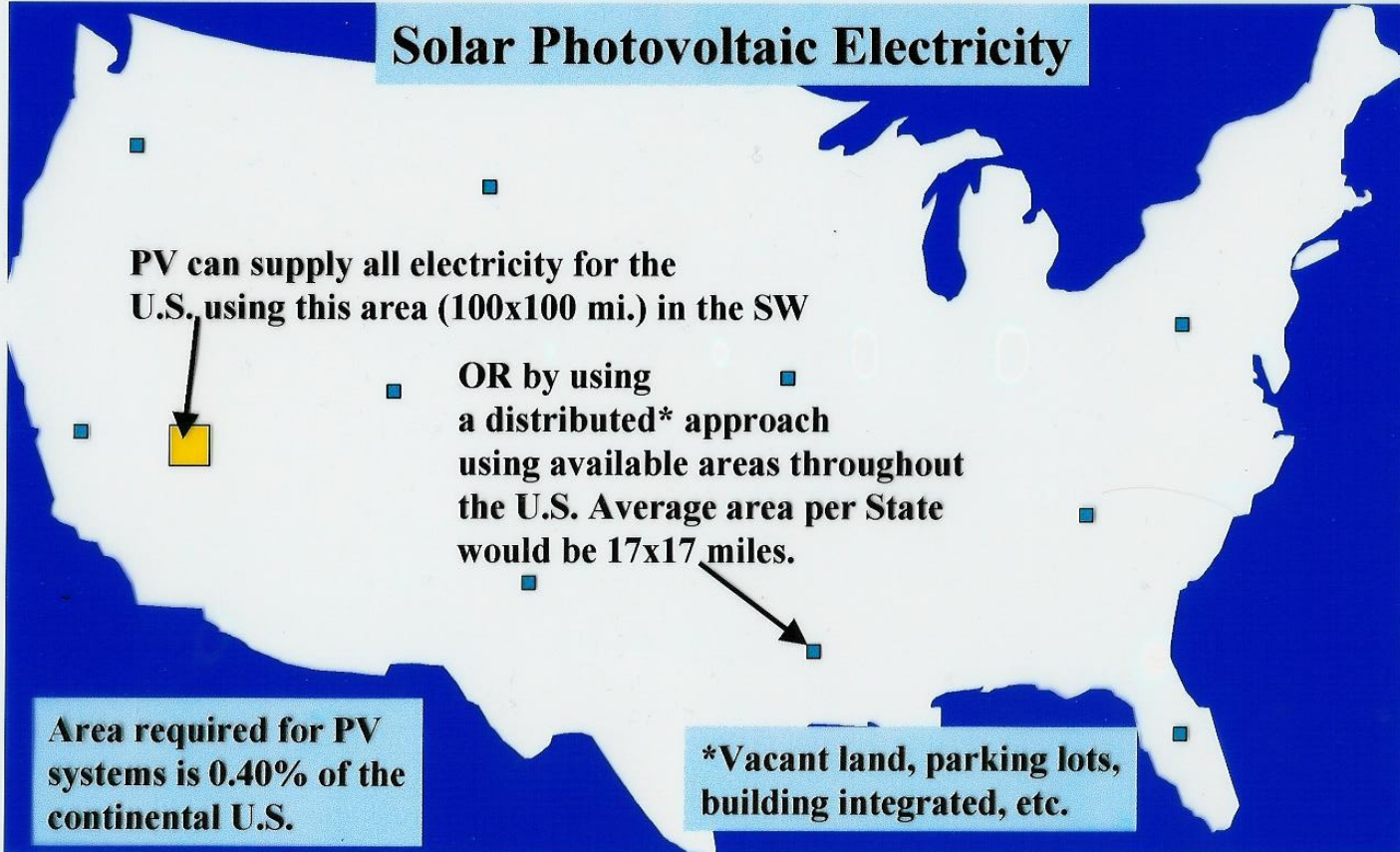
- Current total global energy generation: 13 TW
- Projected increase by 2050: 30 TW
- Requires construction of *two* 1-GW power plants per day!
- The Jim Bridger plant (WY) is ~ 2.4 GW
- Theoretical: 1.2×10^5 TW solar energy potential
- Practical: $\approx 600 - 1500$ TW solar energy potential (Depending on land fraction etc.)

Nathan Lewis, 2003

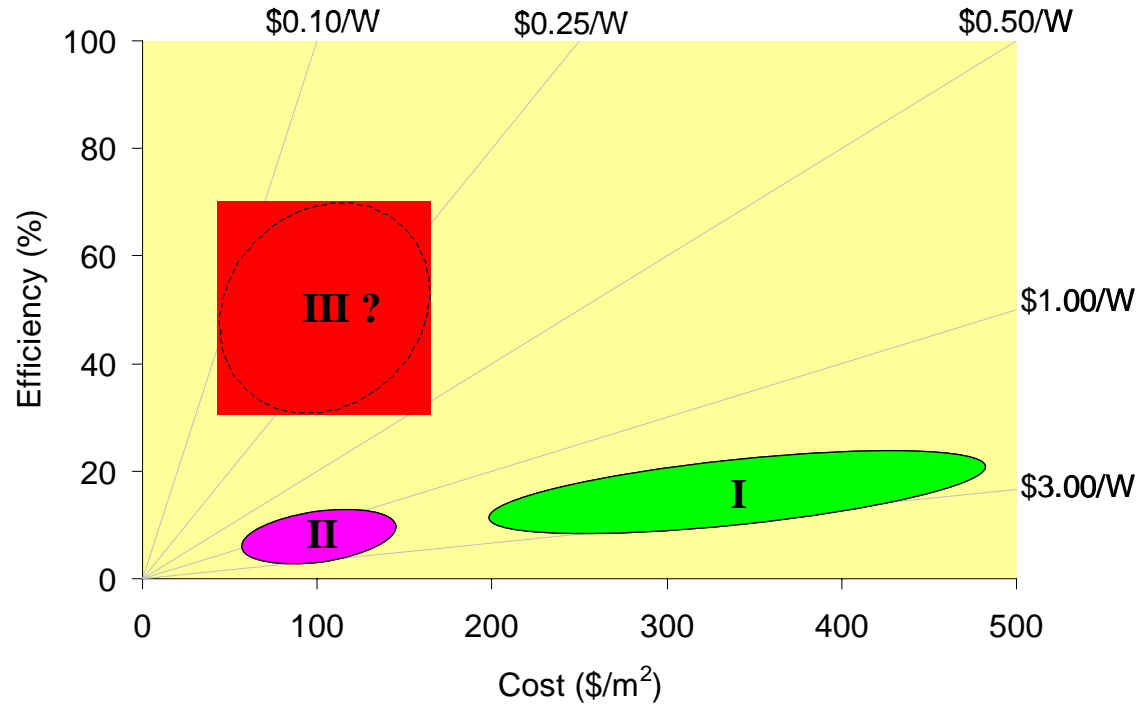




Solar Photovoltaic Electricity



PV Technologies - Generations



Colorado Solar Energy Companies

ITN Energy (Global Solar)

PrimeStar Solar

Ascent Solar

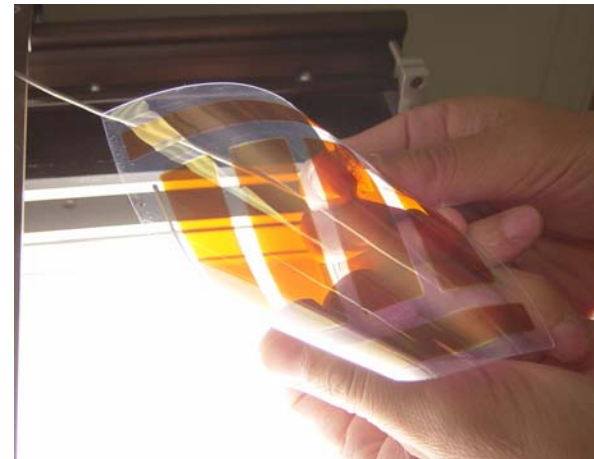
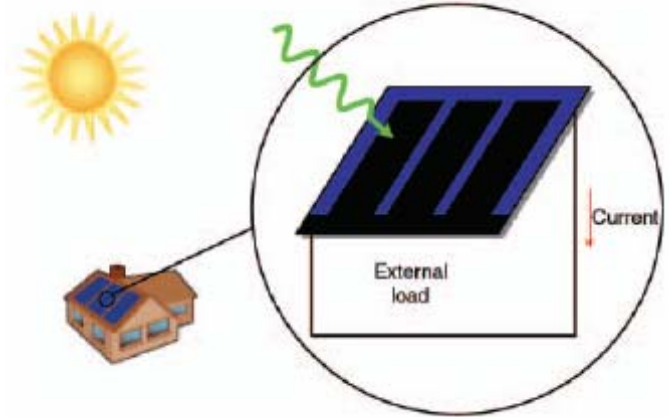
MVSystems

ADA Technologies

Luca Technologies

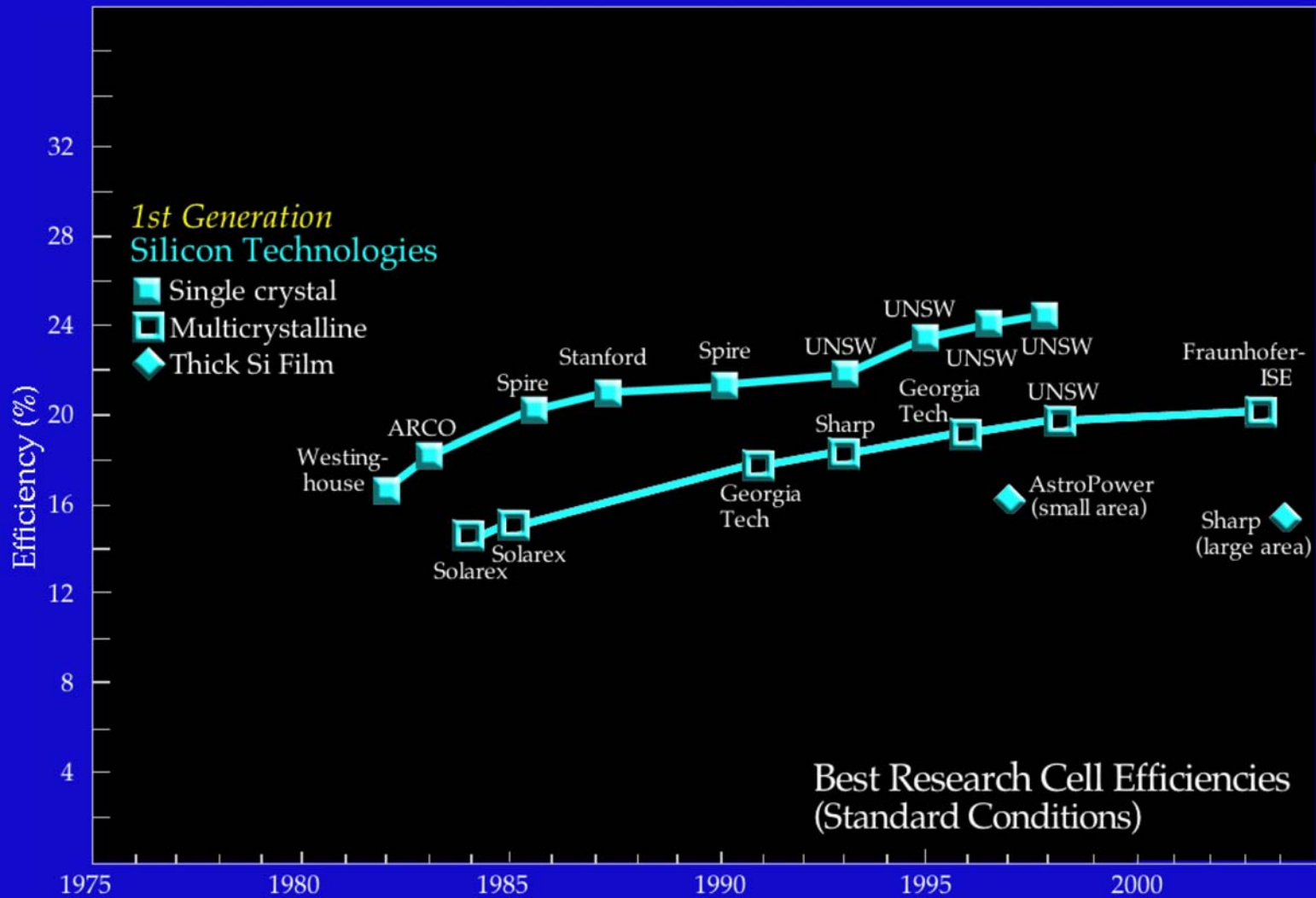
Industrial Solar Technology

PV Technologies

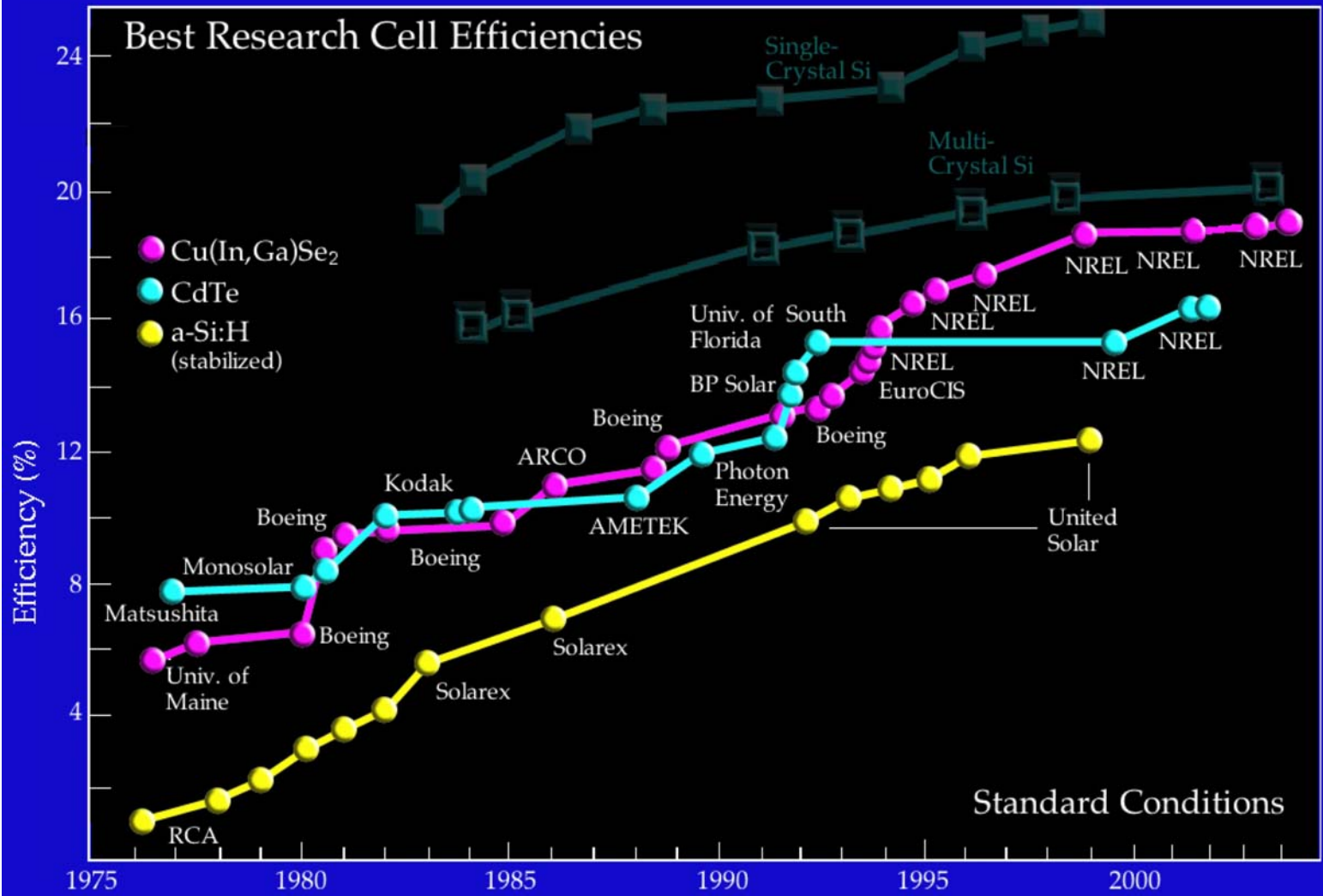


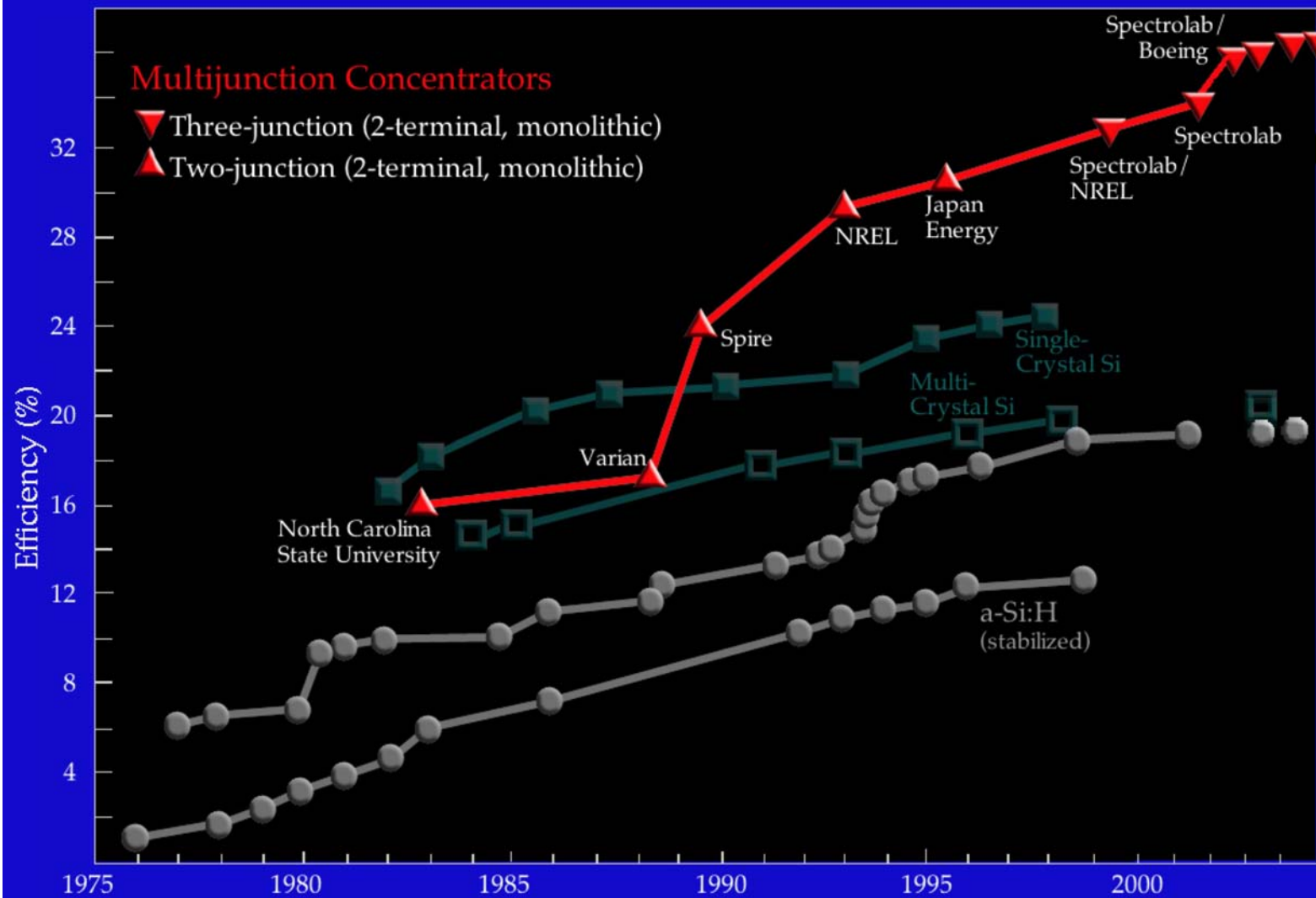
MVSystems flexible Si solar cell





Best Research Cell Efficiencies





Third Generation PV: A Short Digression

- **“Third generation” (thin-film) technologies may come on line:**
 - **Nano-technologies (quantum dots and wires)**
 - **Inorganic-organic hybrids**
 - **Thin-film crystalline silicon**
 - **Large area multi-junctions**
 - **???**



Technology Investment Pathways

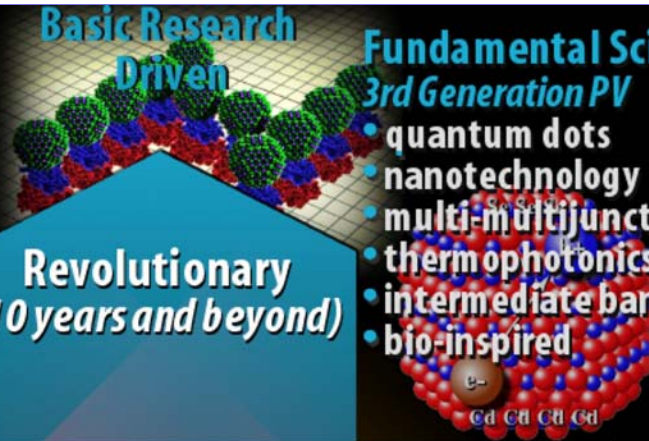
Basic Research Driven

Fundamental Science

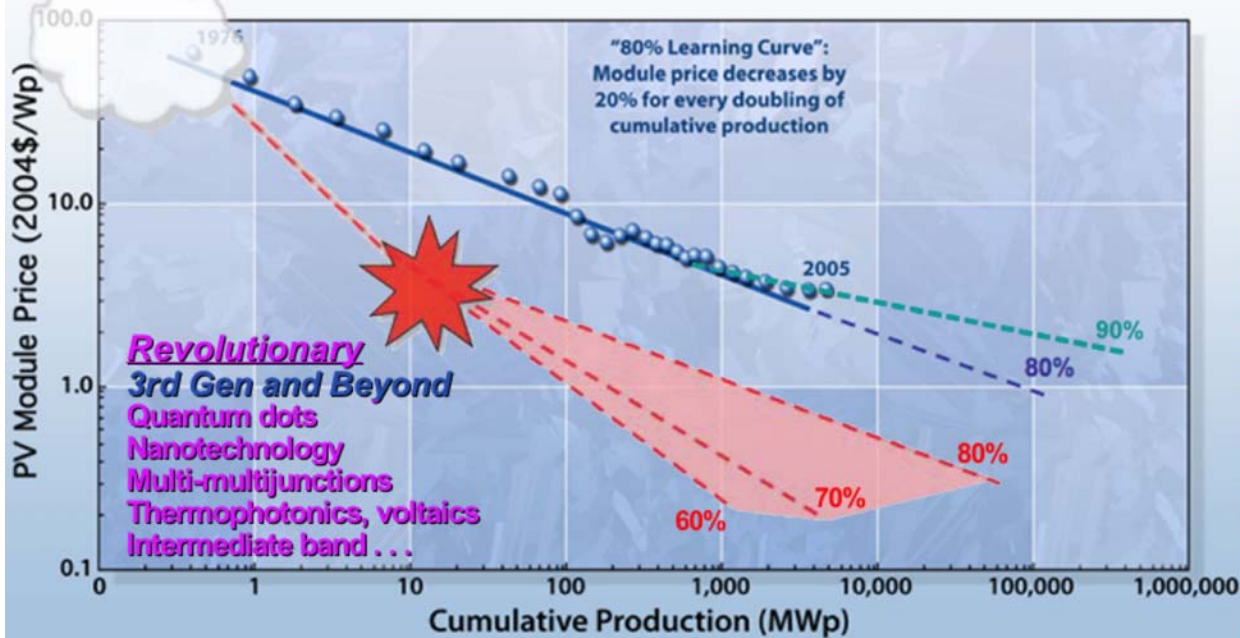
3rd Generation PV

- quantum dots
- nanotechnology
- multi-multijunctions
- thermophotonics
- intermediate band
- bio-inspired

**Revolutionary
(10 years and beyond)**



Module Production Learning or Experience Curve



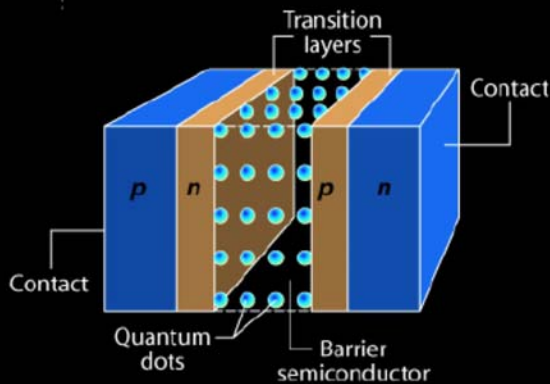
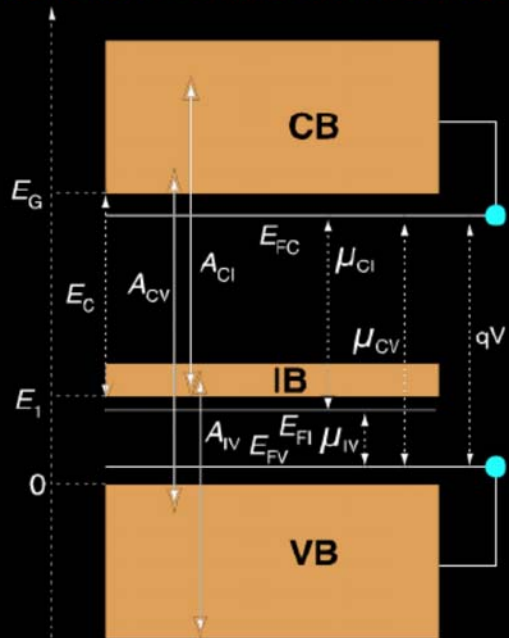
Technology-Driven

Translational Science 3rd Generation PV

- thin films
- concentrators
- organics
- wafers < 100µm
- cells beyond 25%

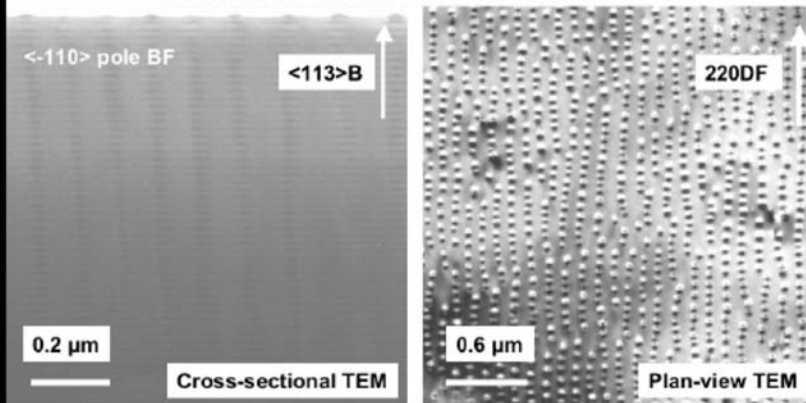


Intermediate Band Solar Cells



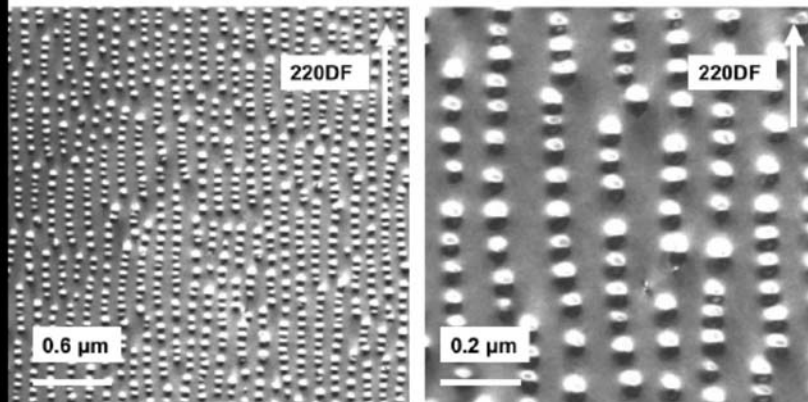
A. Norman, M Romero, and M. Al-Jassim, (NREL),
A. Luque, A. Marti, Spain

MOCVD Growth of InGaAs/GaAs QD arrays on (113)B GaAs substrates for intermediate band solar cells



- QD arrays are being grown to test concept of intermediate band solar cell proposed by A. Marti and A. Luque

(311)B 50 period InGaAs/GaAs QD superlattice plan-view TEM



- Chains of quantum dots along <110>



Summary

- **Several “second generation” (thin-film) technologies exist:**
 - **Amorphous Silicon**
 - **Cadmium Telluride**
 - **Copper Indium Diselenide**
 - **Copper Indium Gallium Sulfide**
- **Other Technologies May Come On Line:**
 - **Organic Materials**
 - **Thin-Film Crystalline Silicon**





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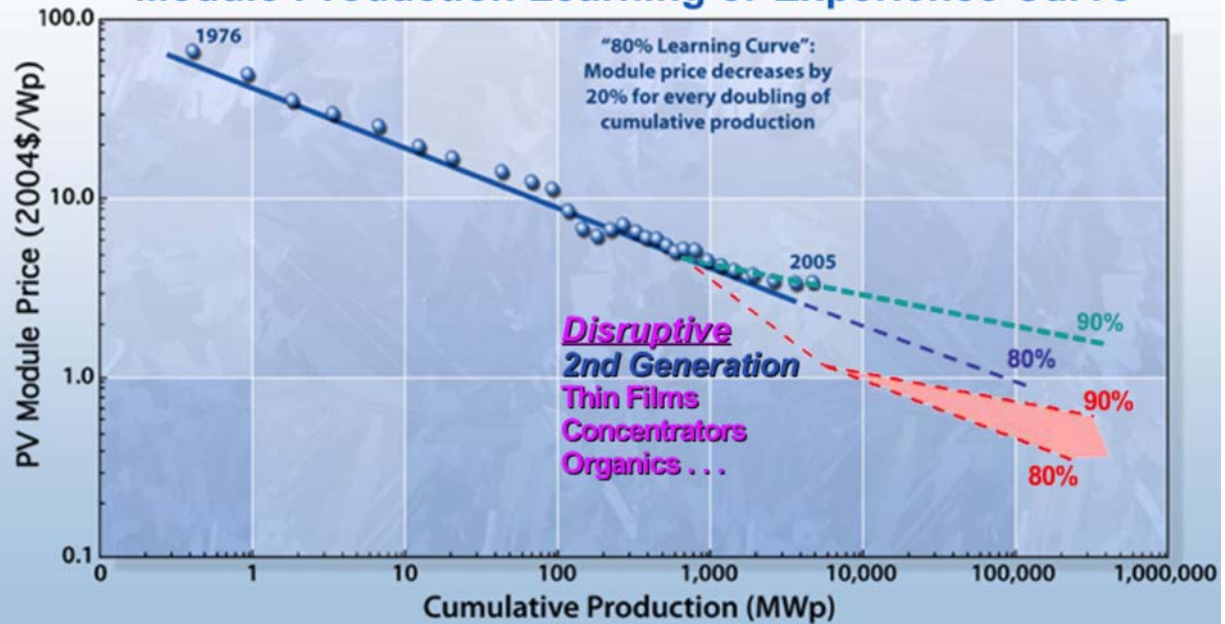
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Technology Investment Pathways

Industry-Driven

Module Production Learning or Experience Curve



Applied Science & Technology 1st & 2nd Generation PV

- lower Si feedstock prices
- thinner Si wafer technology
- thin films
- improved processing
- improved performance
- advanced integration, packaging

Accelerated Evolutionary (3 years)

Disruptive (3-10 years)

2nd Generation PV

- thin films
- concentrators
- organics
- Si wafers < 100µm
- Si cells beyond 25%



CSM Renewable Energy Focus Areas

- **35 years of excellence!**
- Photovoltaics
- Wind Generators
- Fuel Cells
- Energy Storage
- Controls, Grid Optimization, Power Systems Engineering
- Storage of Radioactive Waste
- Geothermal, Hydrogen Research



Colorado Can Grow World-class Photovoltaic and Fuel Cell Industries

- Local Cell Developers
- Local Equipment Manufacturers
- Materials and Service Providers
- Finance & Management Consultants
- World-Class Universities
- R&D Laboratories (NREL)



Colorado Collaboratory

- Recent Developments
 - Salazar letter to legislature and Governor recommending Renewable Energy Institute among NREL, CSM, CU, CSU; being discussed in legislature.
 - State funding (\$2 M/year) to match collaboratory research proposals.
 - One proposal already submitted.
 - Organizational structure being discussed at “highest levels”.



Renewable Energy Initiatives

Fiscal Year 2005-2006

- Renewable Energy Working Group
- “Colorado Collaboratory”
- Joint Institute (CSM and NREL)
- Joint Appointments (CSM and NREL)
- Collaboratory Proposal to Basic Energy Sciences (DOE)
- XCEL Solar Test Facility (SoCom)
- Solar America Initiative**
- CERI Regional Facility (GRL)





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