Photo: Powerlight Corp.

Solar Power and Electric Utilities

A Perspective in 2006

Presented to

MIT·Stanford·UC Berkeley Nanotechnology Forum

by

Terry Peterson,
Solar Power Consultant
Electric Power Research Institute

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EPRI

Two distinct solar electric near-term applications

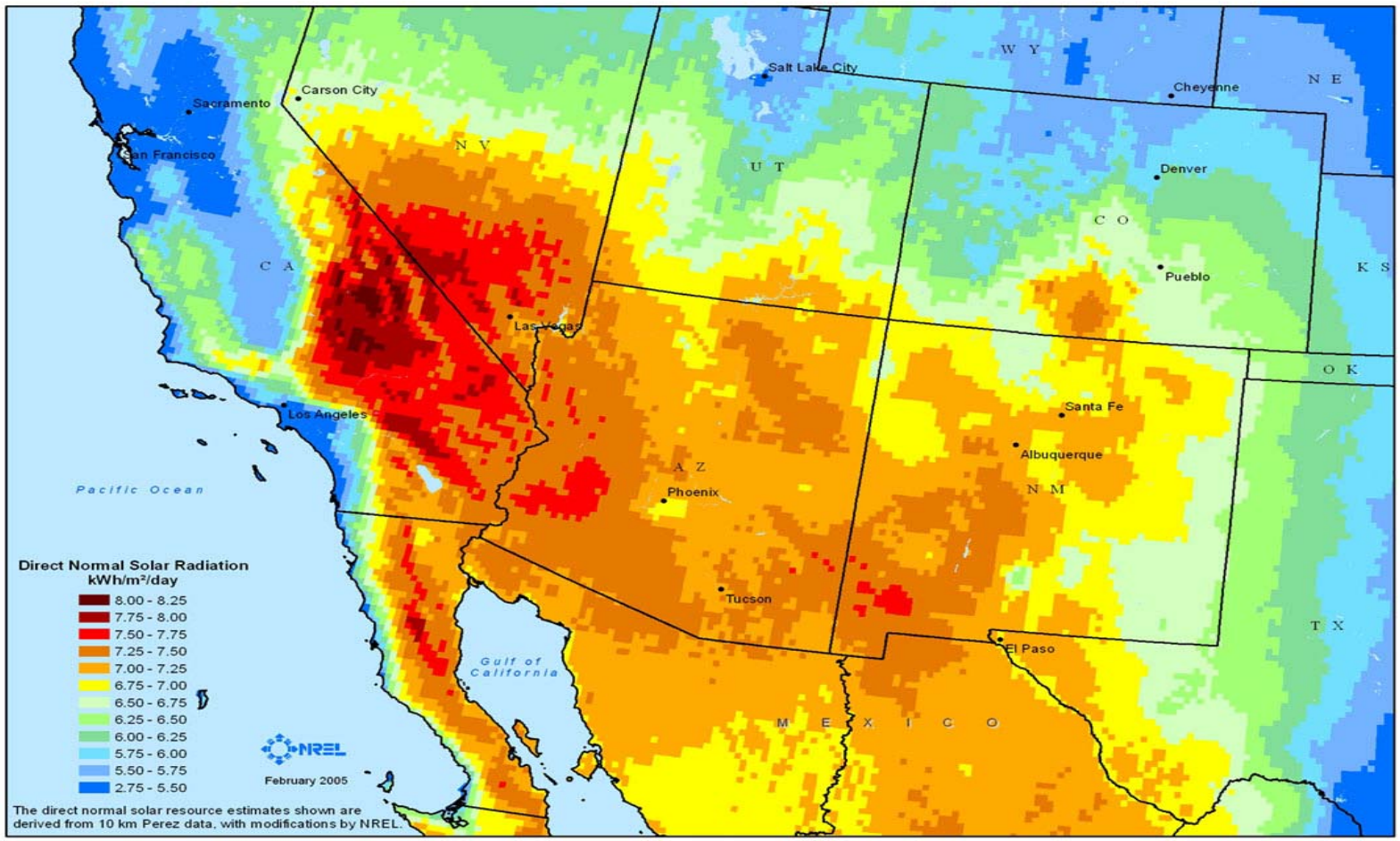
Central station (CSP)

- 4 main technology classes
  - Parabolic trough
  - Tower receiver
  - Dish-engine
  - Concentrating PV
- Well suited to historic utility business
- Difficult market entry (needs large scale)
- At threshold of significant worldwide deployment after 15-year construction hiatus

Distributed (PV)

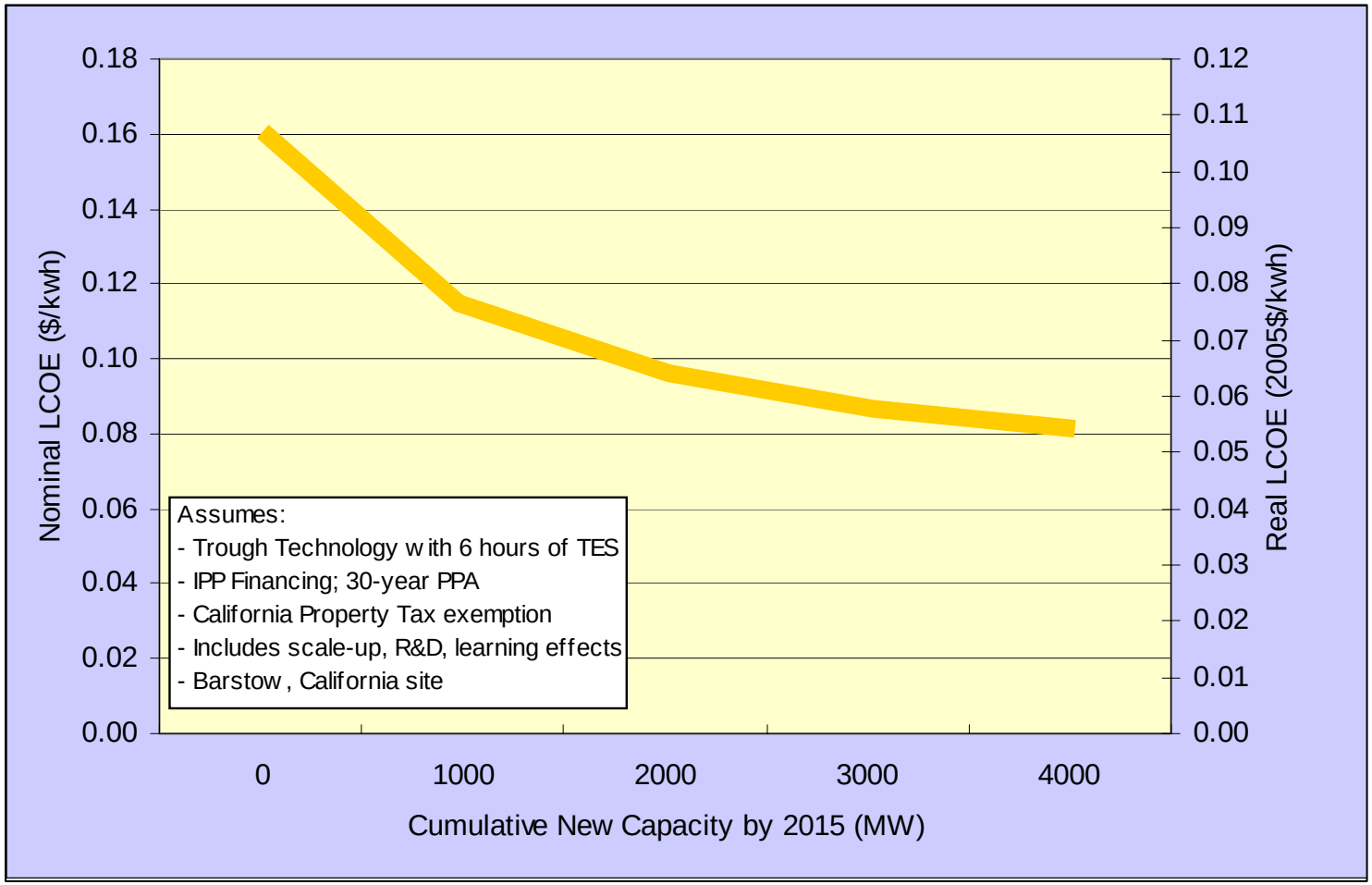
- 2 main technology classes
  - Crystalline silicon – dominant
  - Thin films – emerging (20 yr)
- Dramatic breakthroughs evident…but distant
- Difficult fit with utility business
- Easier market entry (small scale)
- Enjoying exponential deployment growth for past 30-some years

U.S. southwest has enormous CSP resource



(Source: WGA CDEAC Solar Task Force Report, http://www.westgov.org/wga/initiatives/cdeac/solar.htm)

Deployment is key to CSP cost reduction

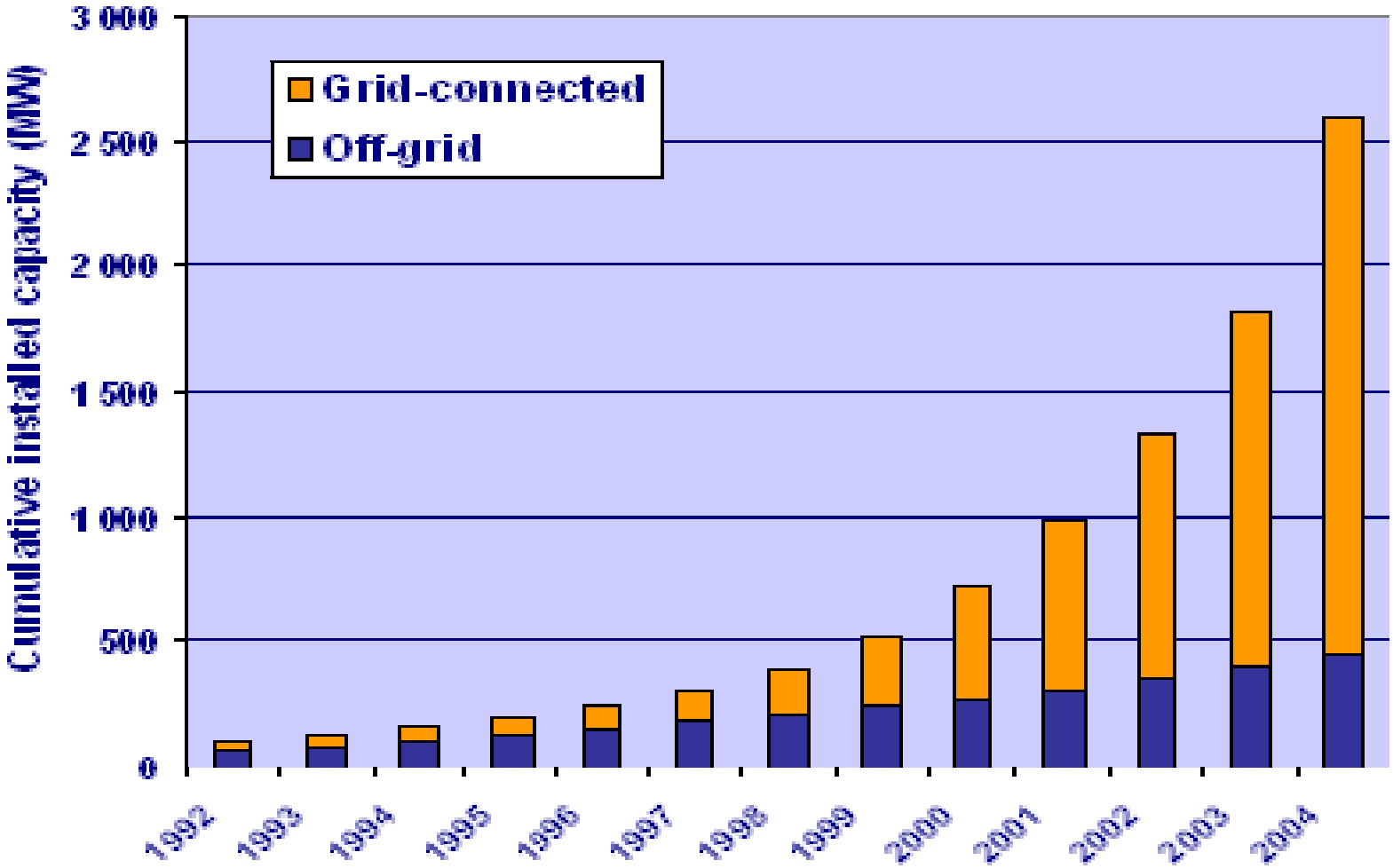


(Source: WGA CDEAC Solar Task Force Report, http://www.westgov.org/wga/initiatives/cdeac/solar.htm)

Central-station solar power status and prospects

- 15-years experience with 354 MW of parabolic trough solar plants in California gives confidence in concentrating solar power (CSP) technologies
- CSP is poised for dramatic expansion in U.S. southwest and other sunny locales (Spain, North Africa, India, Australia)
- Cost of electricity for first-of-a-kind CSP plants needs subsidies to encourage private investments
- Technology “sustaining” innovation is needed to augment learning-by-doing cost reduction
- Cost-competitive deployment appears possible within 10 GW

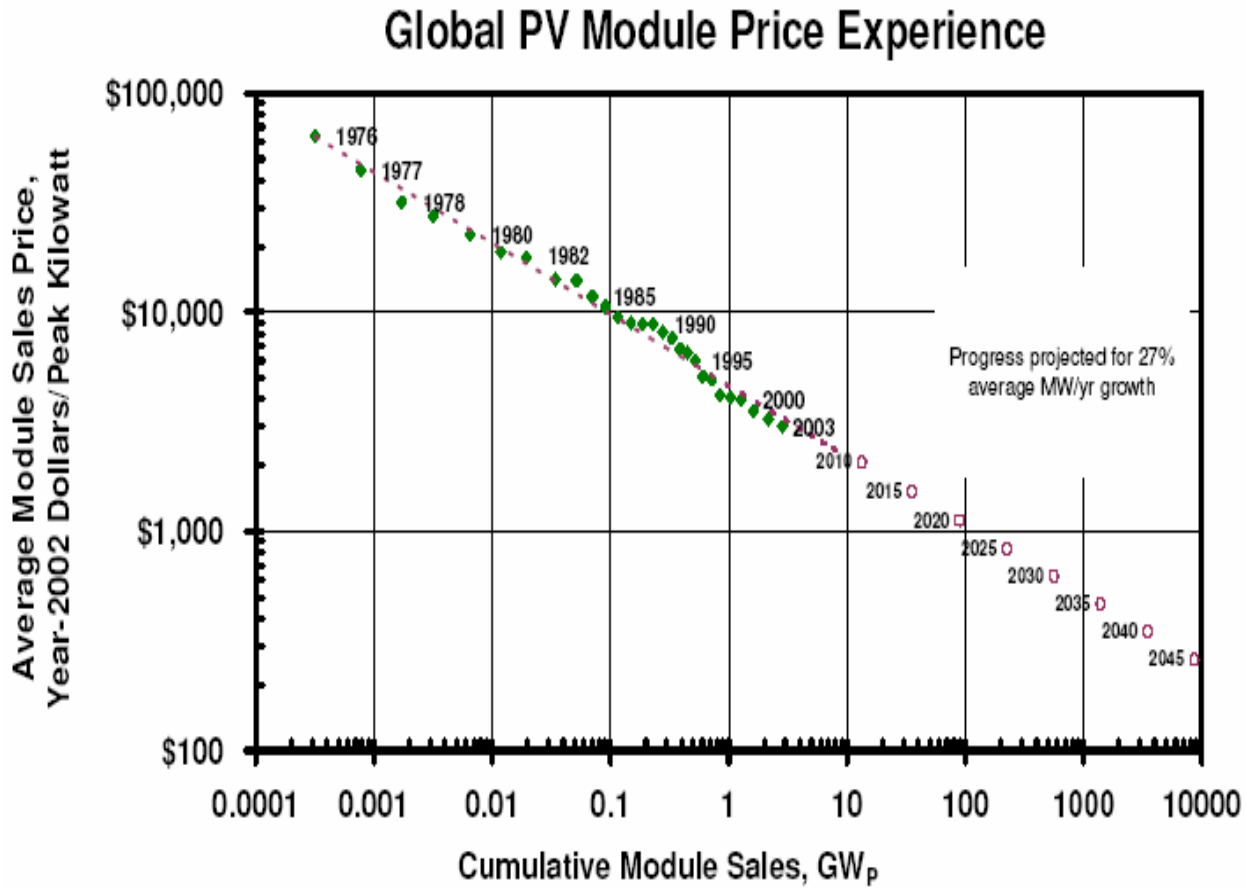
Shift in mainstream PV applications



(Source: International Energy Agency PVPS)

Historic PV module sales and price trend

- Installed system price ≈ 2x module cost
- No “guarantee” future will echo past…but also no evident cause for change
- Present expansion (40%/yr) driven by subsidized grid-connected markets

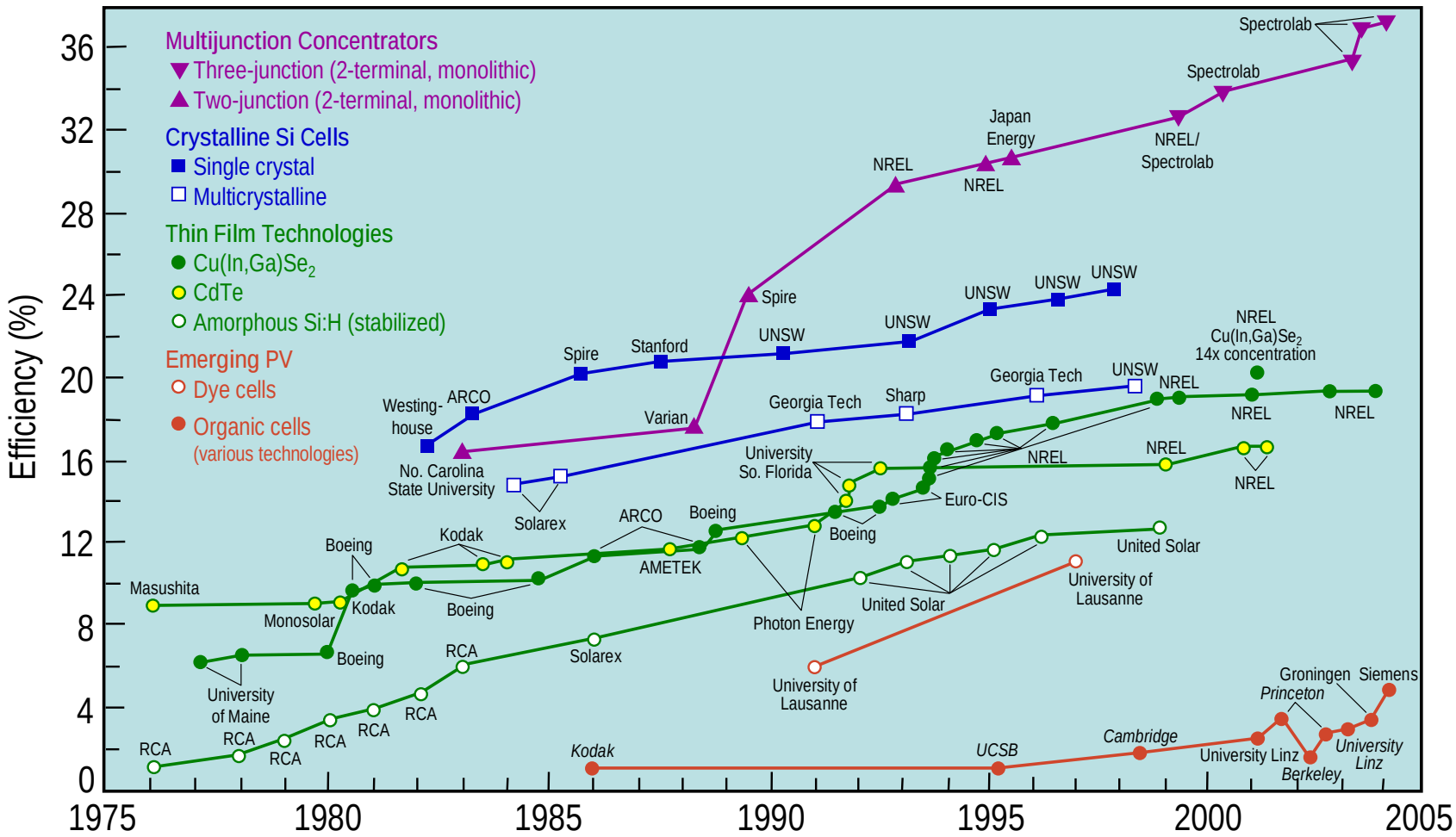


Distributed solar power status and prospects

- 30-years of experience, nearly 5-GW of deployments put distributed solar power on threshold of mainstream retail energy business
- Continued improvement in performance and cost appear likely
- Rate of improvement could be accelerated by sustained, focused R&D to reduce society's cost of transition via "disruptive" innovations
- Present cost of PV electricity with current subsidies is "affordable" for retail power displacement
- TW-scale economic deployment appears possible within 40 years

Additional slides follow for possible use in Q&A

Historic laboratory cell progress

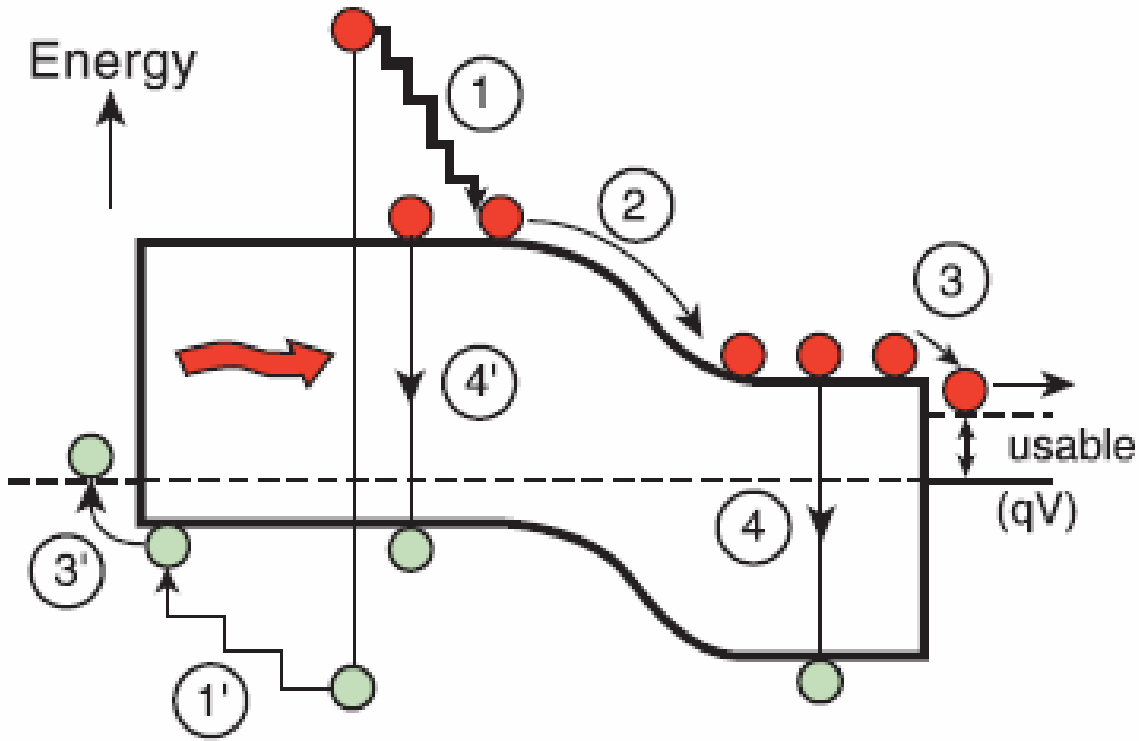


Source: National Renewable Energy Laboratory

Sources of standard PV-cell efficiency loss

Loss Mechanisms

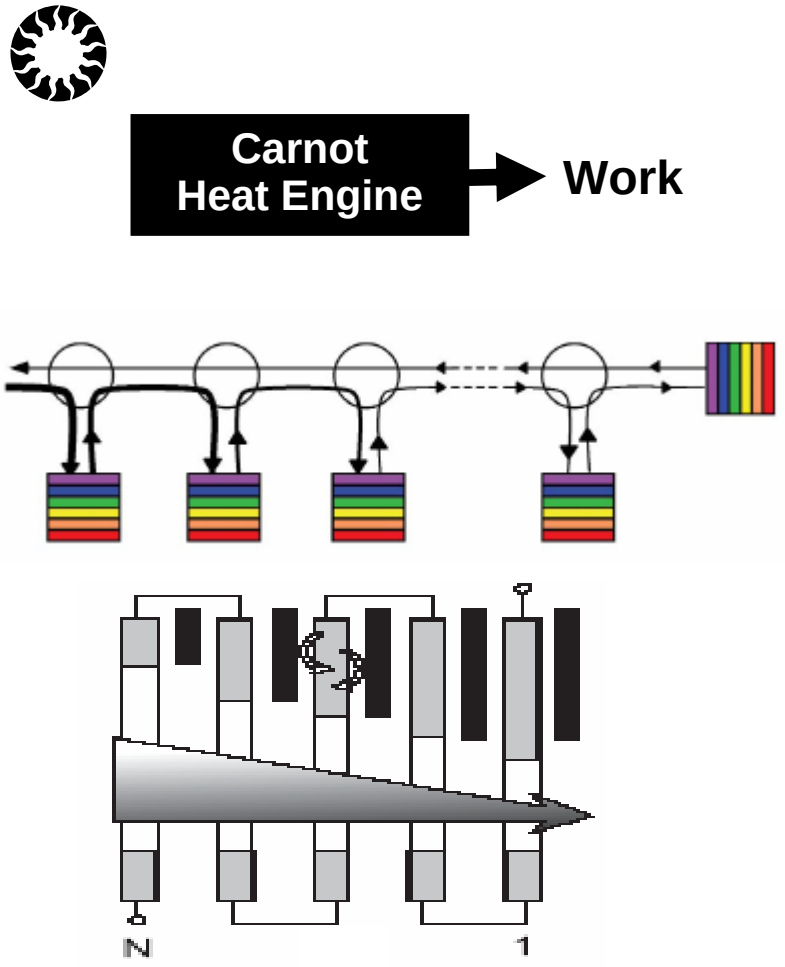
- Lattice thermalization
- Junction voltage drop
- Contact voltage drop
- Recombination
- Non absorbed photons



Source: M. Green et al., Univ. New South Wales

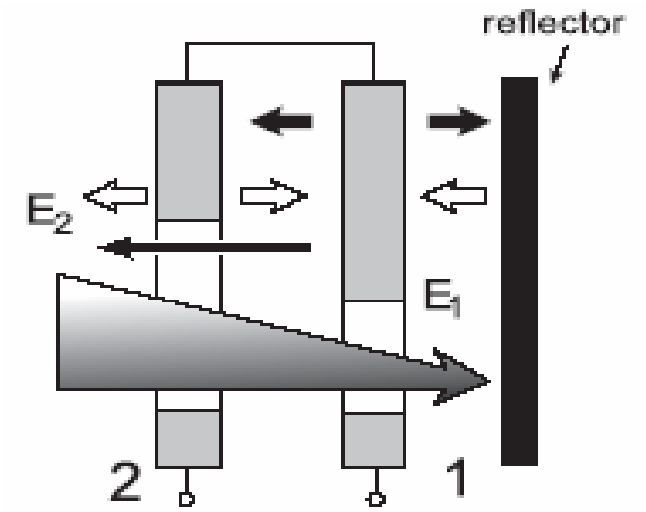
Prospects for significant efficiency enhancements

- Carnot efficiency limit (thermodynamically perfect conversion) is 95% with sun @ 6000K, earth @ 300K
- Infinite number of thermal converters connected via “optical circulators” can achieve 93.3% efficiency
- Infinite number of tandem cells with optimum energy bandgaps can achieve 86.8% efficiency

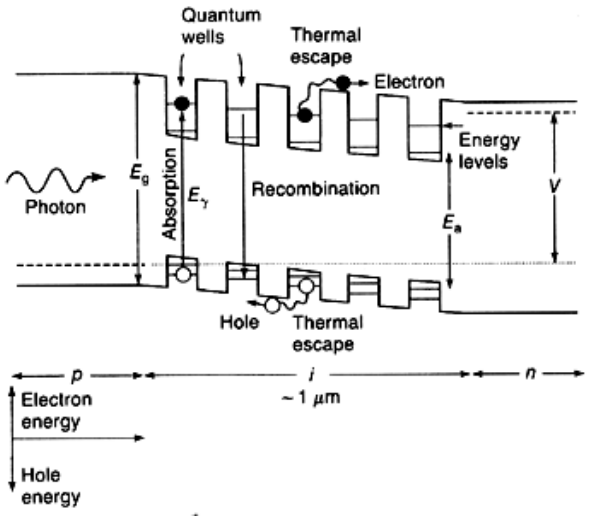


Selected "Third-Generation PV" candidates for tripling module efficiency -- I

Tandem cells

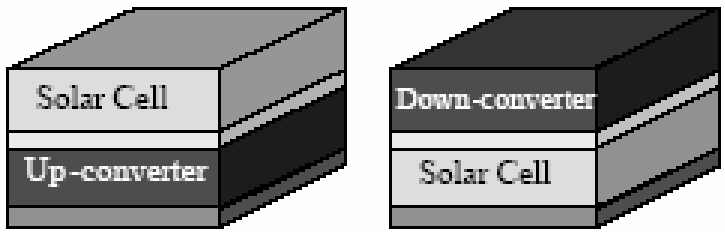


Quantum wells

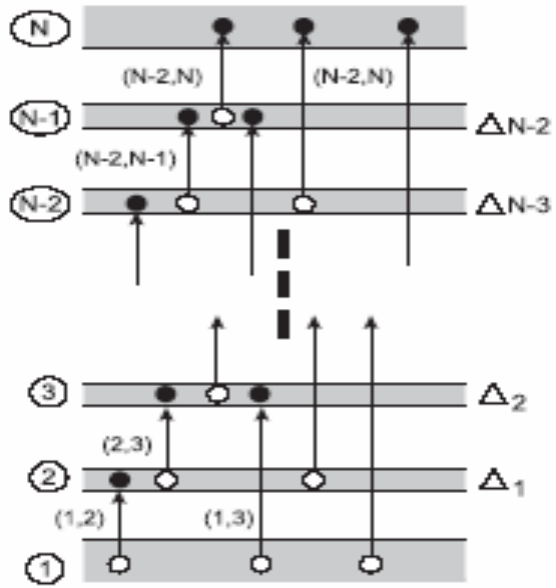


Selected "Third-Generation PV" candidates for tripling module efficiency -- II

Up and down conversion

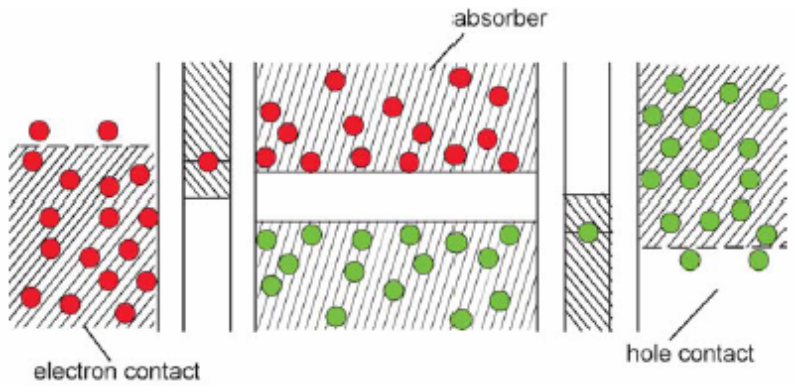


Metallic intermediate bands



Selected "Third-Generation PV" candidates for tripling module efficiency -- III

Hot carriers



Thermophotonics