National Renewable Energy Laboratory
Innovation for Our Energy Future

Overview of Solar Energy Development in the U.S.

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Tribal Energy Program
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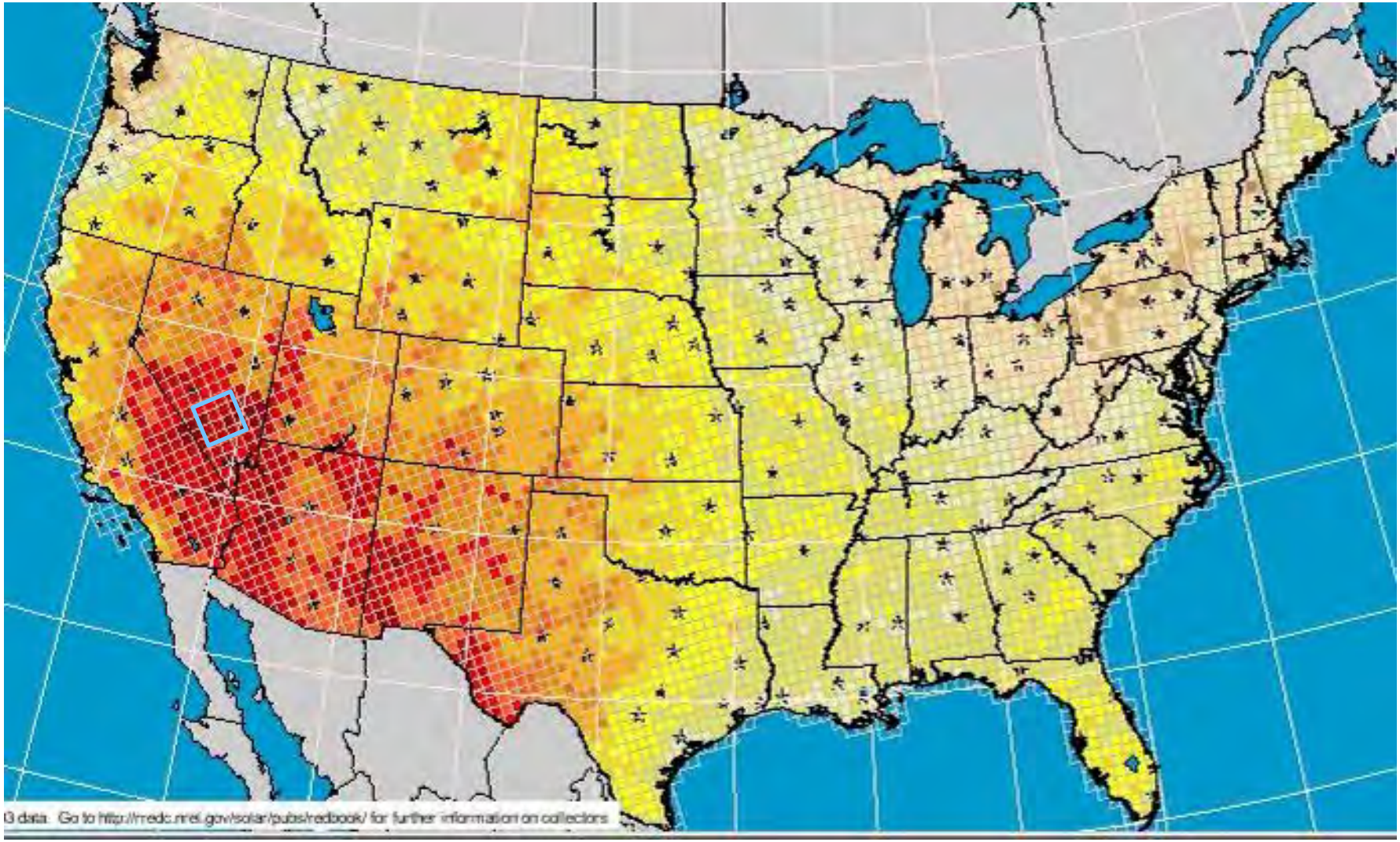
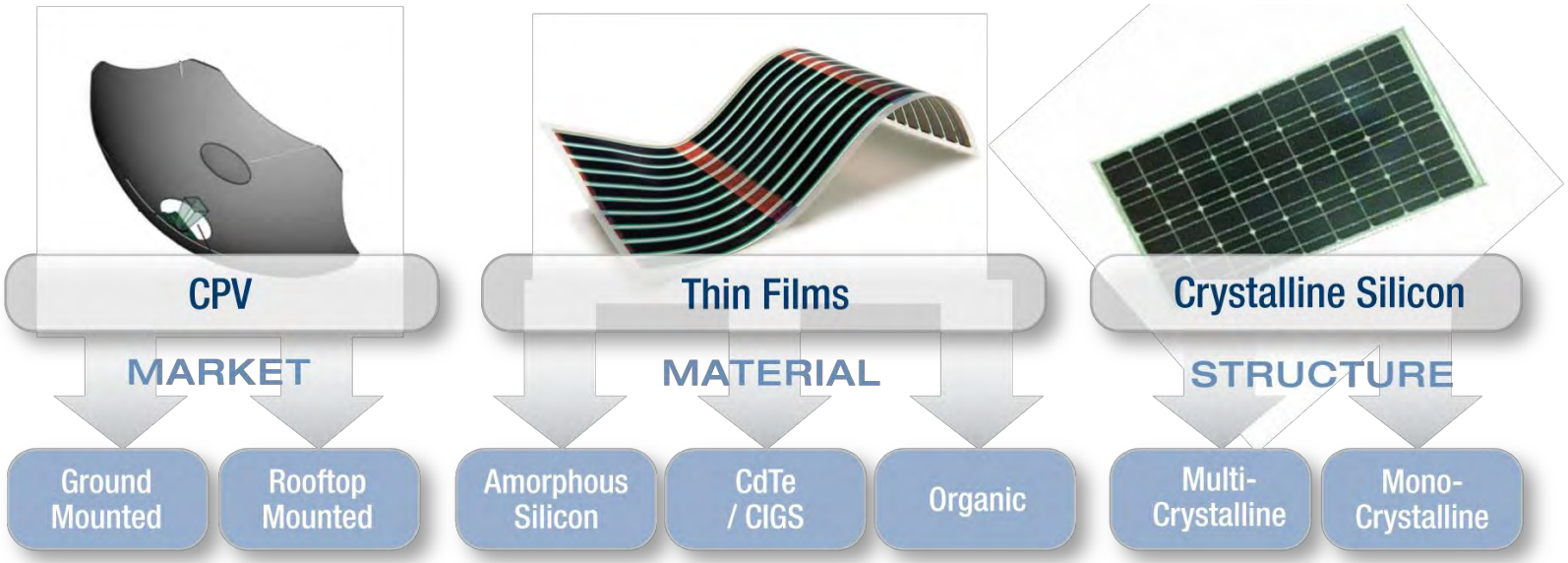
U.S. Solar Program and Subprograms

Solar-Based Technologies

A Plot of Land, 100 Miles on a side, in Nevada could provide all the kWh consumed by the U.S.

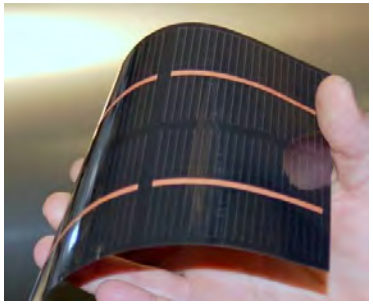


Photovoltaic (PV) technologies

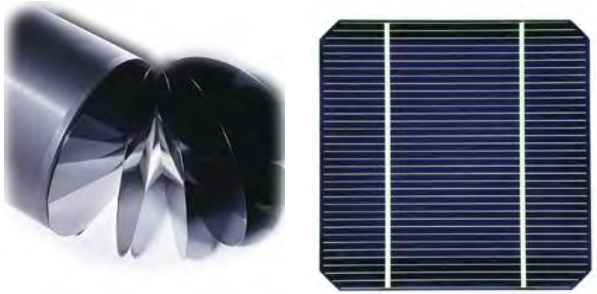


•20x-100x

•500x



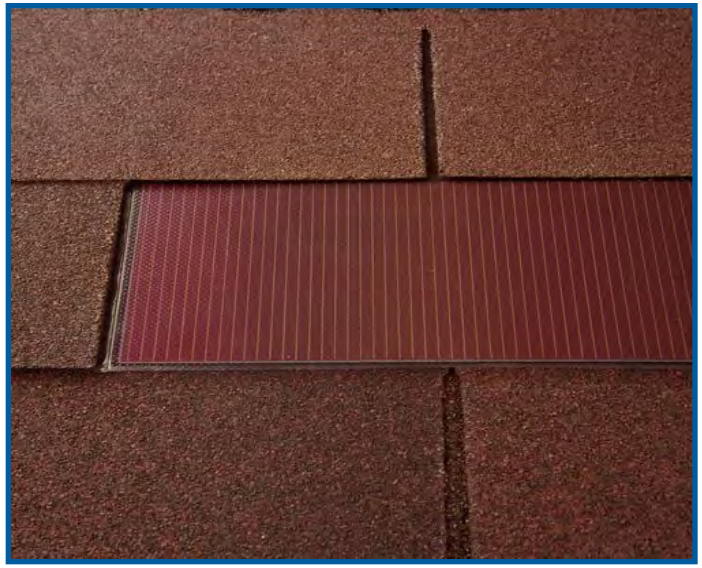
•$Cu(In,Ga)Se_2$ ~ 1-2 um



•c-Si ~ 180 um

Photovoltaic Markets: Very diverse > Large (GWs) Market Potential

Building-Integrated PV (BIPV)



El Dorado, Nevada, USA (10MW); Sempra Energy

Nellis Air Force Base

Silver State North
Location: NV
Operator: Enbridge Corp
Configuration: 50 MWp
Operation: 2012
System supplier: First Solar
EPC: First Solar

Estrella Foothills High School
Location: AZ
Operator: Constellation Energy
Configuration: 1.604 MWp
Operation: 2012
System supplier: Suntech
EPC: Natural Power and Energy LLC, CORE Construction

DeSoto
Location: FL
Operator: Florida Power & Light
Configuration: 25 MWp PV
Operation: 2009
System supplier: SunPower Corp
EPC: SunPower Corp

Copper Mountain
Location: NV
Operator: Sempra Energy
Configuration: 55 MWp PV
Operation: 2008-2010
T/G supplier: First Solar
EPC: First Solar

MAREC PV

Location: MI

Operator: Michigan Alternative and Renewable Energy Center

Configuration: 30 kWp PV

Operation: 2004

System supplier: Unisolar

Challenges for Photovoltaics

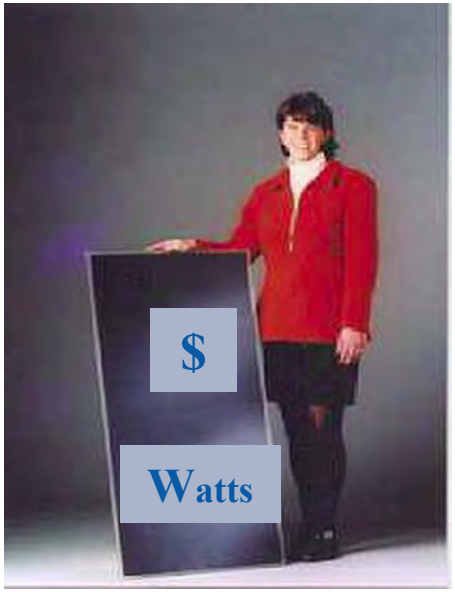
- Continue to drive down costs and develop sufficient product diversity to address and maximize all market segments

- Ensure adequate supply chain for a large and rapidly growing industry → International suppliers = Increasing competition

- Continue to provide reliable products with 30 yr lifetimes (both actual and perceived)

Fundamental Targets Leading to U.S. PV Deployment Success

Module



$ 1/Wp

System

$ 2 to 3/Wp

Electric Power Source

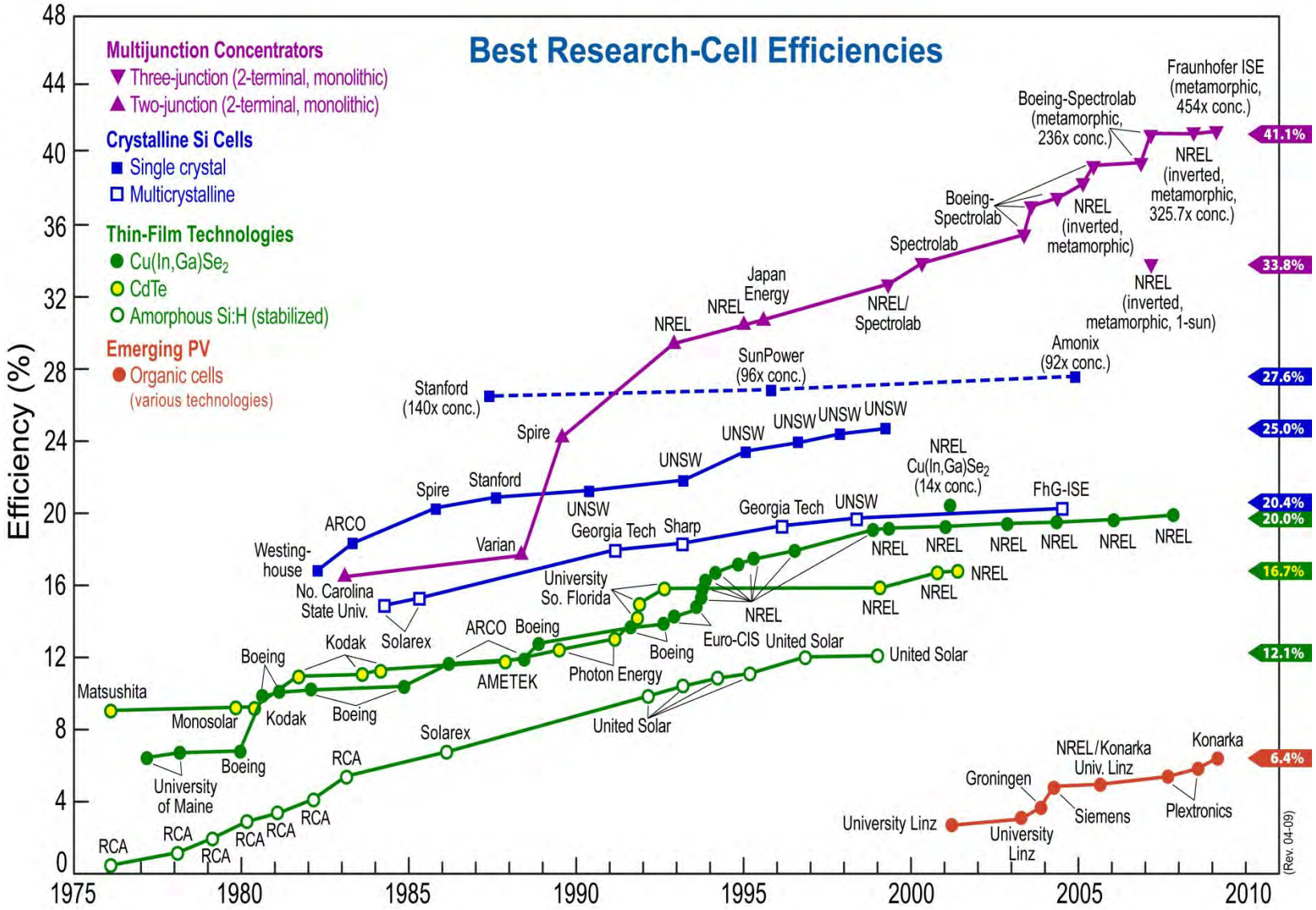
$cents/kWhr [application competitive]

- ❑System Installation Costs
- ❑Grid Integration
- ❑20 to 30 yr. lifetime/reliability
- ❑1 to 2% Degradation
- ❑ Low Operating Costs

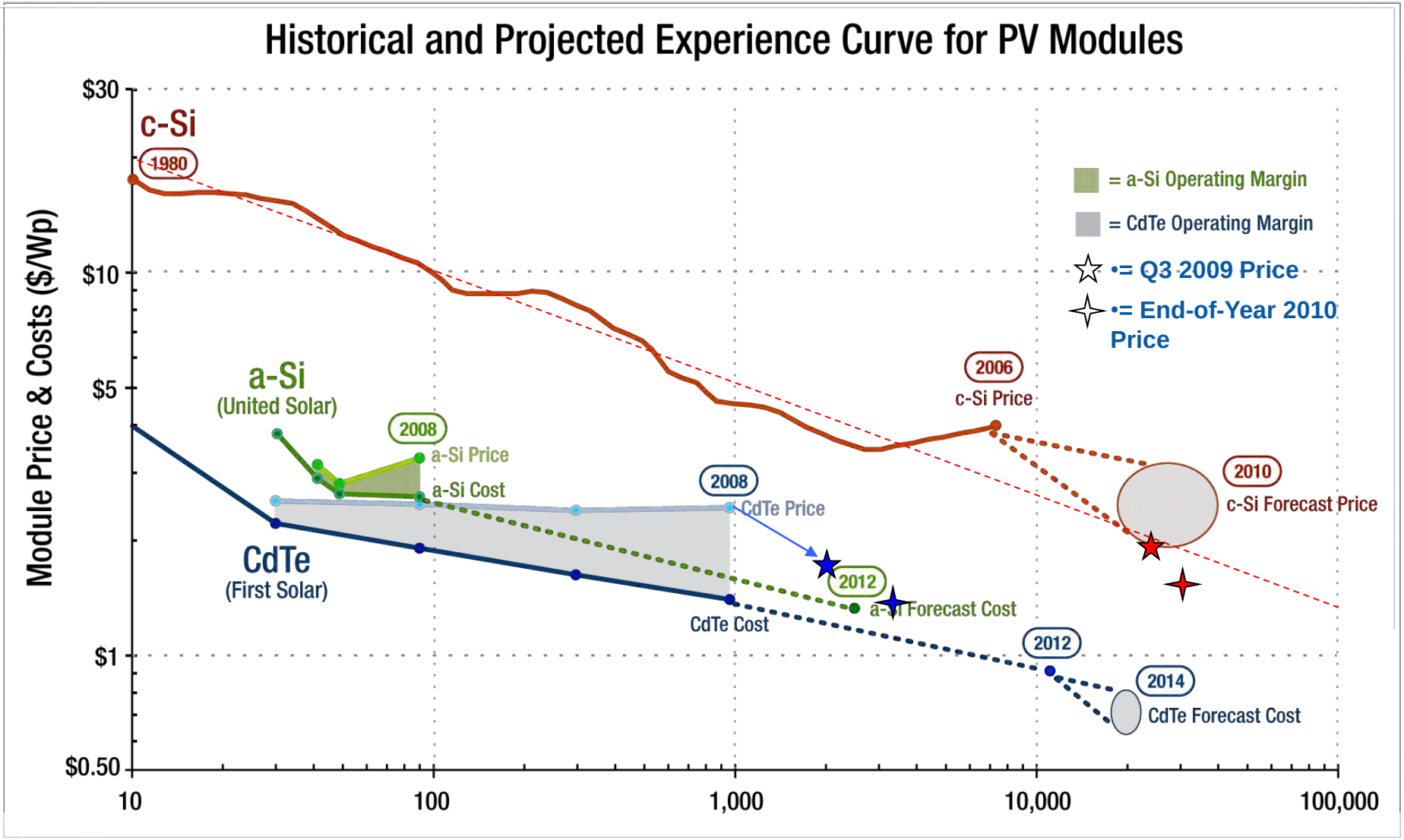
Manufacturing Scale Up

- ❑Supply Chain (gigawatt scale).
- ❑Meeting efficiency & $/m^2 cost targets.
- ❑Maintain Performance/Quality.
- ❑Energy Payback & Environmental .

PV R&D: Current Industry Result of Past 30 Yr.s Research Success



It's remarkable that cost have been dramatically reduced across vastly different technologies



•Public data from SEC, analysts, etc.

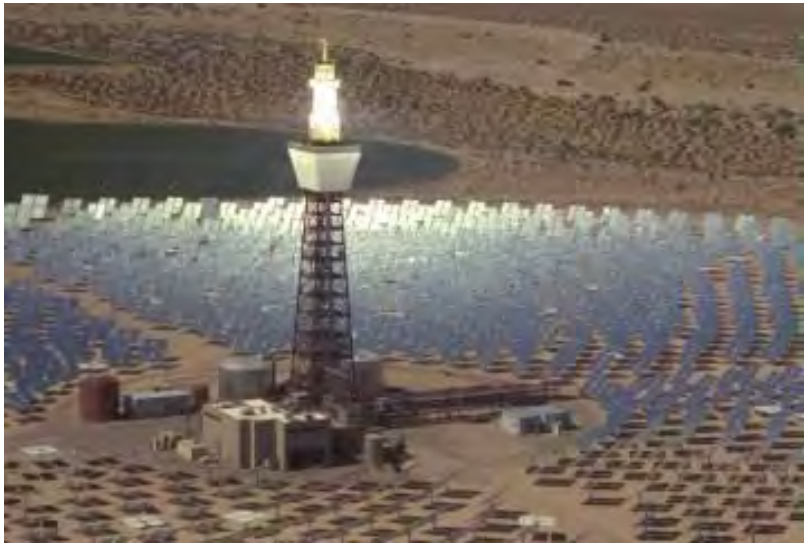
Technical Challenges for High-Penetration PV

- Ensure safe and reliable two-way electricity flow
- Develop smart grid interoperability
- Develop advanced communication and control functionalities of inverters
- Integrate renewable systems models into power system planning and operation tools
- Integrate with energy storage, load management, and demand response to enhance system flexibility
- Understand high-penetration limiting conditions
- Understand how various climates and cloud transients affect system reliability

Concentrating Solar Power: Dispatchable Power

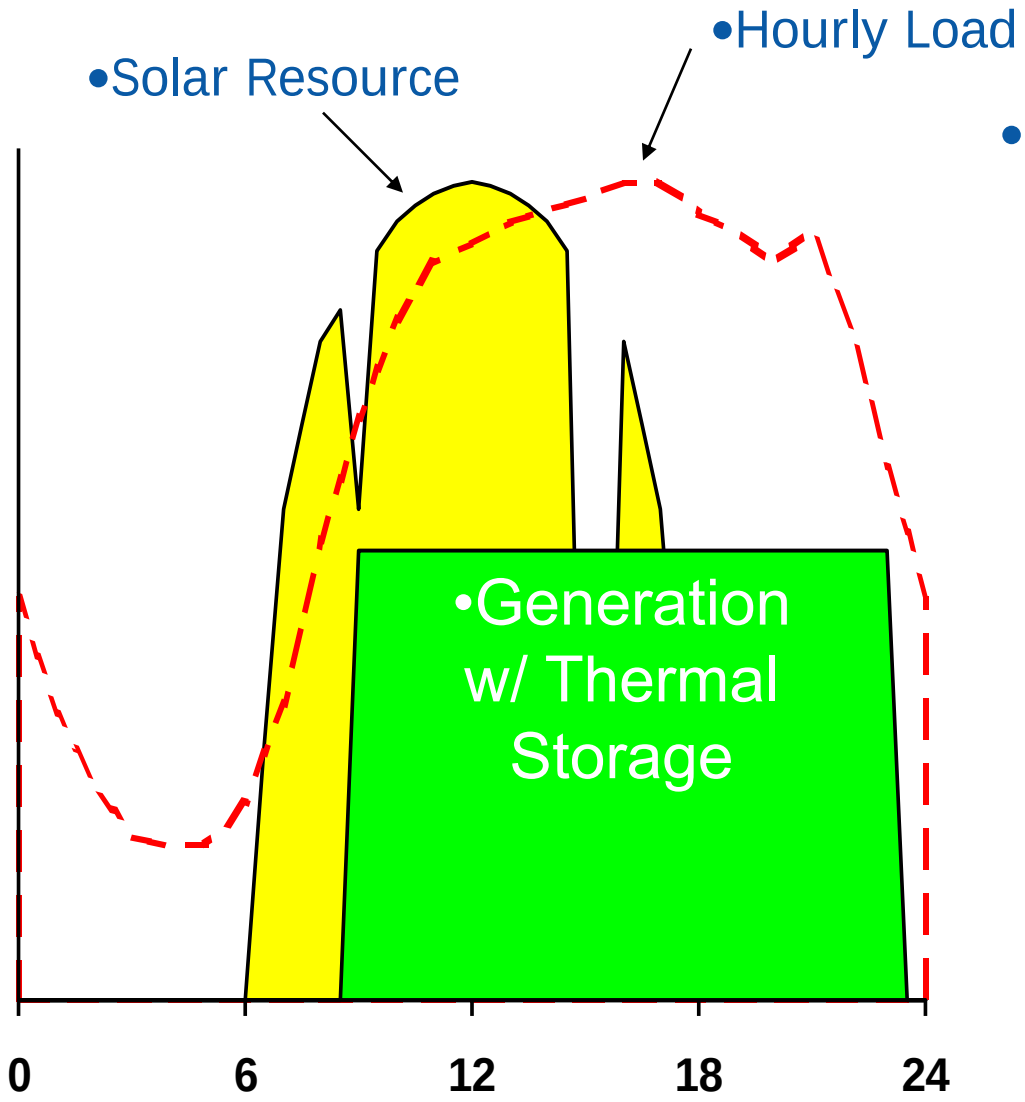
•Parabolic Troughs: Commercial, utility-scale deployments

•Central Receiver: Pre-commercial, pilot-scale deployments



- Up to 250MW plants (or multiple plants in power parks) for peaking and bulk power
- Moderate solar-to-electric efficiency
- Thermal storage offers load following and capacity factors up to 70%

Value of Dispatchable Power - Meeting Utility Power Demands



- Storage provides
  - higher value because power production can match utility needs
  - lower costs because storage is cheaper than incremental turbine costs

•Operating Central Station Systems

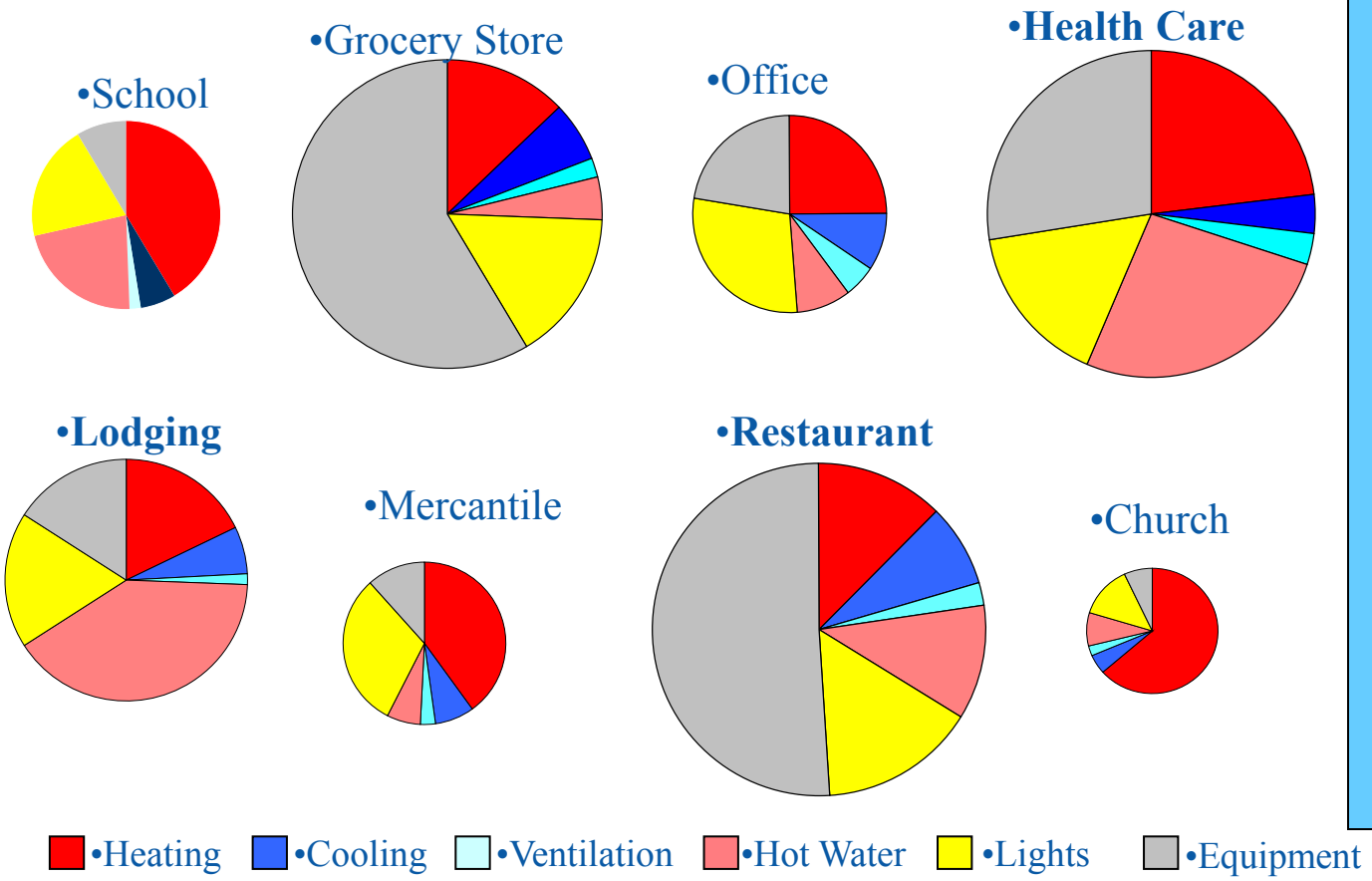
- The Solar Energy Generating Systems (SEGS) at Kramer Junction, CA (SEGS III-VII)
  - Five 30MW hybrid trough plants for a total of 150MW Capacity
  - Commissioned 1986-1988
  - Performance has increased with time
- Four additional SEGS plants located in two locations (Daggett, Harper Lake) for combined total of nine plants and 354 MW capacity

Maricopa
Location: AZ
Operator: Tessera Solar
Configuration: 1.5 MW
Operation: 2009
System supplier: Tessera Solar, Sterling Energy
EPC: Mortenson

Solar Water Heating Is Not New!

- Before the advent of gas pipelines and electric utilities, the technology gained footholds in Florida and California before the 1920's
- Over 1,000,000 systems are in use in American homes and business
- The technology is in widespread use in:
  - Caribbean basin
  - China
  - Israel
  - Greece
  - Japan
  - Australia

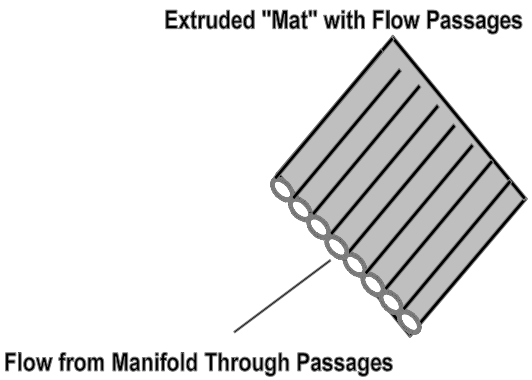
Building Hot Water Energy Use



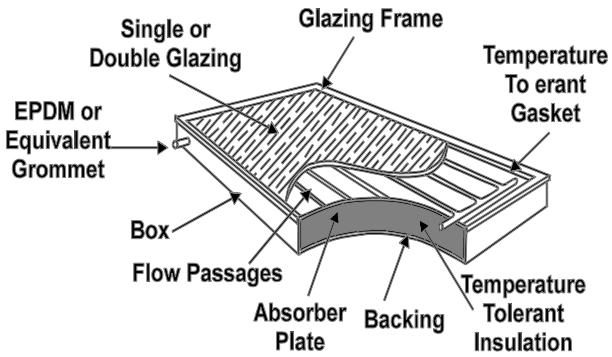
•Energy for Water Heating	
•kBtu/sf/year	
•Office	8.7
Mercantile	5.1
Education	17.4
Health Care	63.0
Lodging	51.4
Pub Assembly	17.5
Food Service	27.5
Warehouse	2.0
Food sales	9.1
Public Safety	23.4
Other	15.3
•All Buildings	13.8

Collector Types

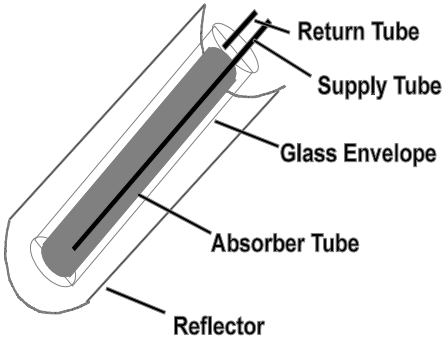
Unglazed EPDM Collector



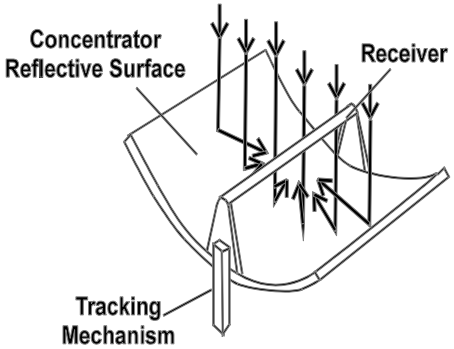
Flat Plate



Evacuated Tubes



Parabolic Trough



Solar Rating and Certification Corp.

•**Contact information**

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- An independent nonprofit organization that tests performance and certifies almost every solar heater on the market today.
- Reports efficiency and annual performance for different climates and temperature uses.