PV and CSP QTR

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US Department of Energy

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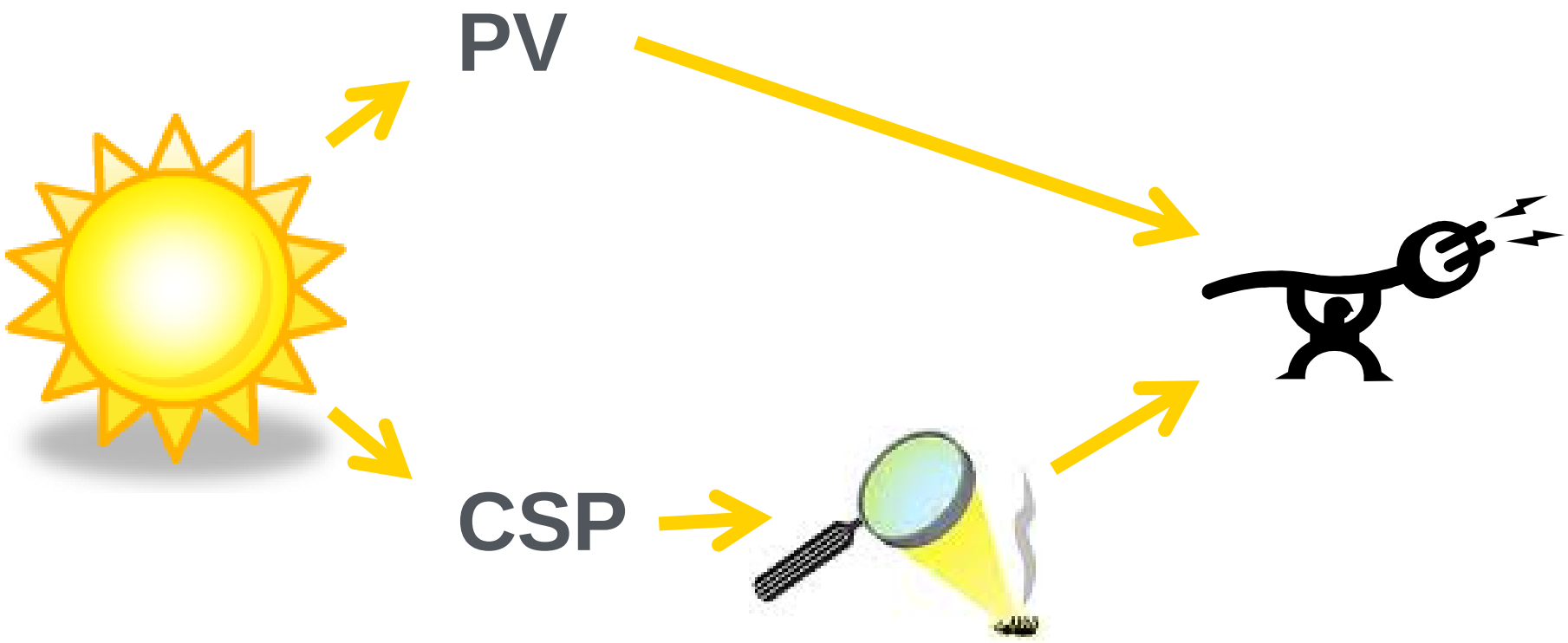
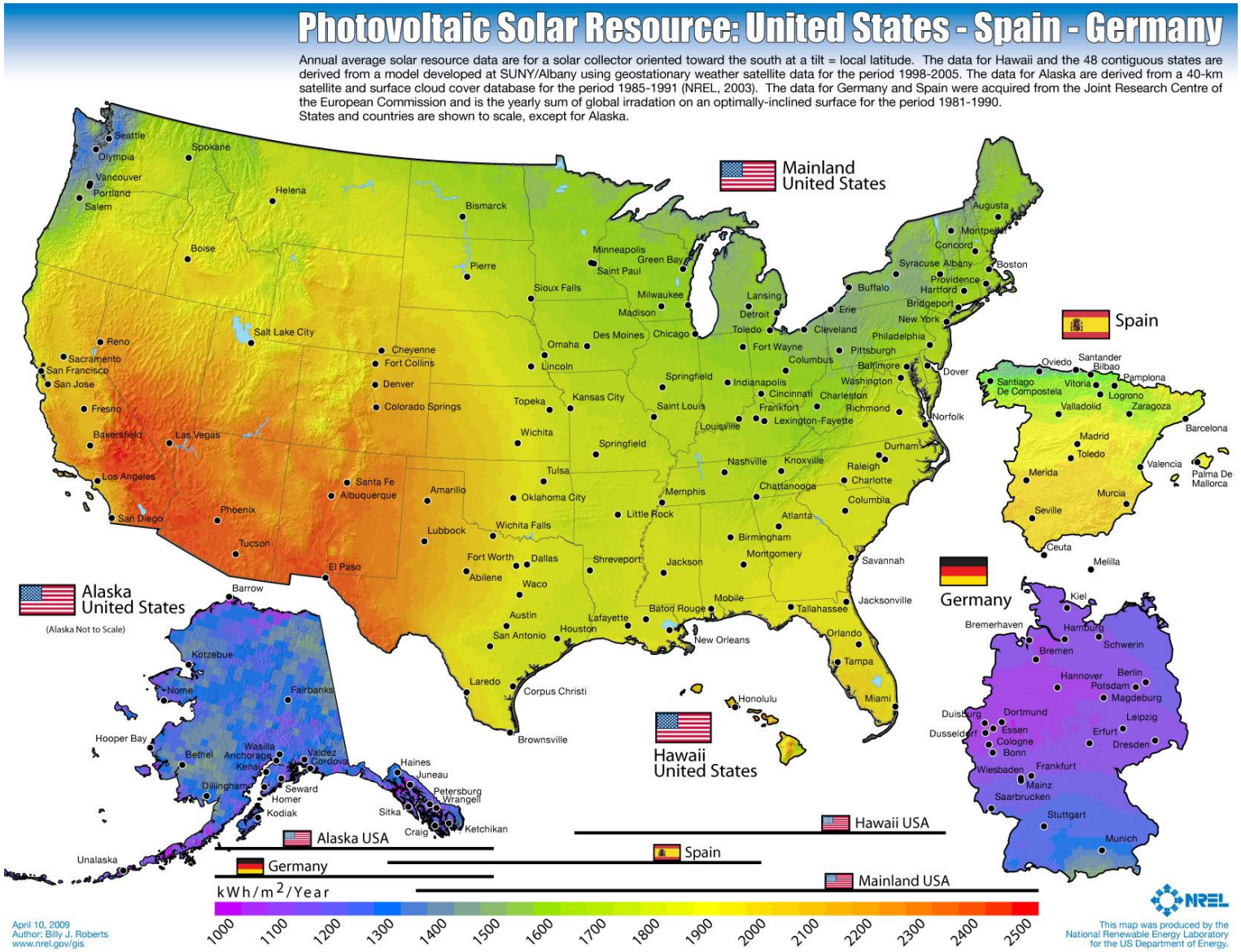
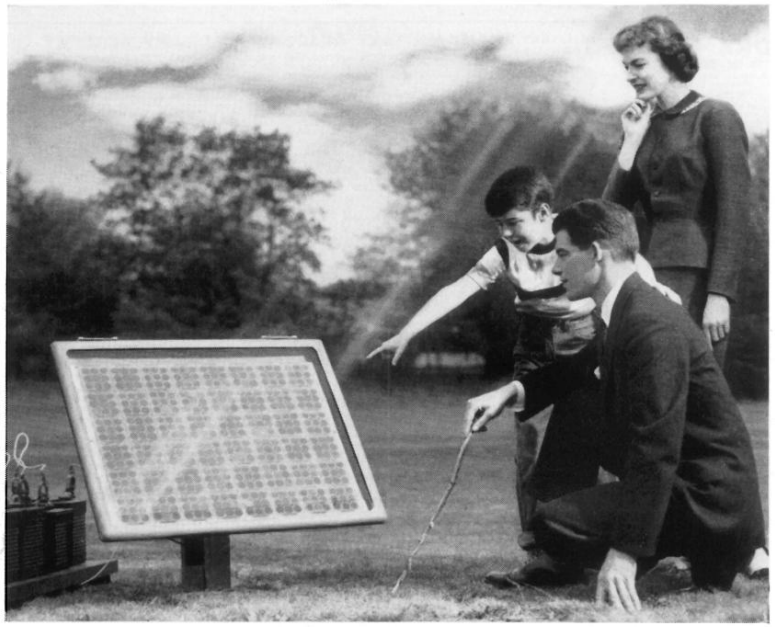
It’s elementary



The US is rich in solar resource



PV – Commercial Beginnings



Something New Under the Sun. It's the Bell Solar Battery, made of thin discs of specially treated silicon, an ingredient of common sand. It converts the sun's rays directly into usable amounts of electricity. Simple and trouble-free. (The storage batteries beside the solar battery store up its electricity for night use.)

Bell System Solar Battery Converts Sun's Rays into Electricity!

Bell Telephone Laboratories invention has great possibilities for telephone service and for all mankind

Ever since Archimedes, men have been searching for the secret of the sun.

For it is known that the same kindly rays that help the flowers and the grains and the fruits to grow also send us almost limitless power. It is nearly as much every three days as in all known reserves of coal, oil and uranium.

If this energy could be put to use — there would be enough to turn every wheel and light every lamp that mankind would ever need.

The dream of ages has been brought closer by the Bell System Solar Battery. It was invented at the Bell Telephone Laboratories after long research and first announced in 1954. Since then its efficiency has been doubled and its usefulness extended.

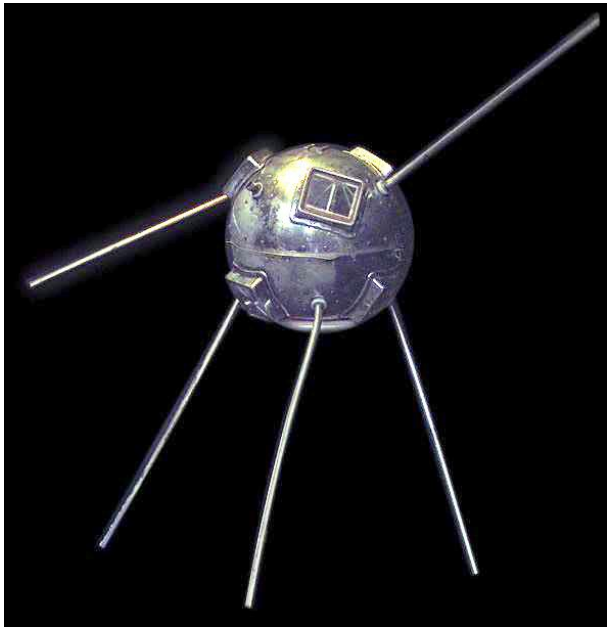
There's still much to be done before the battery's possibilities in telephony and for other uses are fully developed. But a good and pioneering start has been made.

The progress so far is like the opening of a door through which we can glimpse exciting new things for the future. Great benefits for telephone users and for all mankind may come from this forward step in putting the energy of the sun to practical use.

BELL TELEPHONE SYSTEM

1954: Bell Lab creates first silicon solar cell

1958: Vanguard satellite first commercial application



Source: NASA

Scientific Discovery – Increasing Efficiency

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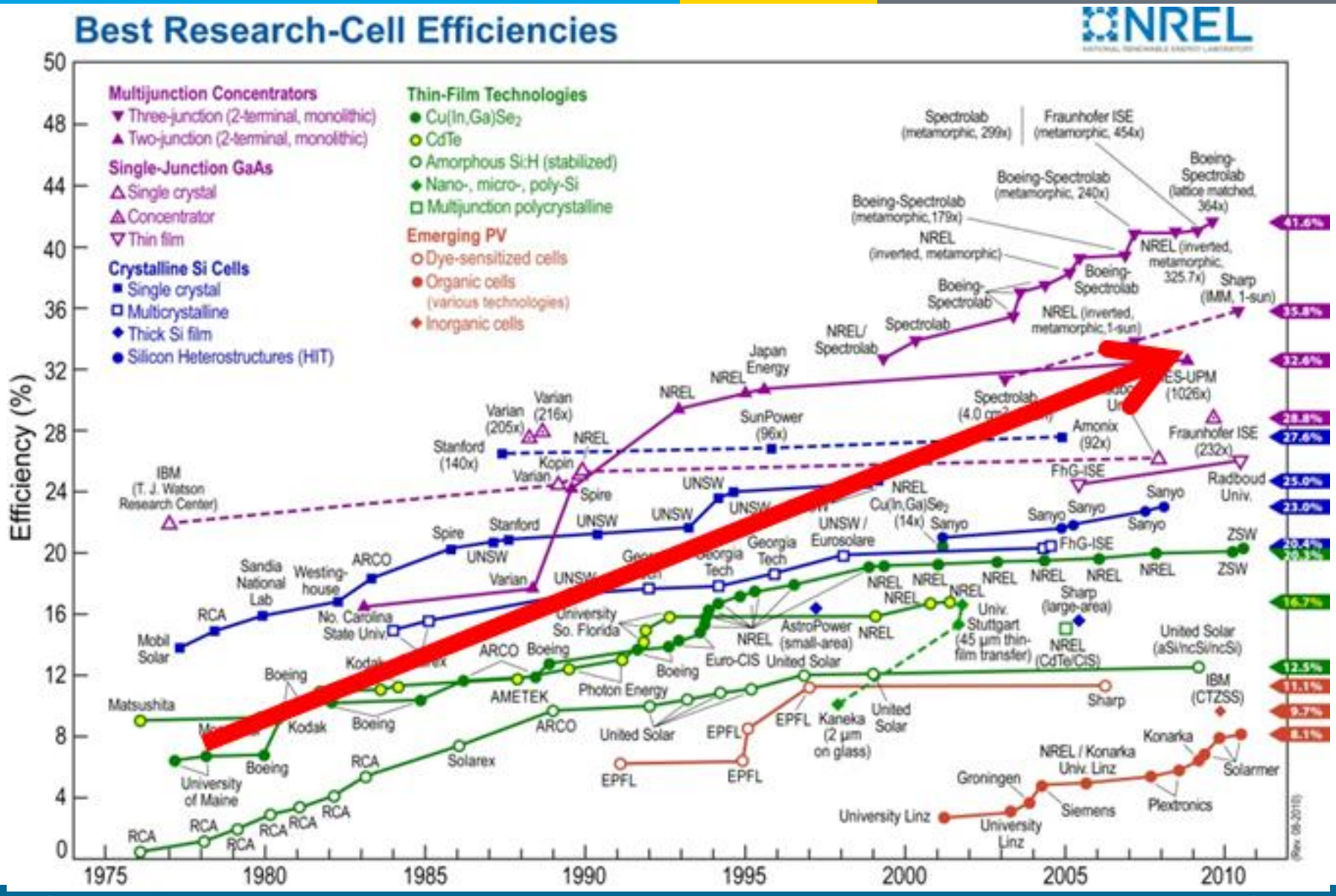

Engineering and Scale – Decreasing Cost

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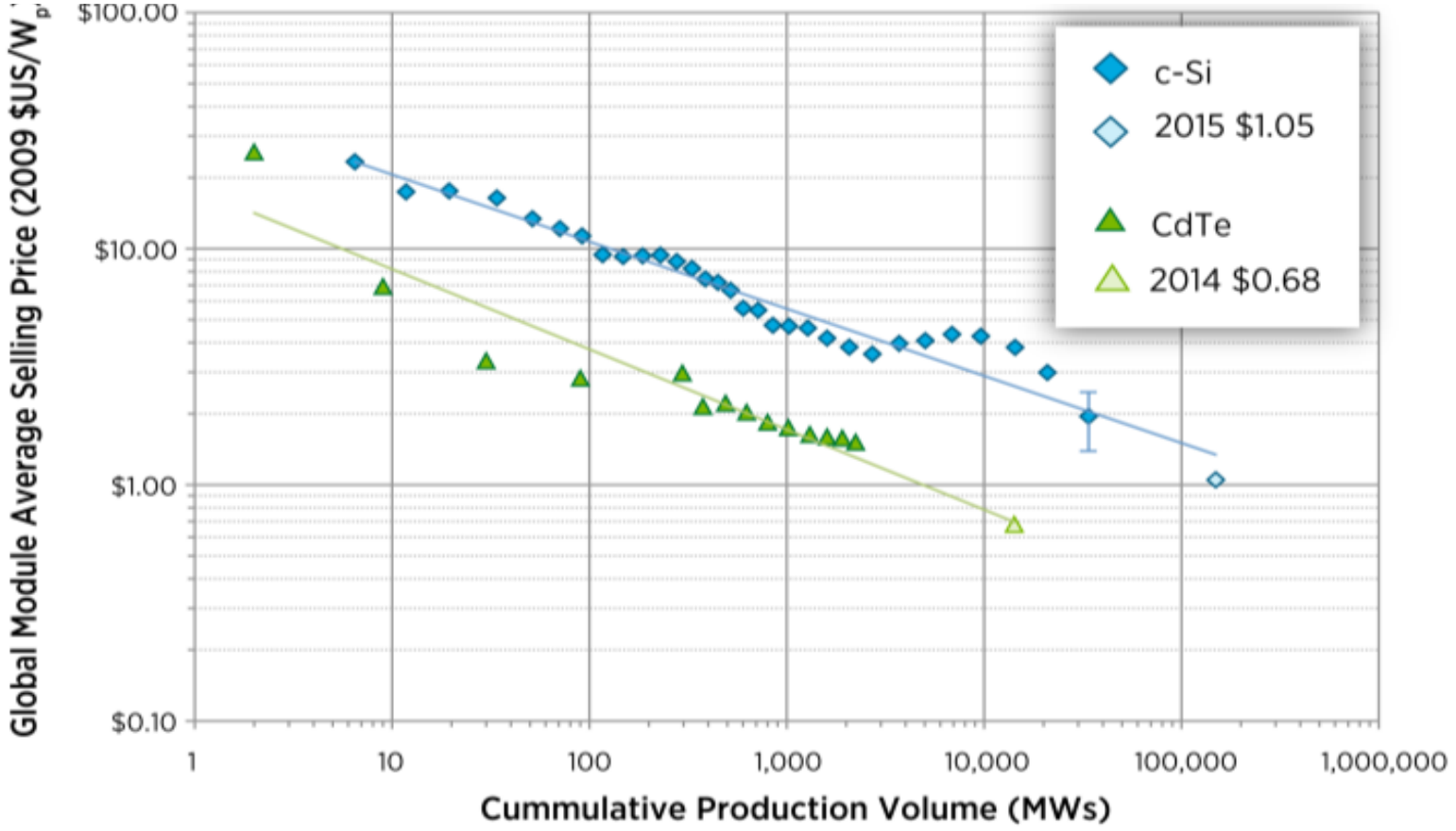
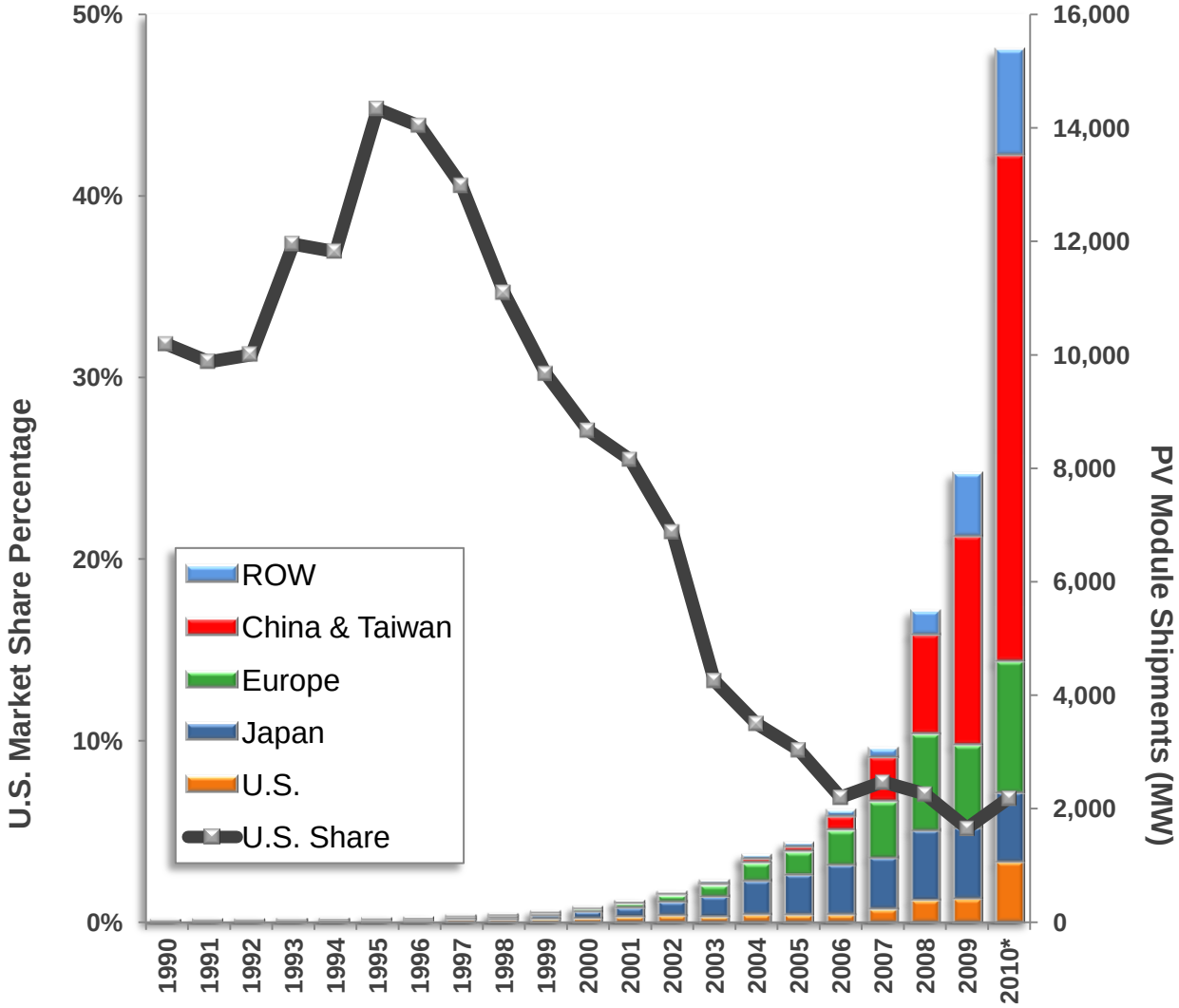
Solar PV Experience Curves:

Leading Technologies: Crystalline Silicon (c-Si), Cadmium Telluride (CdTe)

Source: (CdTe) First Solar Earnings Presentation, SEC Filings; (c-Si) Navigant, Bloomberg NEF, NREL internal cost models



Increasing Market Deployment, Decreasing US Market Share



Technology Improvements – Efficiency, Cost, and Reliability

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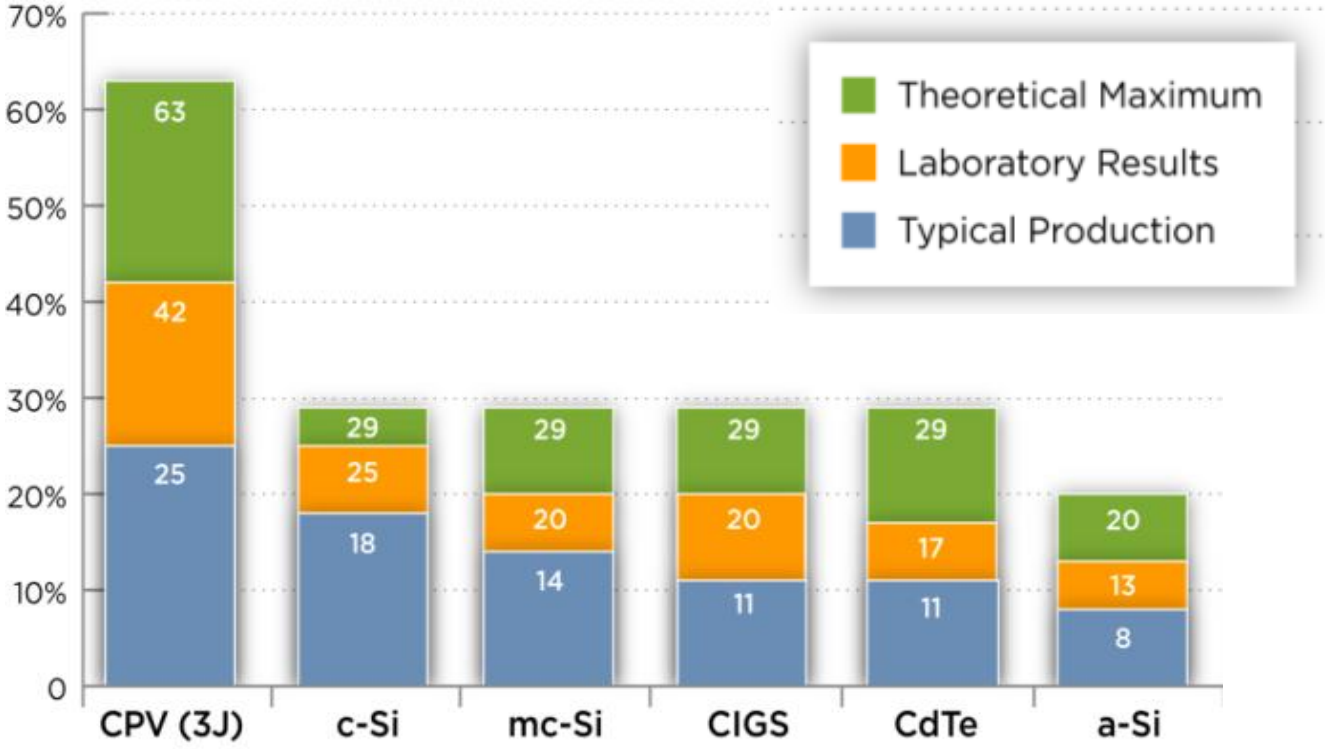
$$\frac{\$}{Watt} \propto \frac{Manufacturing\ Cost}{Efficiency}$$

LCOE



Roadmapping Technology Improvements – Efficiency – CIGS example

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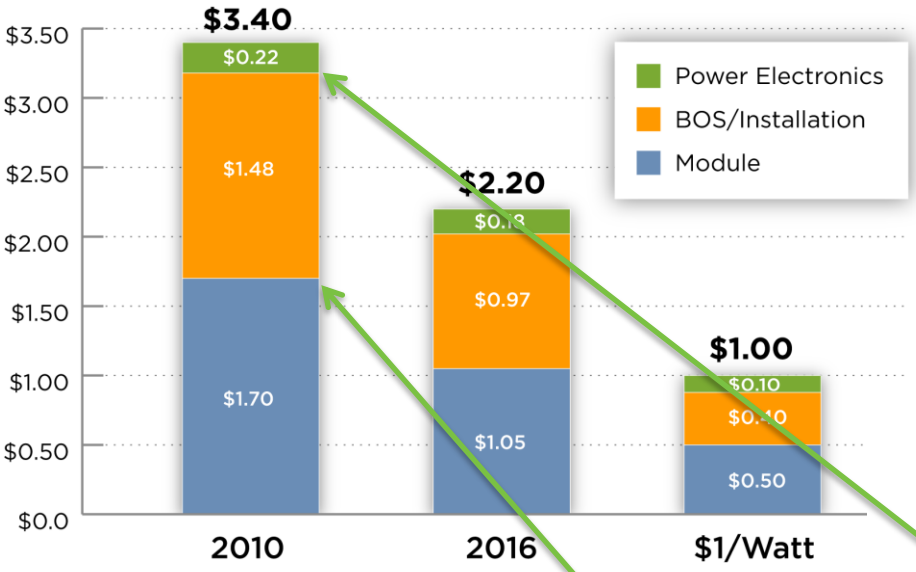
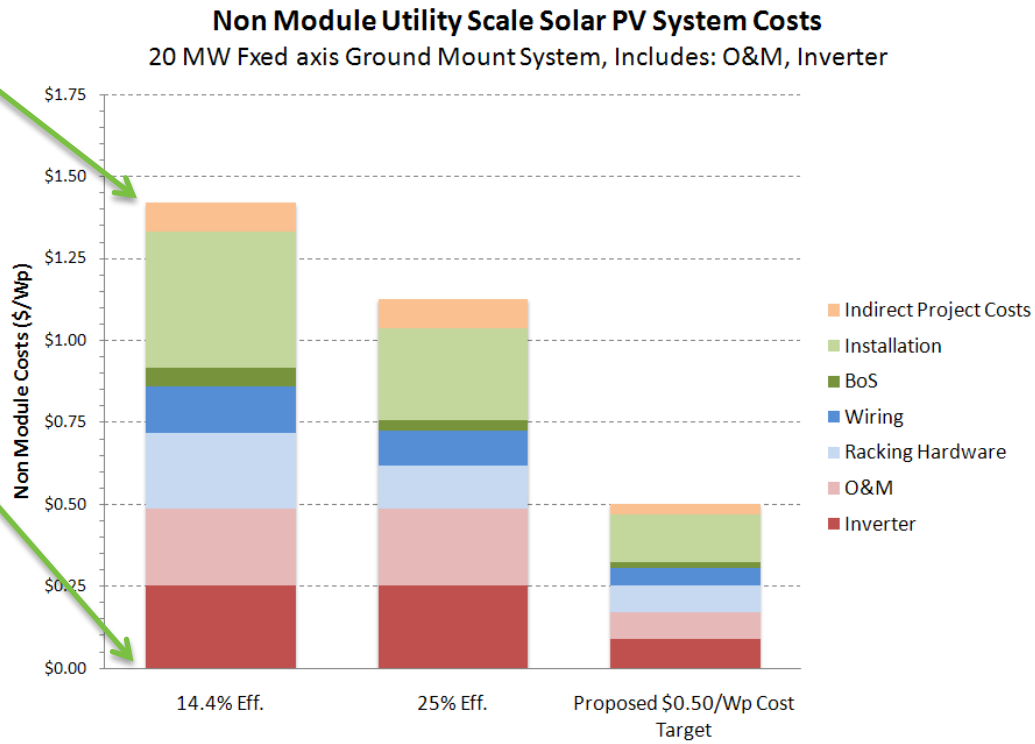
$$\frac{\$}{Watt} \mu \frac{Manufacturing\ Cost}{Efficiency} \rightarrow \eta \propto J_{SC} \cdot V_{OC} \cdot FF$$

Action	Potential Current Increase (mA/cm^2)	Technical Risk	Pathways
Larger band gap junction partner	2.5	Medium	Replace CdS (e.g. 2.5 eV) with wide bandgap emitter (i.e., **ZnS** (3.1 eV))
Improved TCO	1.5	Medium	Develop TCO with high conductivity, transparency, environmental stability (i.e., **a-InZnO**)
Reduce CdS window layer thickness	1.5	Medium	Develop **20 nm thick** continuous CdS layer without shunting.
Minimize reflection off CIGS surface	1.5	Medium	Develop a suitable low cost **anti-reflection coating**
Improved monolithic integration	1	Low	Reduce line width of laser/mechanical scribing

Module costs are only half the battle





Non-Module Costs – Power Electronics, Hardware, Grid Integration

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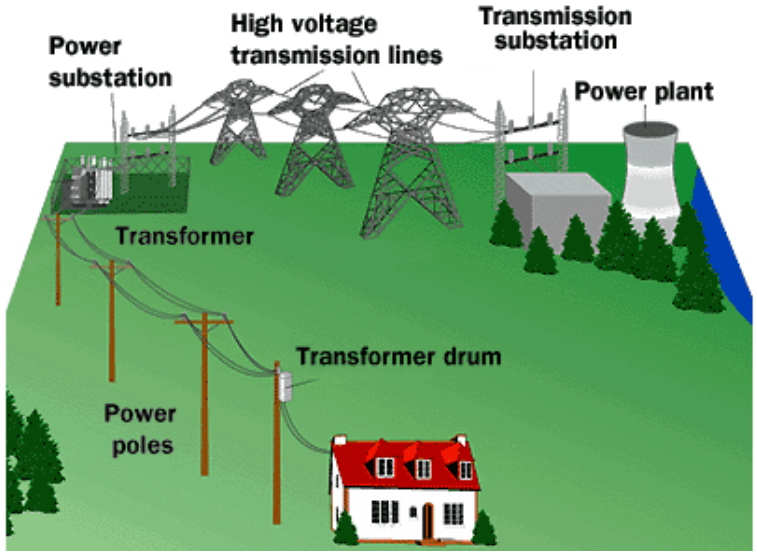
Source: PVPowered

Power Electronics

Wiring, Frameworks, Mechanics

Automation

Hardware BOS



Grid Integration

Non-Module Costs – Soft BOS Costs

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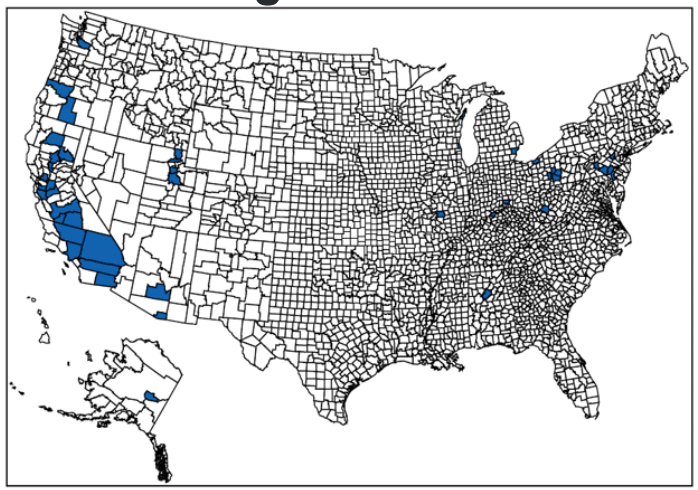
The Challenge:



Source: Center for Disease Control and Prevention

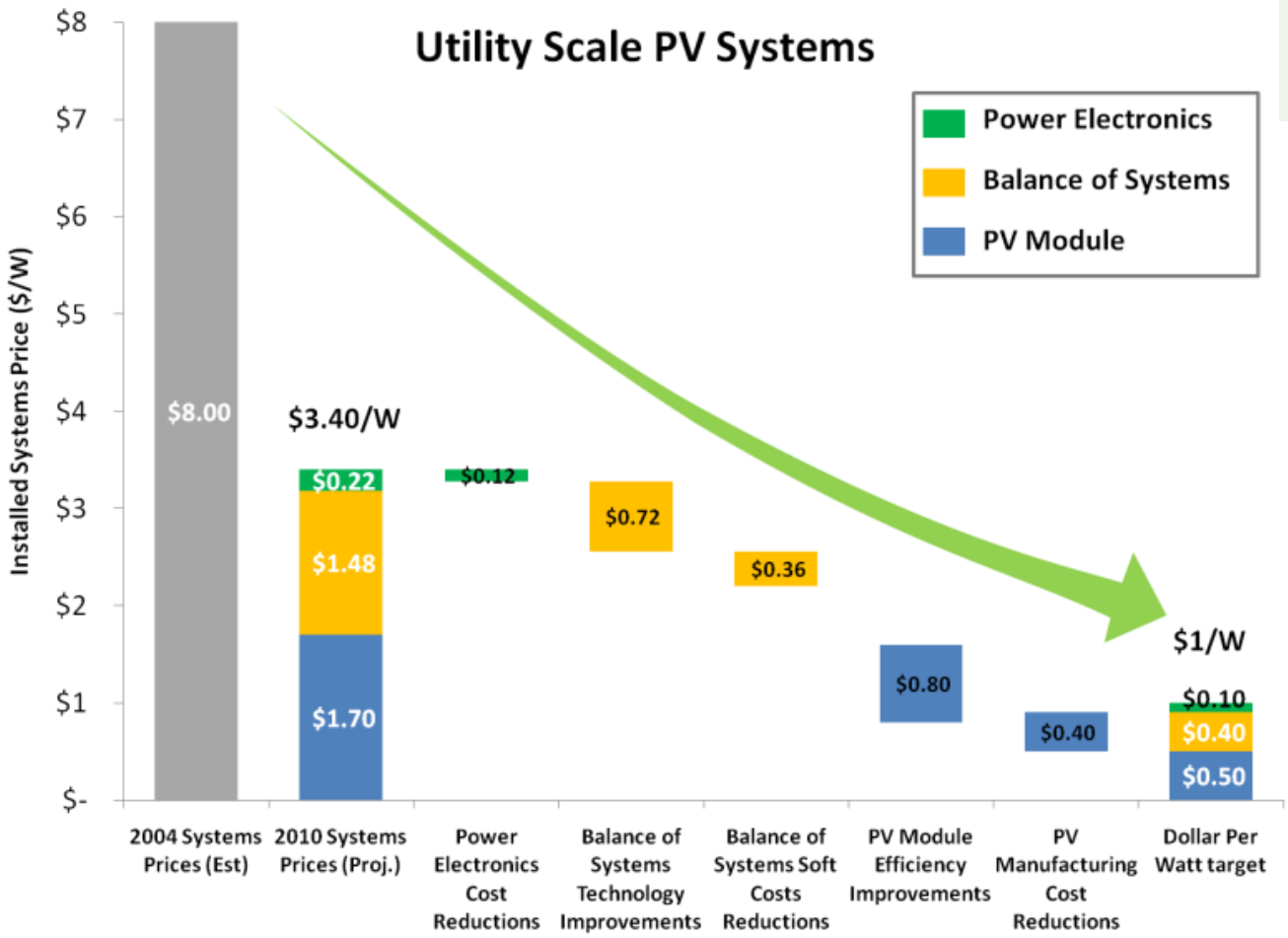
Meeting the Challenge:

- Standardization
- IT/Software Tools
- Information Databases

The Goal:

70% – 80% reduction

DOE Focus


Utility Scale PV Systems
Power Electronics
Balance of Systems
PV Module
Installed Systems Price ($/W)
$8
$7
$6
$5
$4
$3
$2
$1
$-
$8.00
$3.40/W
$0.22
$1.48
$1.70
$0.12
$0.72
$0.36
$0.80
$0.40
$1/W
$0.10
$0.40
$0.50
2004 Systems Prices (Est)
2010 Systems Prices (Proj.)
Power Electronics Cost Reductions
Balance of Systems Technology Improvements
Balance of Systems Soft Costs Reductions
PV Module Efficiency Improvements
PV Manufacturing Cost Reductions
Dollar Per Watt target

Concentrating Solar Power (CSP)

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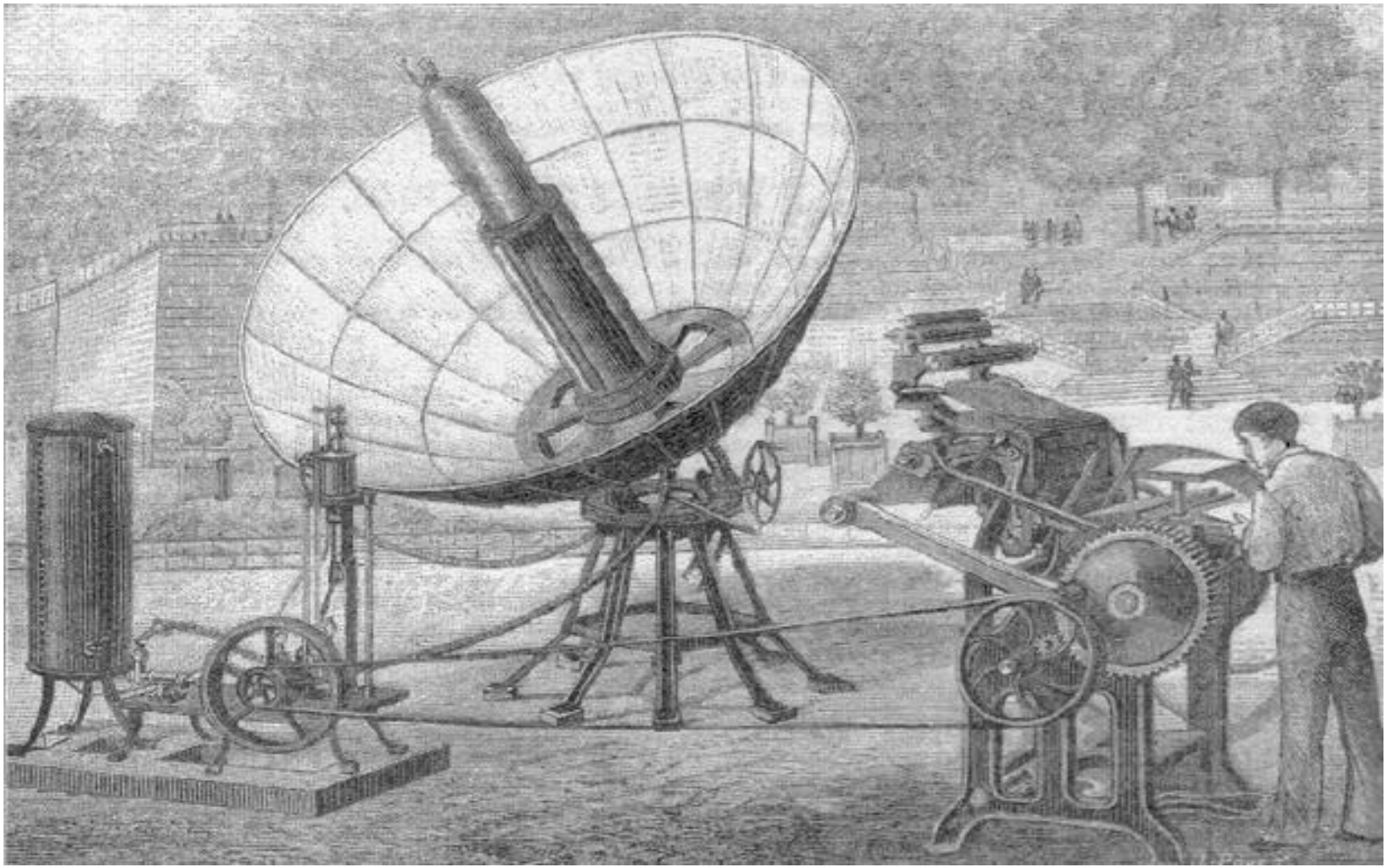
CSP – Time Immemorial



Source: Bibliotheque Nationale de Paris. Lavoisier, Oeuvres, Vol.3, via http://www.solarpoweredthermal.com/historical.shtml

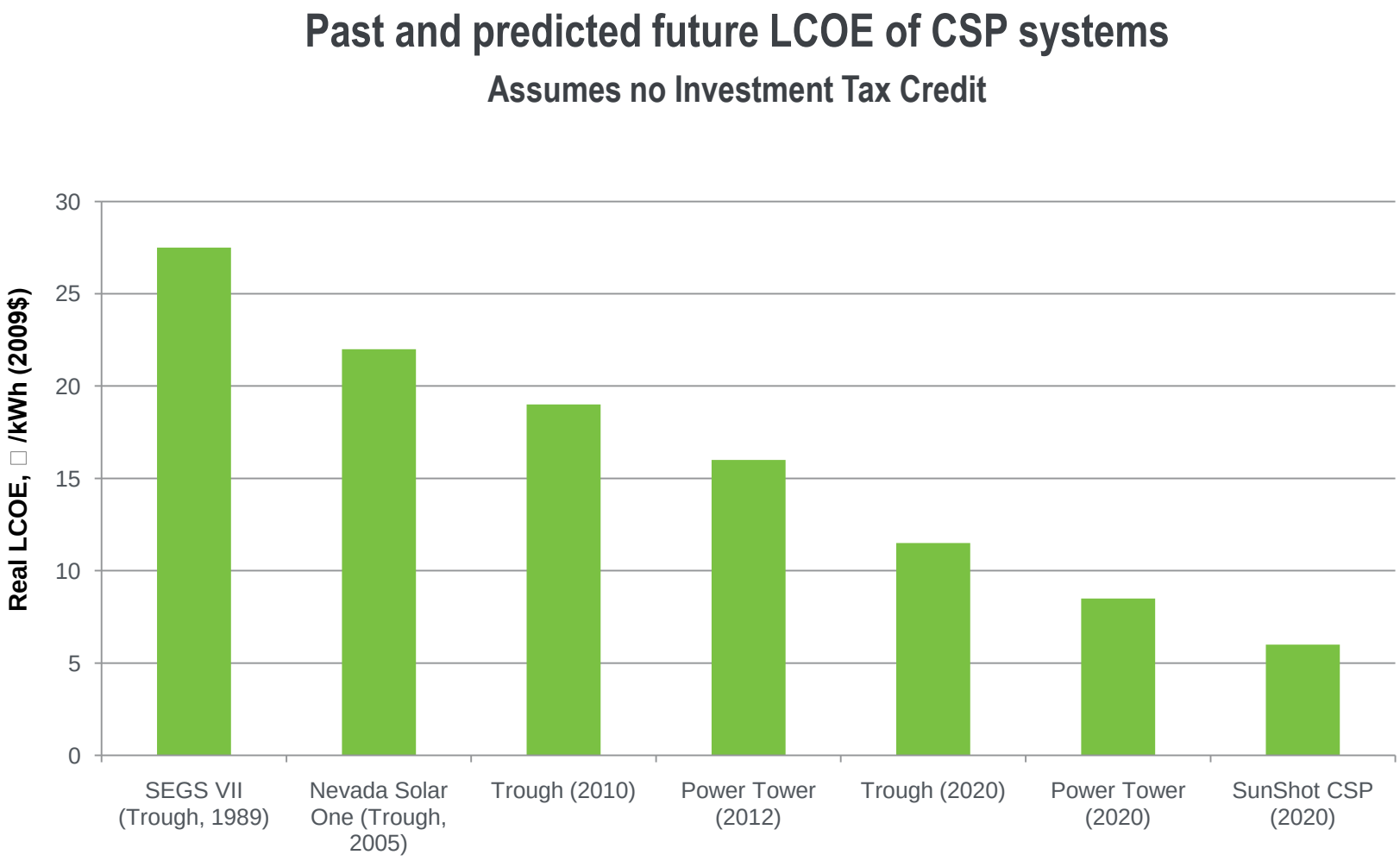
Current Technology

Trough

Tower

Dish

CPS Cost Trends



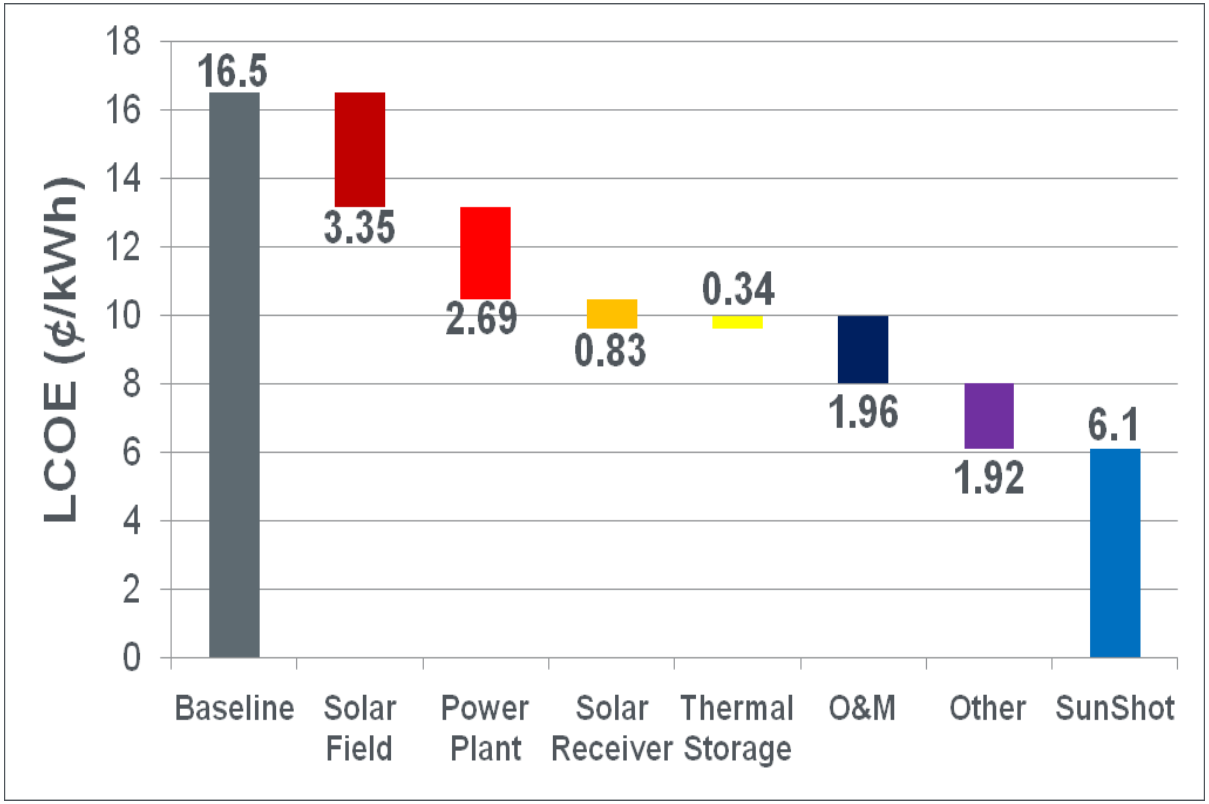
Thermal Energy Storage

PHOTO: Solar Millennium

+ Reduces LCOE
+ Offsets variability
- Increases capital costs

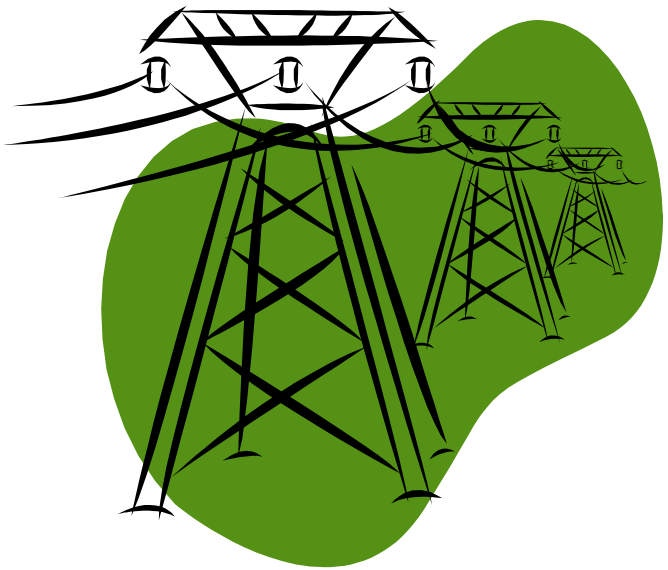
Subsystem Cost Reductions

$$\frac{\$0.06}{kWh} \propto \frac{Capital\ Cost}{Efficiency} \rightarrow \eta_{system} = \eta_{collection} \cdot \eta_{conversion}$$



- Higher operating temperatures
- New HTFs
- Advanced power blocks
- Improved drives, controls, and support structures

Market Barriers

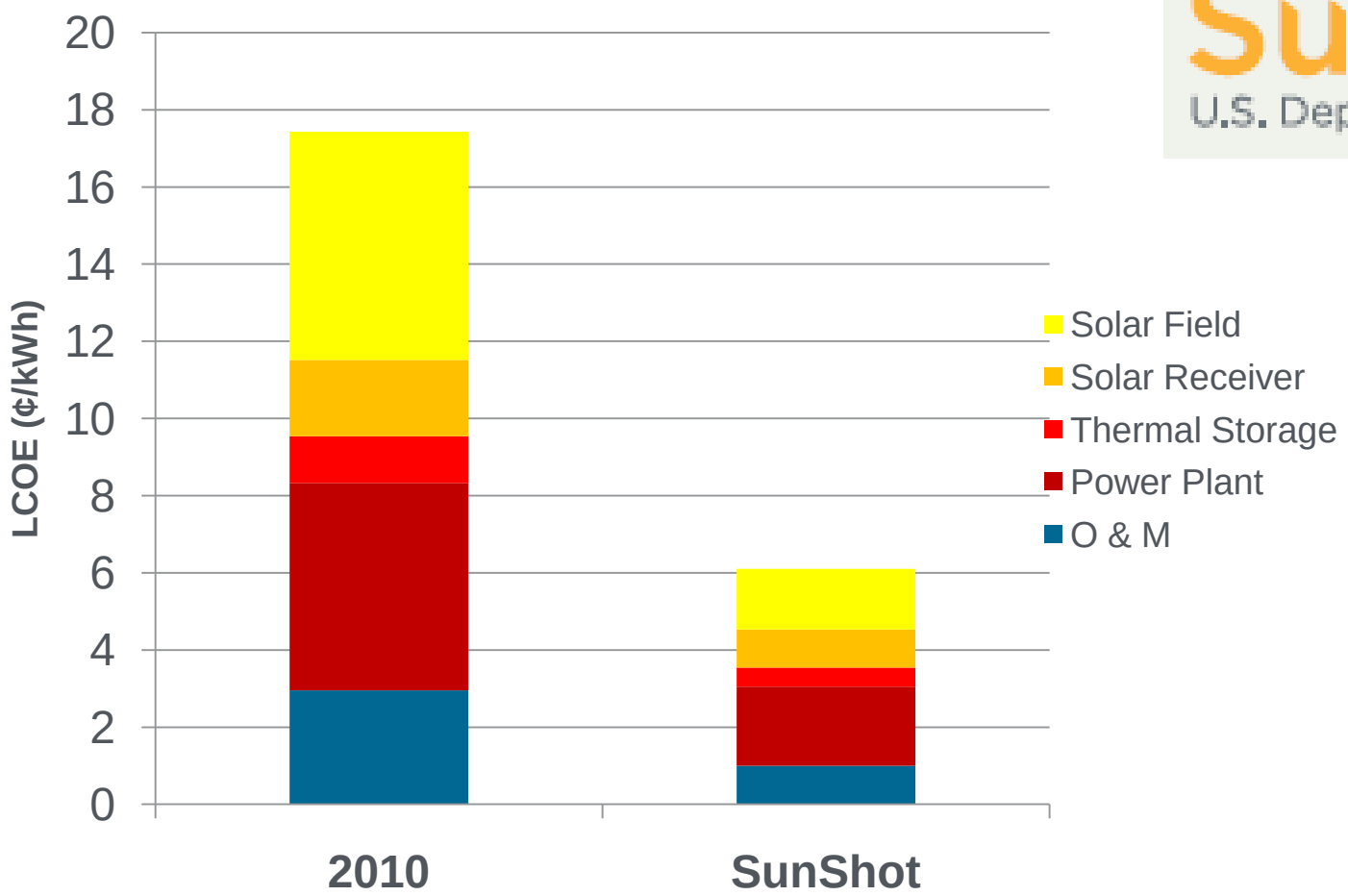


Accessing Transmission

Financing Capital Costs

Securing permits

DOE Focus


20
18
16
14
12
10
8
6
4
2
0
LCOE (¢/kWh)
2010
SunShot
Solar Field
Solar Receiver
Thermal Storage
Power Plant
O & M

Thank You

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