

Energizing American Competitiveness in Solar Technologies

SunShot Grand Challenge Summit and Technology Forum
Denver, CO
13 June 2012

Why do we want/need “Grand Challenges?”

The United States is in a fierce race to be the inventor and manufacturer of clean energy technologies that can drive our future economic growth and national security.

The Department of Energy is identifying the most critical grand challenges in clean energy technology.

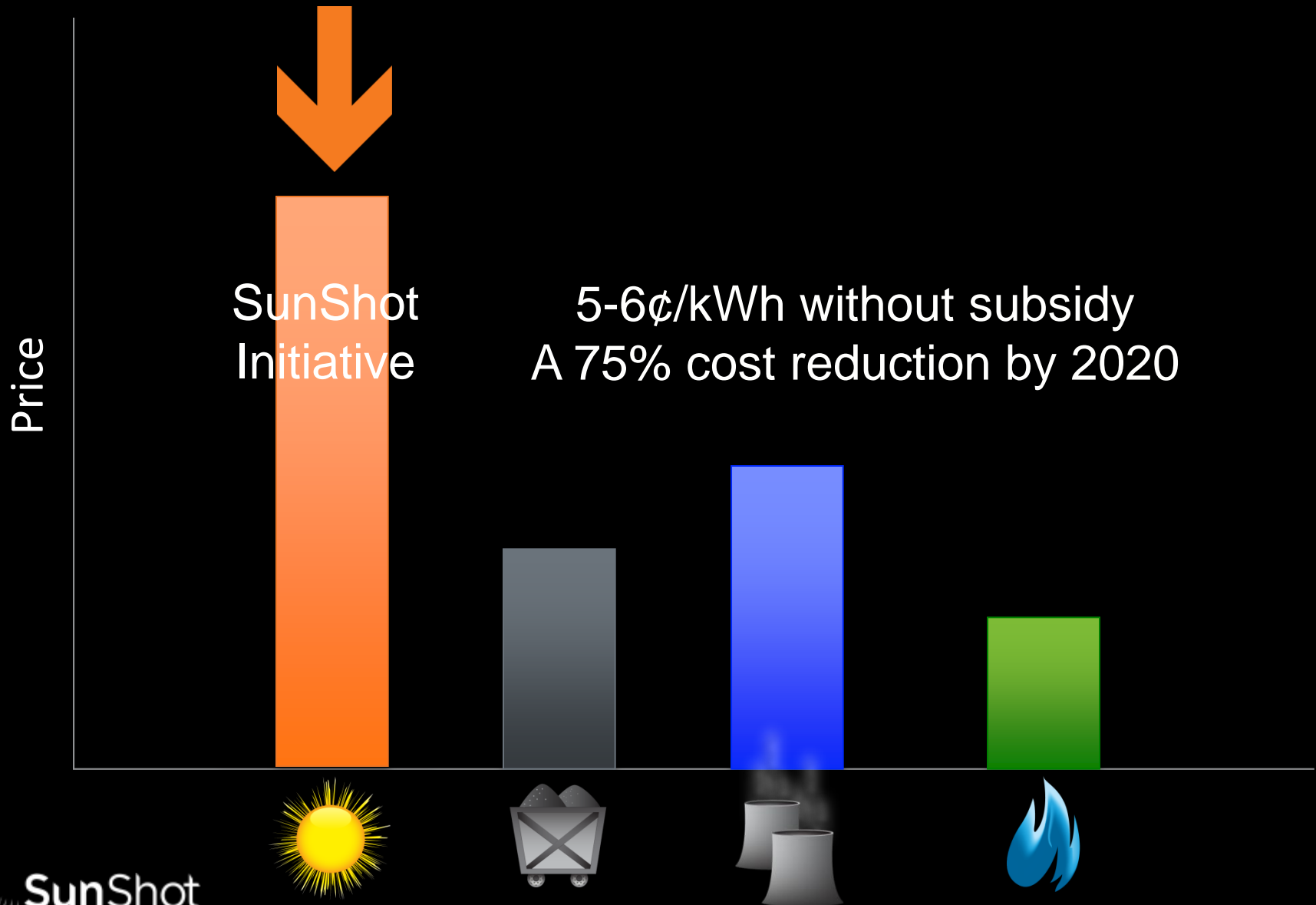
Success will require *Discovery, Invention, Innovation*

...including innovation in technology, business models, finance and policy



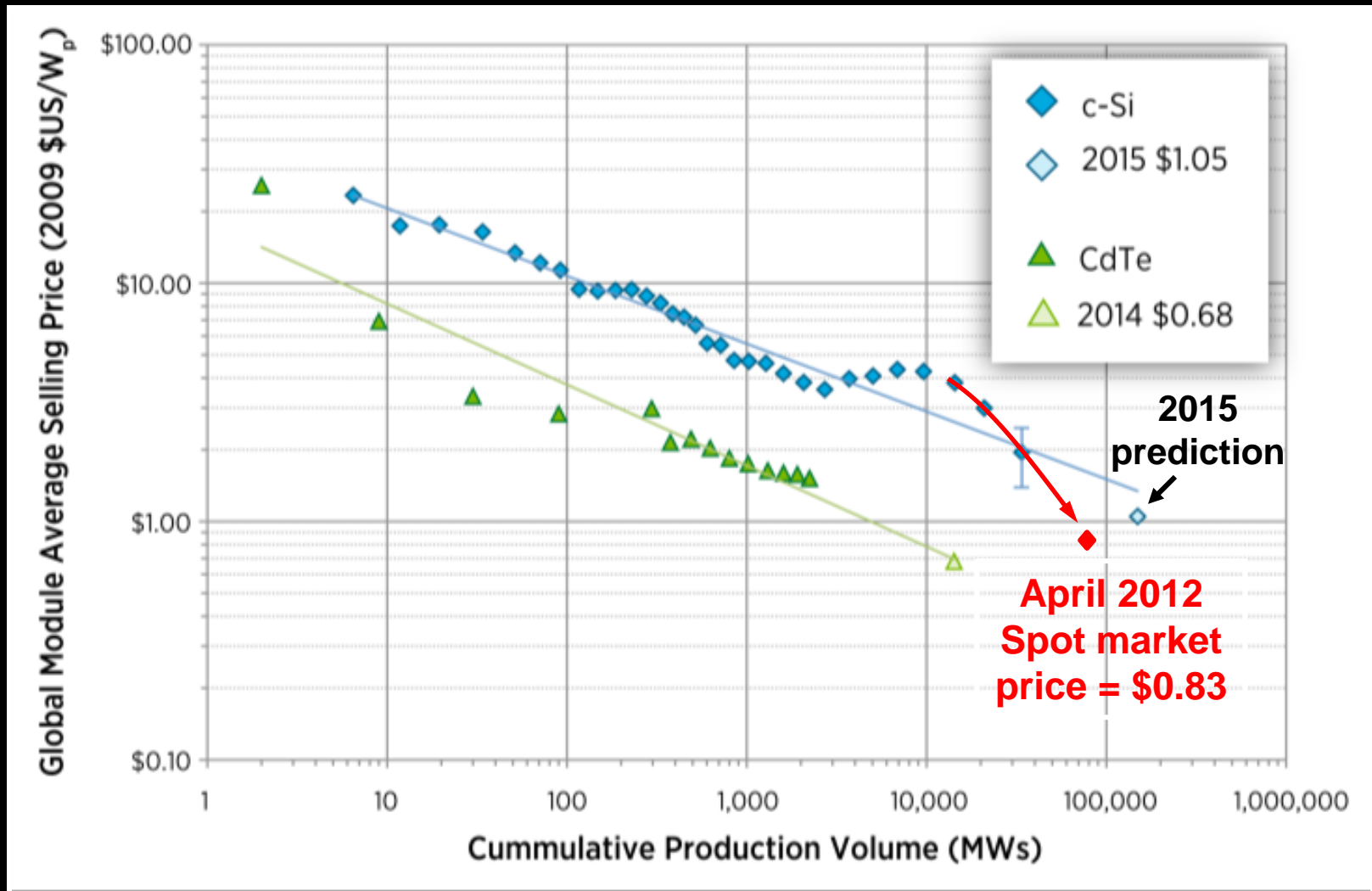
- We want to let the stakeholder community know what the DOE is doing and why we are doing it.
- Identify key technical and non-technical challenges that need to be addressed.
- We want feedback from the community.

So what is the SunShot Initiative?

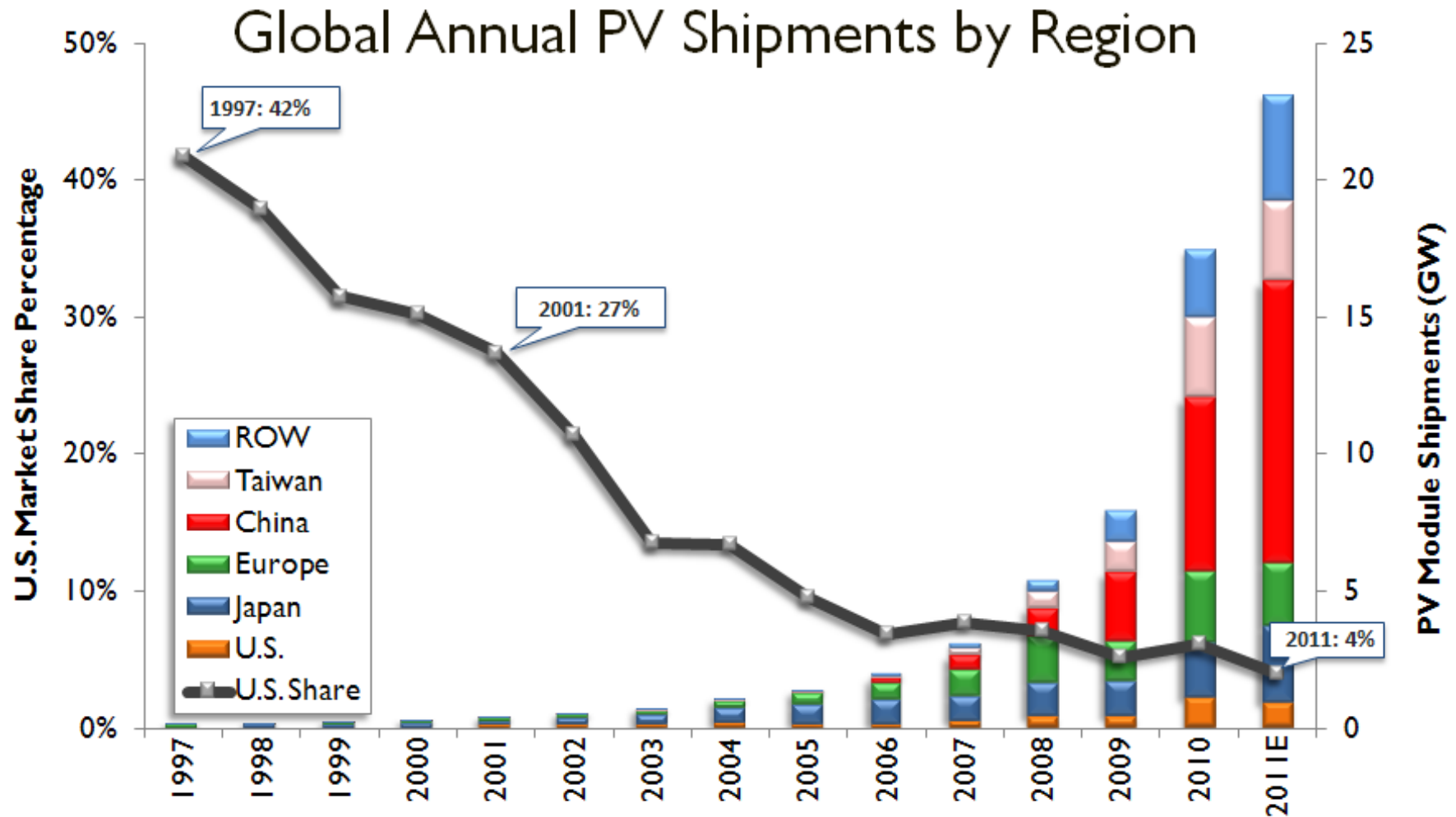


Costs of PV modules are dropping below the power law experience curves

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



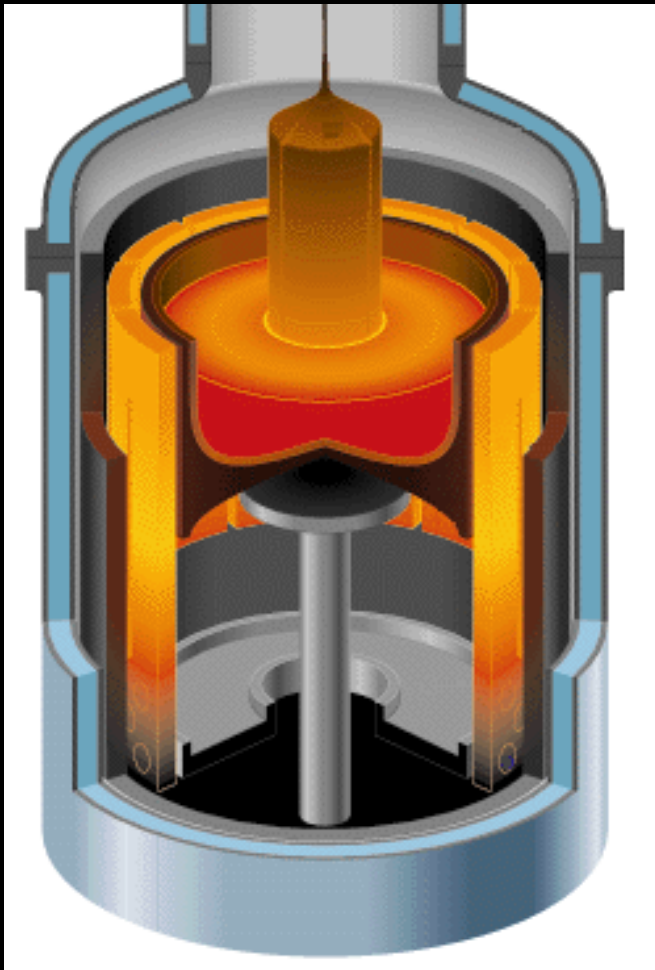
US PV Cell and Module Production



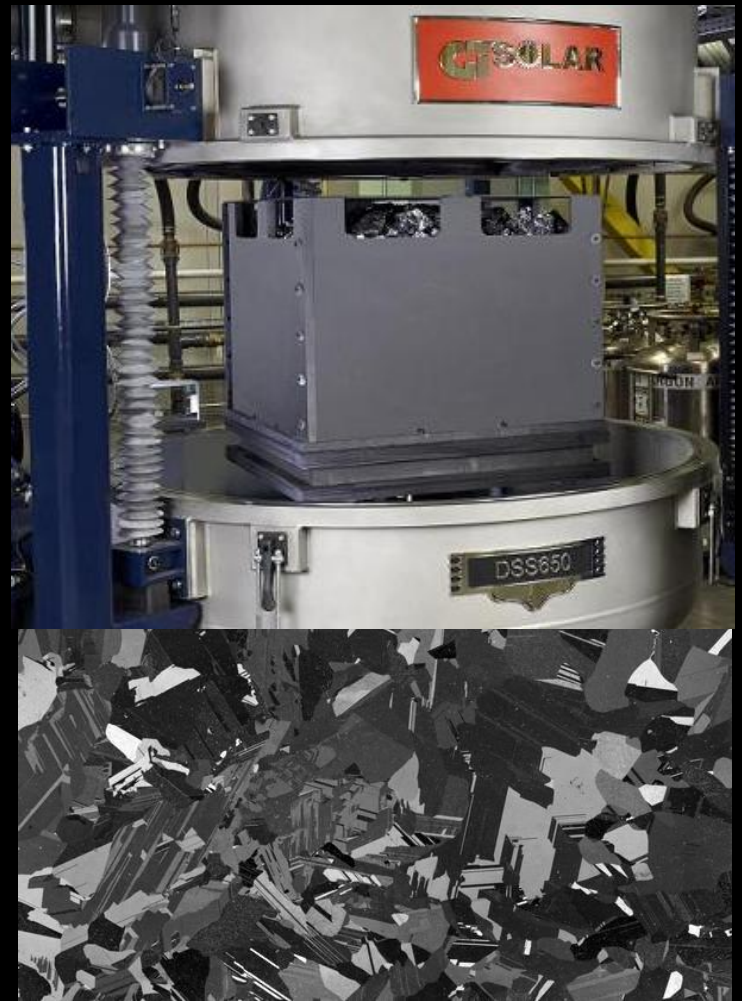
Sources: Navigant Consulting, Solar Services Program – 2011 Shipment Update, NPS-Supply6 - April 2011, Report NPS - Supply4, Report NPS - Supply3

Silicon Crystal Growth

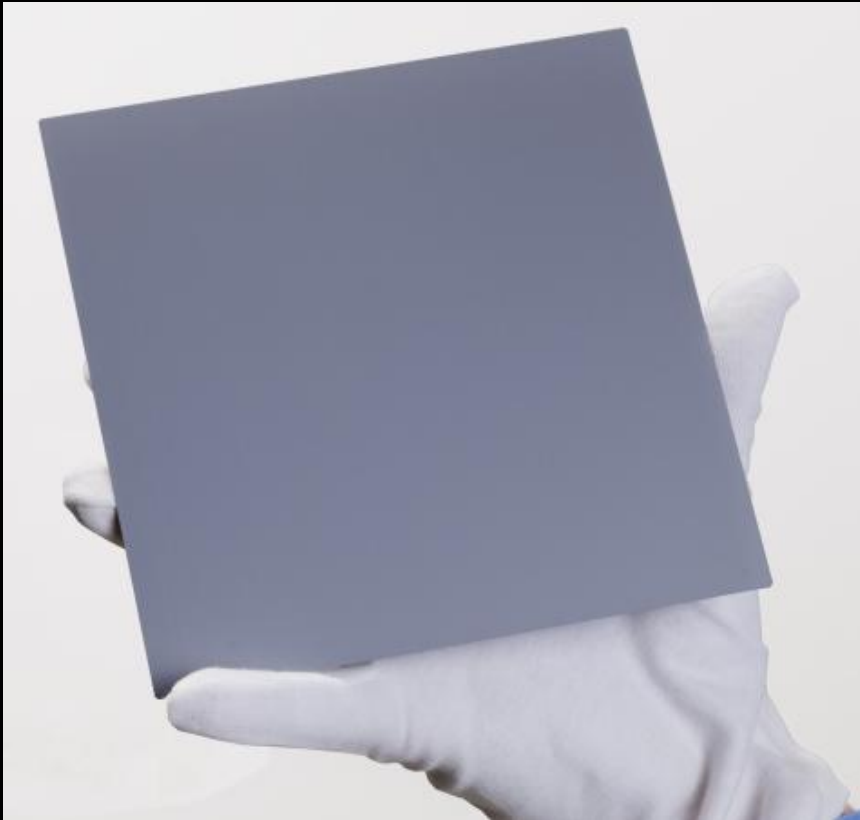
Czochralski growth



Directional solidification



Casting Single Crystal Wafers



In 2007, the DOE supported research of BP Solar in the U.S. to make large single crystals of silicon using the directional solidification method. A prototype version of this technology achieved 20% efficiency, better than many CZ mono wafers in production.

Before the technology was taken to the manufacturing scale, intense competition with Chinese manufacturers caused BP Solar to shut down operations in the U.S.

This technology has been improved in China. Chinese companies may soon go into production of single crystal silicon using directional solidification.

To compete in the clean energy race,
inventing new technologies is not enough.

We have to make them to sell them
world-wide and use them.

Manufacturing

“Abandoning today's ‘commodity’ manufacturing can lock you out of tomorrow's emerging industry.”

Andy Grove
co-founder and former
CEO, and author of
*“Only the Paranoid Survive:
How to Exploit the Crisis
Points That Challenge Every
Company”*

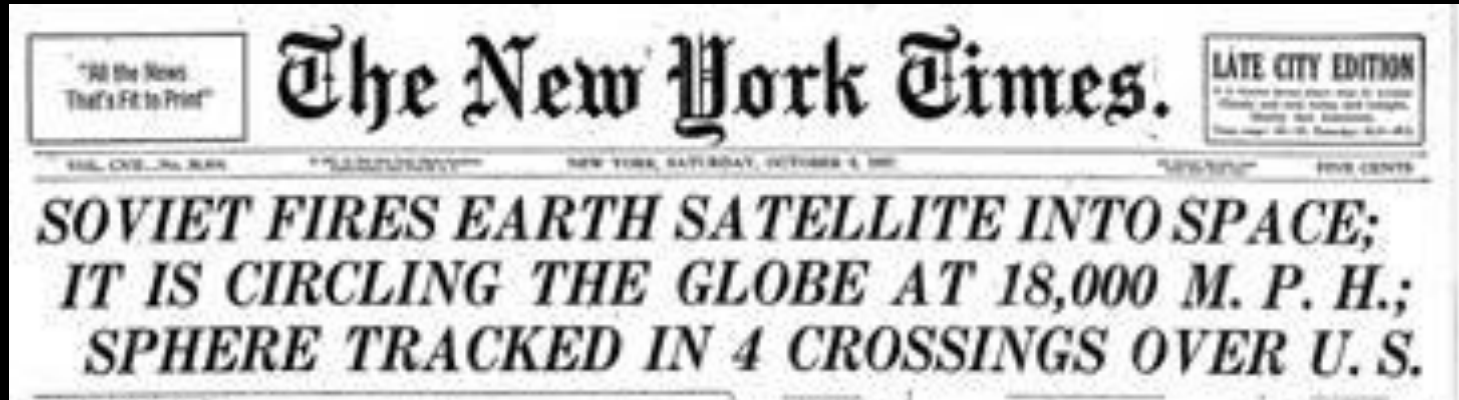


Crisis

Danger 危机 Opportunity
wei ji

**In every Crisis lies
the seed of Opportunity**

October 4, 1957, the Soviet Union placed a 184 pound satellite, "Sputnik," into orbit.



A view of Sputnik from Earth



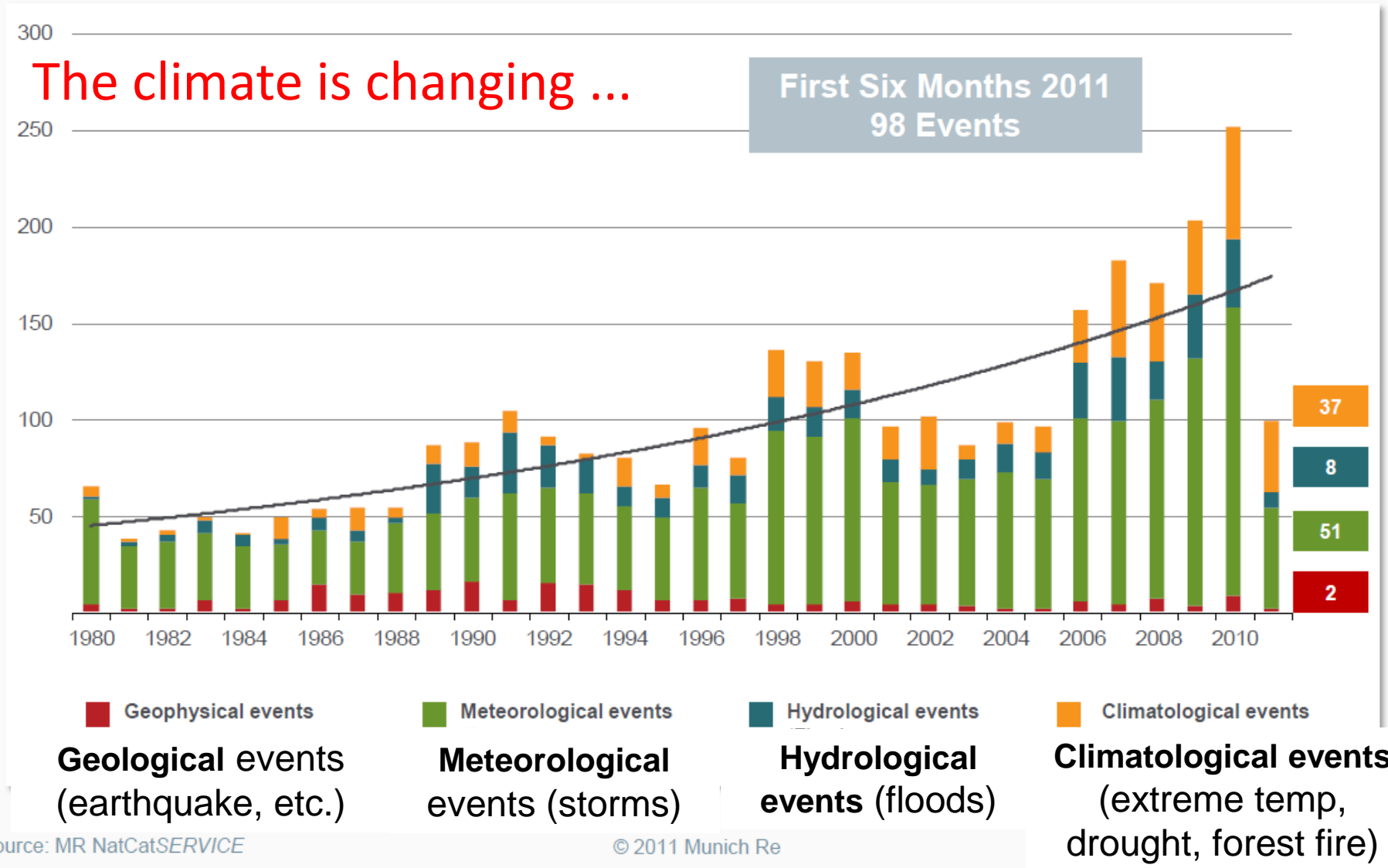
President Kennedy (12 September 1962)



Embedded movie of moon shot speech

Natural Disasters in the United States, 1980 – 2011

Number of Events (Annual Totals 1980 – 2010 vs. First Six Months 2011)



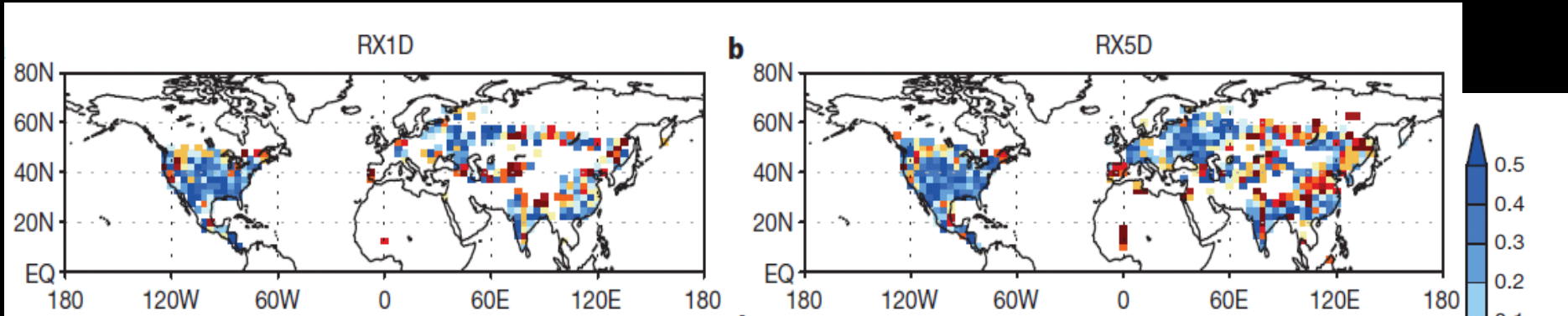
Comparison of measured precipitation extremes and simulations of CO₂ increase, volcanoes and other changes

S.-Ki Min, X. Zhang, F.W. Zwiers & G. C. Hegerl, *Nature* **470**, 378 (2011)

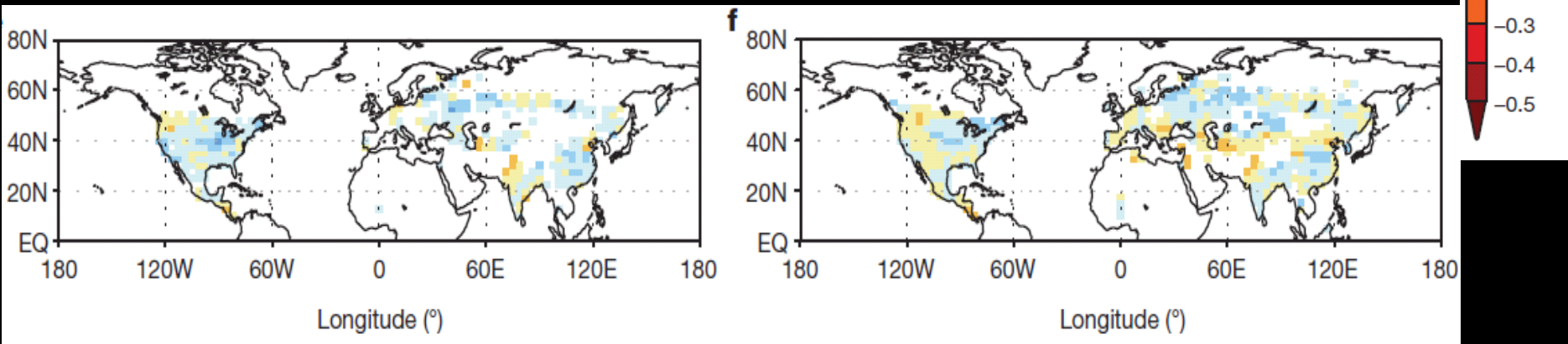
Observations

Highest single day rainfall

Highest 5 day rainfalls



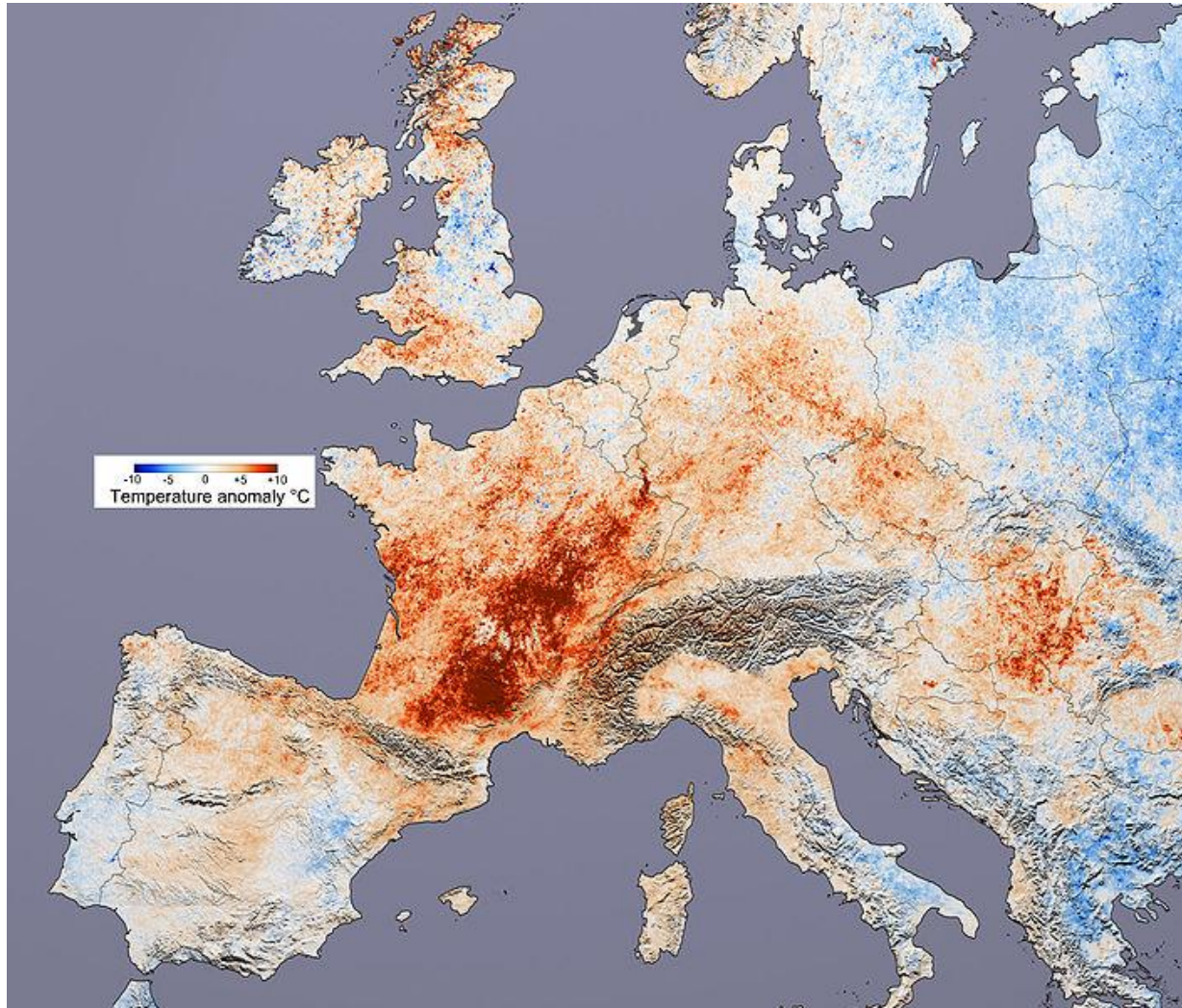
Climate simulations without carbon emissions



Aug. 2003: European heat wave

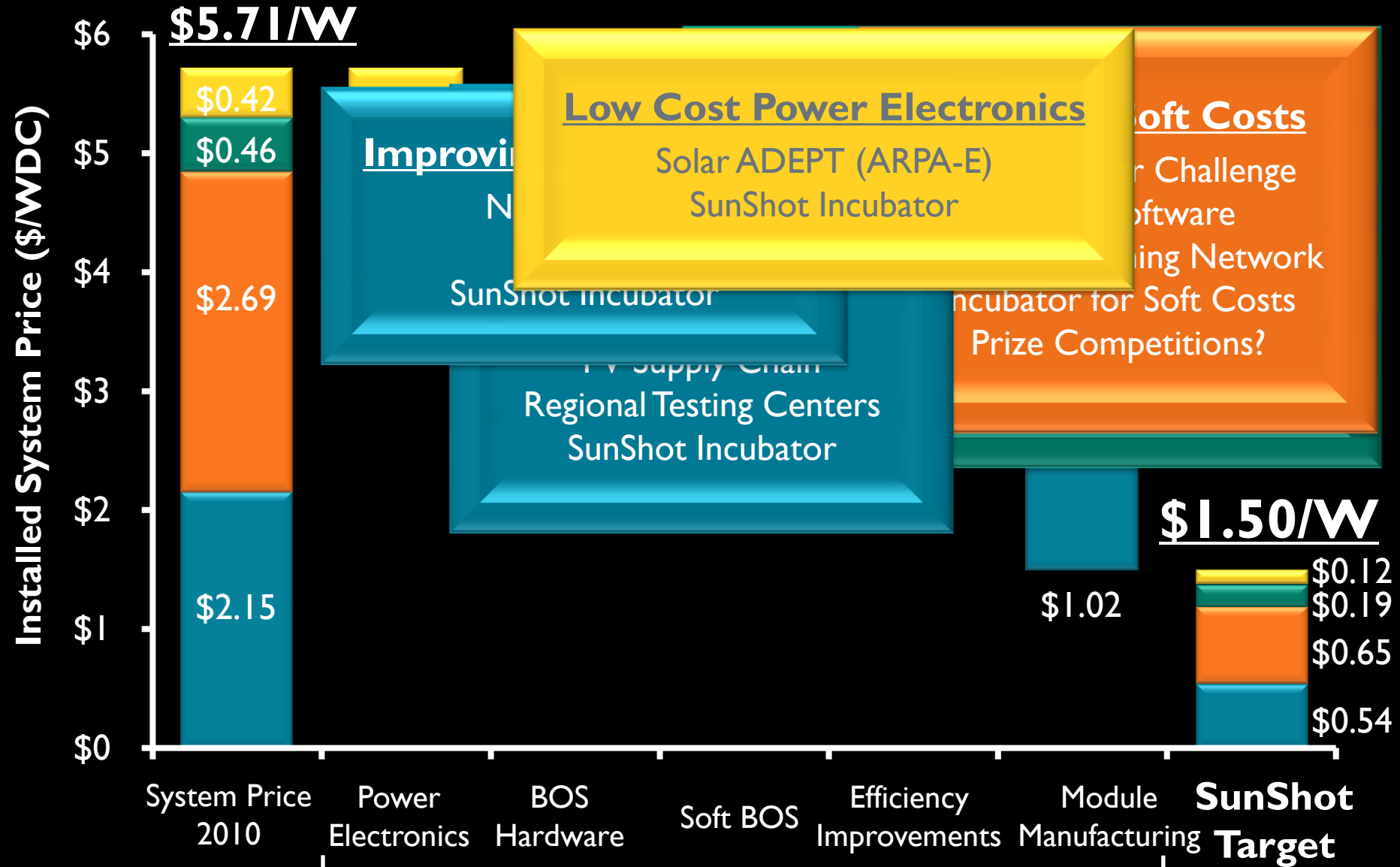
Temperature anomalies reached 10°C

52,000 Europeans died*



Country	Fatalities
Italy	18,257
France	14,802
Germany	7,000
Spain	4,130
England & Wales	2,139
Portugal	2,099
Smaller countries	4,025
Total of above	52,452

Residential SunShot 2020 Target



The Department of Energy is agnostic to any particular solar technologies:

Cryst. Si : 19% → 22% efficiency → lower cost?

Poly-Si : 14% → 16.5% → ?

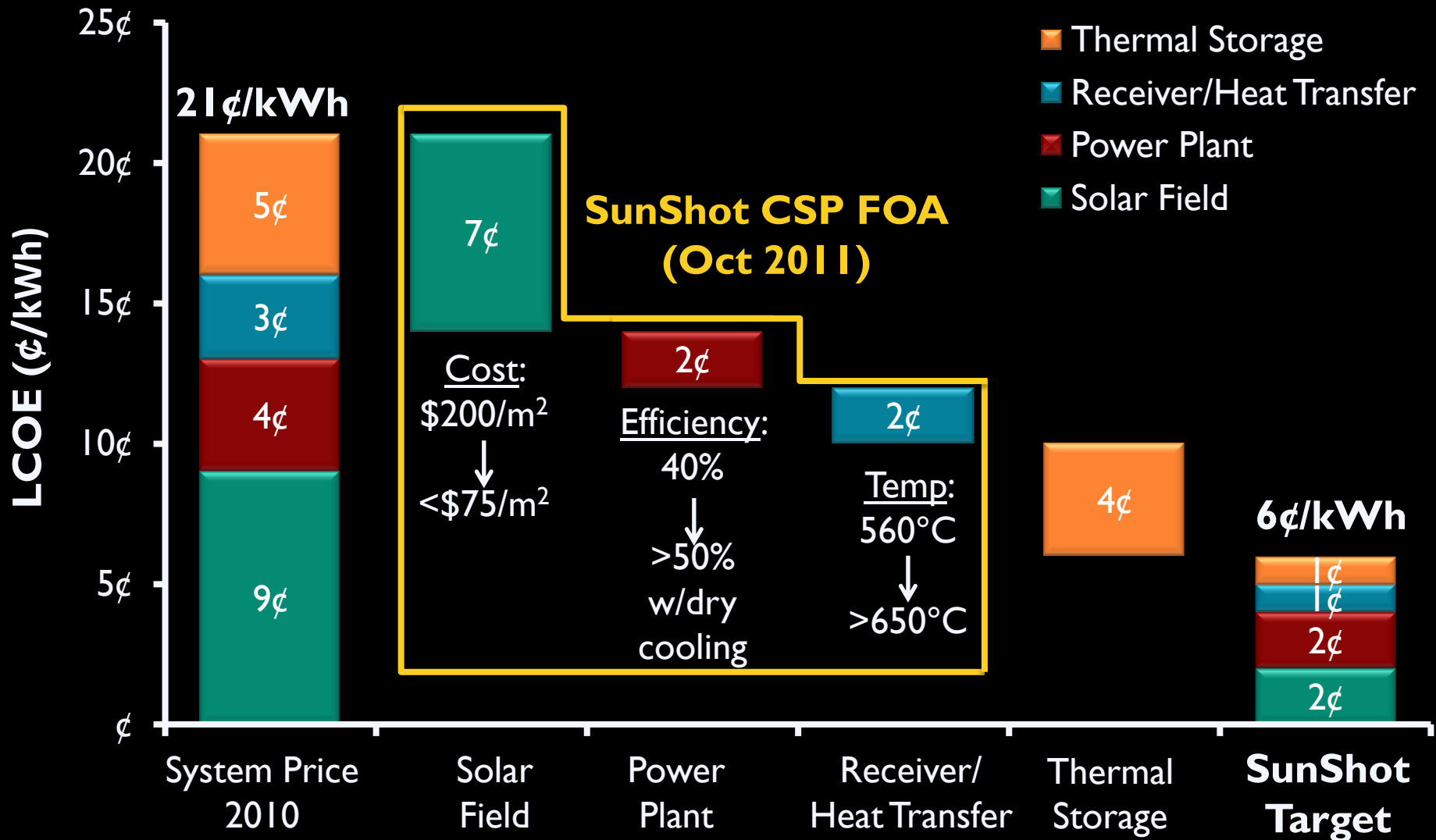
CdTe: 12% → 14.5% → ?

GaAs: 26% efficient → low cost ?

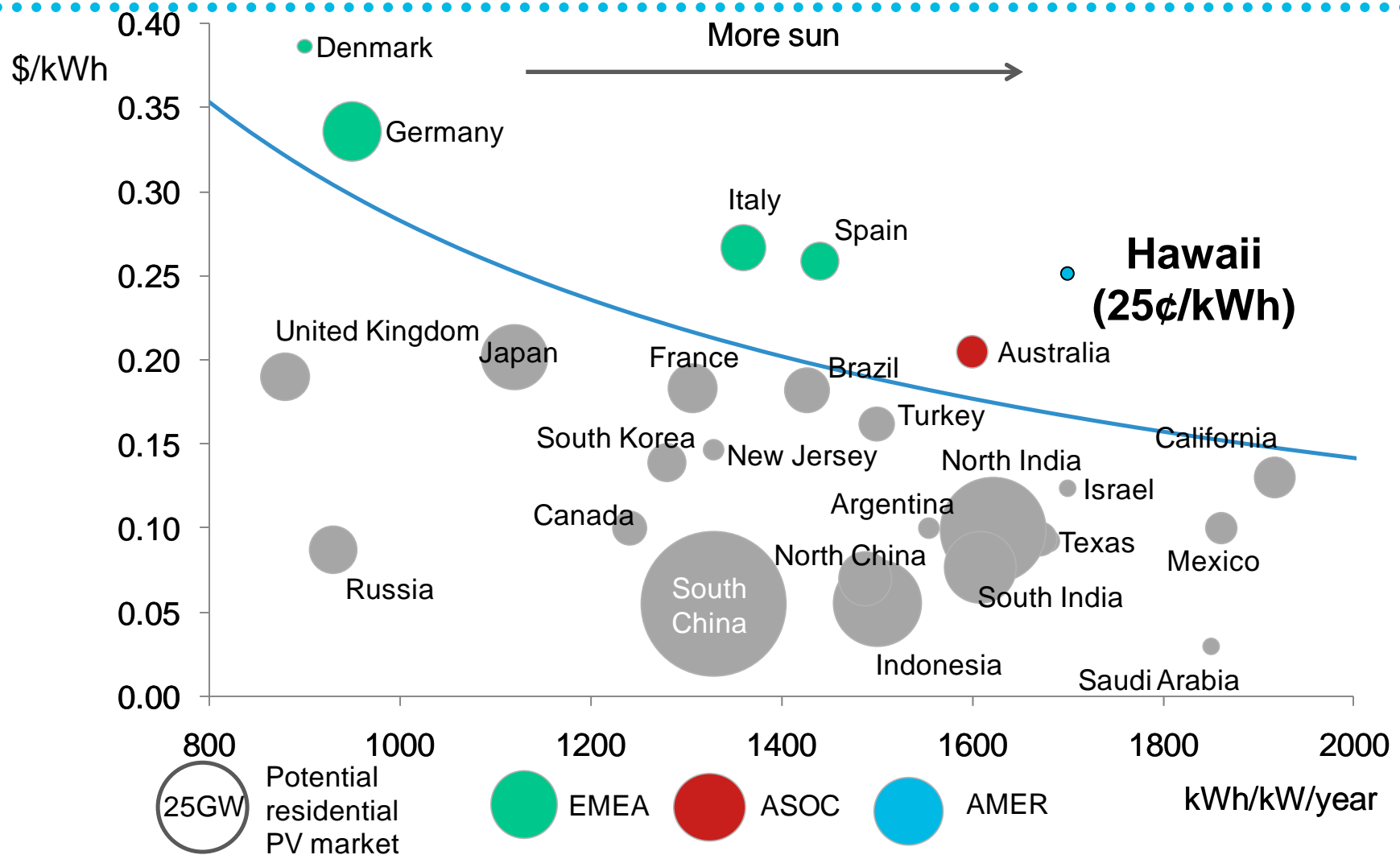
**Multiple Junction with solar concentrators,
CIGS, Gretzel ... ?**

What about Concentrated Solar Power?

SunShot CSP Pathway to 6¢/kWh

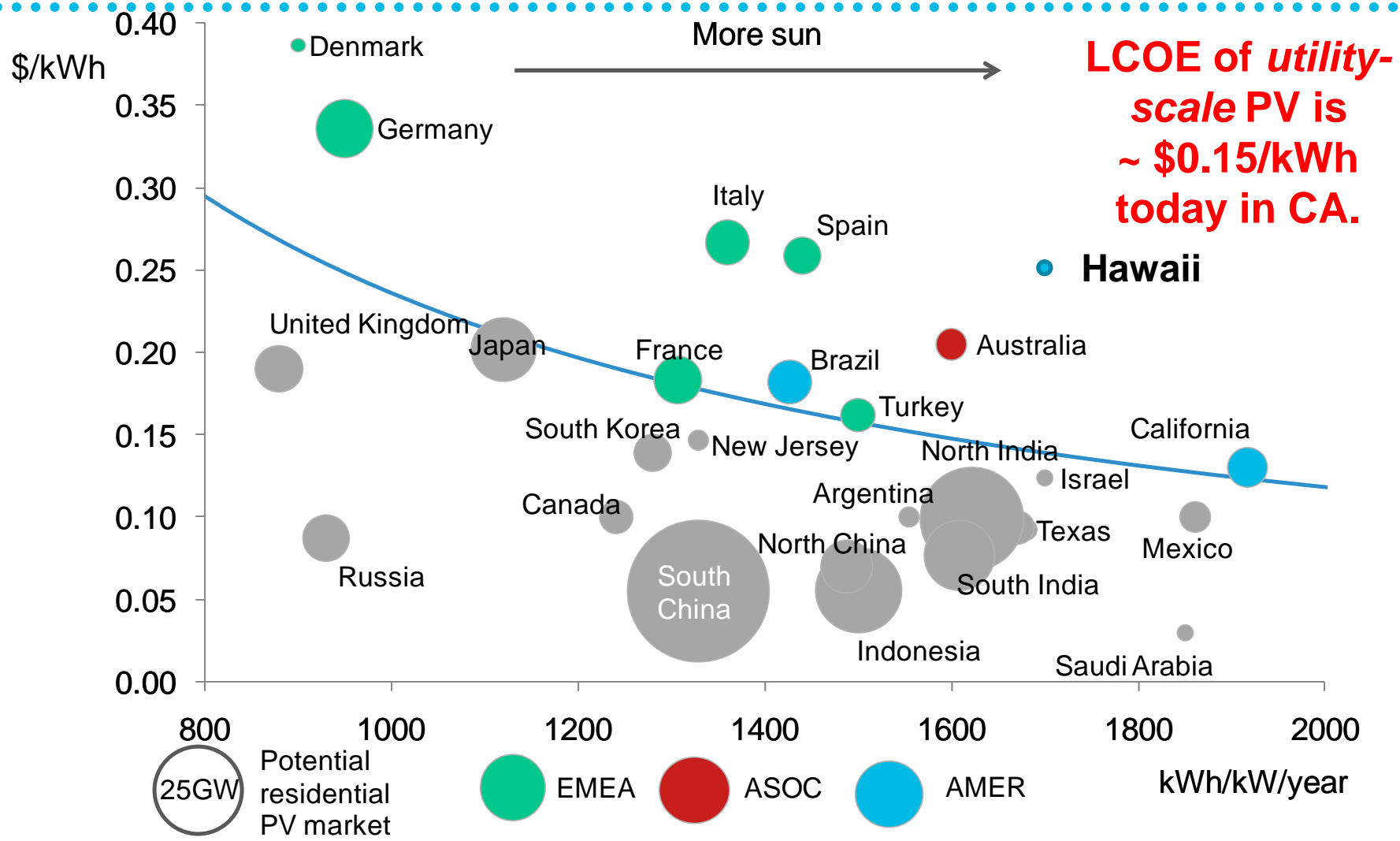


RESIDENTIAL ELECTRICITY PRICE 2012, INSOLATION, RESIDENTIAL PV LCOE 2012



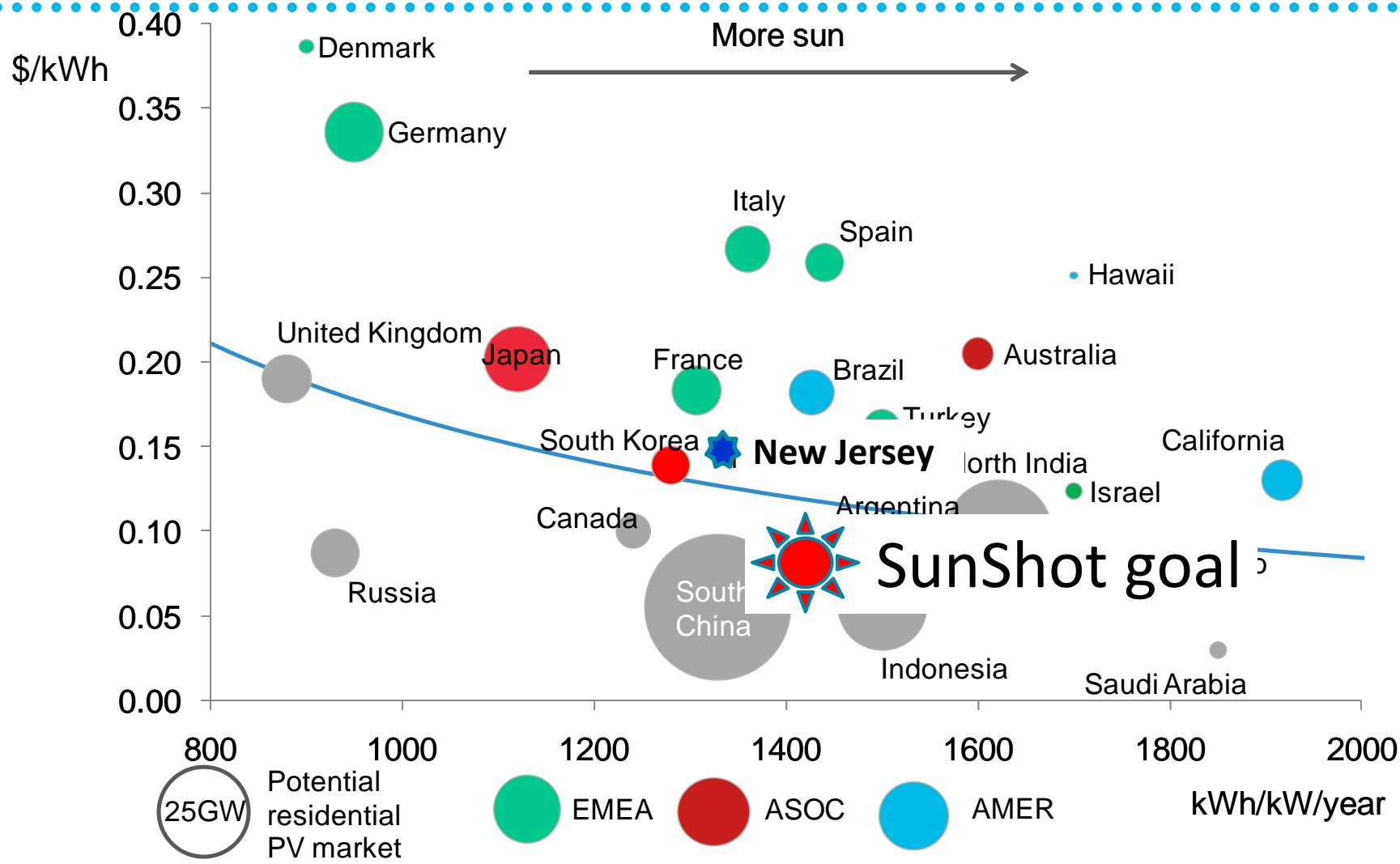
Note: LCOE based on 6% weighted average cost of capital, 0.7%/year module degradation, 1% capex as O&M annually. \$3.01/W capex assumed for 2012
 Source: Eurostat, grid operators, Bloomberg New Energy Finance

RESIDENTIAL ELECTRICITY PRICE 2012, INSOLATION, RESIDENTIAL PV LCOE 2014



Note: LCOE based on 6% weighted average cost of capital, 0.7%/year module degradation, 1% capex as O&M annually. \$2.51/W capex assumed for 2014
 Sources: Eurostat, grid operators, Bloomberg New Energy Finance

RESIDENTIAL ELECTRICITY PRICE 2012, INSOLATION, RESIDENTIAL PV LCOE 2020



Note: LCOE based on 6% weighted average cost of capital, 0.7%/year module degradation, 1% capex as O&M annually. \$1.80/W capex assumed for 2020
 Sources: Eurostat, grid operators, Bloomberg New Energy Finance

Predictions of Technology Naysayers

“The horse is here to stay, but the automobile is only a novelty
— a fad.”

President of the Michigan Savings Bank to Horace Rackham, Henry Ford's lawyer.

Rackham ignored the advice, invested \$5000 in Ford stock, and sold it for \$12.5 million.

Reaction to Alexander Graham Bell's patent for the telephone by
the Chief Engineer of the British Post Office:

“The Americans have need of the telephone, but we
do not. We have plenty of messenger boys.”

ExxonMobil

Taking on the world's toughest energy challenges.™



2012 The Outlook for Energy: A View to 2040

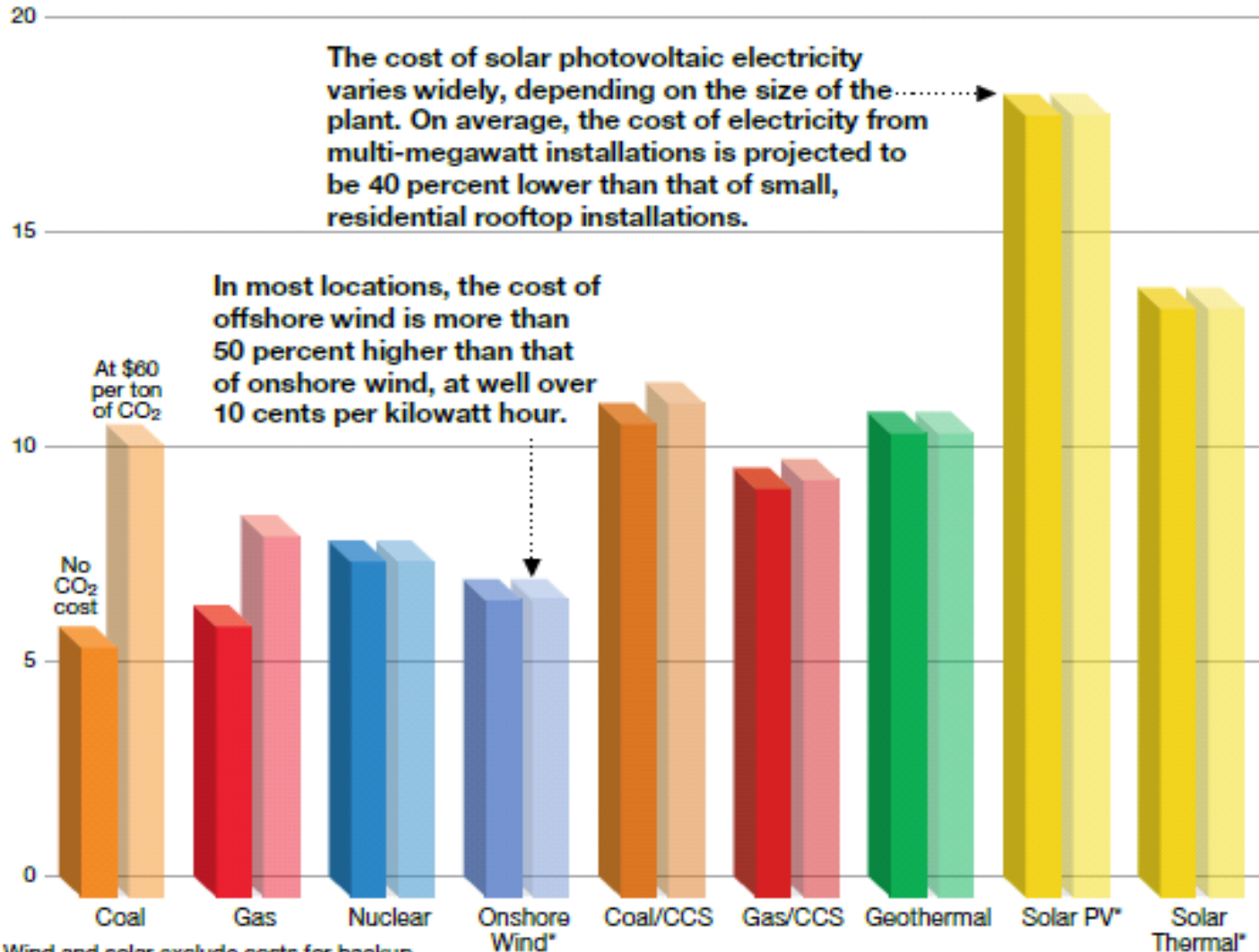


Exxon-Mobil estimate for electricity generation by 2030

Average U.S. cost of electricity generation In 2030

Cost per kilowatt hour in 2011 cents

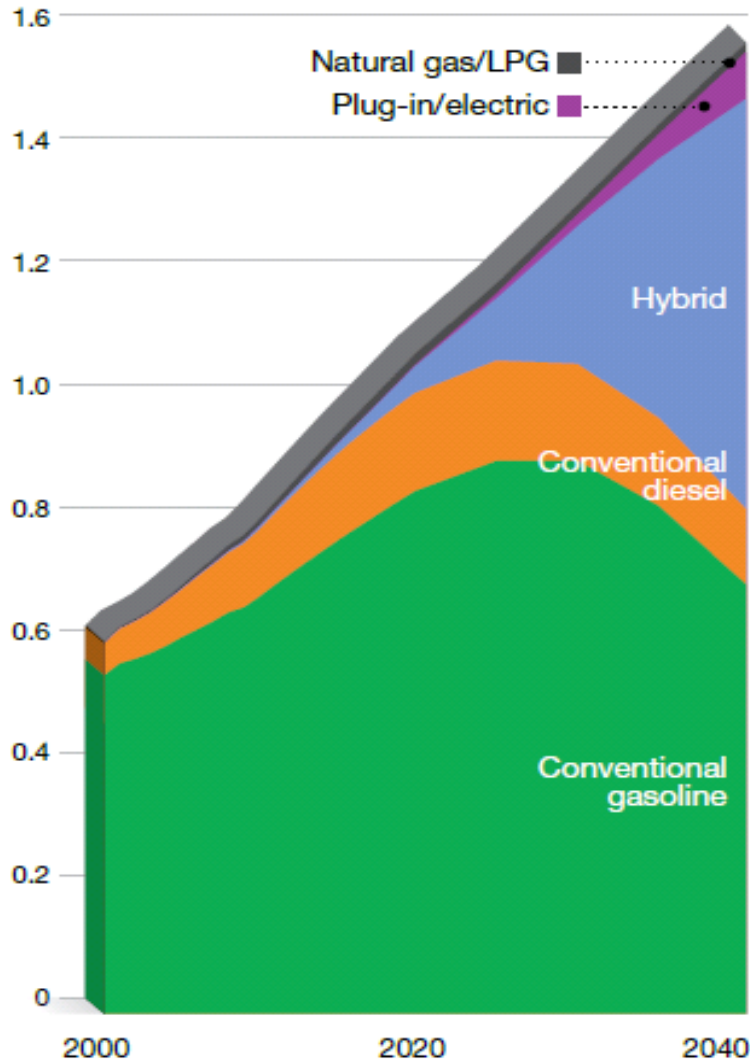
Utility-scale solar will average 18¢/ kWh



Sales of plug-in/electric are projected to be < 7% of the total new car market

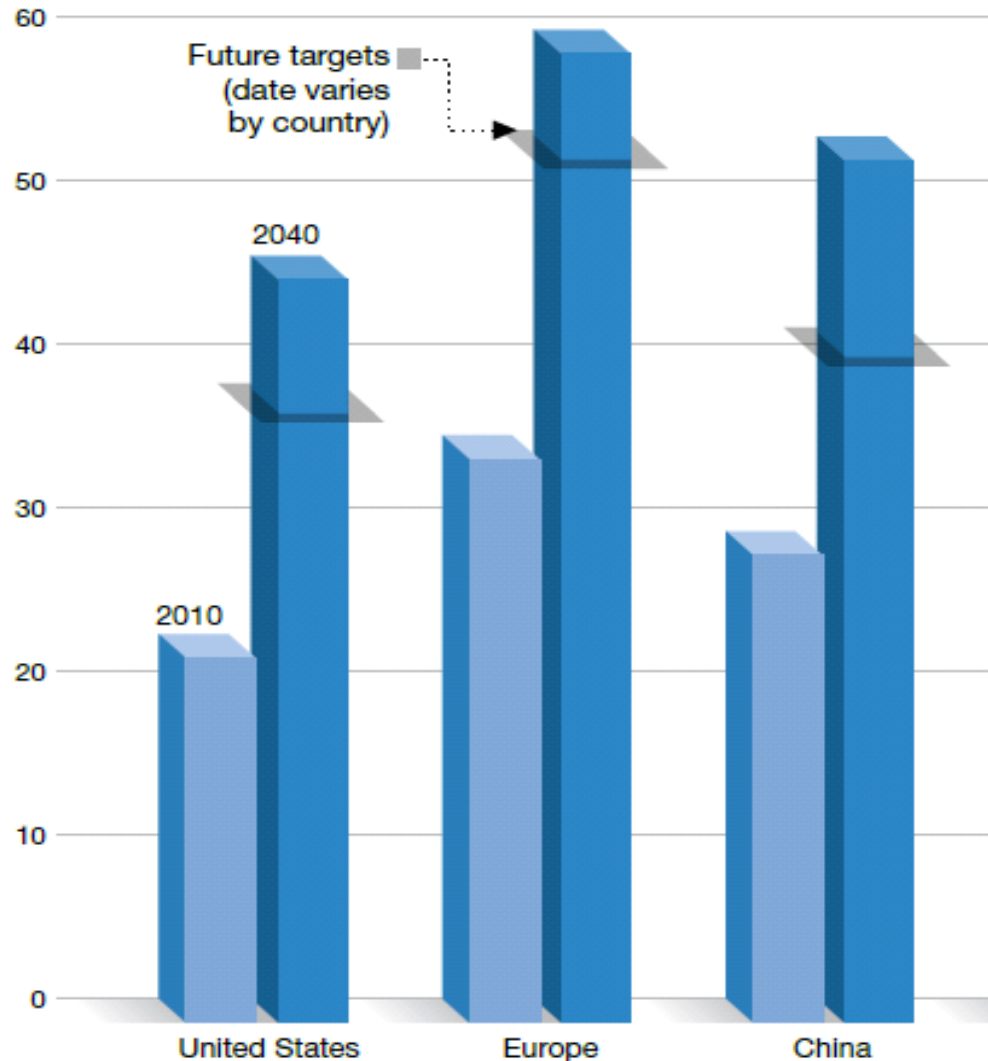
Light duty vehicle fleet by type

Billions of vehicles



Future targets (date varies by country)

The U.S. target is 54.5 mpg by 2025



Why are the projections for plug-in hybrid and electric vehicles so modest?

By 2030, ExxonMobil expects that, on average, an electric vehicle (like Nissan's Leaf) will be \$12,000 more than similar sized conventional vehicles.

What is the potential market for clean energy and energy efficiency technologies ?

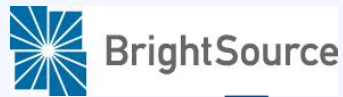


Yogi Berra

“It's hard to make predictions, especially about the future.”

SunShot CSP Funding and Selections

- Goal: To innovate and develop next-generation CSP technologies for low-cost collectors, high-temperature receivers and high-efficiency dry-cooled power cycles to meet the aggressive technical targets of SunShot.
- **Investment: Up to \$55 million over 3 years in 21 projects at companies, universities and national laboratories.**
- See them in the Tech Forum!



Collectors



SAN DIEGO STATE UNIVERSITY

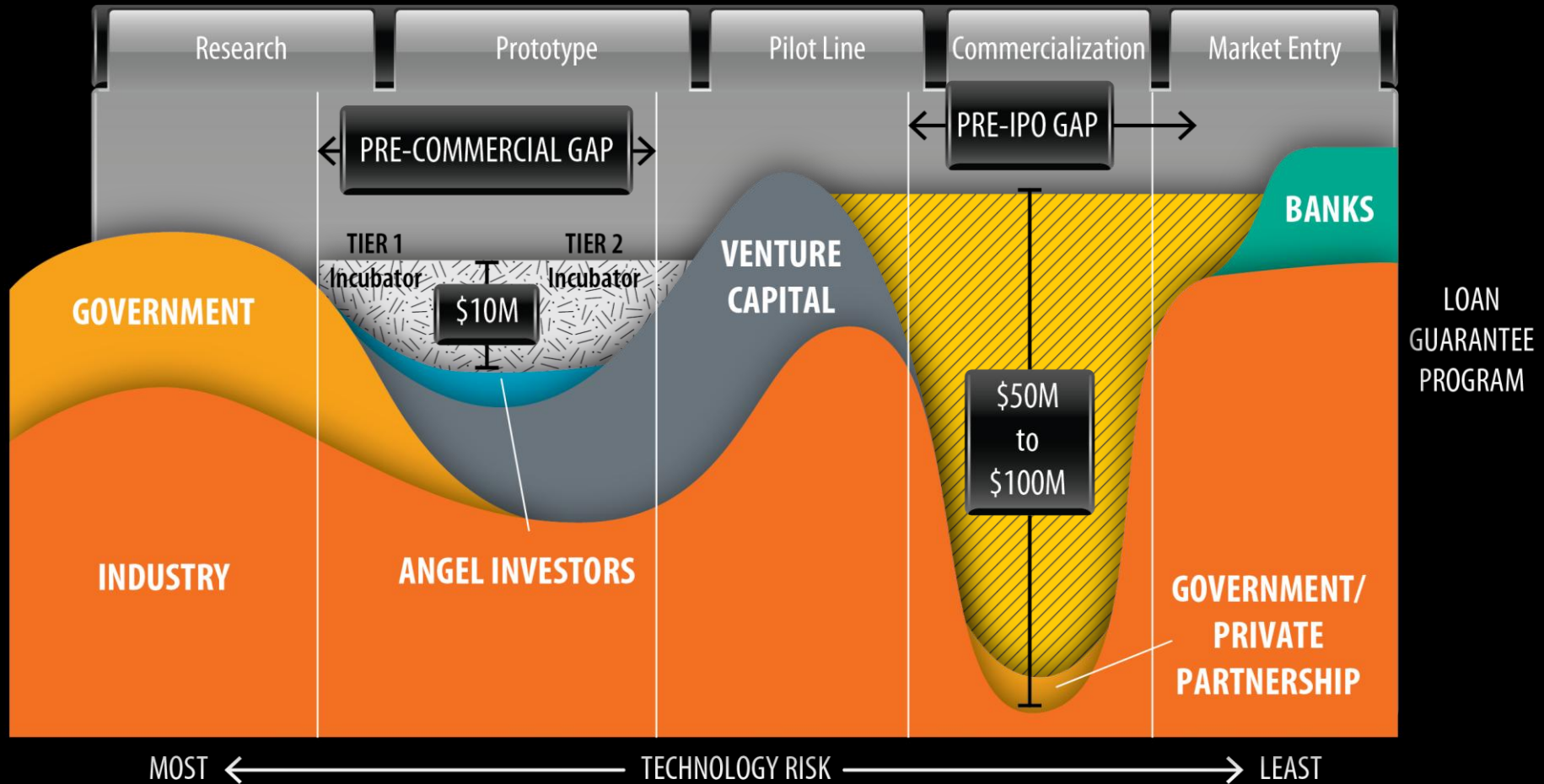


Receivers

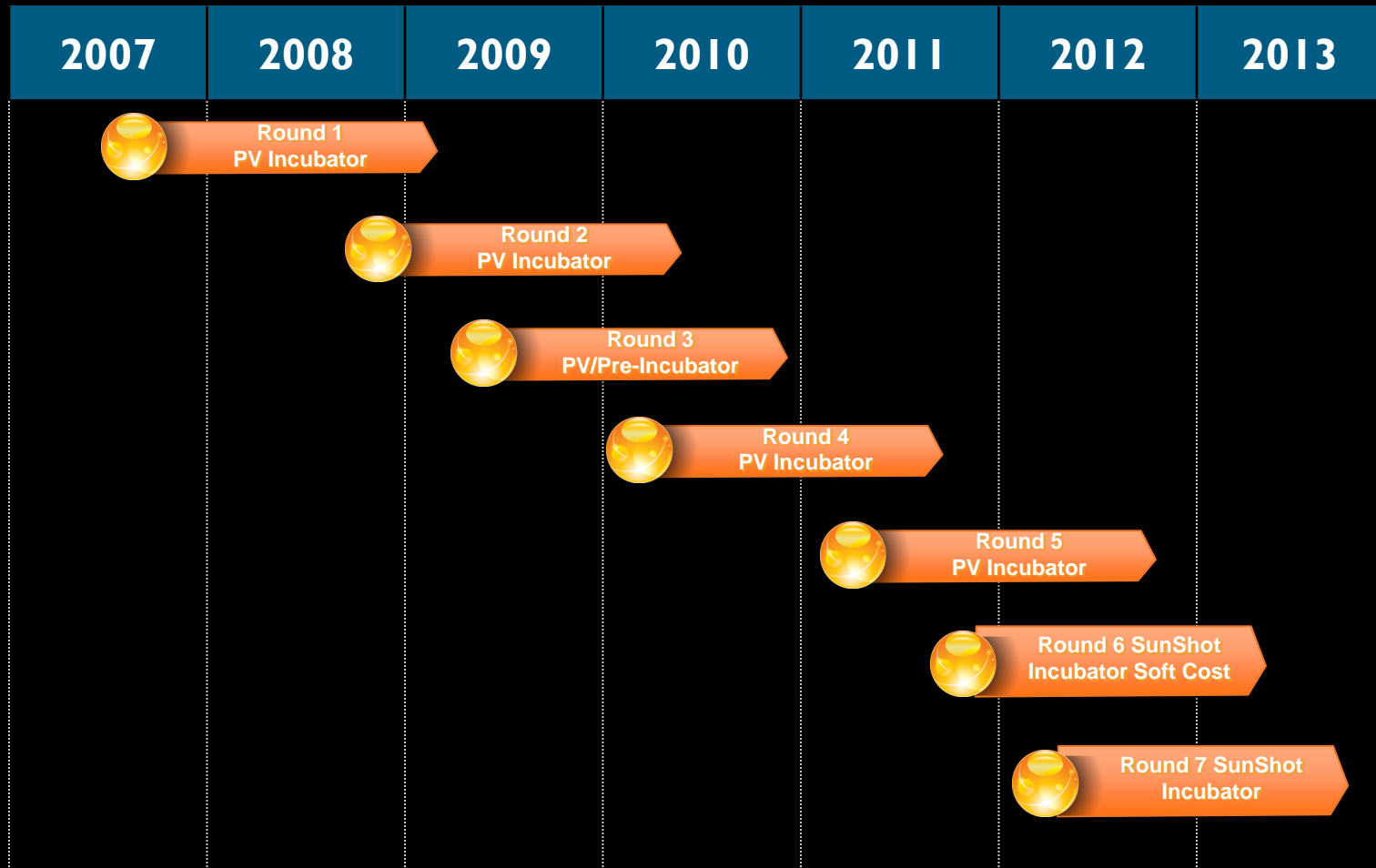


Power Cycles

Incubator Supports Startups



Multiple Incubator Rounds



Incubator Startups

ALTADEVICES



BANYAN
ENERGY



SolFocus



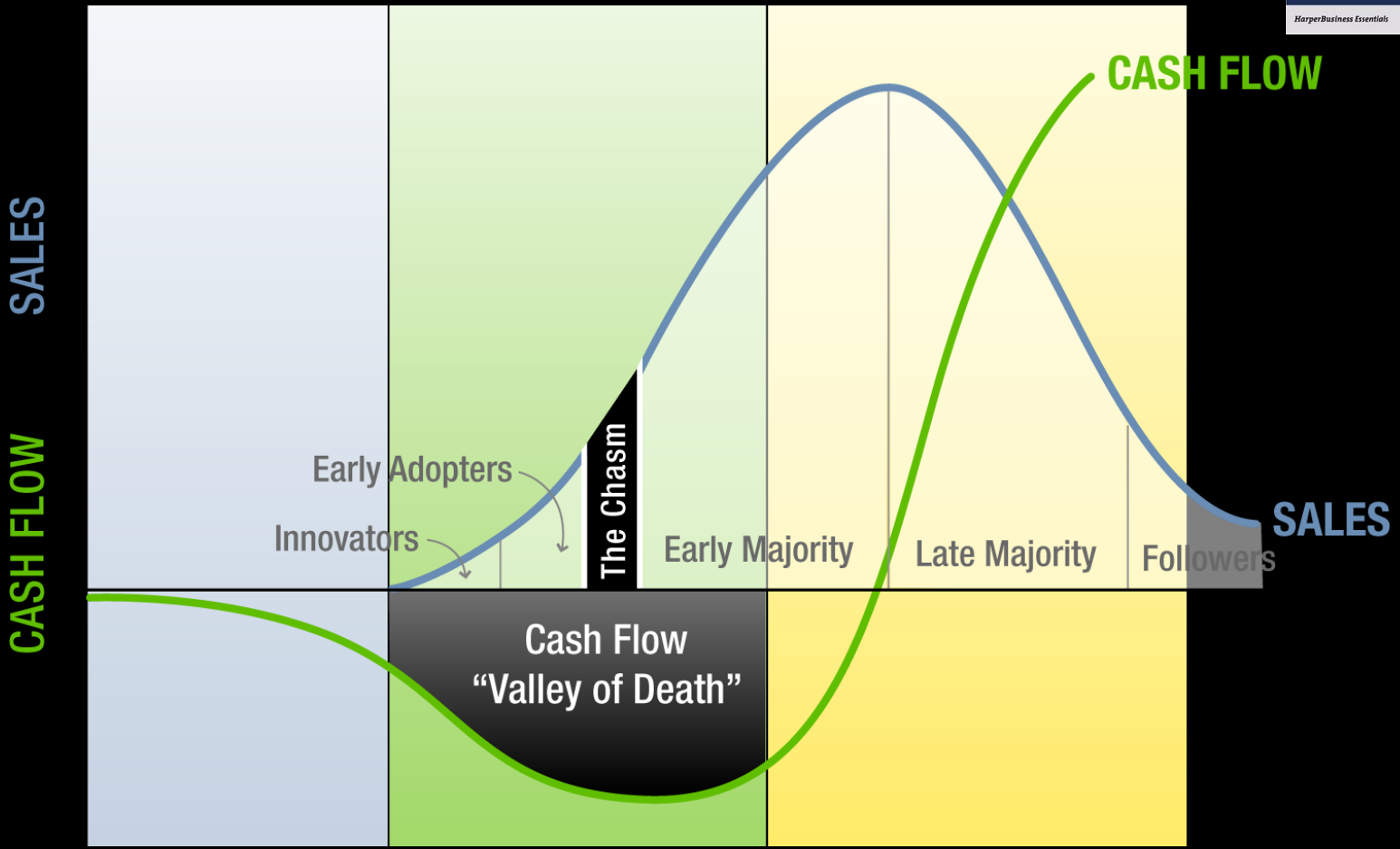
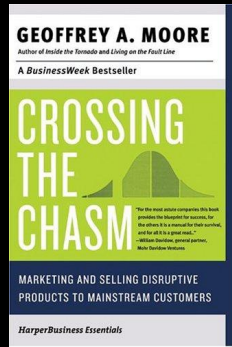
SOLOPOWER



**Renewable
Power
Conversion**

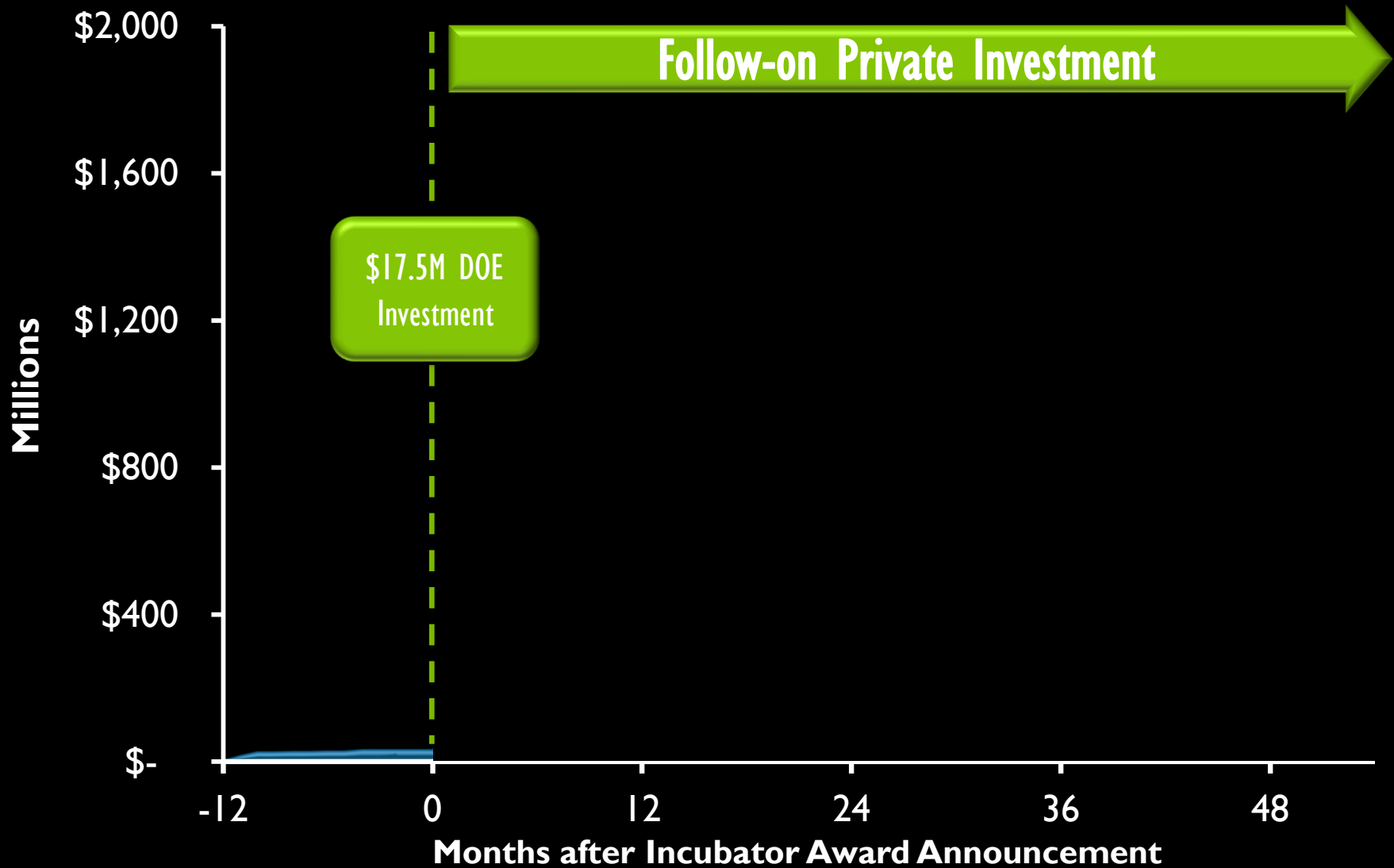
Caelux

Crossing the Chasm



Catalyzing Private Investment

Incubator Round 1 Companies Only



Sources: U.S. Securities and Exchange Commission public filings, Form D (2012); GE press release (2011)

SUNPATH Goals and the SunShot Portfolio

SUNPATH

Contract Duration

2 years

Max Contract Award (\$)

\$25M, 75% cost-share

Maximum Cost to DOE (\$)

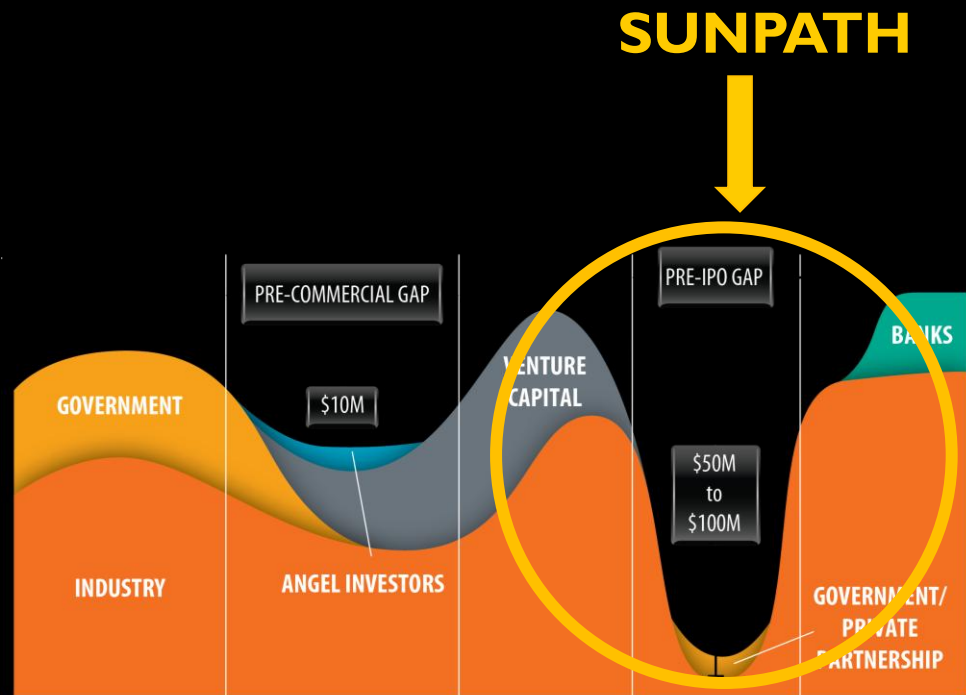
\$50M

Objective

Domestic industrial scale manufacturing demonstration of a PV technology:

- 15% lower in cost per watt compared to the industry leader
- progressing significantly towards the SunShot goal of \$0.50/WV modules
- >25 year lifetime and sufficiently high efficiency for low balance of systems costs.

Replication and expansion of commercial manufacturing in the U.S.

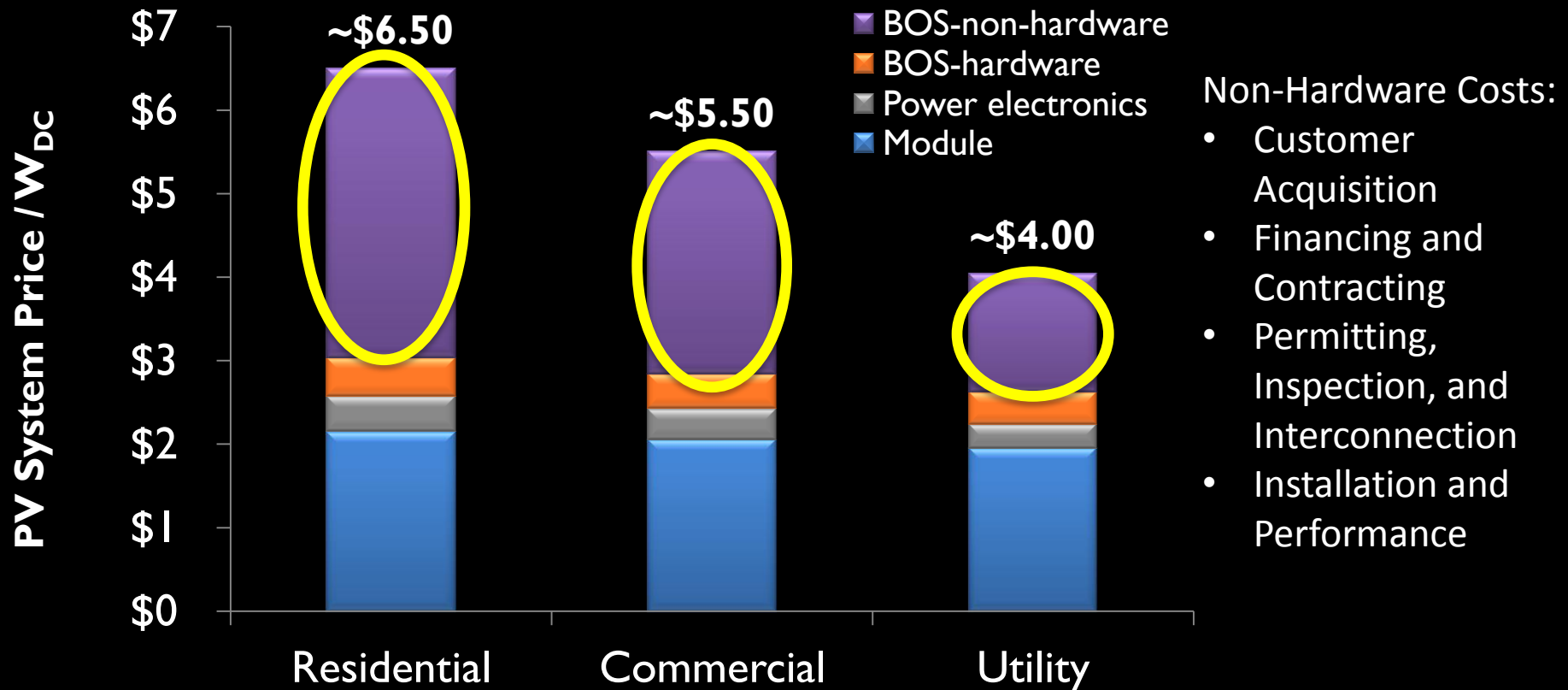


- **New models for finance:**
 - OPIC-like structures**
 - Master Limited Partnerships**

The Issue:

“Even if you paid nothing for the hardware, you'd still pay thousands of dollars to install a residential solar power system” - Secretary Chu

2010 PV System Prices



But Why So Pricey?

- Complicated and confusing process
- Process is different for every locale
- Unnecessarily high permit fees



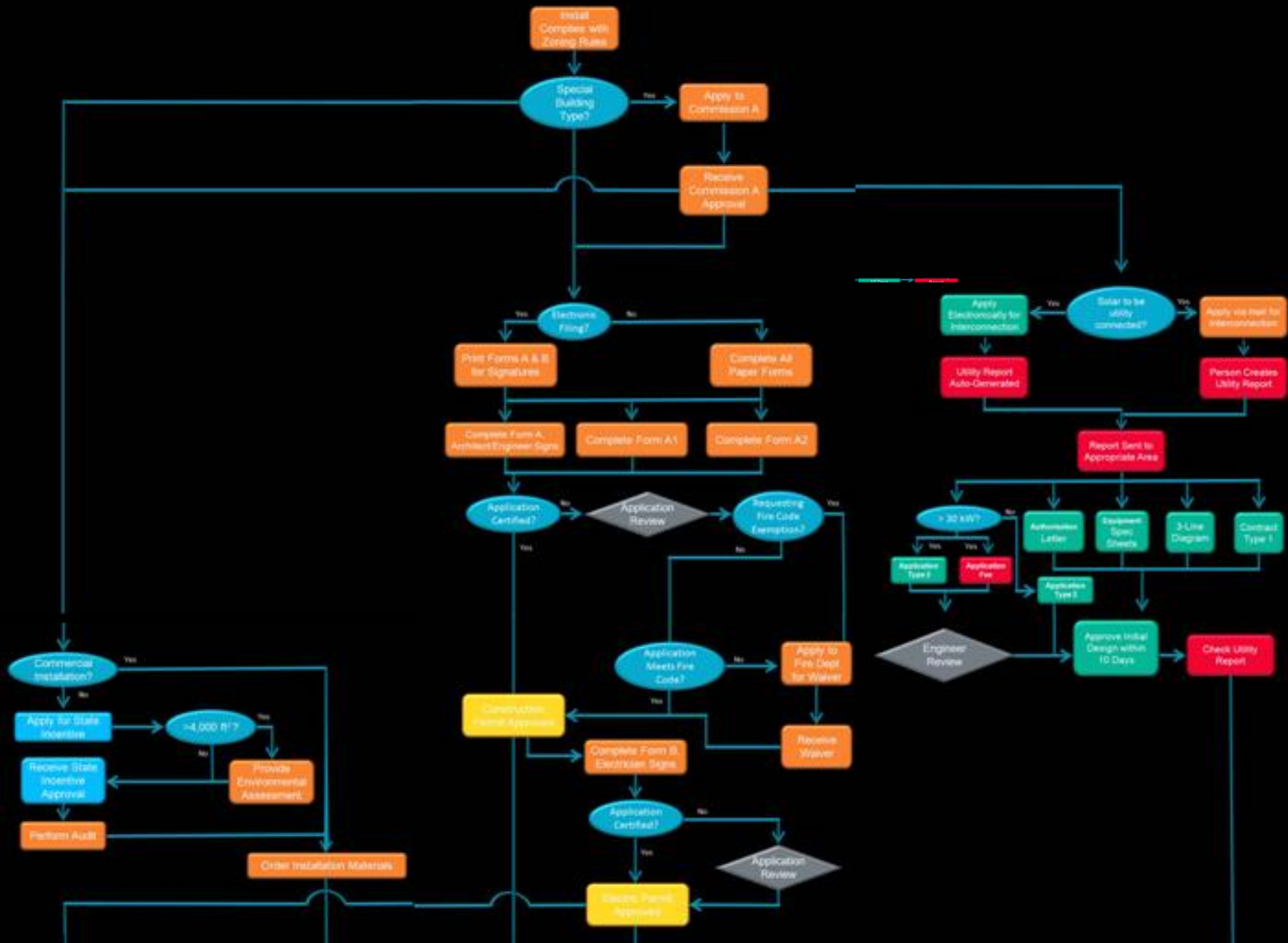
In-person application submission
and inspection

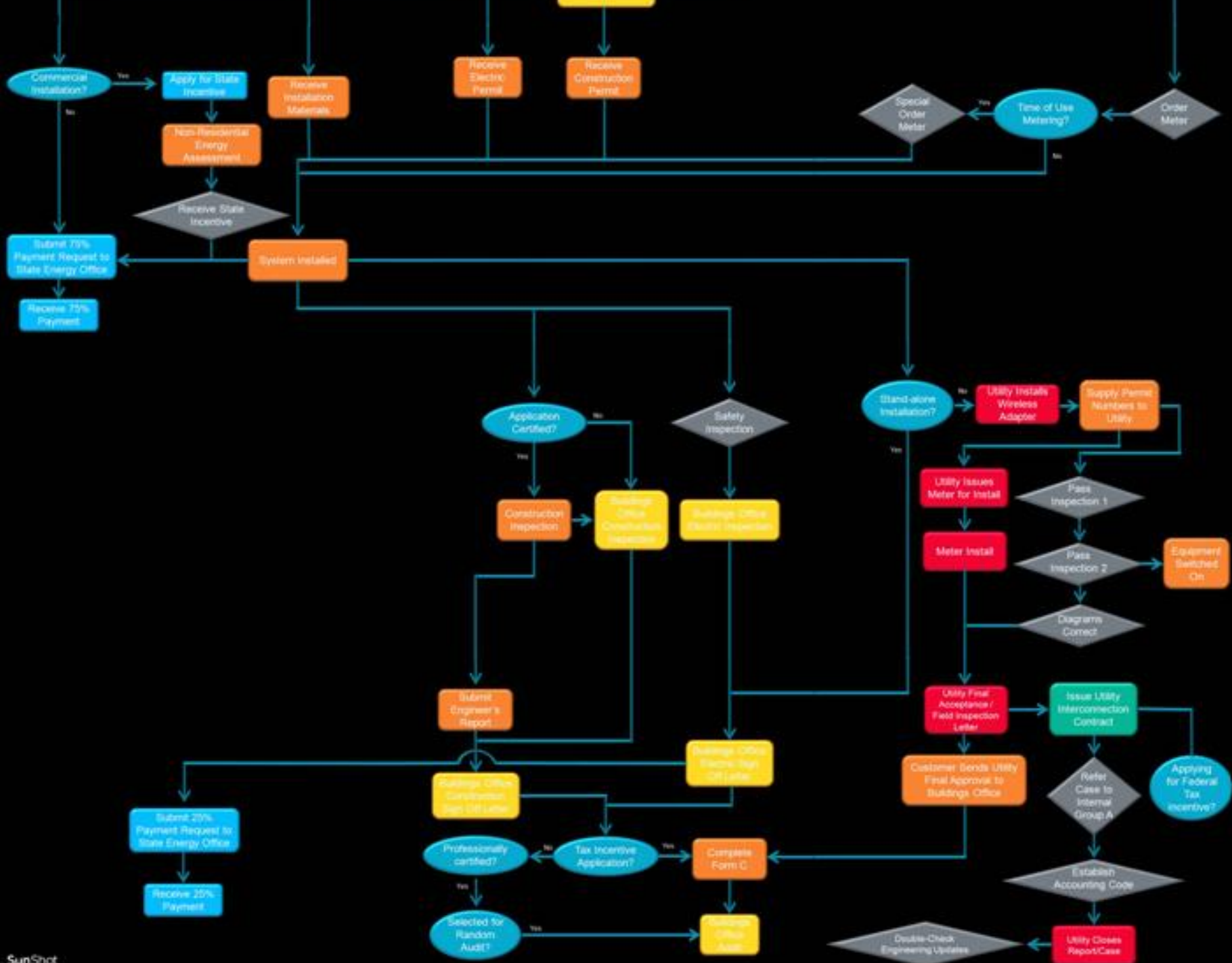
- Long wait times for inspection
and approval



One Hypothetical City's Process...

... With an approval plan so complicated, the flow chart crashed my computer!





Germany's Success



As long as housing structure is built to code, no permits filed for residential PV in Germany

Rooftop Solar Challenge

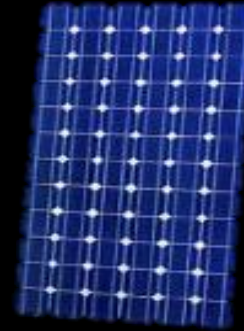
The Problem

- **18,000+** local jurisdictions with different PV permitting requirements
- **5,000+** utilities implementing interconnection standards and net metering programs
- 50 states developing interconnection standards and net metering rules

The Solution

The Challenge invests in **22** teams comprised of jurisdictions, utilities, and local stakeholders to develop the same requirements and processes across large geographic areas (500,000+ population). The Challenge also measures each team's progress to identify approaches that work.

CA



=

NJ



Uniform processes

≠

≠

Why should the installation of a PV system on your roof be handled like the installation of a gas water heater?



Residential PV in Germany costs ~\$2.50/W
Residential PV in the U.S. costs ~\$6/W

Soft Costs

Bold Words From the DOE, MIT, and VC on Solar's Future

MIT Energy Conference
speakers call for soft-cost
reductions and predict that First
Solar will be acquired.



photo courtesy of Convergence Energy, LLC, Steve Johnson

“Unlike physics, where we can fundamentally figure out the upper limit for the efficiency of solar cells, there is no such limit to bureaucracy”