DOE Si Workshop

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SunShot 2020 and beyond

- Near-term mission (SunShot 1.0)
  - Make solar energy fully cost-competitive with traditional energy sources before the end of this decade.

- Long-term mission (SunShot 2.0)
  - Achieve <u>ubiquitous</u> solar energy in the U.S.
  - by
    - Decreasing the price of solar energy further
    - Enabling the integration of tens of percent of solar energy onto the grid (US: 1 TW → 5 TWp)
    - Capturing increased value of domestic innovations and solar supply chain

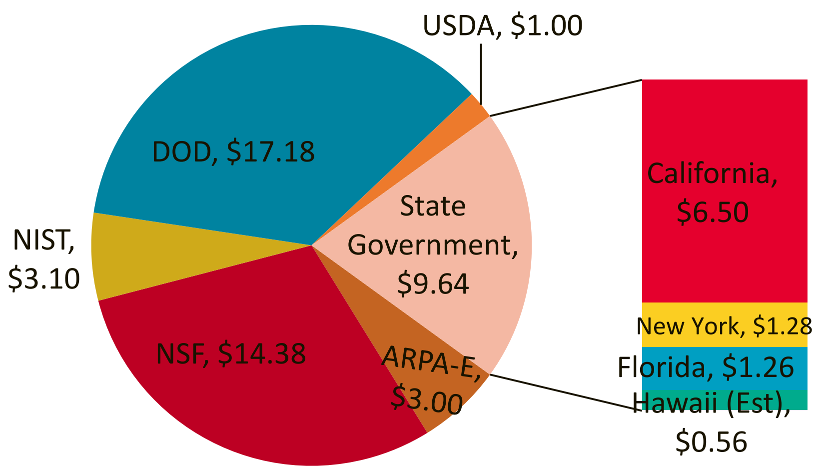
Goal of workshop

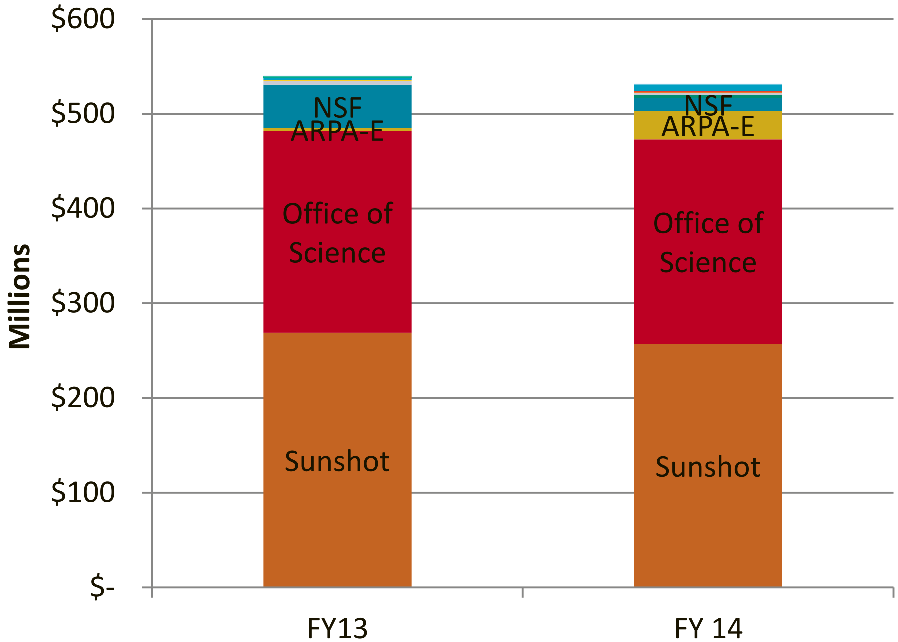
- Present info from SunShot
  - Solar funding and SunShot portfolio
  - Si opportunities and challenges

- Collect feedback from experts in Si PV community
  - Pathways for Si to reach 3 cents/kWh
  - How and where DOE funds can help
    - Sources of funding? Gov't, private, other?

Federal funding & SunShot

Public Research and Development

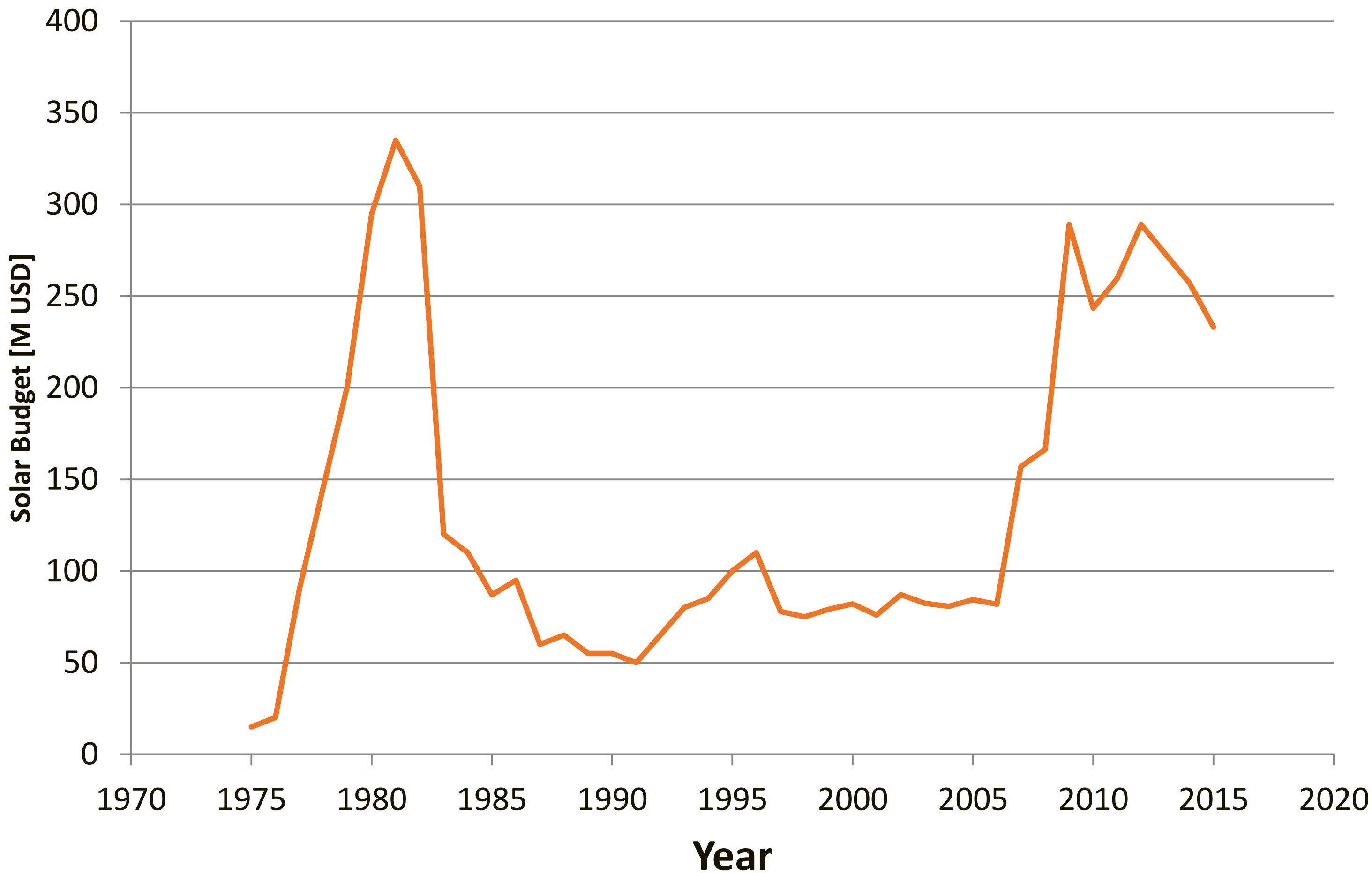




- It is estimated that the United States state and federal government spends approximately $550MM on solar R&D a year
    - SunShot represents approximately 50% of the funding followed by DOE office of science (39%) and NSF (9%)
- Funding has remained relatively flat over past few years, but a more diverse group have begun funding solar R&D
- Three federal agencies began funding solar R&D in 2014 through the National Nanotechnology Initiative
- Grants from some Agencies (NSF, ARPA-E, NASA) function on semi-regular cycles

Note: 2014 Grants from NASA not yet available. State R&D is based on state energy office programs, Hawaii estimate based proportionally on solar related NEHLA research programs divided across biannual budget

Historical DOE Solar Funding

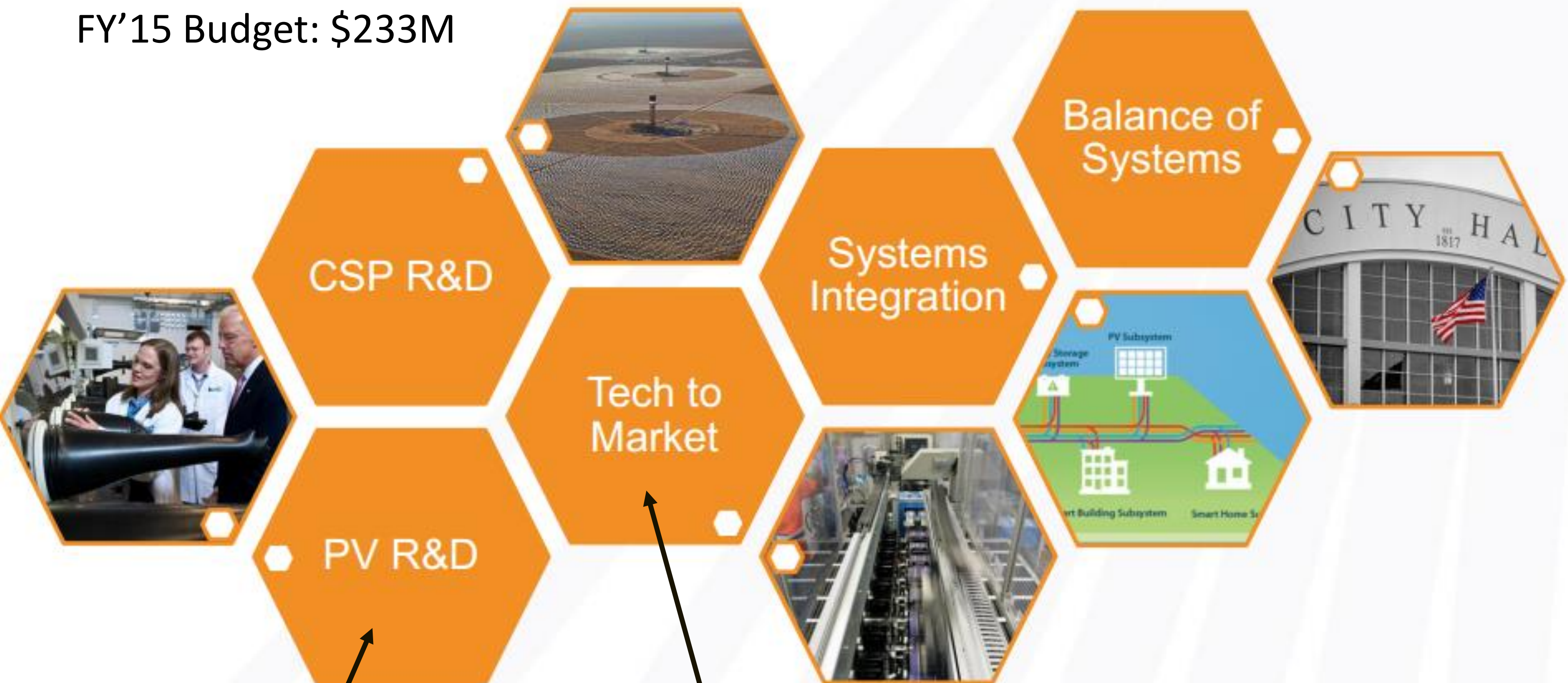


SunShot U.S. Department of Energy

energy.gov/sunshot

The SunShot Portfolio

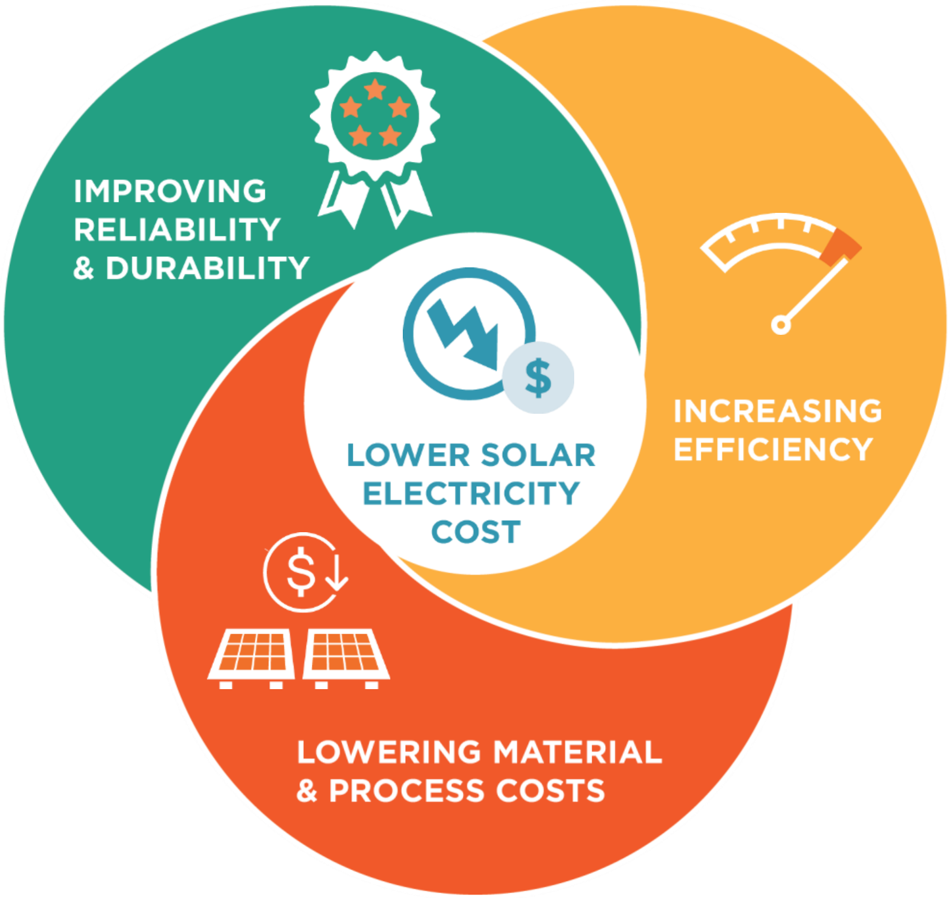
FY’15 Budget: $233M



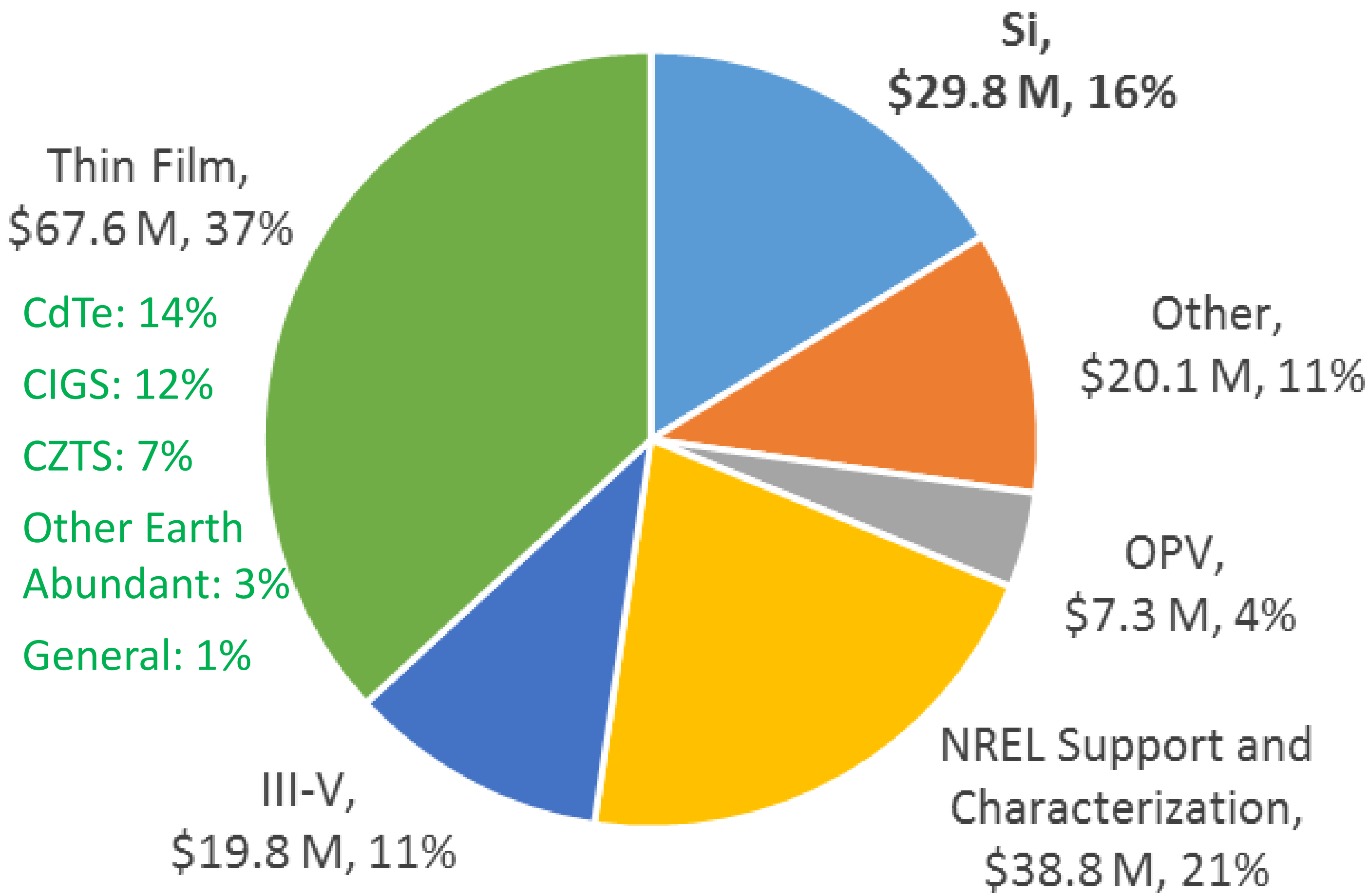
Annual solicitations:
Incubator, SolarMAT

Flagship solicitations:
NextGen, FPACE, PREDICTS

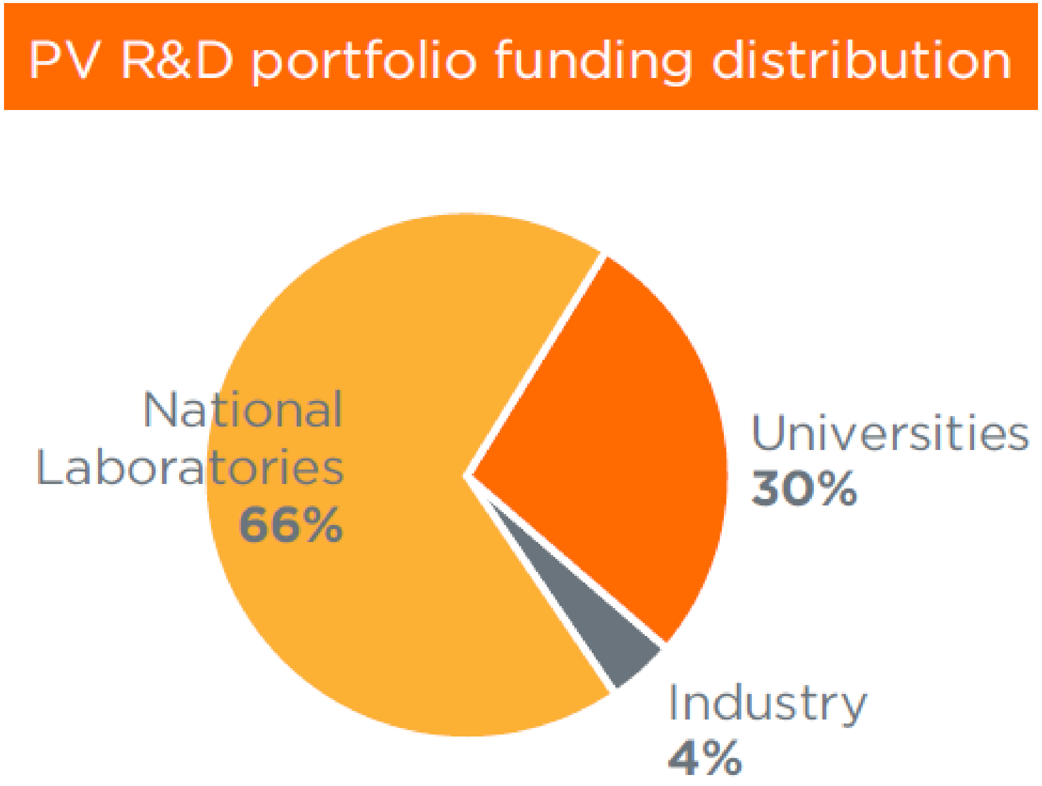
Photovoltaics R&D
Dr. Rebecca Jones-Albertus, Program Manager



PV R&D: Funding by Technology Area

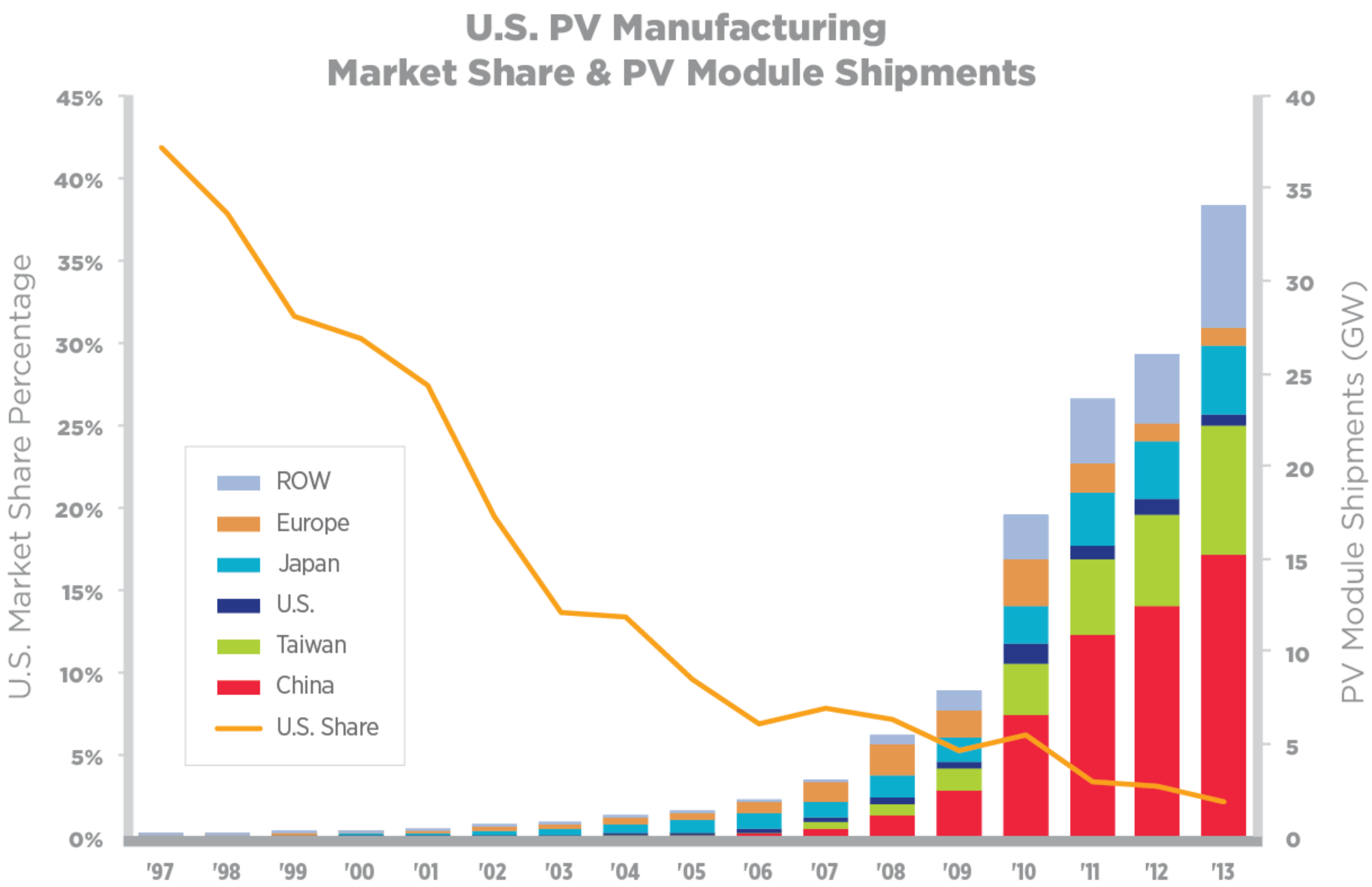


Funding Recipients (Prime Awardees)



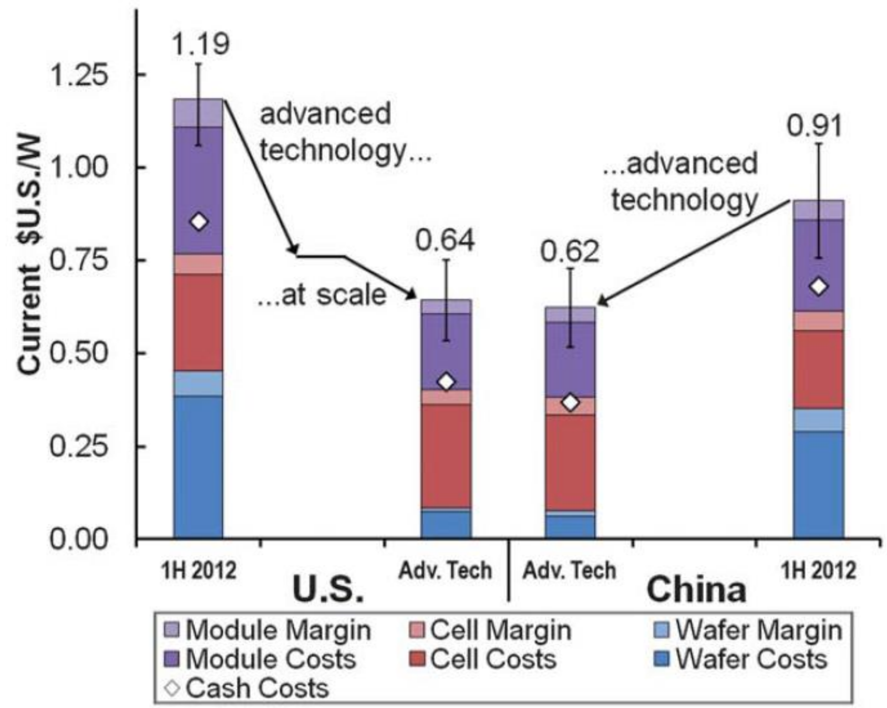
- NREL receives funding through FOAs and National Laboratory R&D

T2M seeks to monetize domestic innovation



T2M Manufacturing Strategy

- Build on our nation's innovation strength
- Develop advanced manufacturing concepts
  - low CapEx technology
  - automation
- Support demonstration through pilot-scale
  - Path towards global best-in class cost
- Regain the supply chain
  - new, high-value tools and components



Goodrich et. al., "Assessing the drivers of regional trends in solar photovoltaic manufacturing," Energy Environ. Sci.

SunShot U.S. Department of Energy

energy.gov/sunshot

T2M funding by category

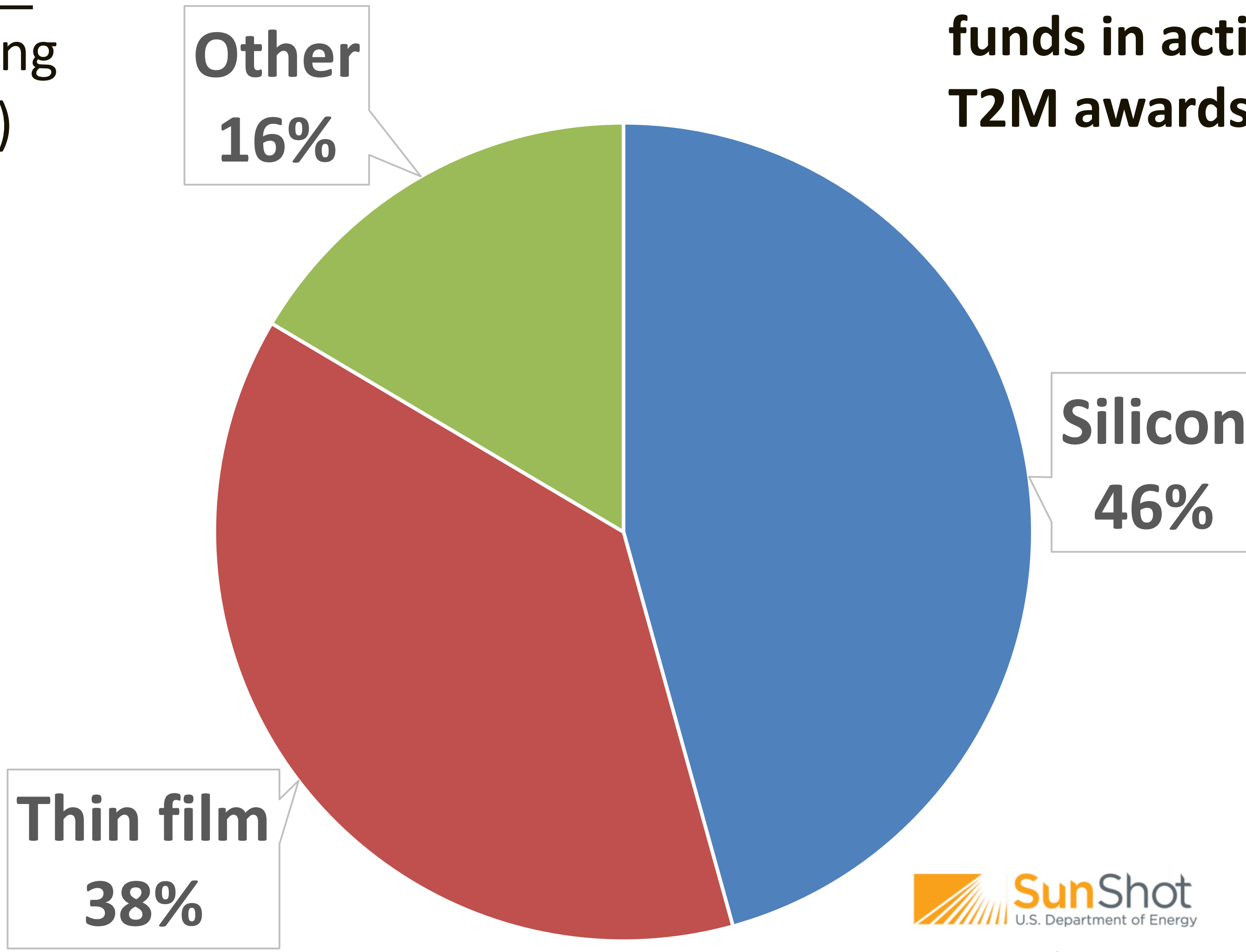
<u>Active awards in:</u>

PV Manufacturing Initiative (PVMI)

Incubator 8 & 9

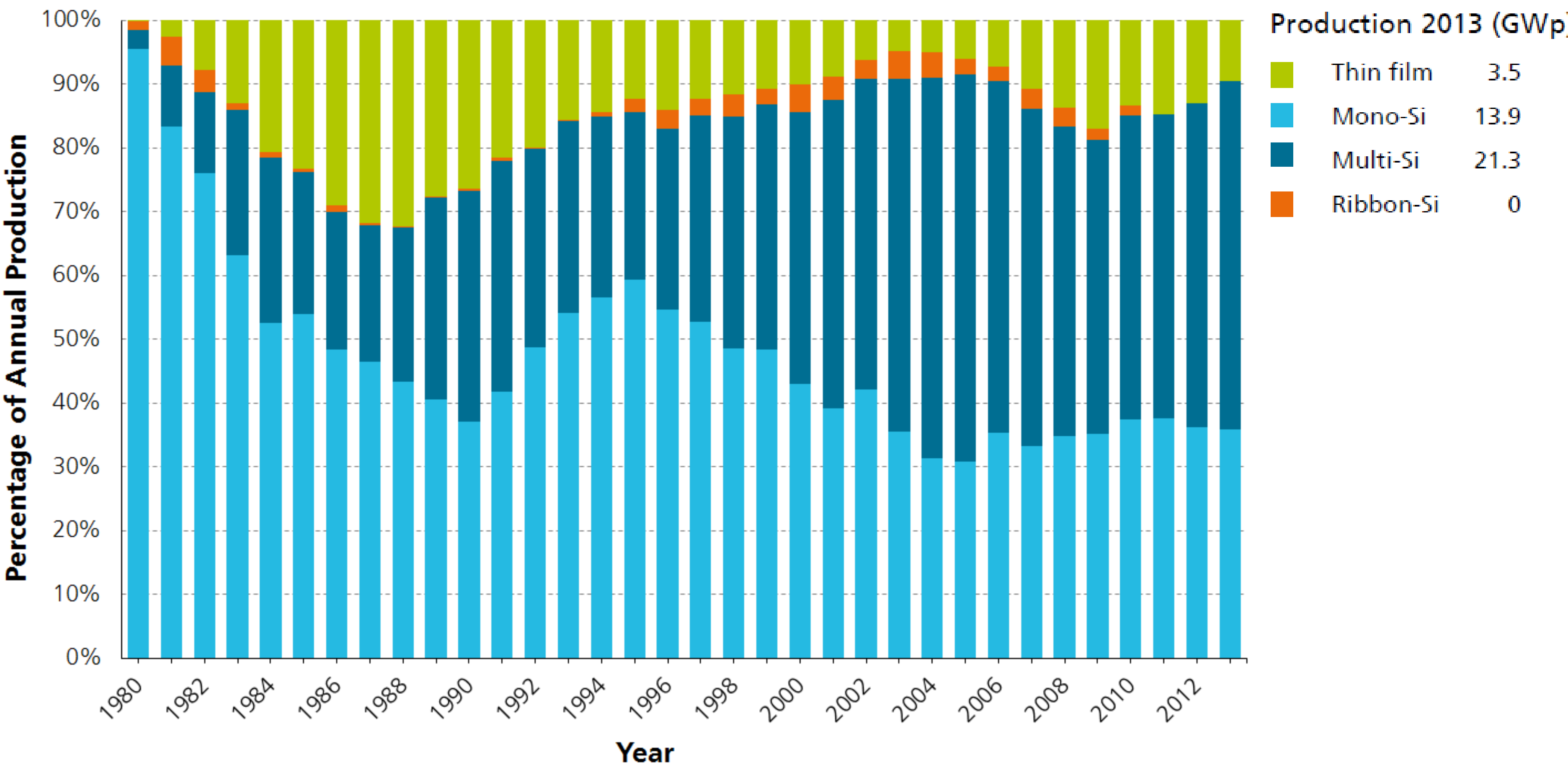
SolarMAT 1 & 2

$173M federal funds in active T2M awards



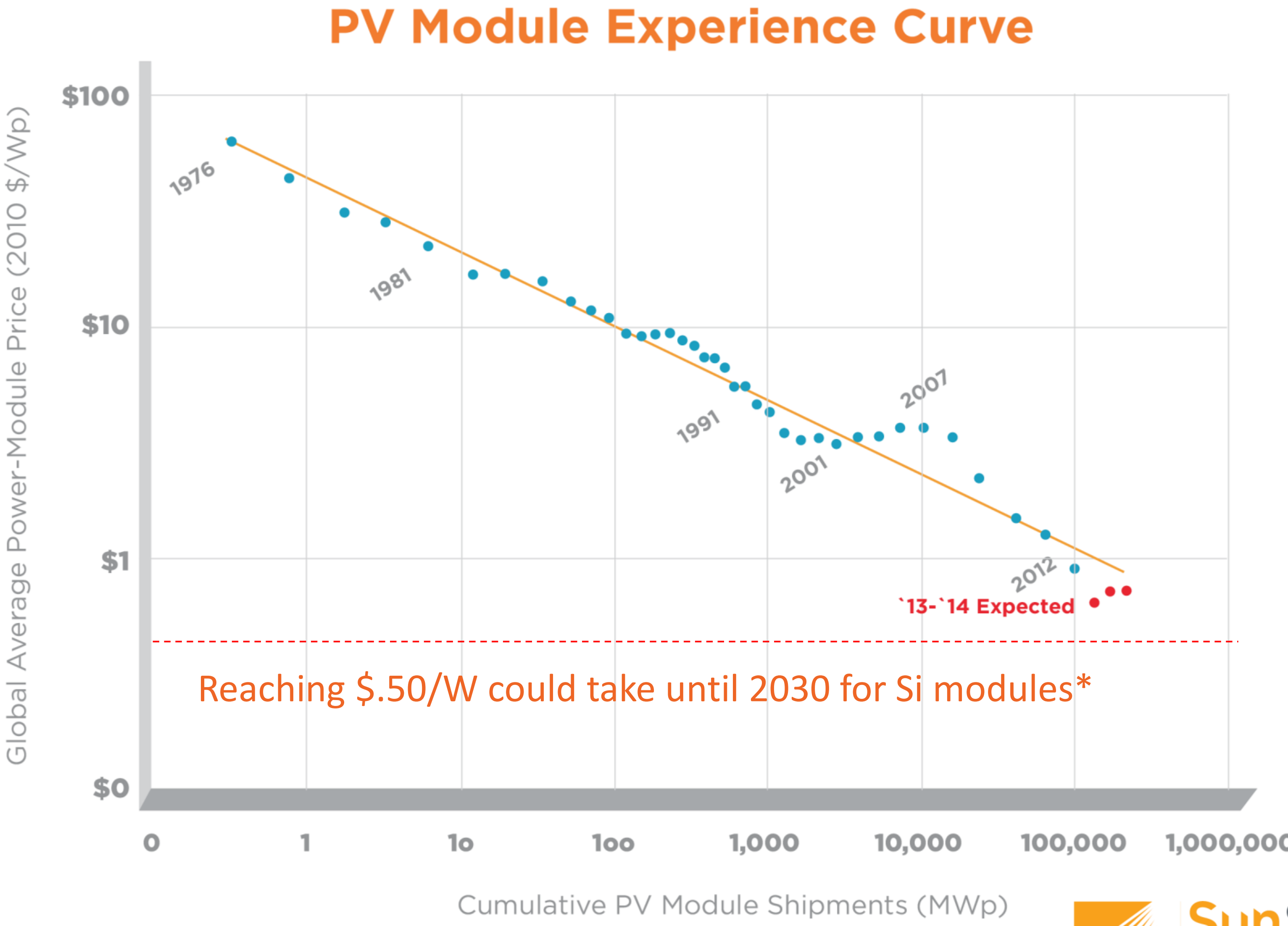
Beyond 2020

Historical PV Production by Technology



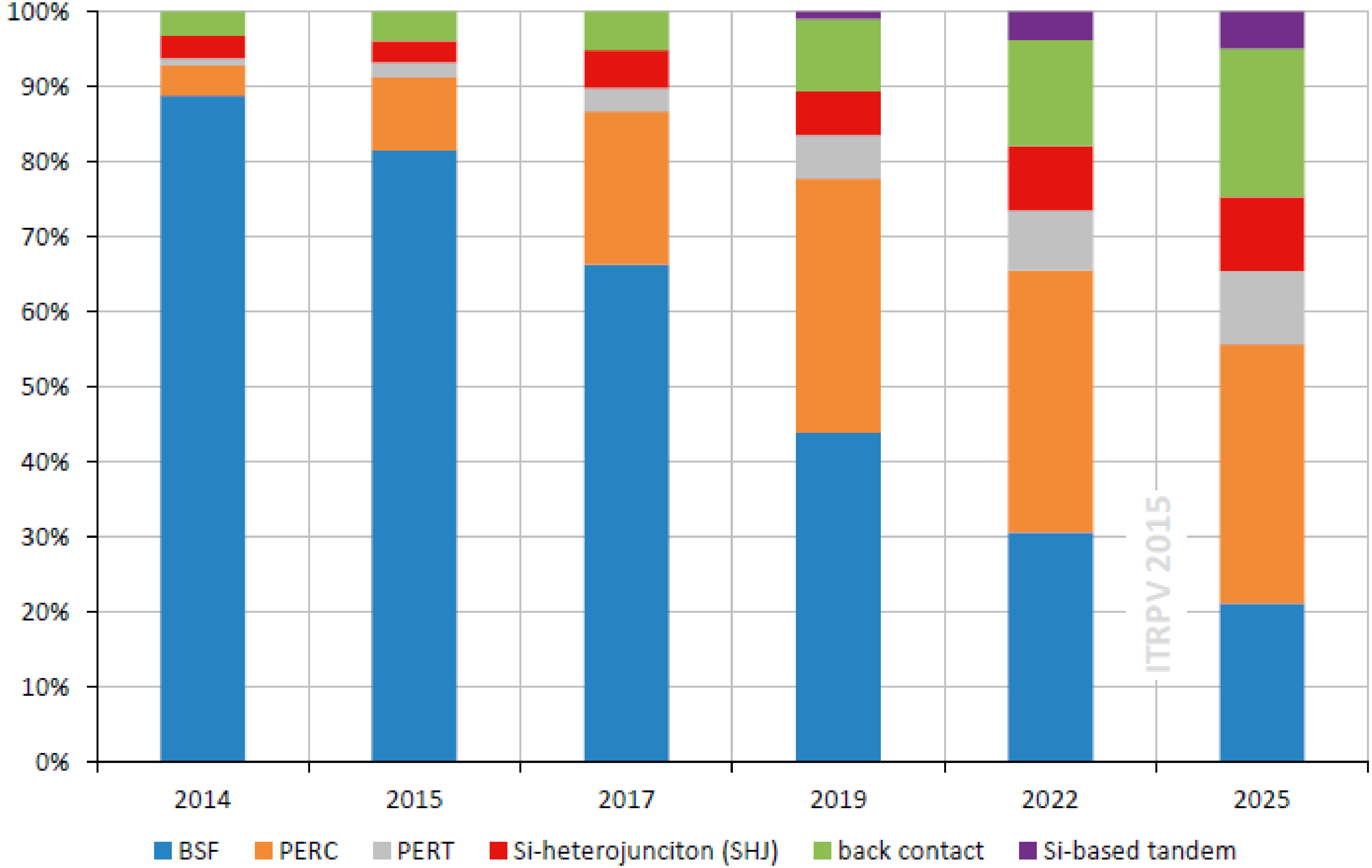
Fraunhofer Institute for Solar Energy Systems ISE 2014
http://www.ise.fraunhofer.de/de/downloads/pdf-files/aktuelles/photovoltaics-report-in-englischer-sprache.pdf

PV Module Prices



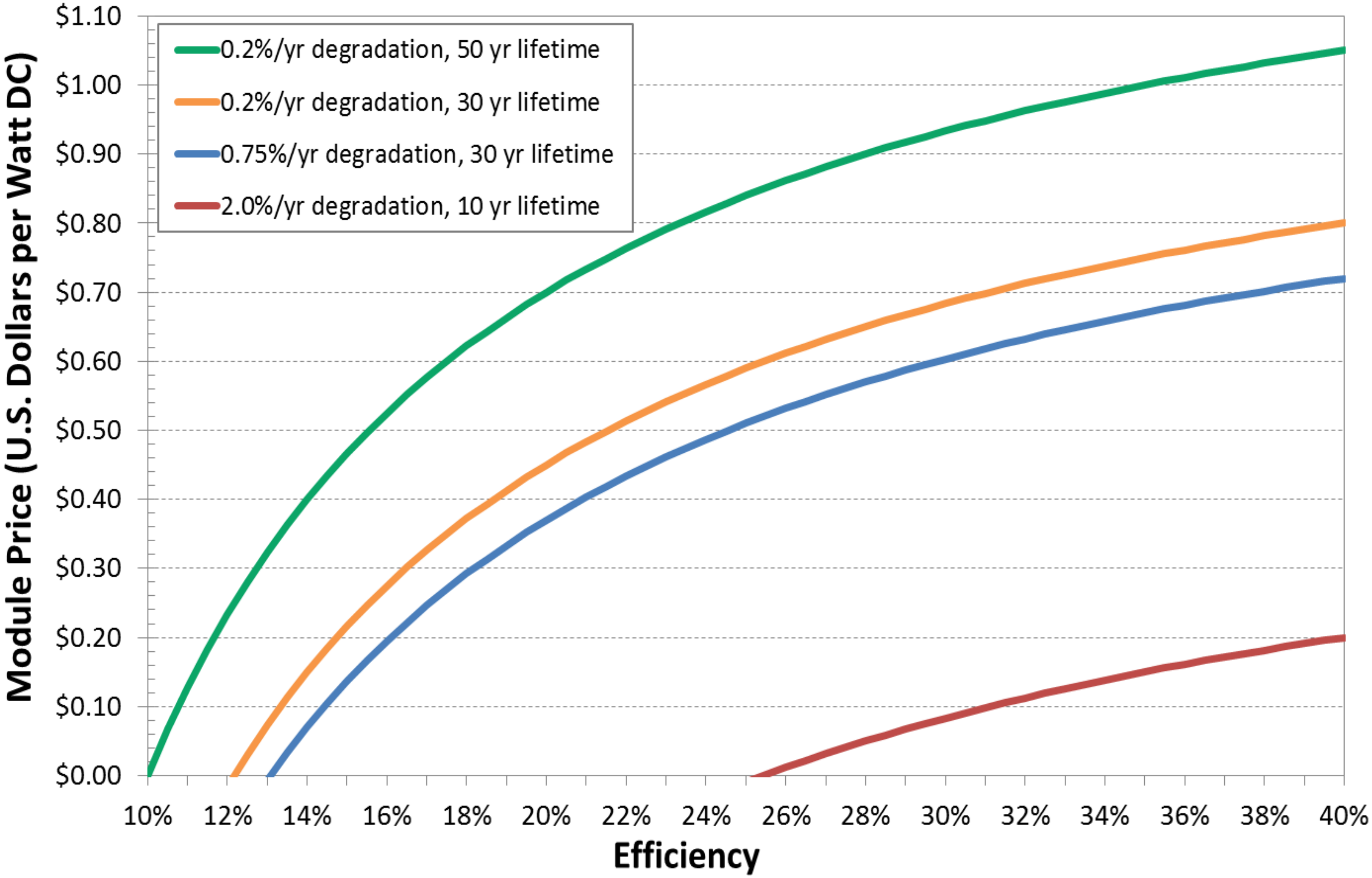
SunShot
U.S. Department of Energy

Si Scenarios

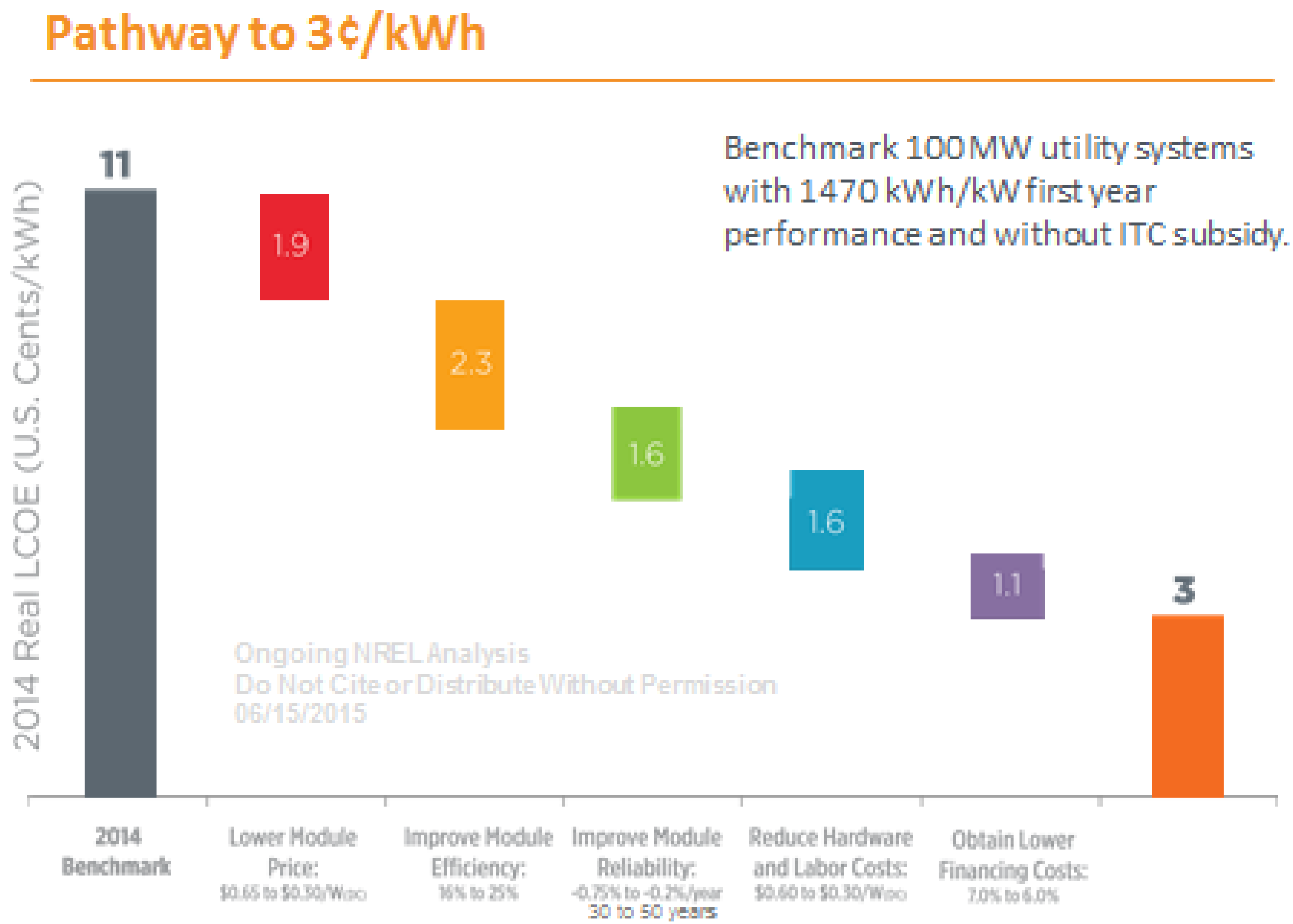


International Technology Roadmap for Photovoltaic 2015

Iso-LCOE Curves of 6 cents per kWh Without Federal or State Incentives and 1,470 kWh/kW First-Year Performance



PV Cost Projections



Logistics

Instructions

Break into groups of <8, thematically based on your expertise

- crystal growth & wafers,
- cell processing & metallization,
- heterojunctions (HIT, passivated, carrier selective, tandems),
- metrology,
- defects,
- other?

Assign a moderator and a scribe to each group.

Timeline

8:30 – 9:15: Si in the future – opportunities and challenges

9:15 – 10:00: Technical targets and spaces to support Si

10 – 10:15: Break and load results to presenter laptop

10:15 – 11: Report outs and discussion

Discussion Questions #1

8:30 – 9:15:

Si in the future – opportunities and challenges

Can the silicon industry reach 3 cents/kWh through evolutionary progression or are revolutionary R&D breakthroughs needed?

What are the biggest opportunities and challenges?

What data is needed to inform your discussion?

Discussion Questions #2

9:15 – 10:00:

Technical targets and spaces to support Si in the future

For the opportunities identified by your team, what are indicators that the path is worth pursuing in the early stages of research?

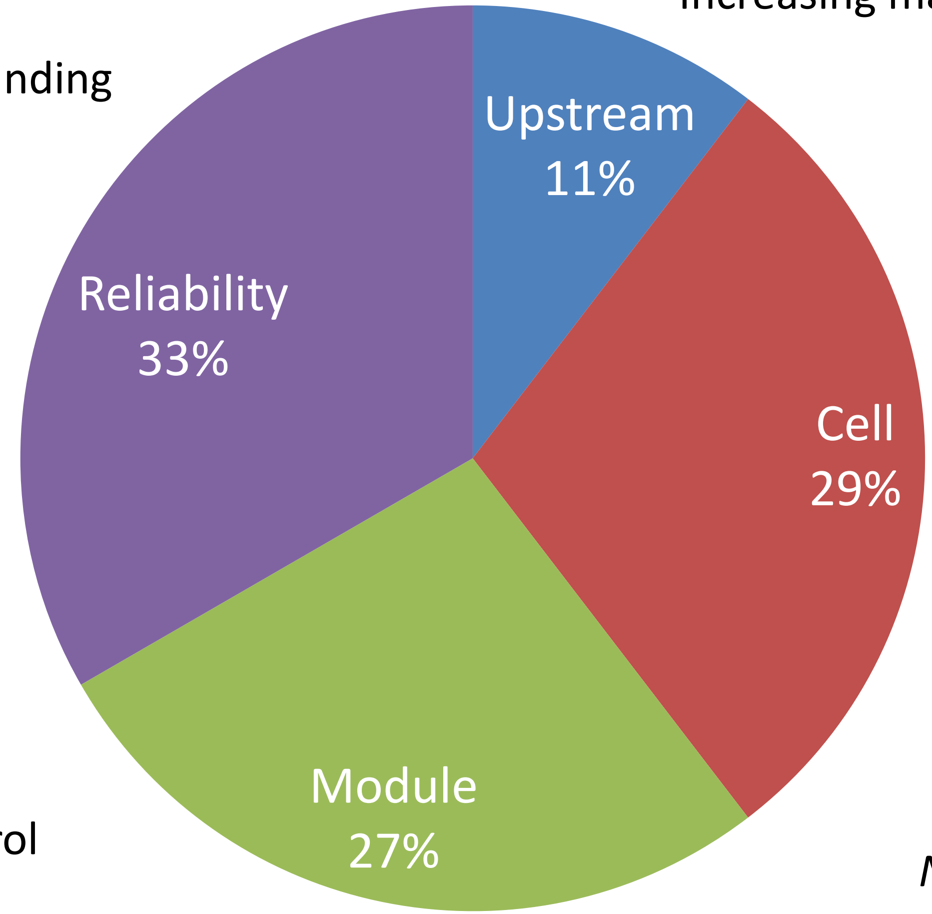
How can government funding effectively contribute to developing these opportunities? What are the right metrics to judge success?

Where do you anticipate future funding coming from? To research what topics?

PV R&D RFI Results (Si focus)

Reducing defects
Reducing energy content
Increasing manufacturing efficiency

Increased understanding
Increase durability
50 year lifetime



Tandems
Kerfless/Thin
Efficiency/Cost
Up/down conversion

Temperature control
Concentration
Cell to module
Smart, light, tailored, standardized

Number of responses received: 64

2014 c-Si workshop discussion

- **Module reliability** (Yu-Chen Shen, SunPower): 71%
  - increase confidence for investors
  - public funding should look into fundamental degradation modes
- **Silicon defects** (Martin Schubert): 54%
  - determine limiting defects to enable higher cell efficiency
  - evolutionary change that would be widely accepted
- **III-V/Si tandems** (Christianna Honsberg, ASU): 26%
  - Si will reach its practical limit, need to move beyond 1-sun limit
- **Ion implanted cells** (Lisa Mandrell, Intevac): 25%
  - eff. gain of ~0.2% abs. over traditional process, reduces processing steps
- **Module assembly** (Roland Einhaus): 22%
  - Innovations : ECA over soldering, glass/glass, more field testing needed
- **Kerfless Si** (Tom Surek): 19%
- **UMG** (Alain Turenne, Silicor): 16%
  - UMG offers capex cost advantage
- **CapEx reductions** (Tonio Buonassisi): 14%
  - 20-25% of module costs is depreciation & maintenance
  - 2 GW = $0.7/W capex

Thank you!

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SunShot website: http://energy.gov/sunshot