U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

# Overview of the PV Track

Lenny Tinker

PV R&D Program Manager

energy.gov/solar-office

April 6, 2020

# The PV R&D Team

Christopher Anderson
Technical Project Officer

Susan Huang
Technical Advisor

Jeremey Mikrut
Technical Project Officer

Andenet Alemu
Fellow

Inna Kozinsky
Technical Advisor

Emanuele Pecora
Technical Advisor

Brion Bob
Technology Manager

Peter Lobaccaro
Fellow

Nancy Truong
Financial Analyst

Andrew Dawson
Technical Advisor

Marie Mapes
Technology Manager

Tasso Golnas
Technology Manager

Emily Marchetti
Operations

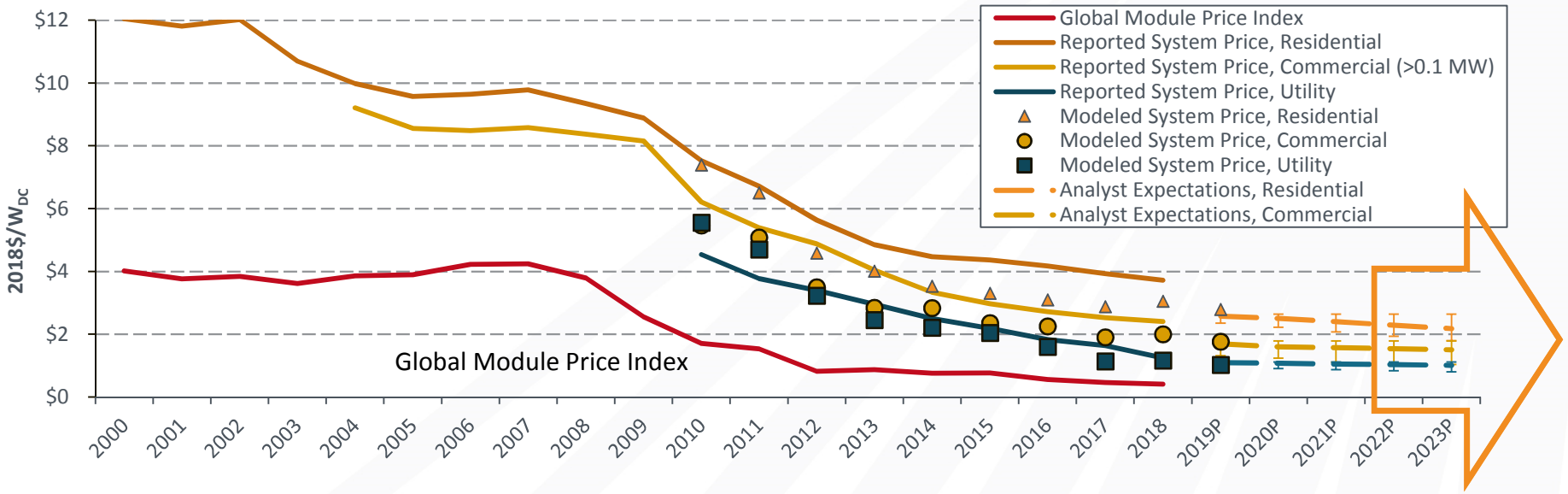
# Solar Energy Technologies Office Mission

Our mission is to accelerate the development and application of technology to advance low-cost, reliable solar energy in the U.S.

To achieve this mission, solar energy must:

- Be **affordable** and **accessible** for all Americans
- Support the **reliability**, **resilience**, and **security** of the grid
- Create a sustainable industry that **supports jobs**, **manufacturing**, and the **circular economy** in a wide range of applications

# A Brief Perspective on SETO PV R&D History




**Where we're going:** Low incremental value of PV at some times of day; TWyrs of US system data

- Moving from qualification tests to durability tests
- "Big data" aggregation with increased experience and observing degradation at the system level
- Ultra-cheap PV enabling different system constructions and room for increased product differentiation

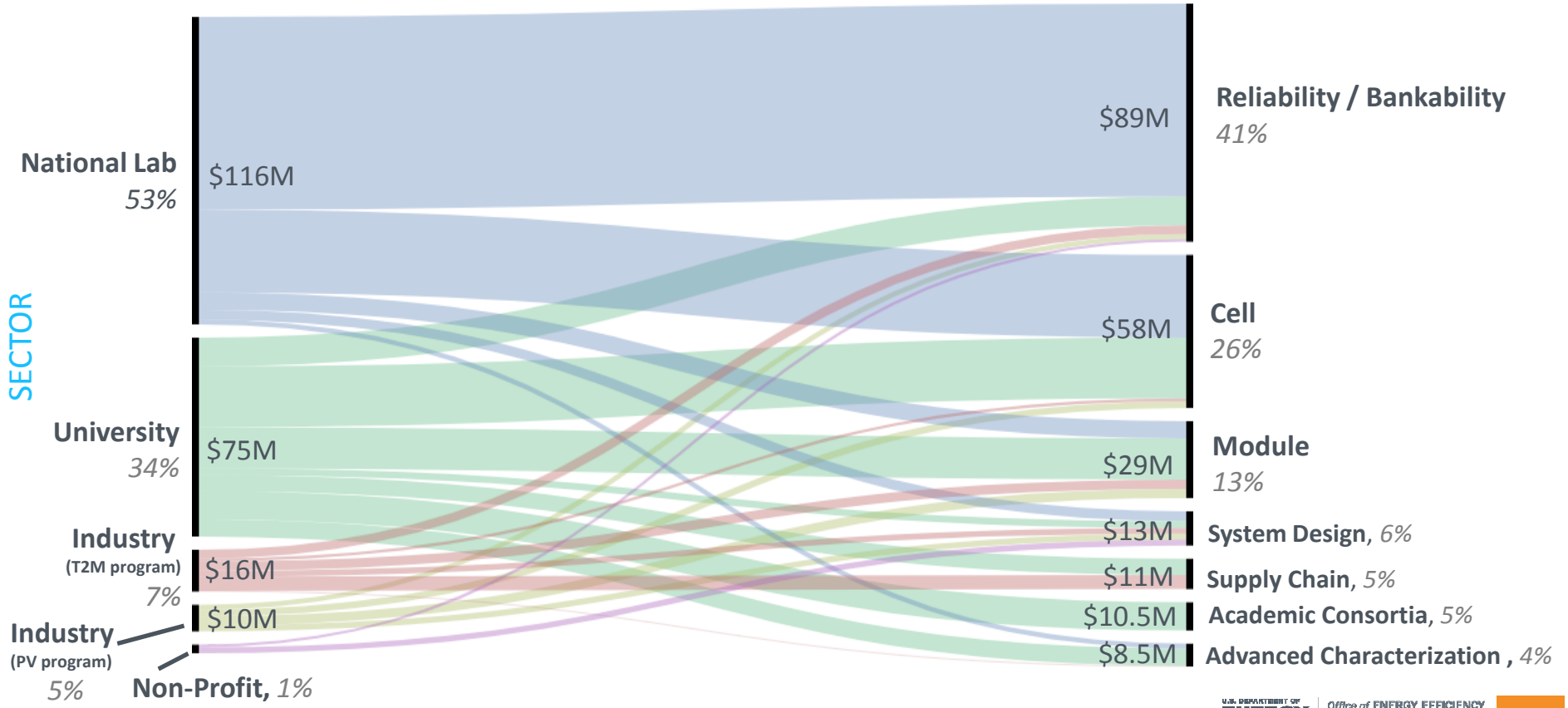


**Note:** Reported prices represent the median national U.S. averages. Error bars represent the high and low analyst expectations.
**Sources:** Reported residential and commercial system prices (Barbose and Darghouth 2019); reported utility system prices (Bolinger, Seel, and Robson 2019); modeled system prices (Feldman, Fu, Ramdas, Desai, and Margolis 2019); analyst expectations (NREL 2019 Annual Technology Baseline); The Global Module Price Index is the average module selling price for the first buyer (P. Mints SPV Market Research).

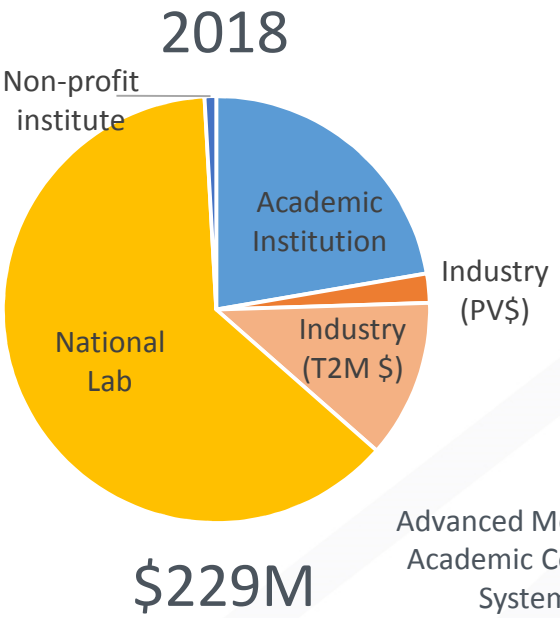
# Solar Energy Technologies Office Budget ($K)

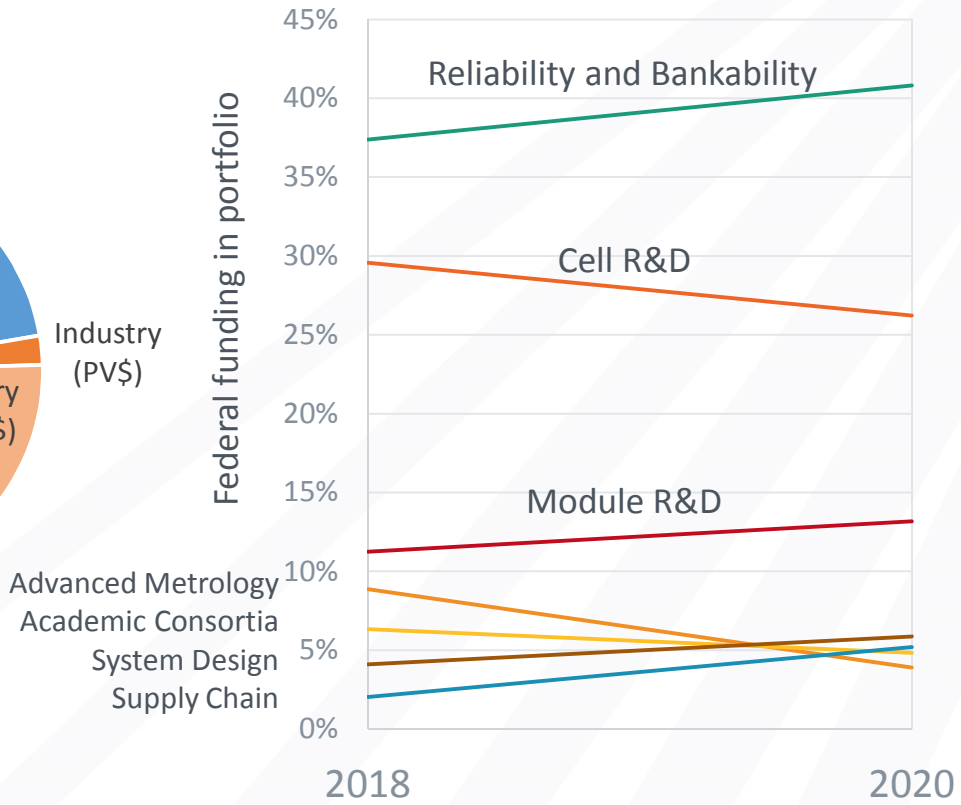
| SETO SUBPROGRAM | 2016 | 2017 | 2018 | 2019 | 2020 | Active PV Projects (April 2020) |
|---|---|---|---|---|---|---|
| Concentrating Solar Power | $48,400 | $55,000 | $55,000 | $55,000 | $60,000 | - |
| Photovoltaic R&D | $53,152 | $64,000 | $70,000 | $72,000 | $72,000 | $209,761 |
| Systems Integration | $52,447 | $57,000 | $71,200 | $54,500 | $53,000 | - |
| Balance of Systems (Soft Costs) | $34,913 | $15,000 | $11,000 | $35,000 | $35,000 | $800 |
| Manufacturing and Competitiveness (T2M) | $43,488 | $16,600 | $34,400 | $30,000 | $60,000 | $8,763 |
| NREL Facility Support | $9,200 | | | | | |
| TOTAL | **$241,600** | **$207,600** | **$241,600** | **$246,500** | **$280,000** | **$219,324** |

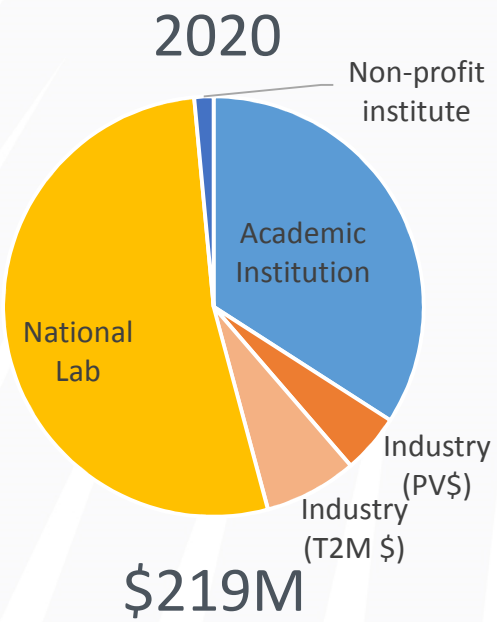
# SETO PV Research Funding Allocation - 2020 ($219M)



# SETO PV Research Funding Allocation 2018 to 2020



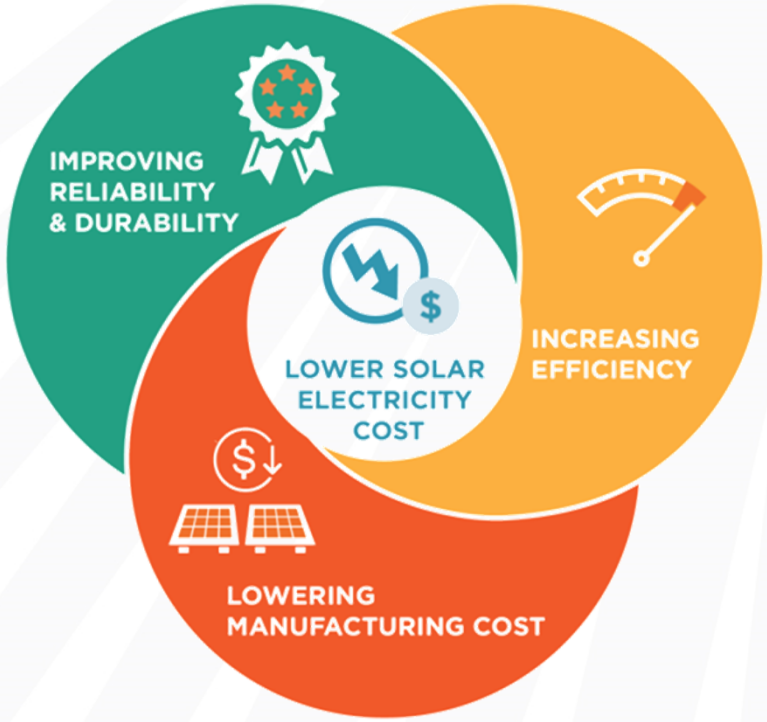



# The Photovoltaics Subprogram Approach

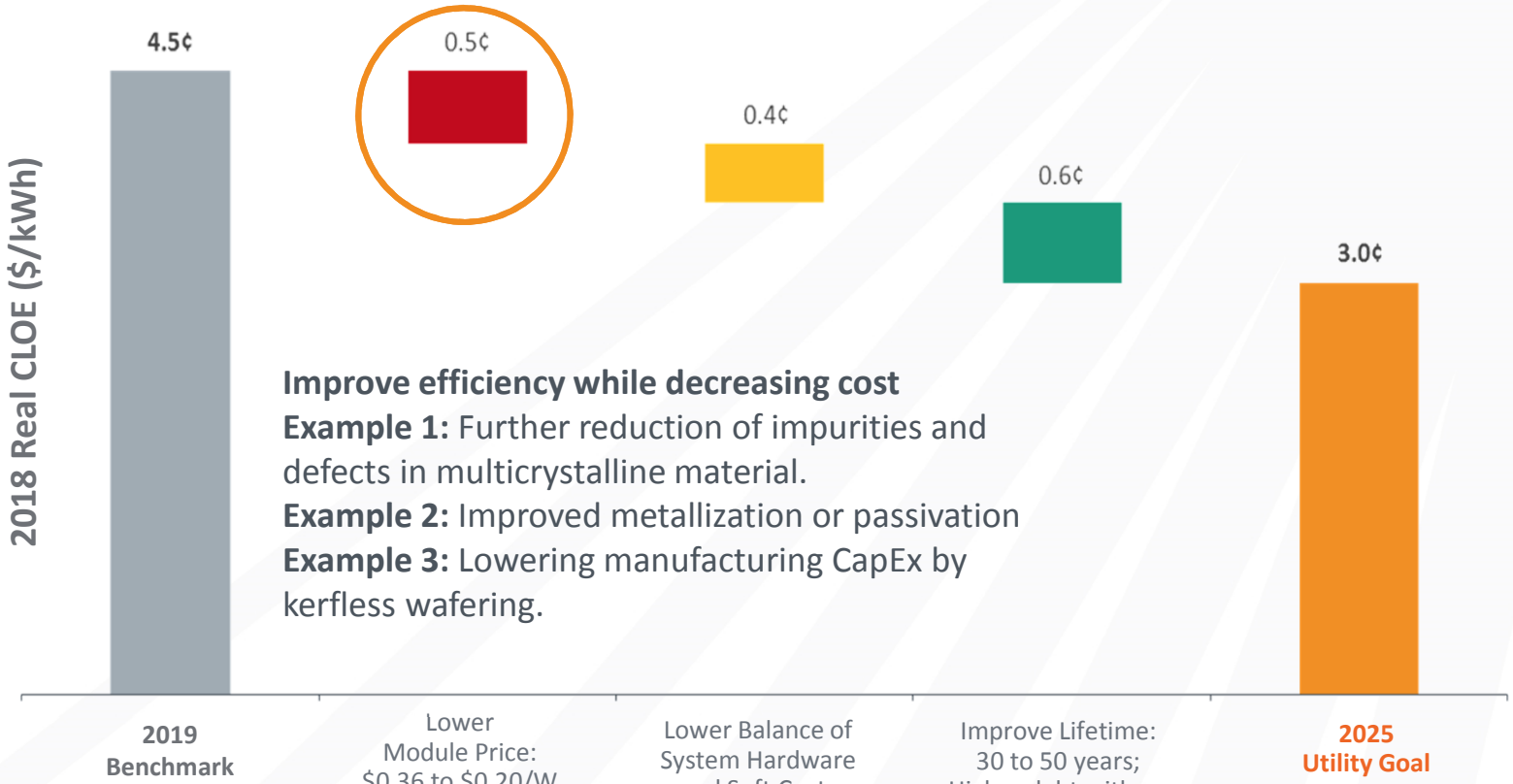
Funds research with a 3-15 year horizon, which is beyond industry focus or capabilities

Supports an innovation ecosystem that includes universities, students, professors, and the private sector

Fosters the transition of research developments into the marketplace



# A Pathway to $0.03 per kWh for Utility-Scale PV



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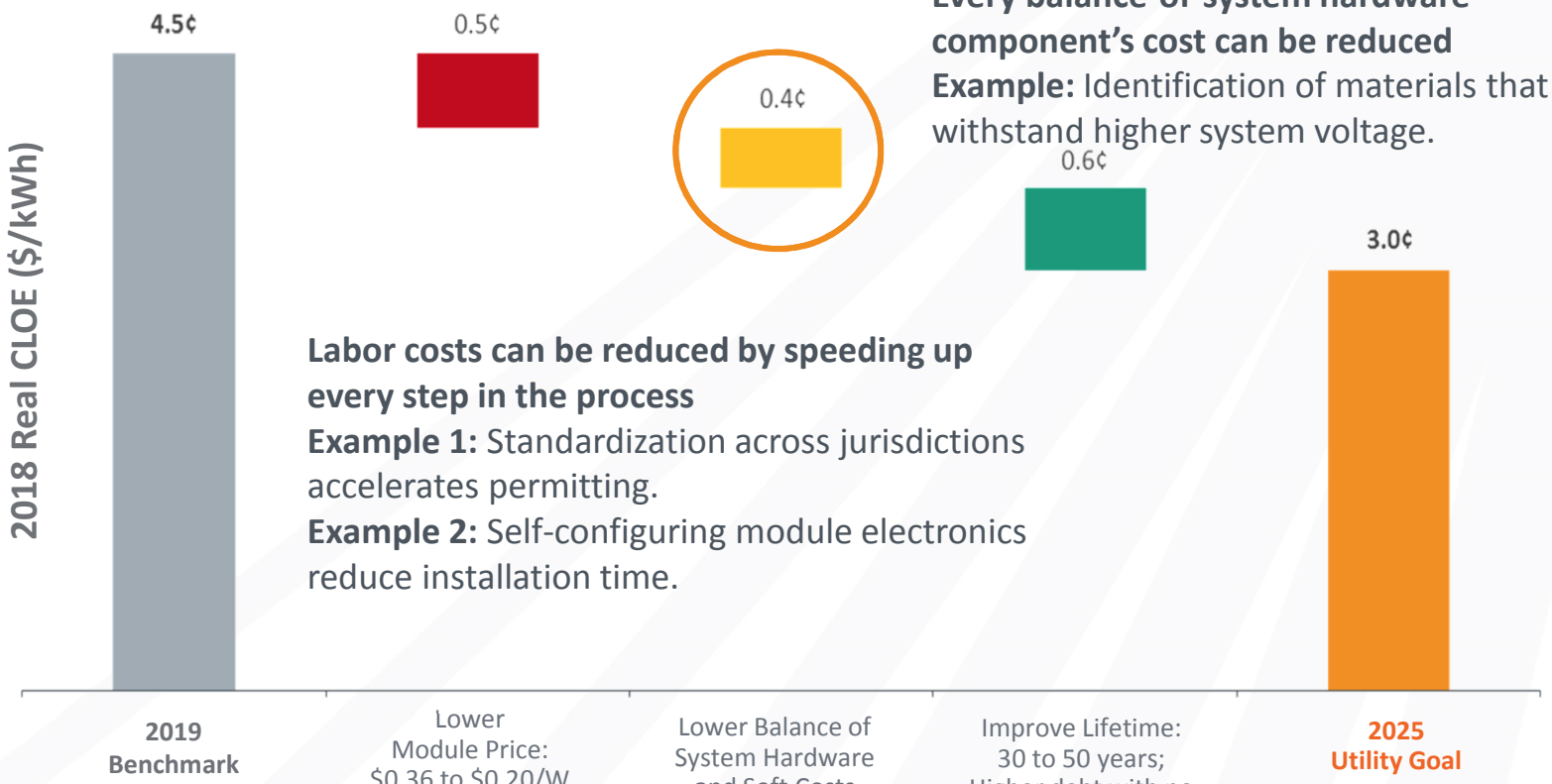
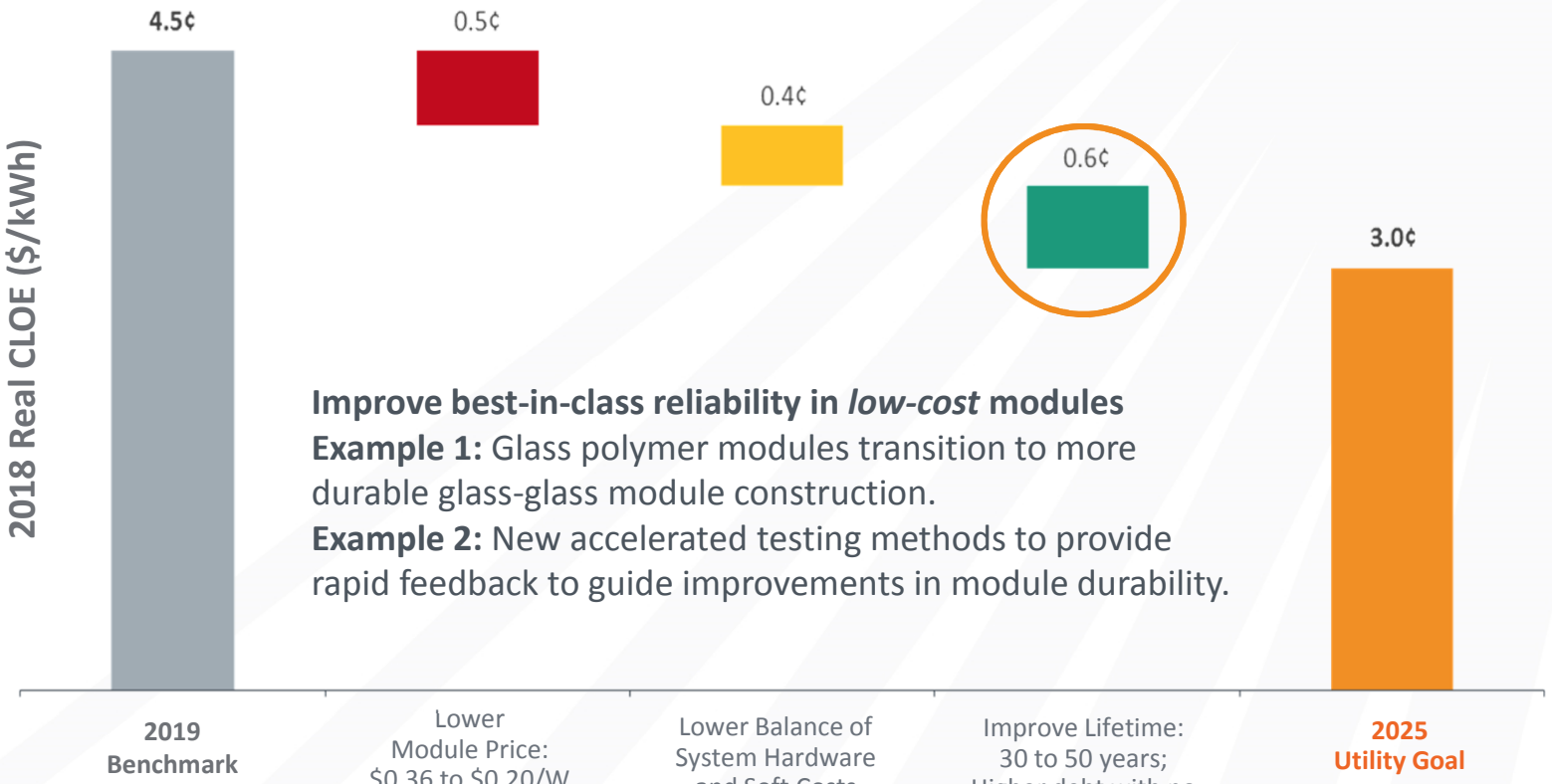



**Every balance-of-system hardware component's cost can be reduced**
**Example:** Identification of materials that can withstand higher system voltage.

**Labor costs can be reduced by speeding up every step in the process**
**Example 1:** Standardization across jurisdictions accelerates permitting.
**Example 2:** Self-configuring module electronics reduce installation time.

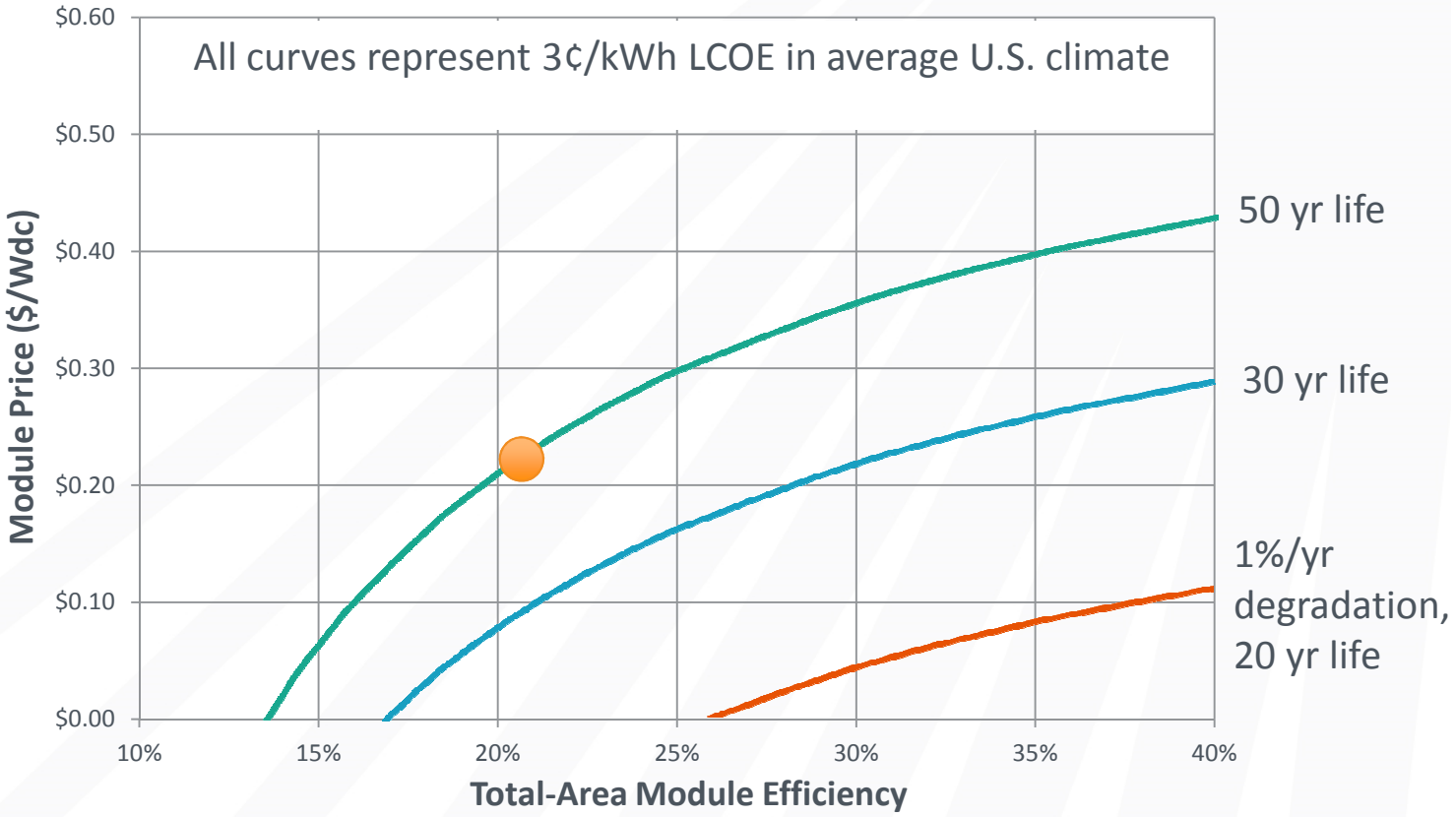
# A Pathway to $0.03 per kWh for Utility-Scale PV




**Improve best-in-class reliability in *low-cost* modules**
**Example 1:** Glass polymer modules transition to more durable glass-glass module construction.
**Example 2:** New accelerated testing methods to provide rapid feedback to guide improvements in module durability.

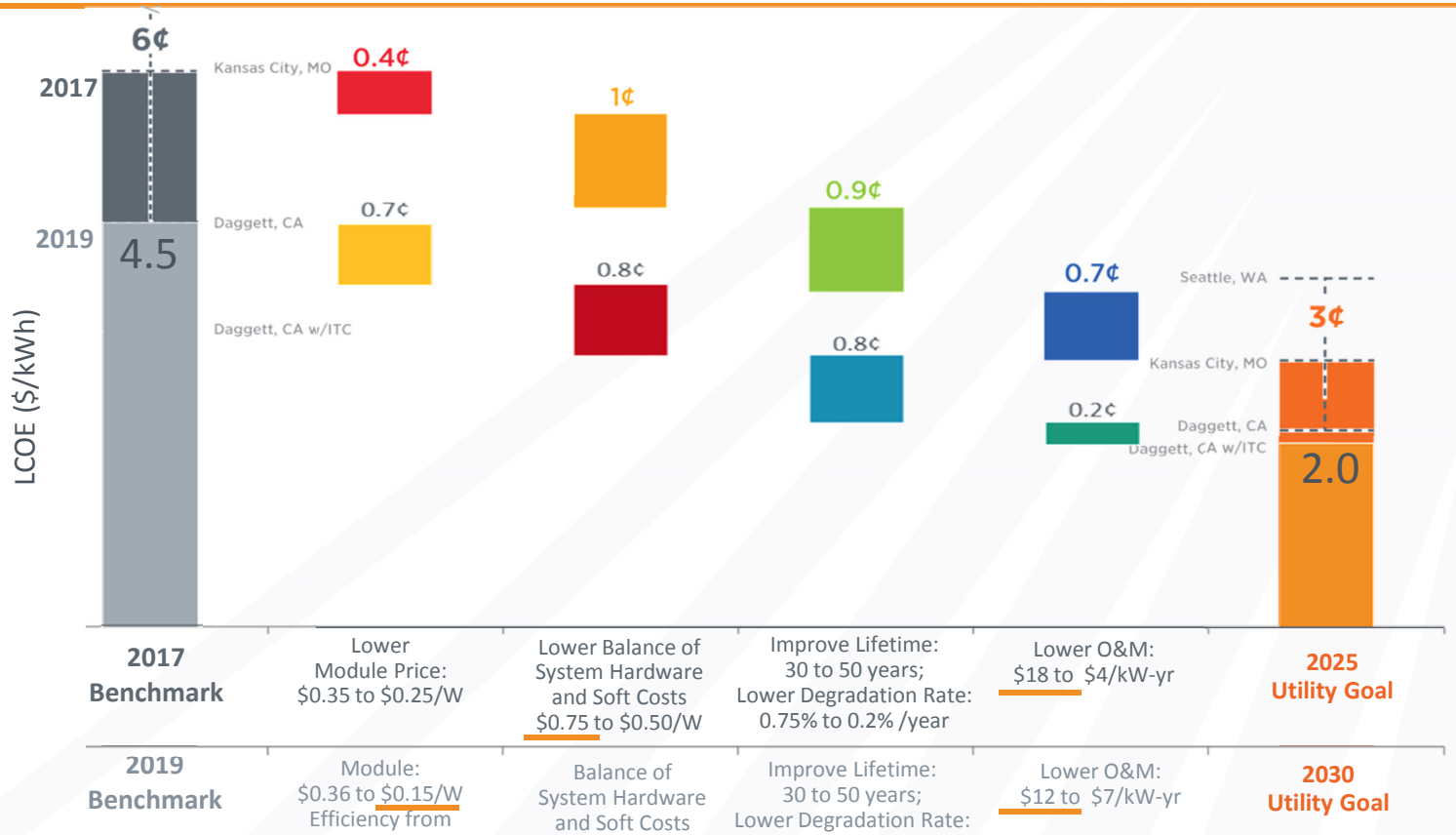
# There are Many Technology Pathways to $0.03/kWh

- Cost and performance tradeoffs open up numerous pathways.
- All pathways require sustained, multifaceted innovation.




Scenarios assume: 7% WACC, 2.5% inflation, $4/kW-yr O&M, 21% capacity factor

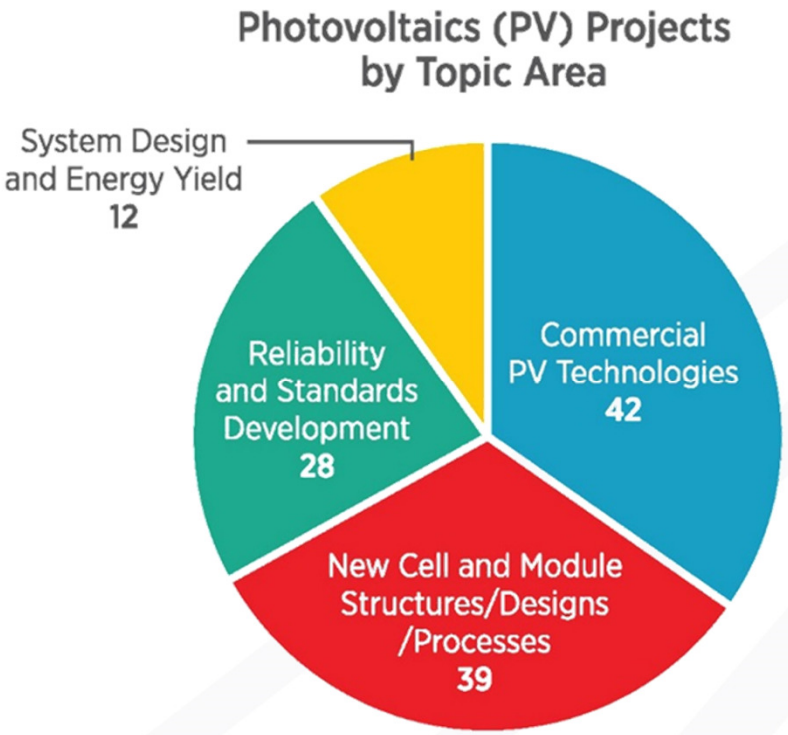
# Can we get to $0.02/kWh?

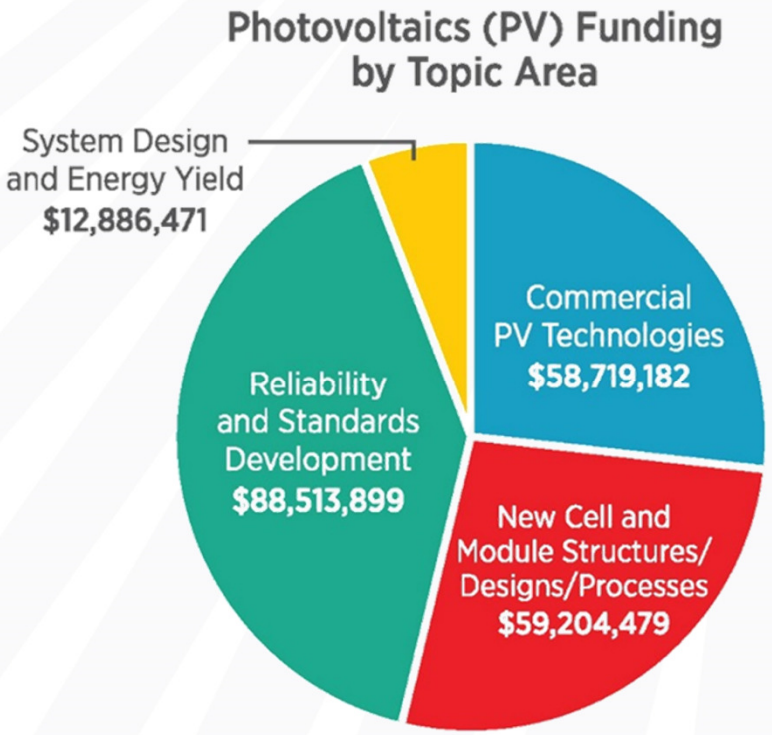


# SETO Photovoltaics R&D

- Commercial Photovoltaic Technologies (Monday)
- New Cell and Module Structures, Designs, and Processes (Tuesday)
- Reliability and Standards Development (Tuesday)
- System Design and Energy Yield (Tuesday)

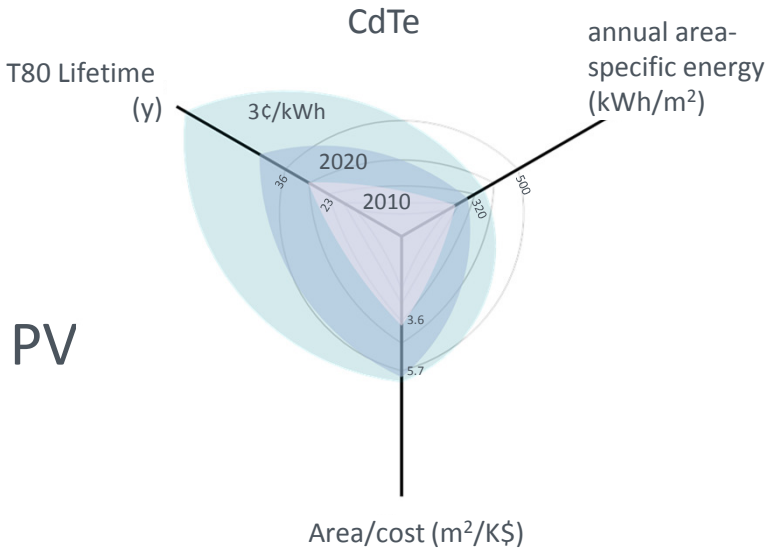
# Active PV Projects (121 projects, $219M)



# SETO Advances Commercial PV Technologies

- Currently a $59M portfolio
- Federal funds used to accelerate advancement in the most competitive technologies
- Bulk of funding directed to CdTe and Si PV




Examples:

- Passivation and heterojunction Si cells
- Understanding defects to increase CdTe performance
- Metallization and paste development



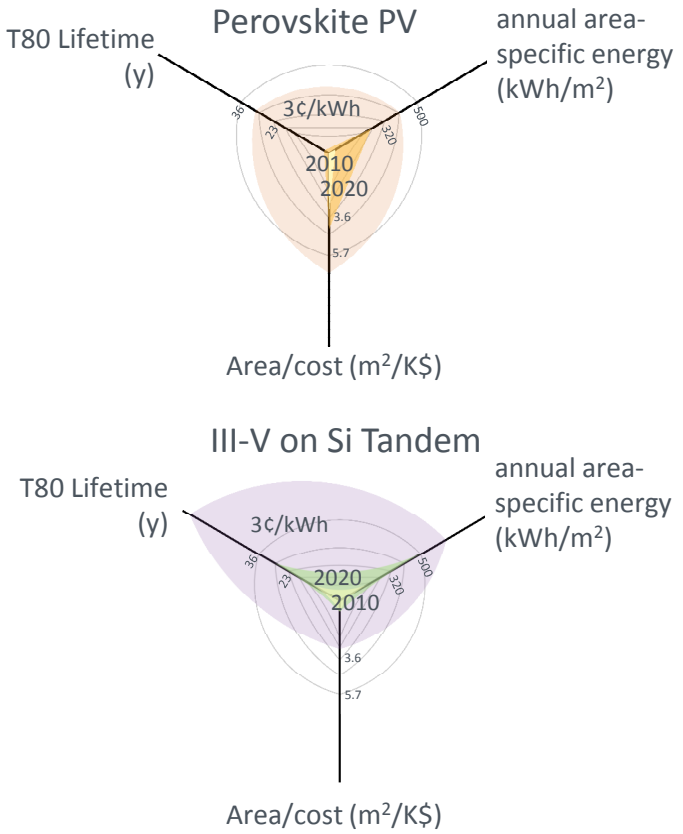
Technology Evaluation Framework development in process by Brittany Smith, Mike Woodhouse, and Robert Margolis (NREL)

# SETO Supports Development of New PV Hardware

- Currently a $60M portfolio
- Provide technology options and diversification of R&D portfolio to enable potentially radially low-cost PV
- Aim to fund areas where there US could have a competitive advantage or strategic capability

Examples:

- Perovskite PV
- New ways to grow III-V cells and reuse substrates
- Tandem modules






Technology Evaluation Framework development in process by Brittany Smith, Mike Woodhouse, and Robert Margolis (NREL)

# … and Advanced System Designs to Increase Energy Yield

- $13M portfolio that has been growing
- Federal funds used to increase the energy yield (kWh/kW) in a variety of climates
- Research and development to expand PV deployment options so that the solar resource can be more fully utilized

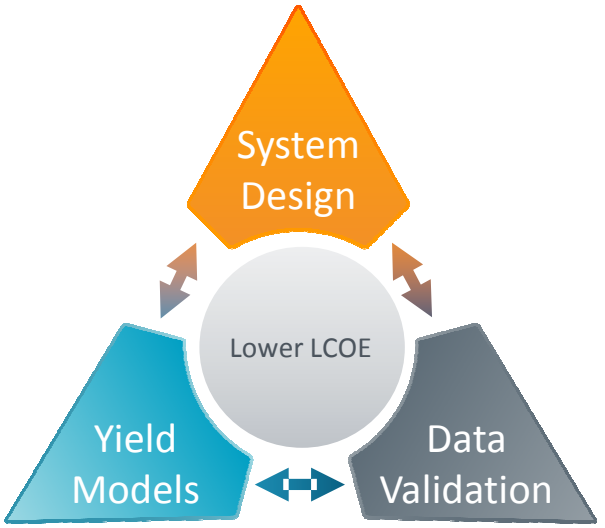
Bifacial test centers at NREL and SNL

Examples:

- Characterizing bifacial gain and creating an albedo database
- Improved performance in snowy climates
- Low-cost PV mounting systems

# SETO Works to Ensure Systems Deliver as Expected

- Currently an $89M portfolio
- System lifetime is a large lever on LCOE but must be reliable and financeable
- Most of global fleet is young and technologies are continually changing
- PV deployment is accelerating and the industry needs to be able to predict, understand, and mitigate degradation

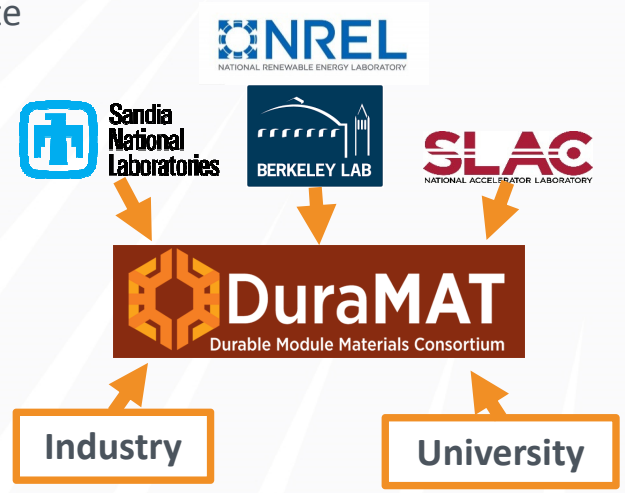



- We need performance data, acceleration protocols, and advanced modules to extend the bankable service life of PV systems

# DuraMat: Durable Module Materials Consortium

- Brings *national laboratory* and *university* infrastructure together with photovoltaic (PV) *supply chain and manufacturing industry* to accelerate development of durable packaging materials and technology transfer
- Industry Advisory Board guides strategic and technical direction of consortium

| | Capability Network | | | | | |
|---|---|---|---|---|---|---|
| | Data Management & Analysis | Predictive Simulation | Materials Forensics | Module Phototyping & Test | Outdoor Testing | Techno-economic Analysis |
| DuraMAT Projects | DataHub | Multi-scale Module Simulation | Material Properties and Aging | Accelerated Testing | Non-Destructive Testing | Quantify LCOE |
| | Software Development and Machine Learning | Materials Modeling | Correlating Accelerated Testing and Field Data | UV Ionization Damage | Field Aged Module Library | Decision Support |
| | PVDAQ Upgrade | Flexible Modules | Barrier and Encapsulants | ECA and Contacts | Wind Loading and Structural Materials | Financial Modeling |
| | Data Visualization | Materials Selection | Cell Cracking | Module Design and Fabrication | | Circular Economy |
| | | | Front Coating | | | |



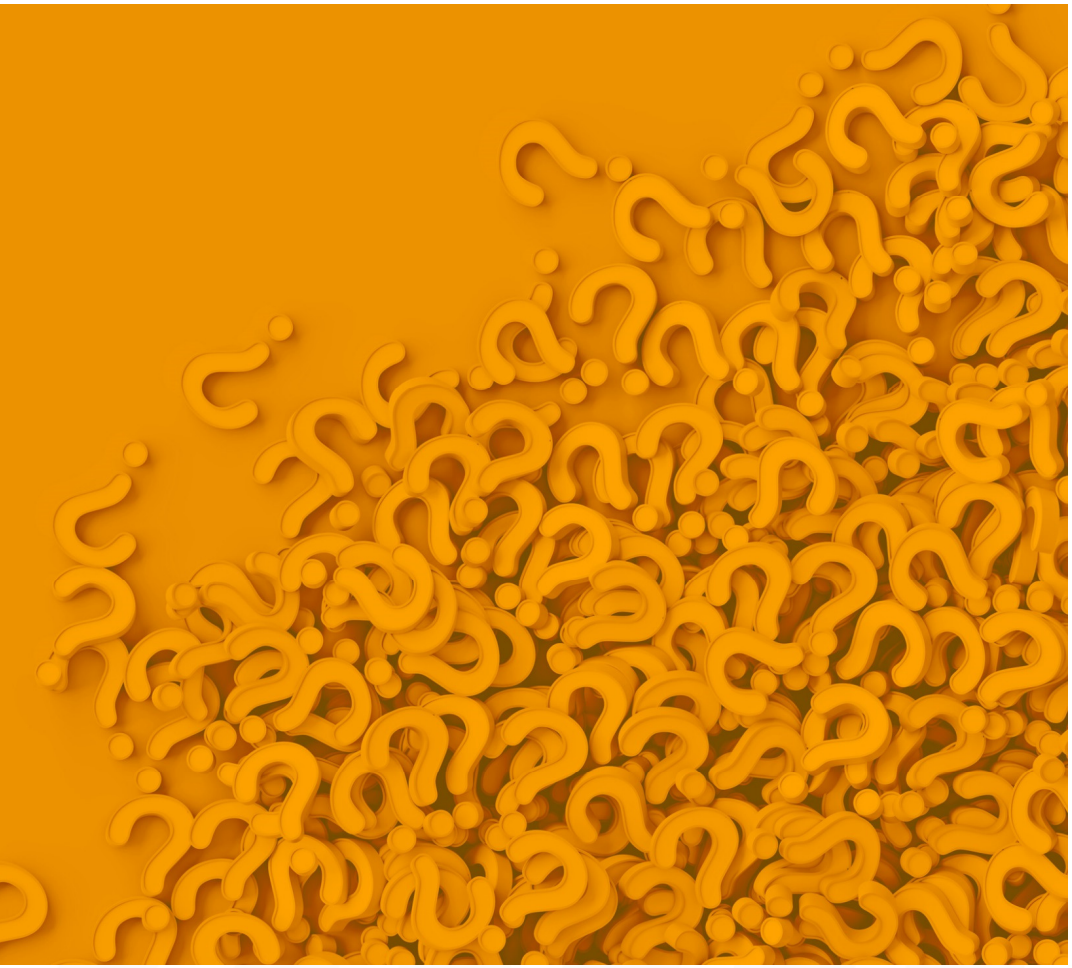

***Combined accelerated stress testing at NREL to identify PV degradation modes***

https://www.duramat.org/

# A Quick Recap

- SETO funds a diverse PV portfolio that spans academic, industrial and National Lab research with the goal of driving down the LCOE costs of PV
- We emphasize information dissemination and diffusion that is appropriate for the activity
- Reliability is an increasing part of our portfolio which is guided by techno economic analyses
- We're looking forward to your feedback on how we can improve our program!

# QUESTIONS?



# Reviewer Panel Introductions

Chair: Sarah Kurtz

Lead Reviewers:

- Rhonda Bailey (Reliability and Standards Development)
- John Benner (New Cell and Module Structures, Designs, and Processes
- Terry Jester (Commercial Photovoltaic Technologies
- Scott Stephens (System Design and Energy Yield

Reviewers:

- Atiye Bayman
- Jason Bobruk
- Howard Branz
- Evelyn Butler
- Danny Cunningham
- Denis DeCeuster
- Jianming Fu
- Katharina Gerber
- Markus Gloeckler
- Ethan Good
- Steve Hogan
- Zakya Kafafi
- Greg Kimball
- Alex Mayer
- Rommel Noufi
- Robert Opila
- Jon Previtali
- Paul Sharps
- William Shisler
- Bruce Sohn
- Joe Song
- John Wohlgemuth

| | MONDAY | TUESDAY |
|---|---|---|
| **11:00 AM** | Plenary | System Design Research Thesis and the Importance of Performance Data – Tassos Golnas |
| 11:20 | | System Design Discussion |
| 11:40 | | |
| **12:00 PM** | | Intro to Reliability Research Thesis– Marie Mapes |
| 12:20 | | PV Reliability Discussion with Reviewers |
| 12:40 | | |
| **1:00 PM** | BREAK | BREAK |
| 1:20 | | |
| 1:40 | Introduction to PV Track – Lenny Tinker | New PV Tech Research Thesis and Overview of III-Vs – Susan Huang |
| **2:00 PM** | Introduction of Review Panel – 10 min – Sarah Kurtz Peer Review Agenda Overview and Desired Outcomes of the Review – 5 min – Lenny | New III-V R&D Discussion |
| 2:20 | Intro to Commercial PV Research Thesis and Portfolio Overview of Si Research – Susan Huang - 20 min | Portfolio Overview PVSK and OPV – Andrew Dawson |
| 2:40 | Silicon PV Discussion | 1) PVSK and OPV R&D Discussion<br>2) Other New PV Technologies Discussion |
| **3:00 PM** | | |
| 3:20 | BREAK | BREAK |
| 3:40 | Thin Film Research Portfolio Overview – Brion Bob | Final questions about overall portfolio or federal processes? |
| **4:00 PM** | Thin Film PV Discussion | Reviewer Internal Discussion |
| 4:20 | | |
| 4:40 | Reviewer Internal Discussion | |
| **5:00 PM** | | |

| | WEDNESDAY |
|---|---|
| **11:00AM** | Reviewer Roundtables by Topic, Lenny available in case needed for any questions |
| 11:15 | |
| 11:30 | |
| 11:45 | |
| **12:00PM** | |
| 12:15 | |
| 12:30 | BREAK |
| 12:45 | Reviewer Roundtables with Staff - All PV together |
| **1:00PM** | |
| 1:15 | |
| 1:30 | |
| 1:45 | |
| **2:00PM** | |
| 2:15 | BREAK |
| 2:30 | |
| 2:45 | Chair and P&S Roundtable (Track chairs meet with Strategy and Planning reviewers) |
| **3:00PM** | |
| 3:15 | |
| 3:30 | |
| 3:45 | Chair and P&S Roundtable with SETO Leadership |
| **4:00PM** | |
| 4:15 | |
| 4:30 | |
| 4:45 | |
| **5:00 PM** | |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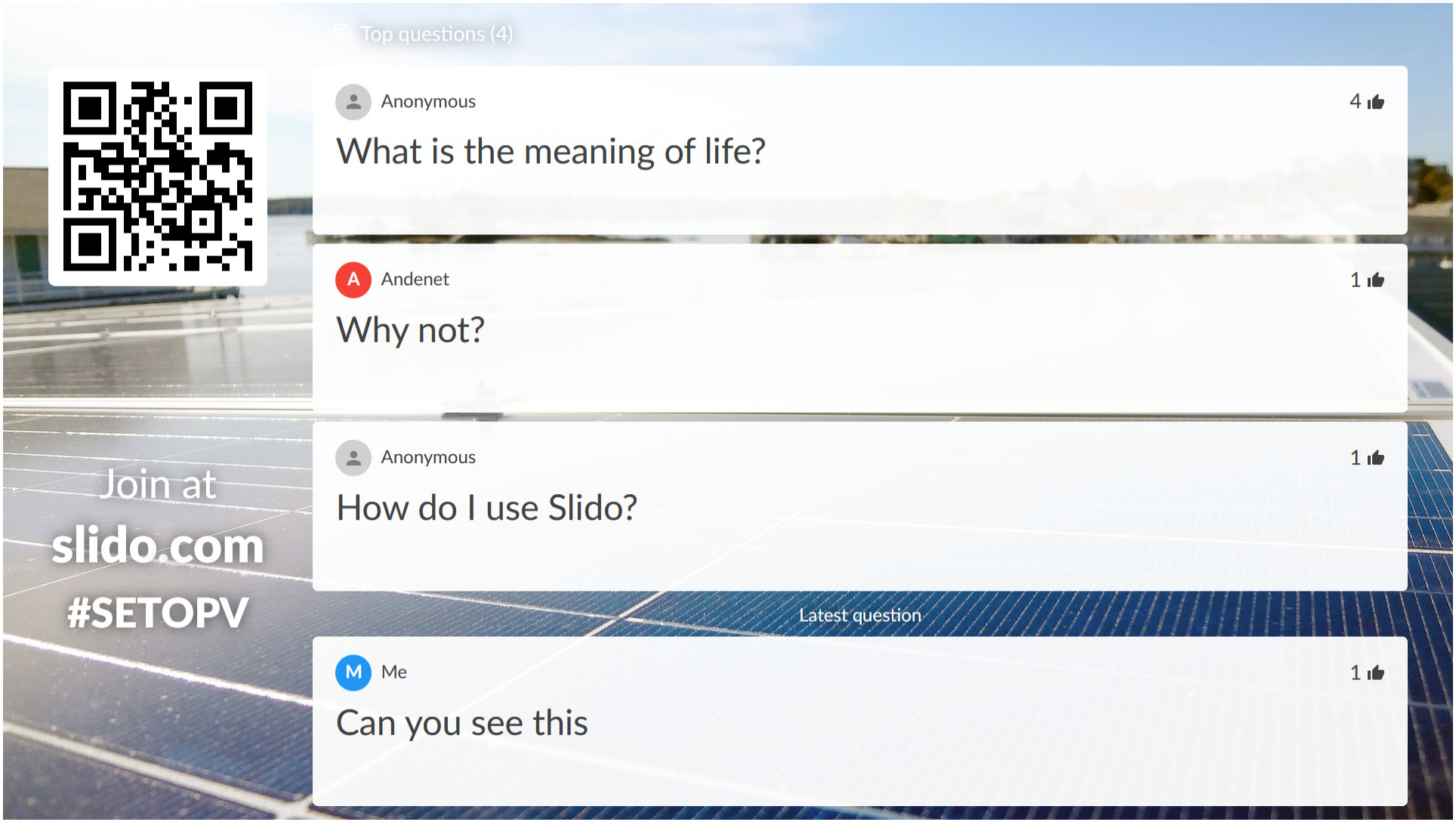
Top questions (4)
Anonymous
4
What is the meaning of life?
A
Andenet
1
Why not?
Anonymous
1
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Me
1
Can you see this

# Engaging in Q&A

- Discussion will begin with the most popular questions listed in the Slido
  - Please type “Comment” in the WebEx chat box if you would like to ask a follow on question or comment etc.
  - We will use this to create a sort of queue and hopefully prevent us from speaking over each other
- If you are experiencing any kind of technical difficulty or other difficulty, please use the WebEx chat to message the “Host” and we will sort it out as quickly as possible