
Welcome to the 2020
SETO Peer Review

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

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

Keynote and Welcome

Daniel R Simmons, Assistant Secretary
Office of Energy Efficiency and Renewable Energy (EERE)

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

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

SETO in 2020:

A Decade of Progress, A Promising Future

Dr. Becca Jones-Albertus, Director

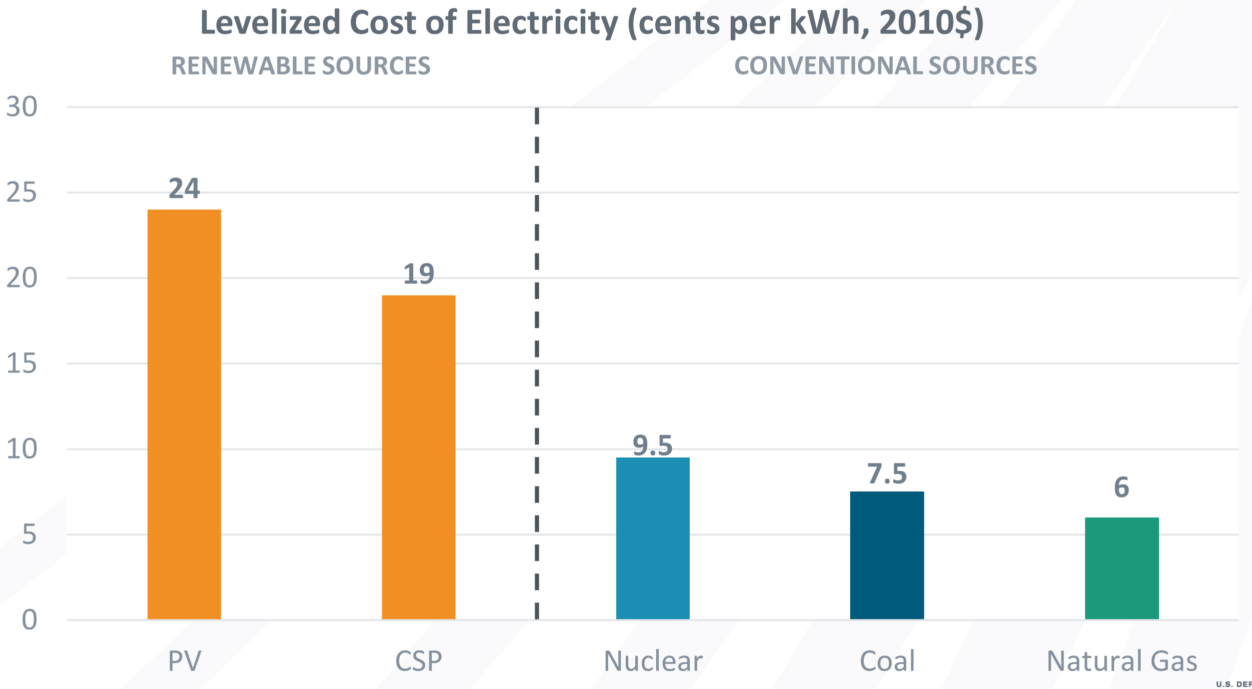
Solar Energy Technologies Office

A Decade of Progress, A Promising Future

- Solar since 2010: A Decade of Progress
- 2020: Where Are We Now?
- Looking to 2030: A Bright Future for Solar

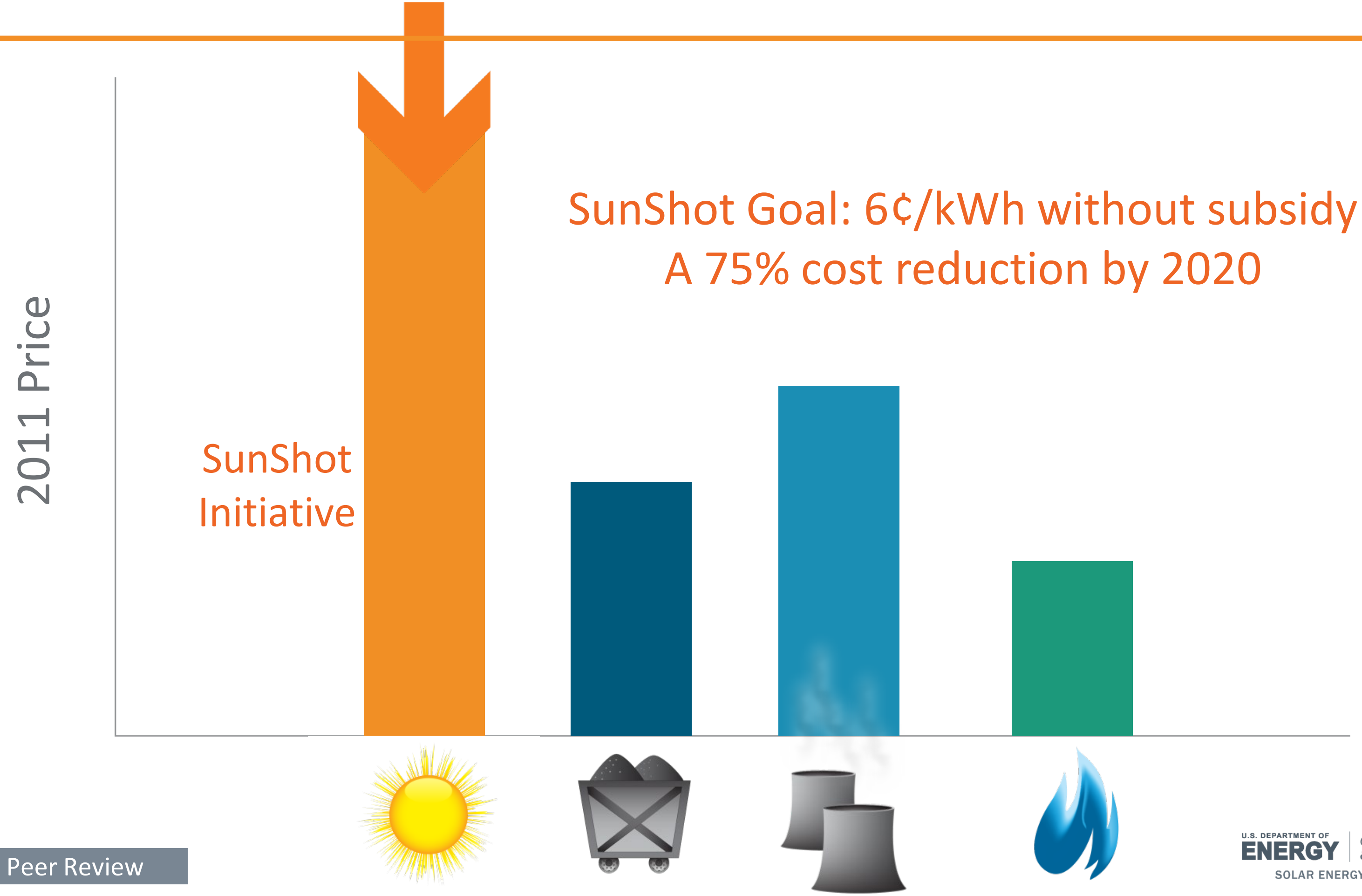
Just 10 Years Ago

0.5 gigawatts solar capacity in the United States

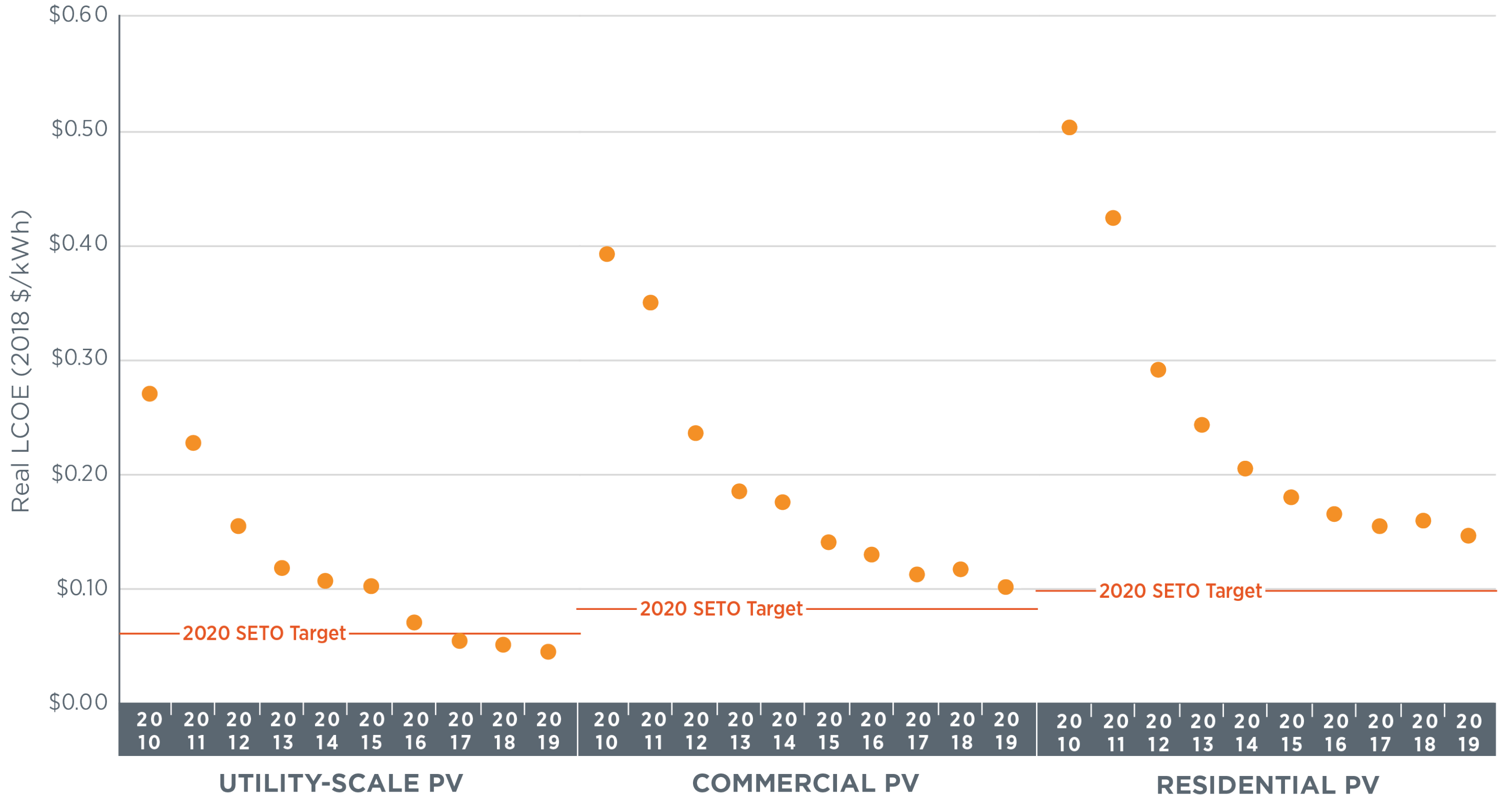


Notes: Assumes Federal & state incentives. CSP assumes trough technology. Natural gas price of $4.57/MMBTU
Sources: Navigant Consulting, Inc. 2010

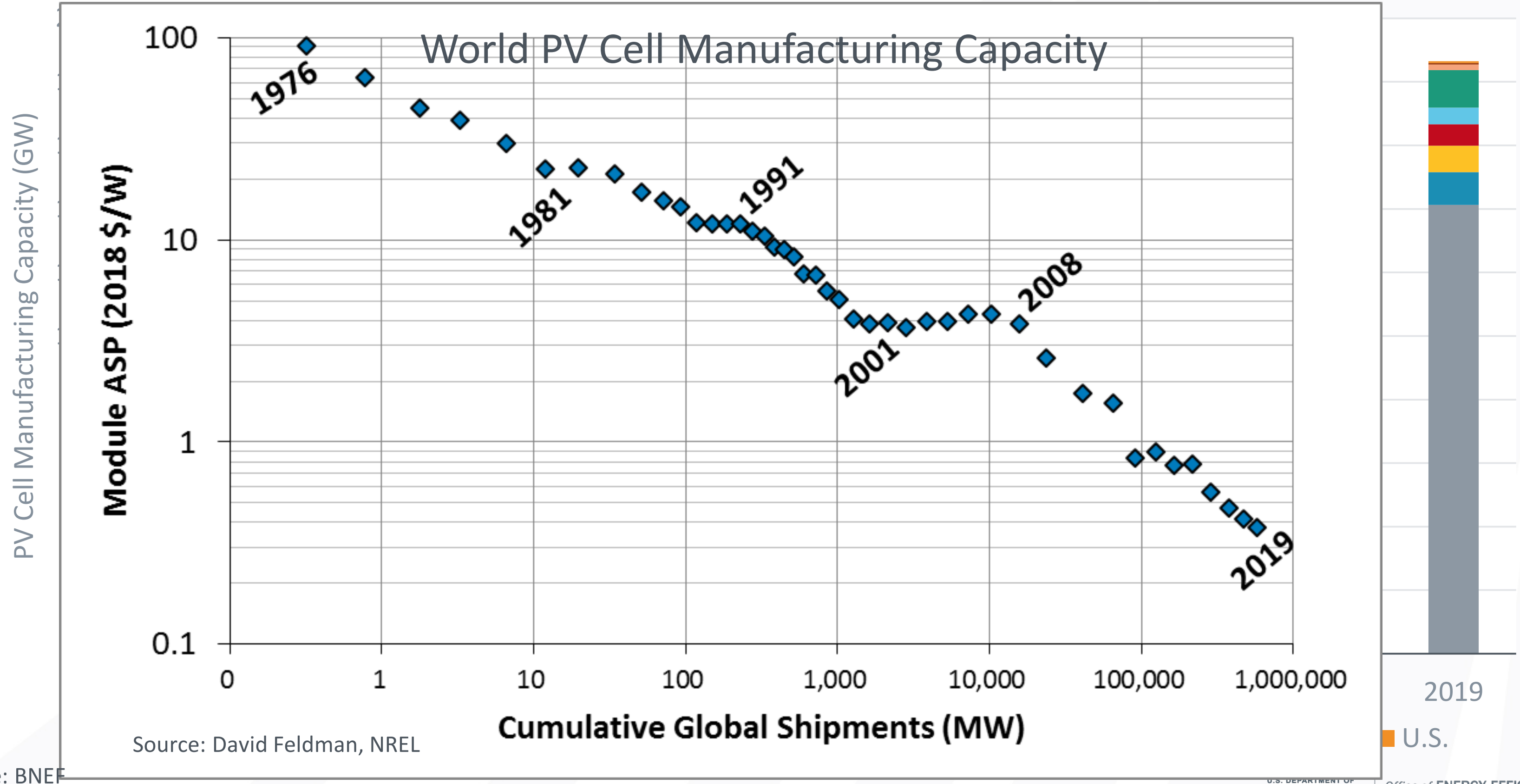
SunShot Initiative



Cost Declines of 70% - 80%

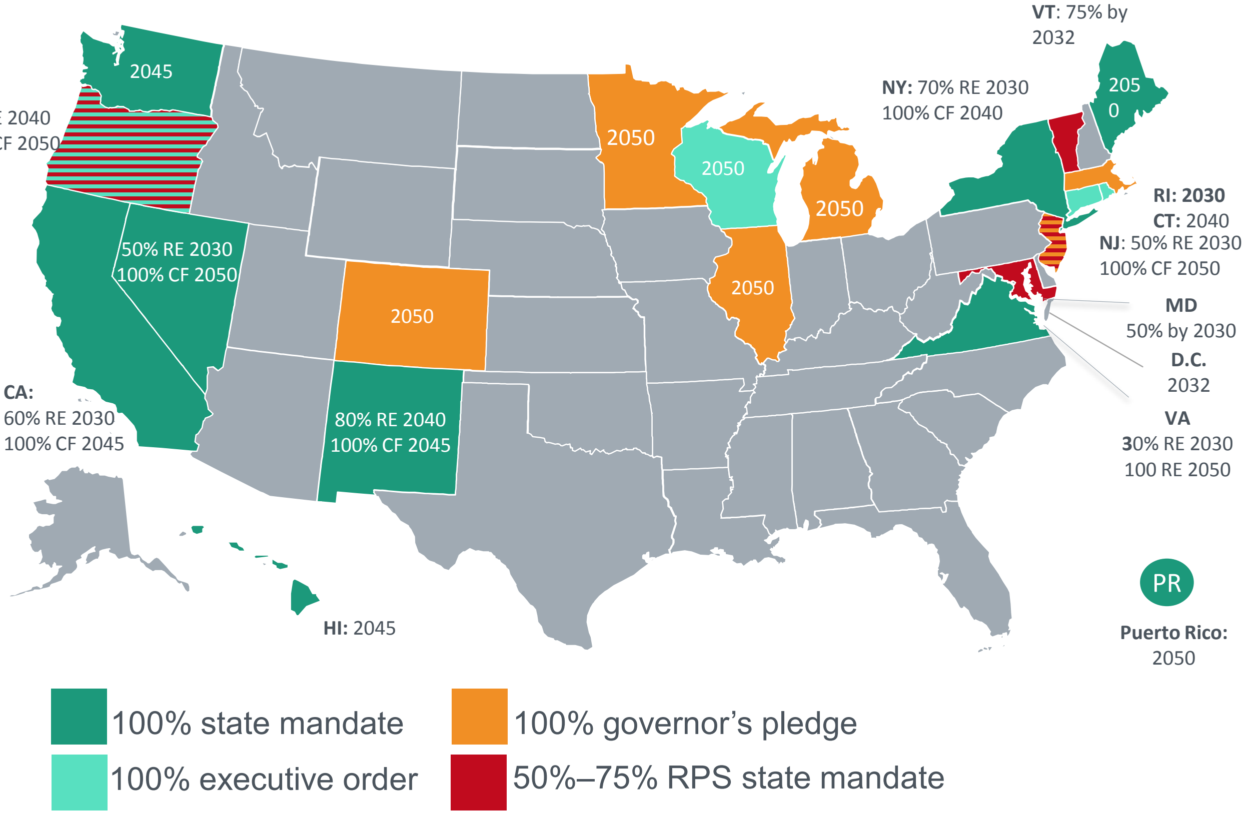


Advancing the Learning Curve with Economies of Scale



Source: BNEF

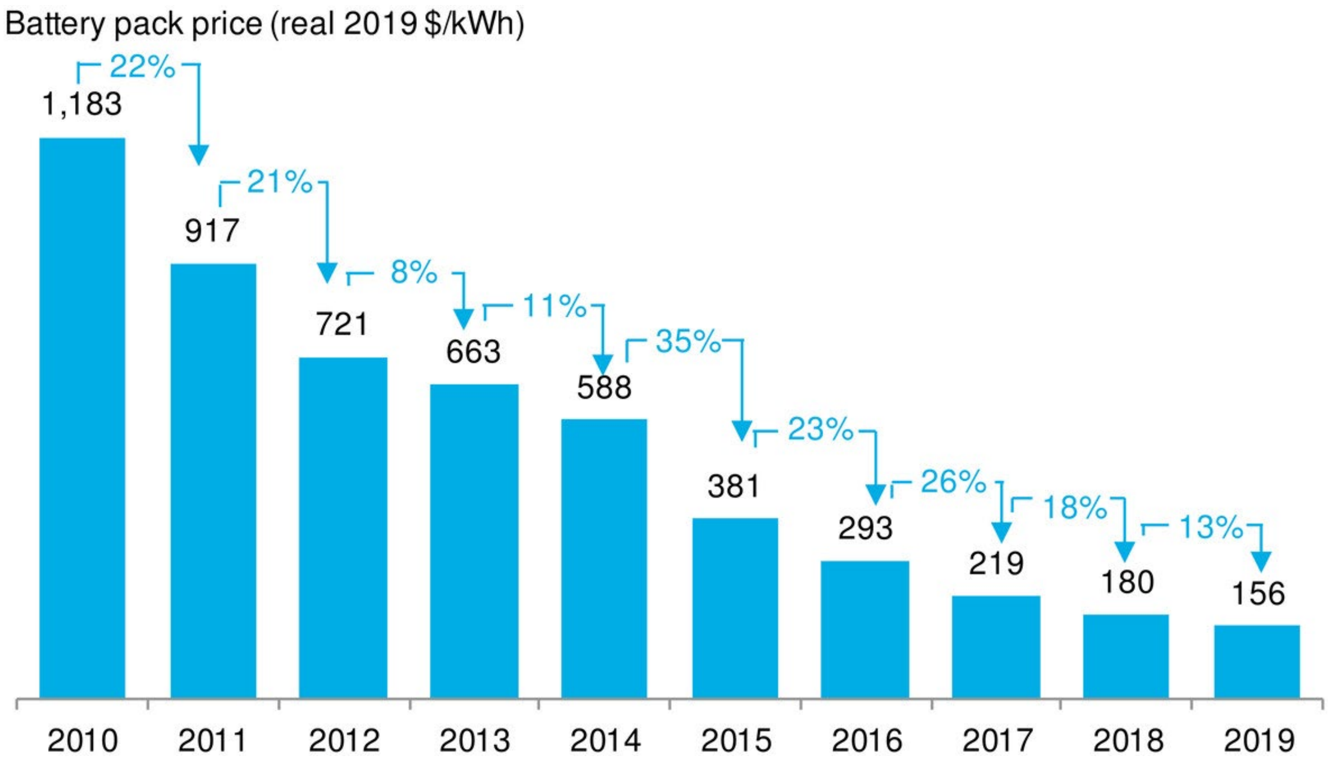
Policies Driving Demand



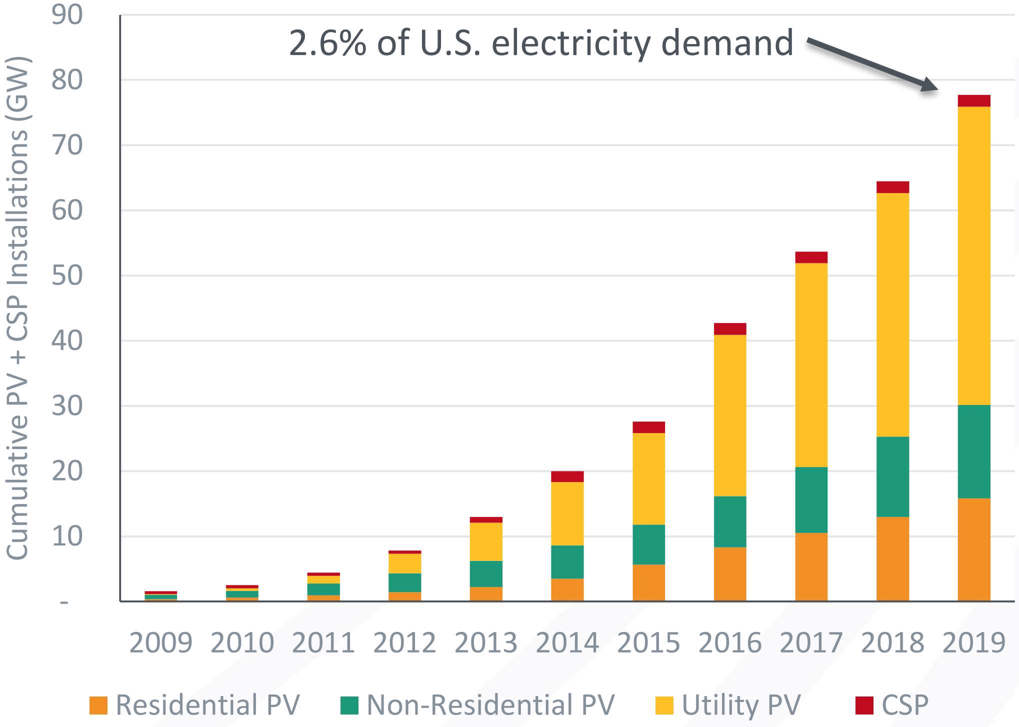
The Federal Investment Tax Credit provided 30% off the system cost.

State and local governments, as well as corporations, have been driving demand with their own policies and incentives.

Battery Costs Falling

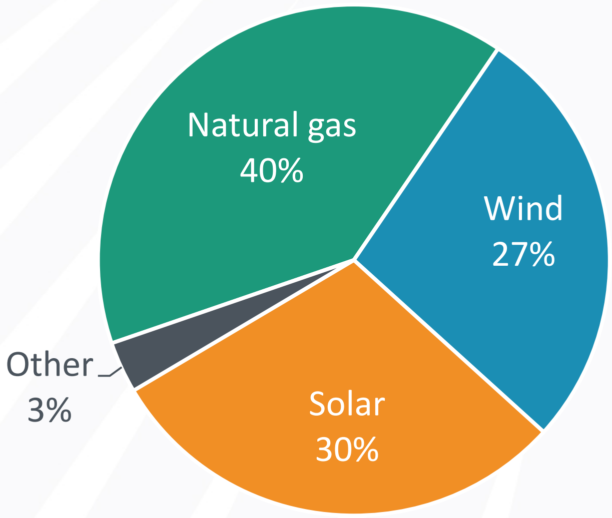


The Result: U.S. Solar Capacity Grows 50x in 10 Years



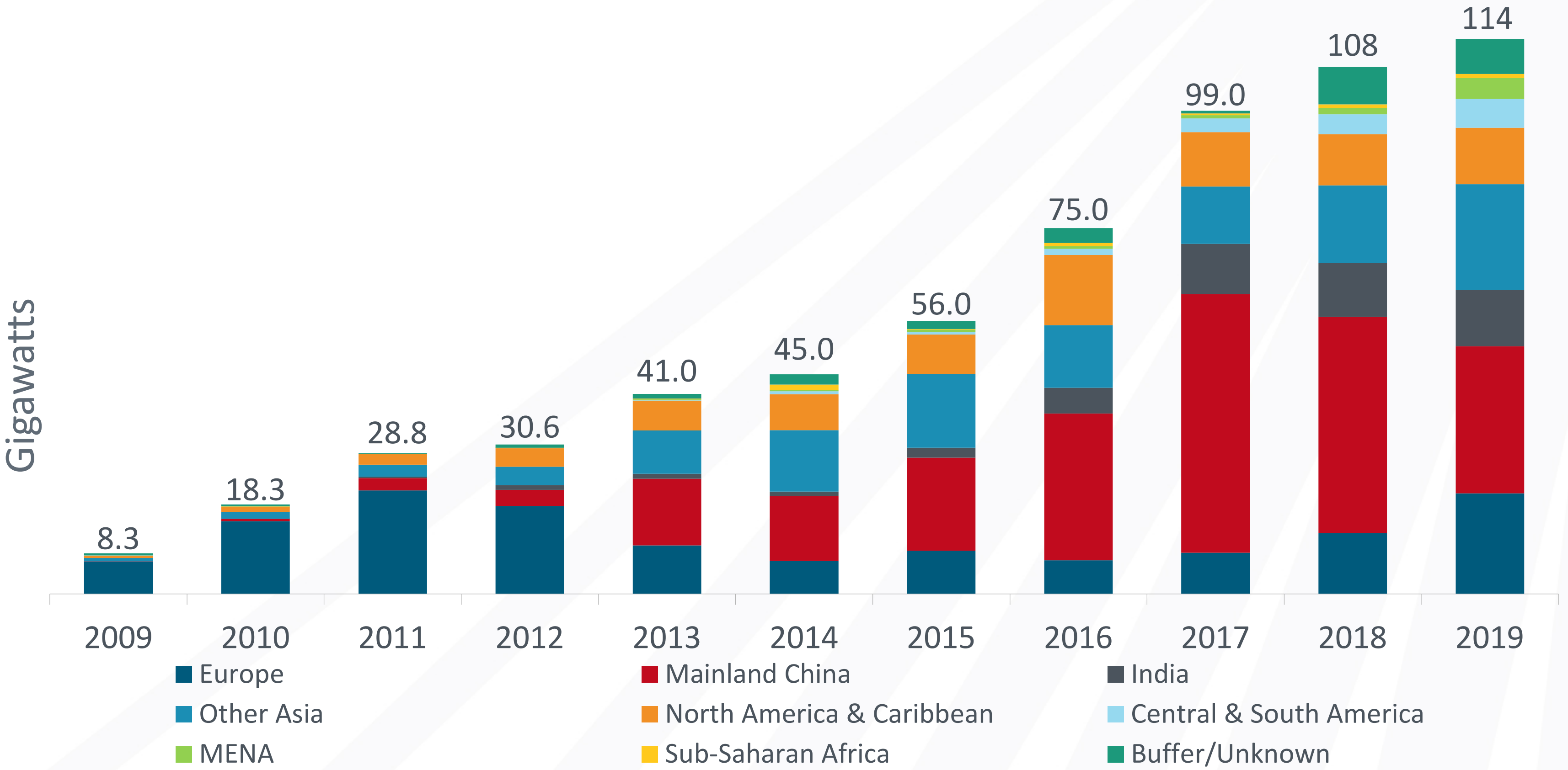
Sources: Wood Mackenzie

New Capacity from 2015 - 2019



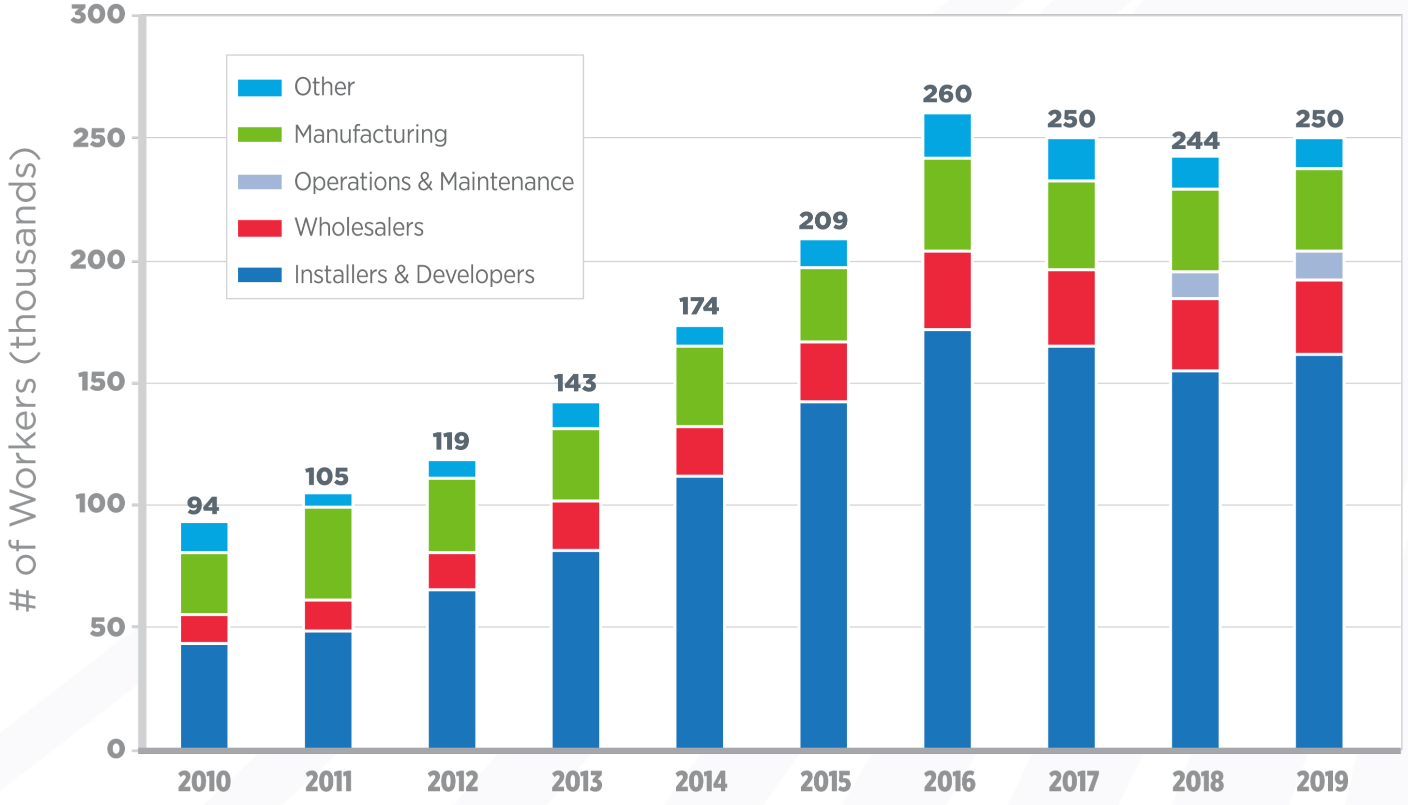
Solar energy represented **30%** of new capacity additions **over the past 5 years** and now supplies over 2.5% of the nation's annual U.S. electricity.

Global PV Capacity Grows as well



Source: BloombergNEF

Job Growth



Source: The Solar Foundation

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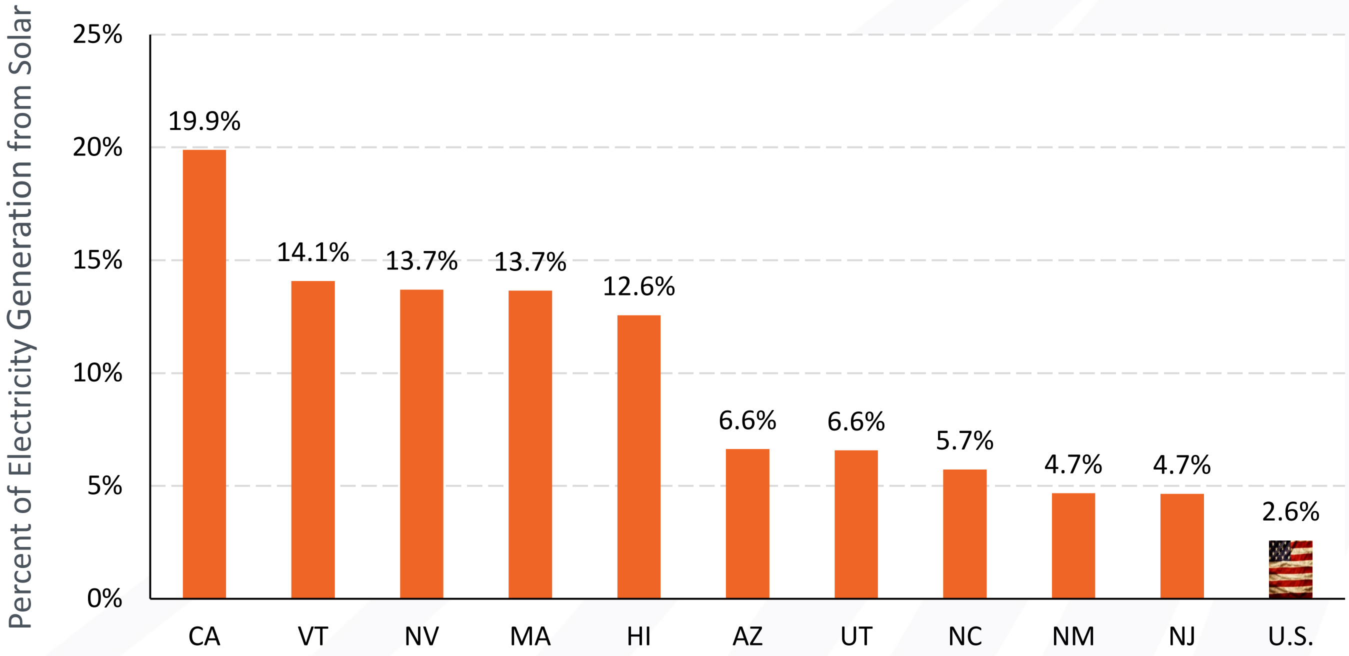
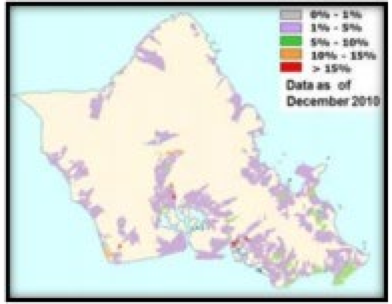
Percent of U.S. Electricity from Solar (2019)



Sources: U.S. Energy Information Administration, "Electric Power Monthly," forms EIA-023, EIA-826, and EIA-861. U.S. Energy Information Administration, "Electricity Data Browser." Accessed March 27, 2020. IEA, "PVPS 2019 Snapshot of Global PV Markets."

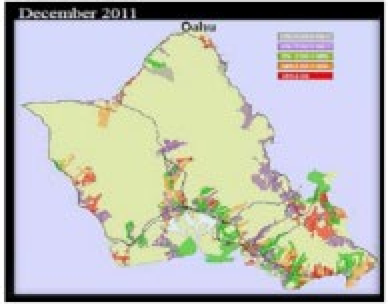
Note: EIA monthly data for 2019 are not final. Additionally, smaller utilities report information to EIA on a yearly basis, and therefore, a certain amount of solar data has not yet been reported. "Net Generation" includes DPV generation. Net generation does not take into account imports and exports to and from each state and therefore the percentage of solar consumed in each state may vary from its percentage of net generation.

Grid Integration Concerns with Increasing Deployment



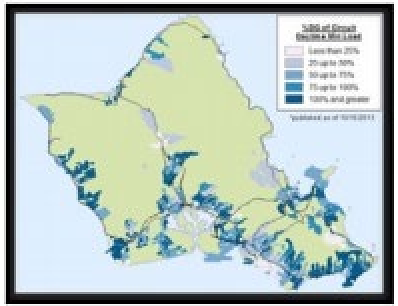
2010

Many feeders
> **1%**
Gross daytime minimum load (GDML*)



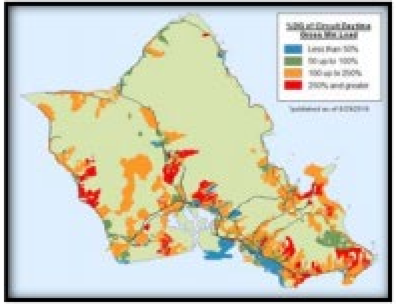
2011

Many feeders
> **15%**
GDML



2013

Many feeders
> **100%**
GDML



2016

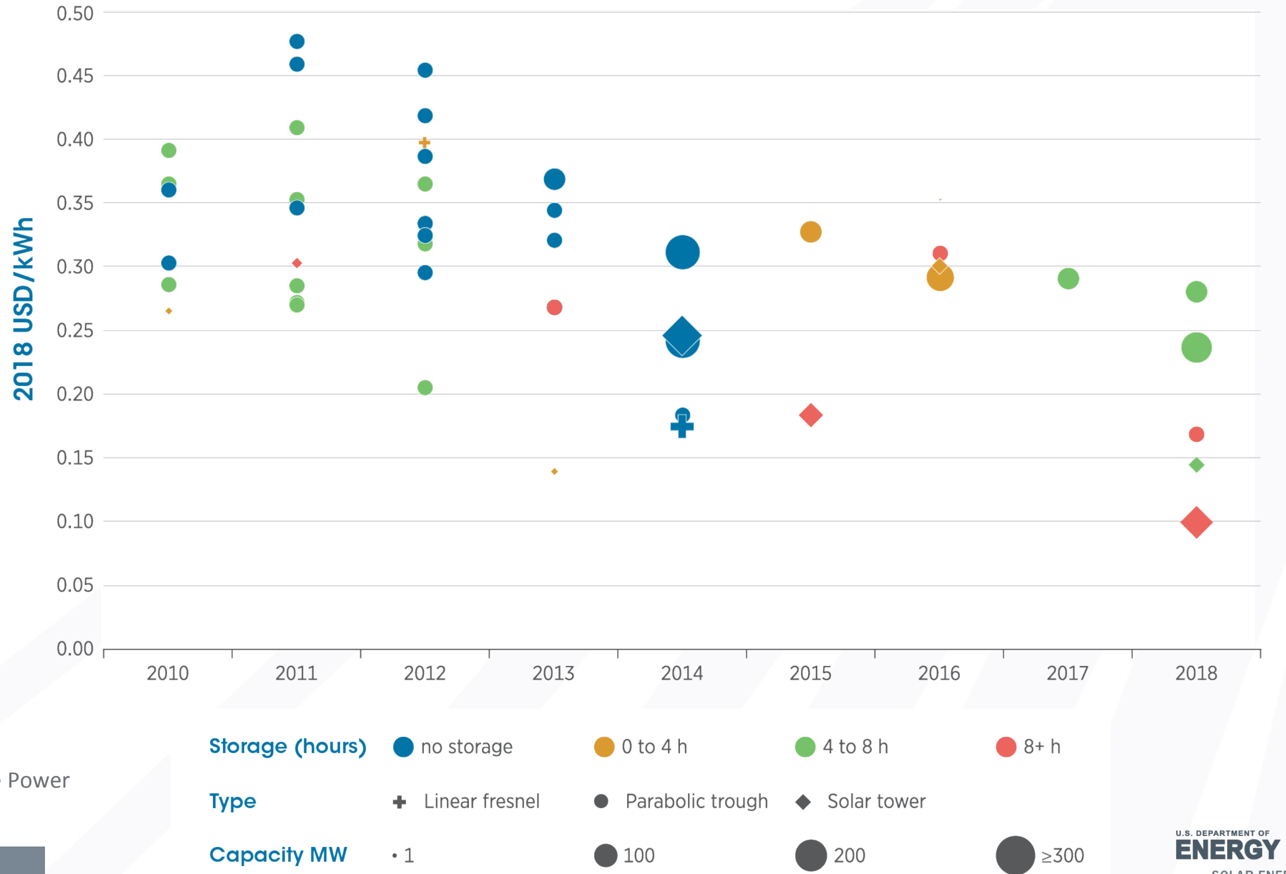
Many feeders
> **250%**
GDML

Source: Andy Hoke, NREL

*GDML = The minimum feeder load the utility would see during daylight hours if PV were not present

Slide courtesy of Adam Warren, NREL. (Modified)

LCOE of Concentrating Solar-Thermal Power (CSP)



Source: IRENA, "Renewable Power Generation Costs in 2018."

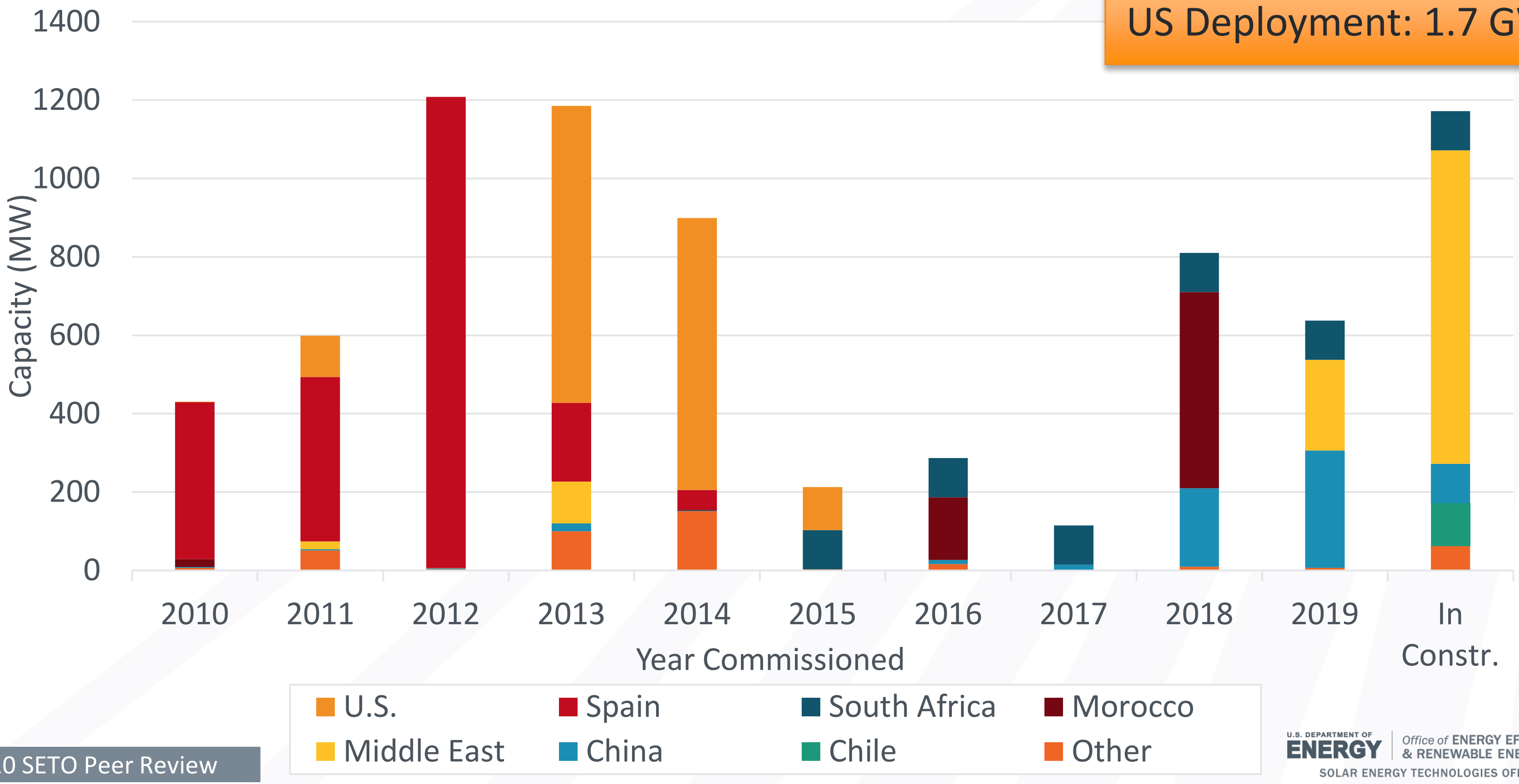
CSP Has Reached Competitive LCOE in Limited Cases

2018 PPA Price $0.06-$0.07/kWh

10MW Retrofit of Shouhang CSP Underway with sCO_2 and EDF Financing

CSP Deployment: 7 GW Worldwide

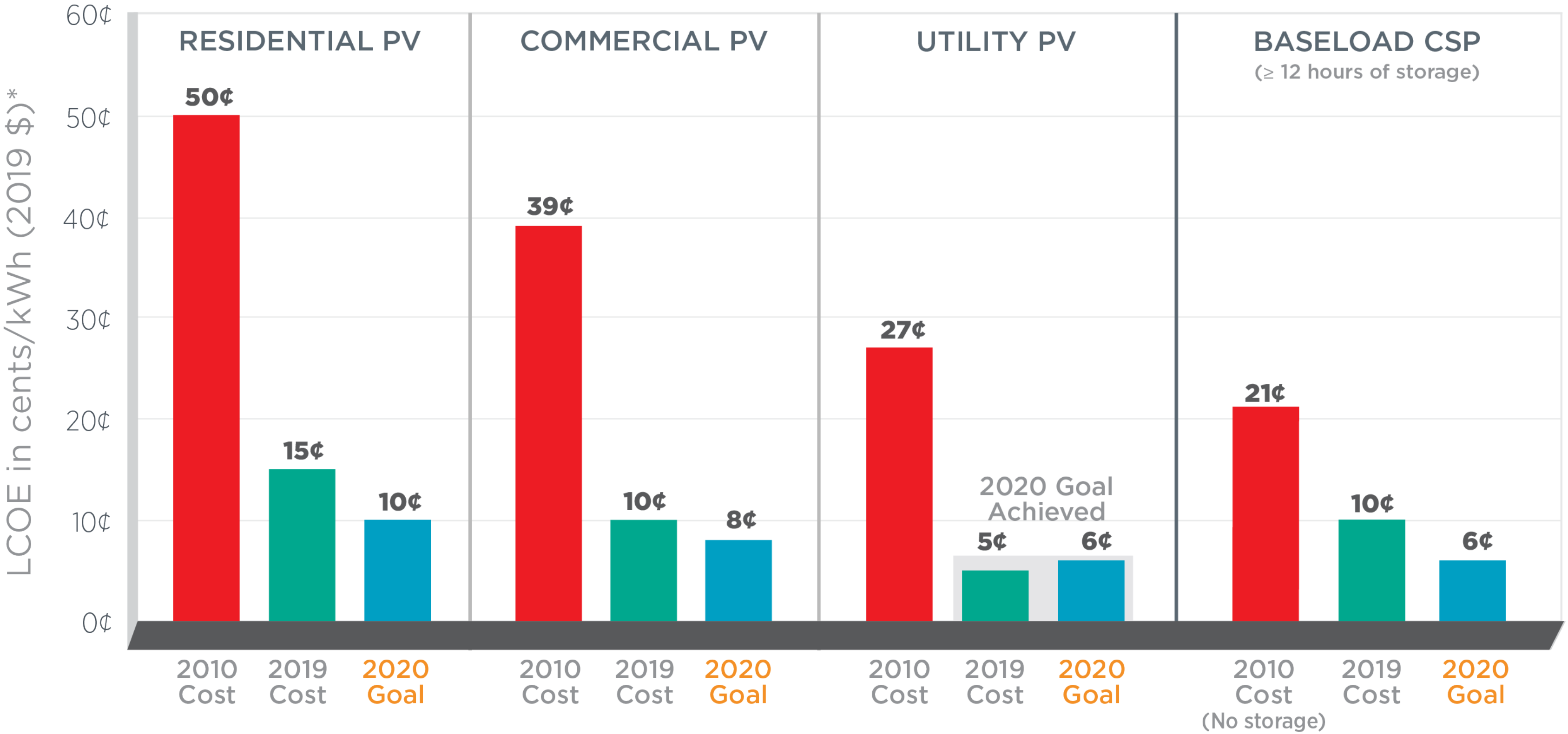
US Deployment: 1.7 GW



A Decade of Progress, A Promising Future

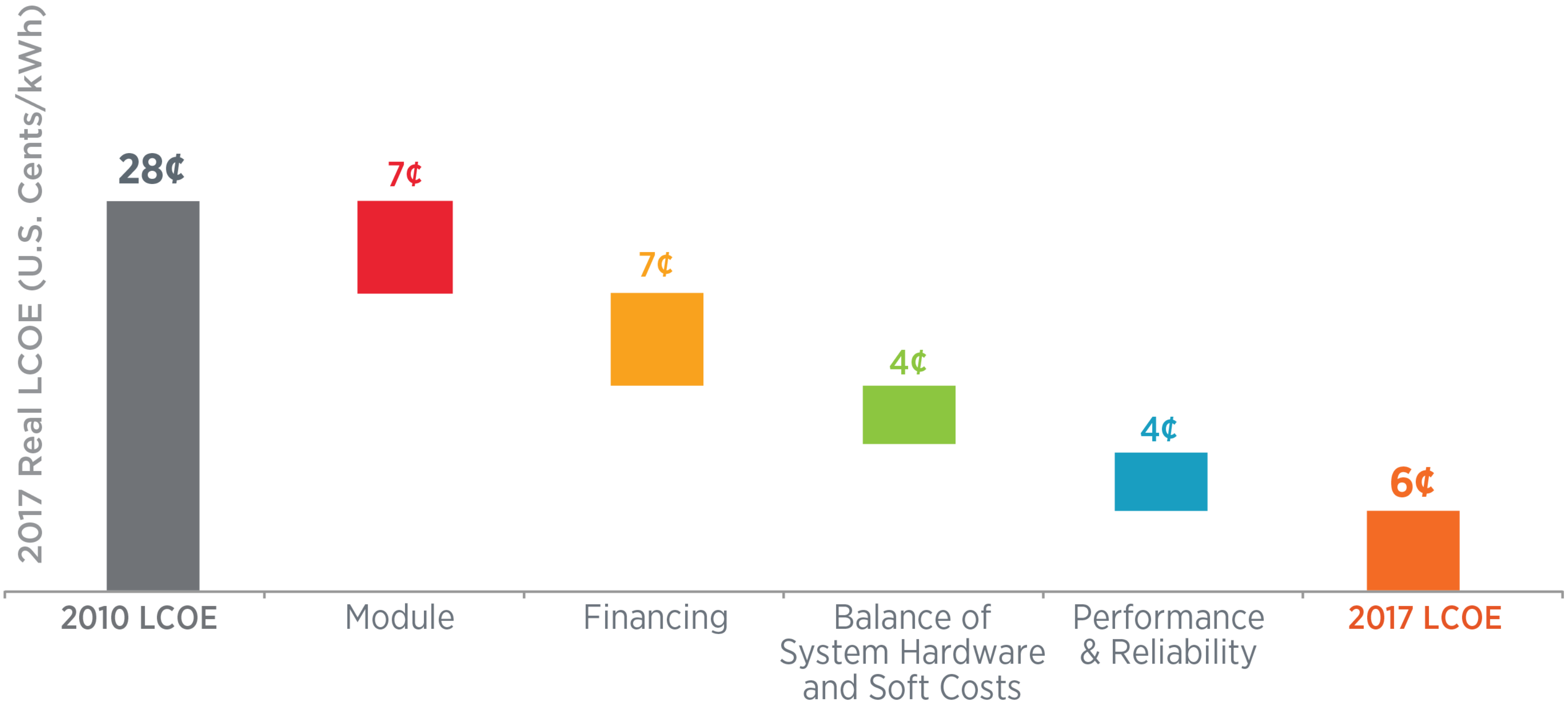
- Solar since 2010: A Decade of Progress
- 2020: Where Are We Now?
  - 2020 Goals Review
- Looking to 2030: A Bright Future for Solar

Status of 2020 Goals



*Levelized cost of energy (LCOE) progress and targets are calculated based on average U.S. climate and without the Investment Tax Credit or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010-19.

Cost Reductions to Reach Utility-Scale PV Goal



Source: Fu, R., D. Feldman, R. Margolis, M. Woodhouse, and K. Ardani, 2017. *U.S. Photovoltaic (PV) Prices and Cost Breakdowns: Q1 2017 Benchmarks for Residential, Commercial, and Utility-Scale Systems*. Golden, CO: National Renewable Energy Laboratory.

Lessons Learned

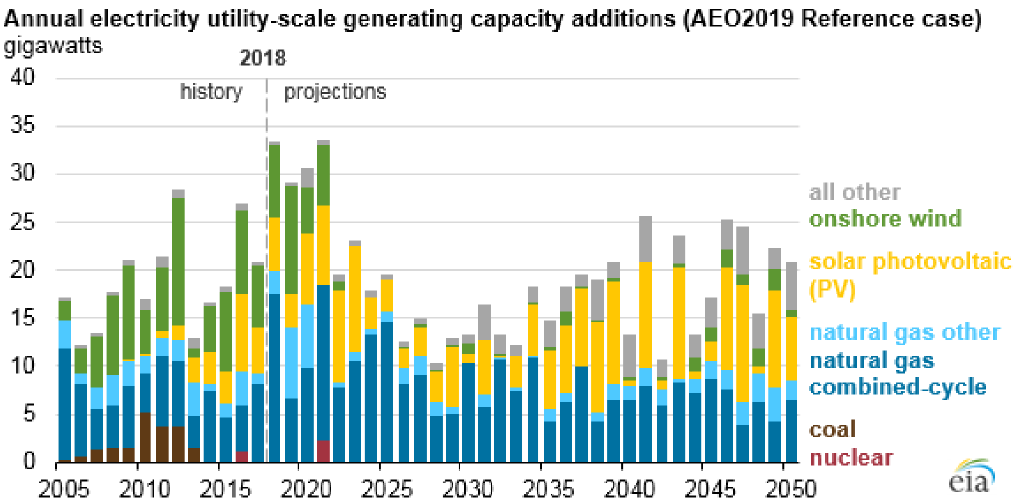
SunShot U.S. Department of Energy

- Don't underestimate incumbent technologies.
- Economies of scale had greater ability to reduce hardware costs than expected.
- Soft costs are more difficult to reduce than hardware costs, especially for residential and commercial systems.
- Solar technology has been proven reliable and bankable, reducing financing costs.
- *Value* of solar matters in addition to cost.

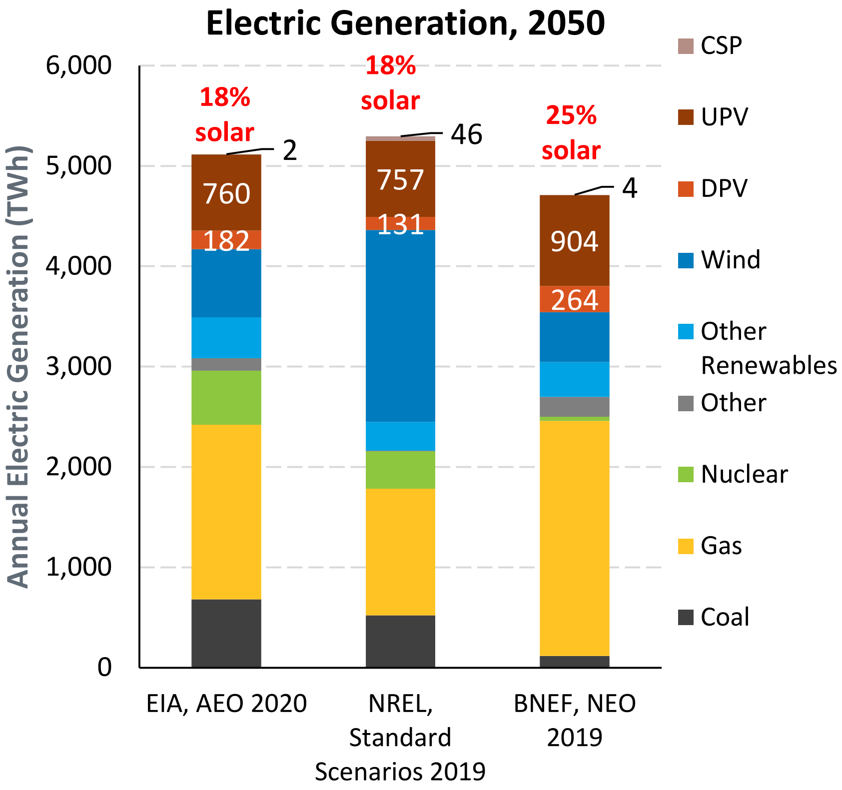
A Decade of Progress, A Promising Future

- Solar since 2010: A Decade of Progress
- 2020: Where Are We Now?
- **Looking to 2030: A Bright Future for Solar**
  - Prioritizing Systems Integration: Reliability, Resilience, Security
  - Advancing CSP for Dispatchable Solar and Process Heat
  - Continuing to Reduce Costs: 2030 Goals
  - Supporting U.S. Innovation
  - Exploring New Markets

Looking Forward: Solar Continuing to Grow



Source: Energy Information Administration, 2019 Annual Energy Outlook



Sources: BNEF, "New Energy Outlook 2019;" EIA, "2020 Annual Energy Outlook;" reference case; EIA, "2020 Annual Energy Outlook;" NREL, "2019 Standard Scenarios," mid case.

What is the Future of Solar Energy?

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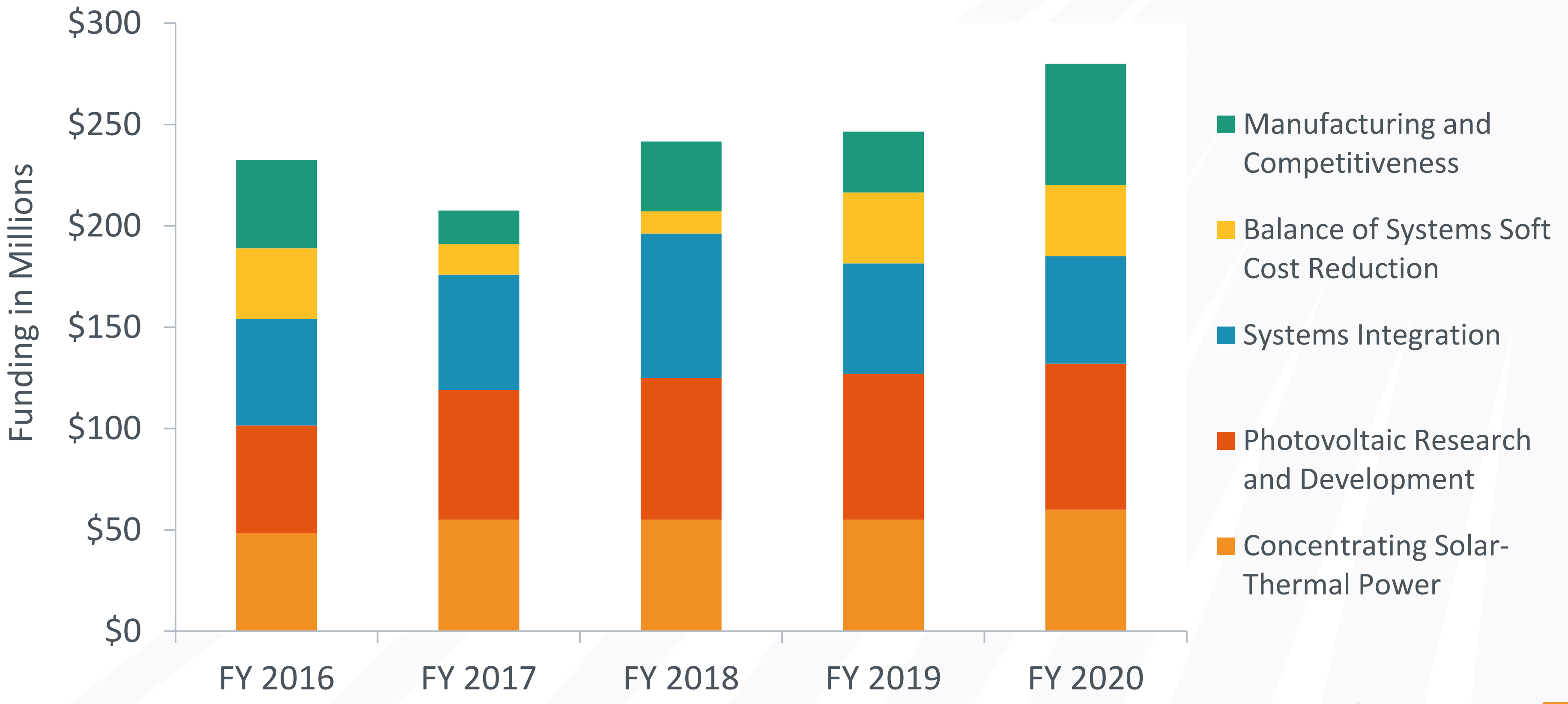
Solar Energy Technologies Office

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

SETO Budget Overview ($280M in Fiscal Year 2020)



DOE Solar Office Funds 375+ Active Projects

Projects and partners in 48 states plus the District of Columbia

40% of projects led by **national labs**

35% of projects led by **universities**

25% of projects led by **businesses, non-profits, and state and local government**

Updating SETO's Multi-Year Program Plan (MYPP)

Our Multi-Year Program Plan…

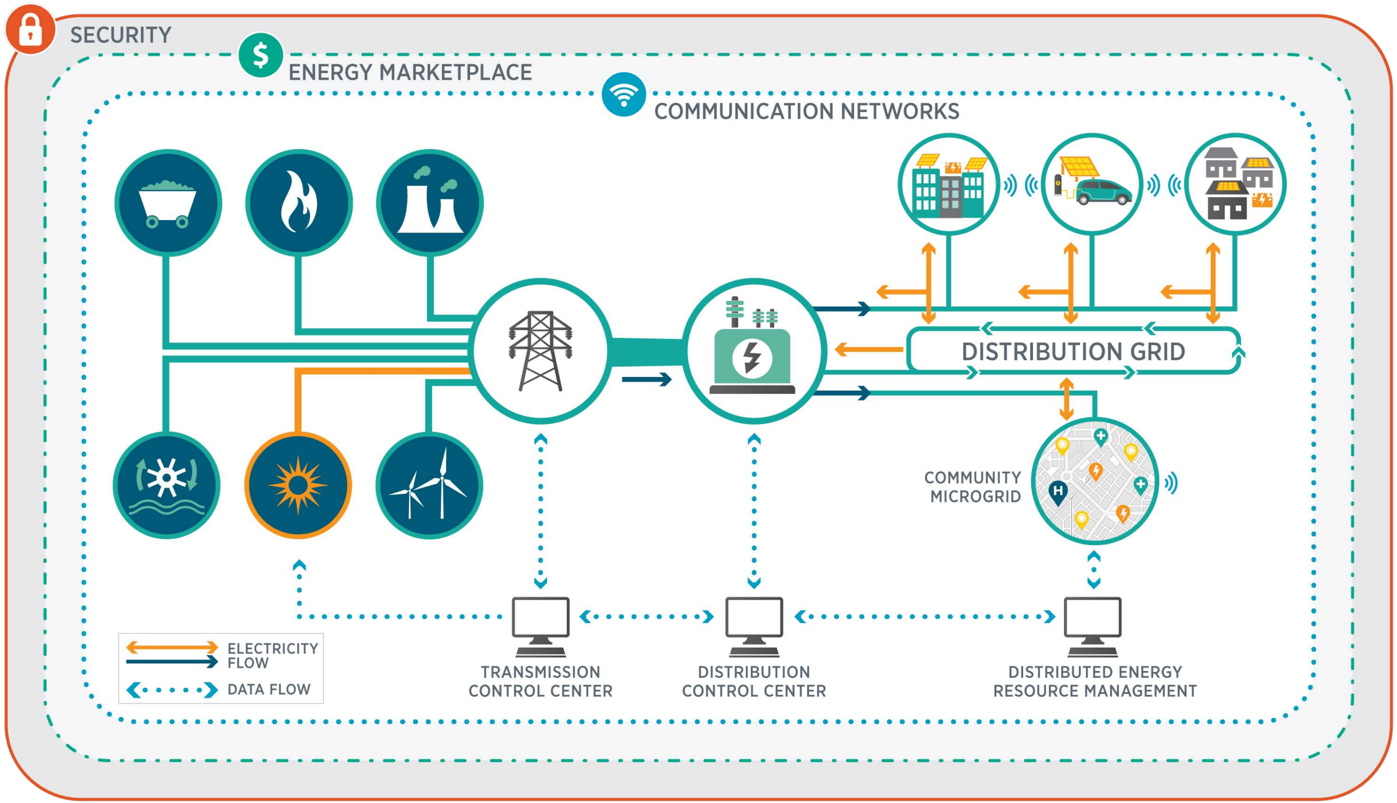
- Explains the purpose and principles of the office
- Sets goals for solar energy – not just the office – for 2025
- Explains what we do to accelerate progress towards these goals

Target Date for Completion: **Fall 2020**

Prior MYPP Completed: Fall 2017

To see the current summary of the MYPP, contact Tim Silverman at **timothy.silverman@nrel.gov**

Solar Energy in the Modernizing Grid



Systems Integration: Working Toward 2025

Reliable operation of a grid is demonstrated at scale during times when >50% of power is solar

A grid has demonstrated ramping up by 80% of peak net load in 2 hours beginning when >50% of power is solar

Zero interruption of solar electric supply is demonstrated under conditions of cyberattack and physical hazard

- Creating the infrastructure for acquisition, transfer, curation, and management of data, including measurements and forecasts, that provide observability of solar generation on the grid
- Building analytical tools and using them to provide insight into integrating solar generation with the grid
- Developing control, optimization, decision-support, and cyberdefense methods
- Studying and improving the hardware at the interface between solar energy and the grid, including power electronics, inverters, transformers, energy storage systems, and sensors
- Demonstrating the integration of solar technology with storage, flexible loads, and the grid

Solar Supporting Reliable Grid Operation

Today: PV only contributes energy to the grid; PV doesn't support grid operation and reliability

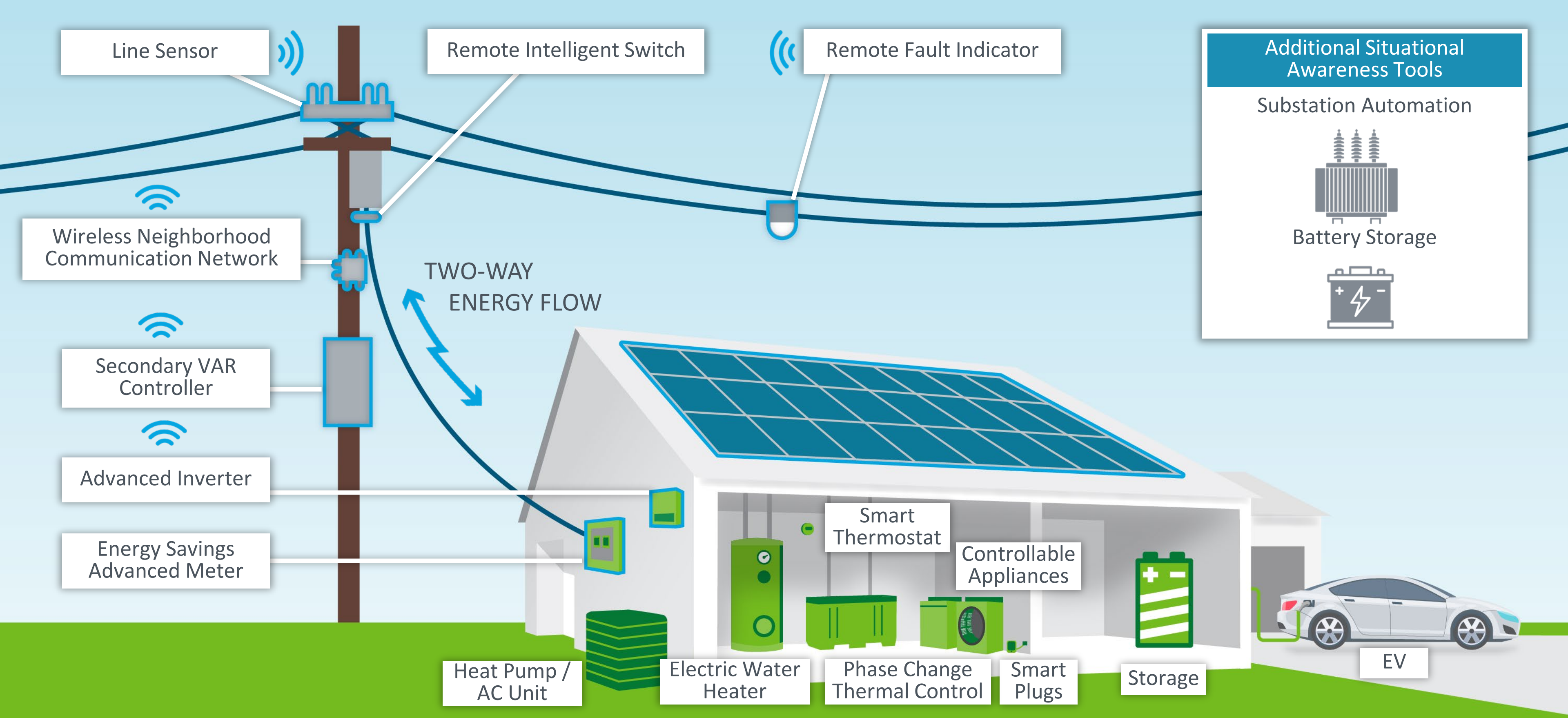
Next 5 Years: Smart PV inverters contribute essential grid reliability services like a conventional generator (e.g., voltage and frequency regulation)

Next 10 Years: Harness the fast-responding capabilities of power electronics-based generators to improve the efficiency and reliability of the grid in areas with high penetrations of wind and solar.

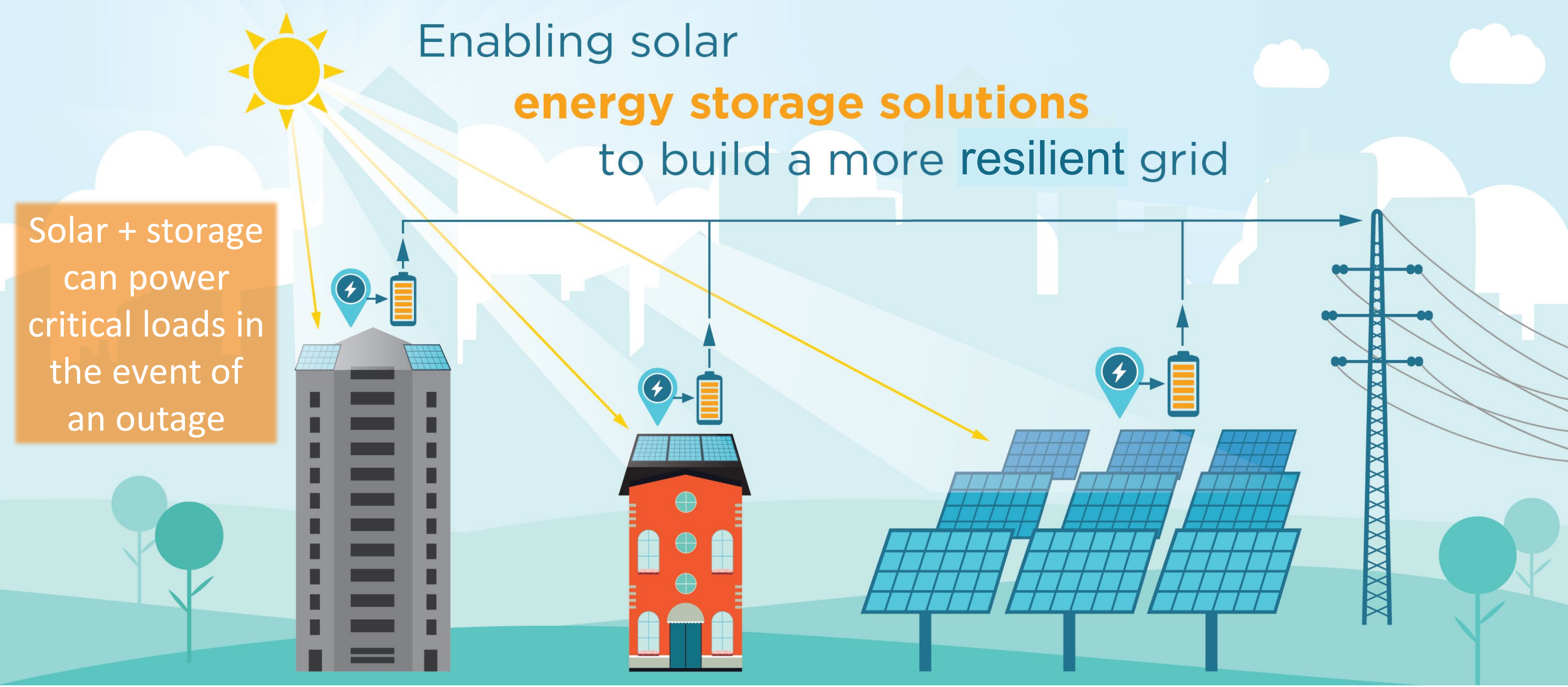
Ongoing foundational research topics (e.g., PV cyber-security, situational awareness, integration with storage, controllable loads, and distributed energy resource management systems)

Situational Awareness: Sensors and Controls

Sensors throughout the grid system allow grid operators to better understand how energy moves along the grid.



Solar Enhancing Grid Resilience



Solar + Storage Enhancing Grid Resilience

Today

- PV + storage can power simple building loads in the event of an outage for short period.
- PV can reduce need for fuel storage for back-up power

Next 5 Years

- PV black-start capabilities validated in field trials
- PV + storage operating in microgrid mode for longer durations.
- PV can provide significant fuel savings compared with back-up generators

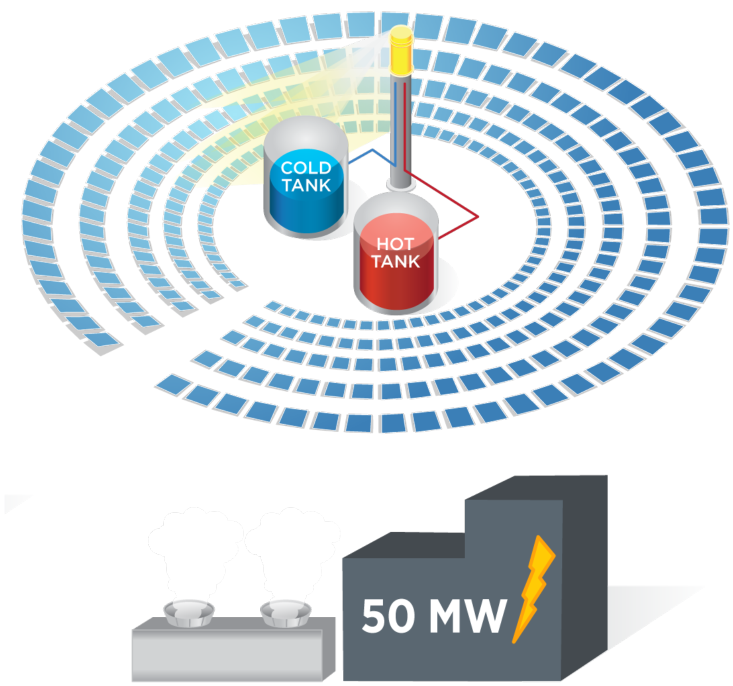
Next 10-15 Years

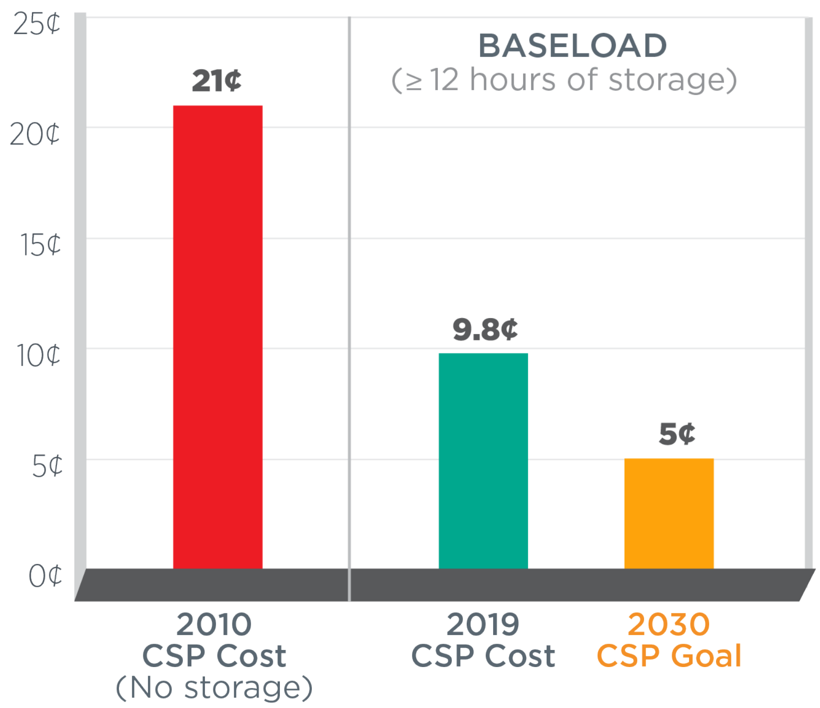
- PV + storage black-start solutions adopted to start up microgrids in the event of an electricity outage
- Coordinated microgrid capabilities enable dynamic formation of networked microgrids to supply critical loads during an outage

Ongoing foundational research topics (e.g., solar forecasting, integration with storage, controllable loads, distributed energy resource management systems, and control optimization algorithms)

Concentrating Solar-Thermal Power for Solar on Demand

BASELOAD POWER
(≥12 hours of storage)





Raising the Temperature of Solar-Thermal Systems

GEN3 CSP FUNDING PROGRAM	
Thermal Pathway	**Primary Challenges**
Liquids	Reliable corrosion management with advanced molten salts
Solids	High-efficiency transfer of heat in and out of particles
Gas	Integrating low-density gases with cost-effective thermal energy storage

CSP: Working Toward 2025

A 700°C solar thermal receiver, storage, and delivery system has been demonstrated to be compatible with a >50% efficiency power cycle at a modeled cost of <$900/kW

An integrated heliostat field with >55% annual optical efficiency costs <$100/m²

Levelized cost of solar process heat is <$0.02/kWh at a range of temperatures

2030 Goal: LCOE of $0.05/kWh for baseload CSP systems

- Improving the reliability and efficiency of power cycle and collector field components and systems
- Demonstrating low-cost, long-duration thermal storage as a dispatchable solar resource
- Developing technology for economical industrial process heat, including for applications such as solar fuels synthesis and desalination

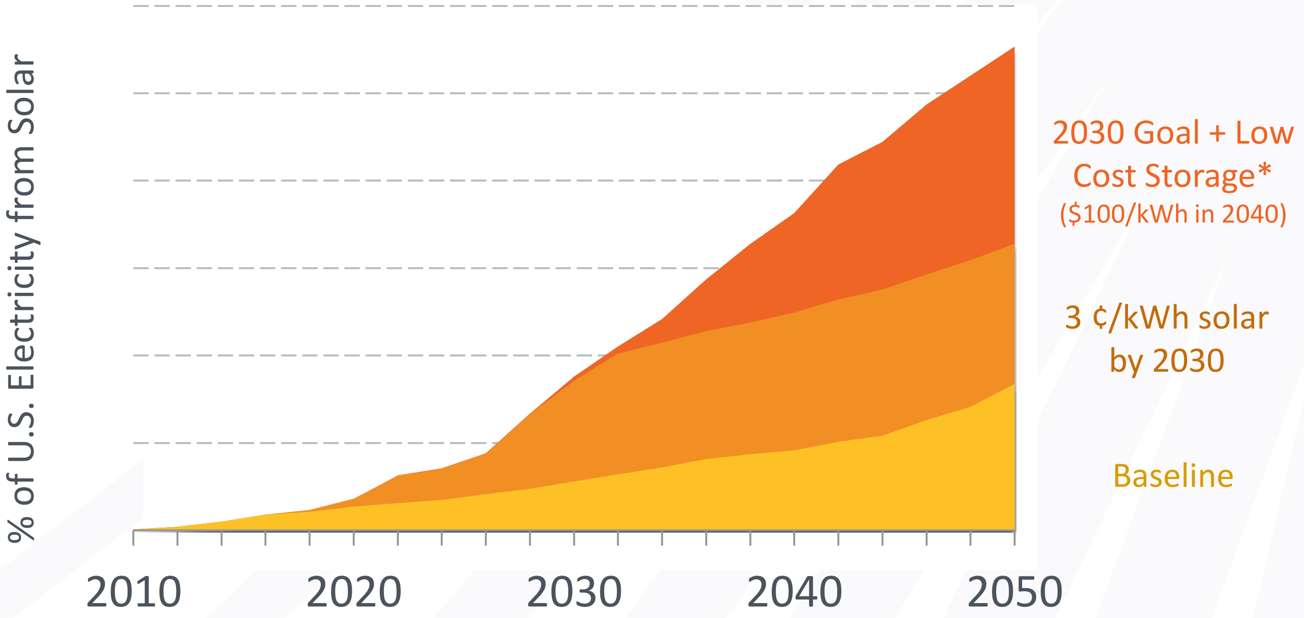
Solar-Thermal Heat Applications

- Desalination
- Enhanced Oil Recovery
- Agriculture and Food Processing
- Fuel and Chemicals Production
- Mining and Metals Processing

Solar desalination systems use CSP technologies to generate low-cost heat, which can be used to clean water.

Continuing Cost Reduction: 2030 Targets

Lower Cost Solar and Storage Drive Deployment



Source: W. J. Cole, B. Frew, P. Gagnon, J. Richards, Y. Sun, J. Zuboy, M. Woodhouse, and R. Margolis, "SunShot 2030 for Photovoltaics (PV): Envisioning a Low-cost PV Future," NREL/TP-6A20-68105, National Renewable Energy Laboratory, Golden, CO (2017).

Continuing PV Innovation: Long History of Collaboration Supports Commercial Success

BACKGROUND

- **Early 1990s:** With DOE support, NREL and Solar Cells, Inc (later, First Solar) scientists researched cadmium telluride (CdTe) solar cells as a cheaper alternative to silicon.
- First Solar continues to develop its CdTe product and becomes a leading global supplier of solar cells. Research colloborations with NREL along the way supported their rapid innovation. For example:
  - NREL and First Solar develop “High Rate Vapor Transport Deposition Technique,” **winning a 2003 R&D 100 award**
  - In 2019, an NREL and First Solar collaboration overcomes a fundamental material science challenge for CdTe, achieving 20.8% efficiency using doping with Group V elements

SUCCESS

- First Solar holds the **record efficiency** for a laboratory CdTe solar cell at 22.1%; average commercial module efficiency is over 17%.
- First Solar announced plans in April 2018 for a new 1.2 GW/year CdTe PV manufacturing facility in Ohio.
- **NOW:** First Solar has almost 2 gigawatts of module manufacturing capacity across the United States—**representing a quarter of all U.S. module manufacturing.**

Continuing to Improve (Confidence in) PV Lifetimes

DuraMAT
Durable Module Materials Consortium

DuraMAT brings national laboratories and universities together with the photovoltaic supply chain and manufacturing industry to accelerate development of durable packaging materials and technology transfer.

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			

https://www.duramat.org/

Photovoltaics: Working Toward 2025

Primary Goal:

LCOE is <$0.03/kWh in utility-scale PV systems

90% of the mass of a PV module can be recovered in the US for a total cost of <$10

New capacity is combined with other uses, such as in agricultural PV or BIPV

- Extending service life, improving efficiency, and reducing risk
- Improving end-of-life materials characterization and separation
- Reducing cost through materials, manufacturing, and value-stacking in hybrid systems

Soft Costs: Working Toward 2025

LCOE <$0.10/kWh for residential PV systems

Increasing access to solar energy

Reducing the time to permit, install and interconnect PV systems

- Providing tools and training to make permitting and interconnection fast and easy
- Performing analysis to support the scalable and equitable integration of solar technology into the energy system
- Supporting new processes and mechanisms for efficient solar integration and deployment
- Providing objective information and analysis to inform decision-makers in business and government
- Offering workforce development for solar workers

Reducing Soft Costs

ACTIVITIES	EXAMPLE RESEARCH TOPICS
PROVIDE OBJECTIVE INFORMATION	• How real estate costs are impacted by solar installations • Characterization of the community solar market • How the value of solar changes with its location on the grid
PILOT SMART INNOVATION	• Co-locating solar with agricultural production • Community solar models for low income communities • Co-locating solar with electric vehicle charging
DEVELOP AND DISSEMINATE BEST PRACTICES	• Permitting and interconnection of solar + storage • National recognition programs (SolSmart) • Workforce training

Solar Energy Innovation Network

The Solar Energy Innovation Network is a collaborative research program that supports multi-stakeholder teams to research and share solutions to real-world challenges associated with solar energy adoption.

Approach

- Teams identify local and regional challenges, and receive technical and financial assistance to formulate and test innovations, and validate new models
- Teams meet in person for several multiday workshops to further refine solutions and learn from other teams
- Research and innovative solutions shared through peer network and stakeholders nationally

Objective

- Develop innovative solutions that make solar energy adoption easier and enable adoption by stakeholders across the United States facing similar challenges.

SOLAR ENERGY INNOVATION NETWORK
U.S. DEPARTMENT OF ENERGY

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

BERKELEY LAB
Lawrence Berkeley National Laboratory

ROCKY MOUNTAIN INSTITUTE

Increasing Access: National Community Solar Partnership

The National Community Solar Partnership is a coalition of community solar stakeholders working to expand access to affordable community solar to every American household by 2025.

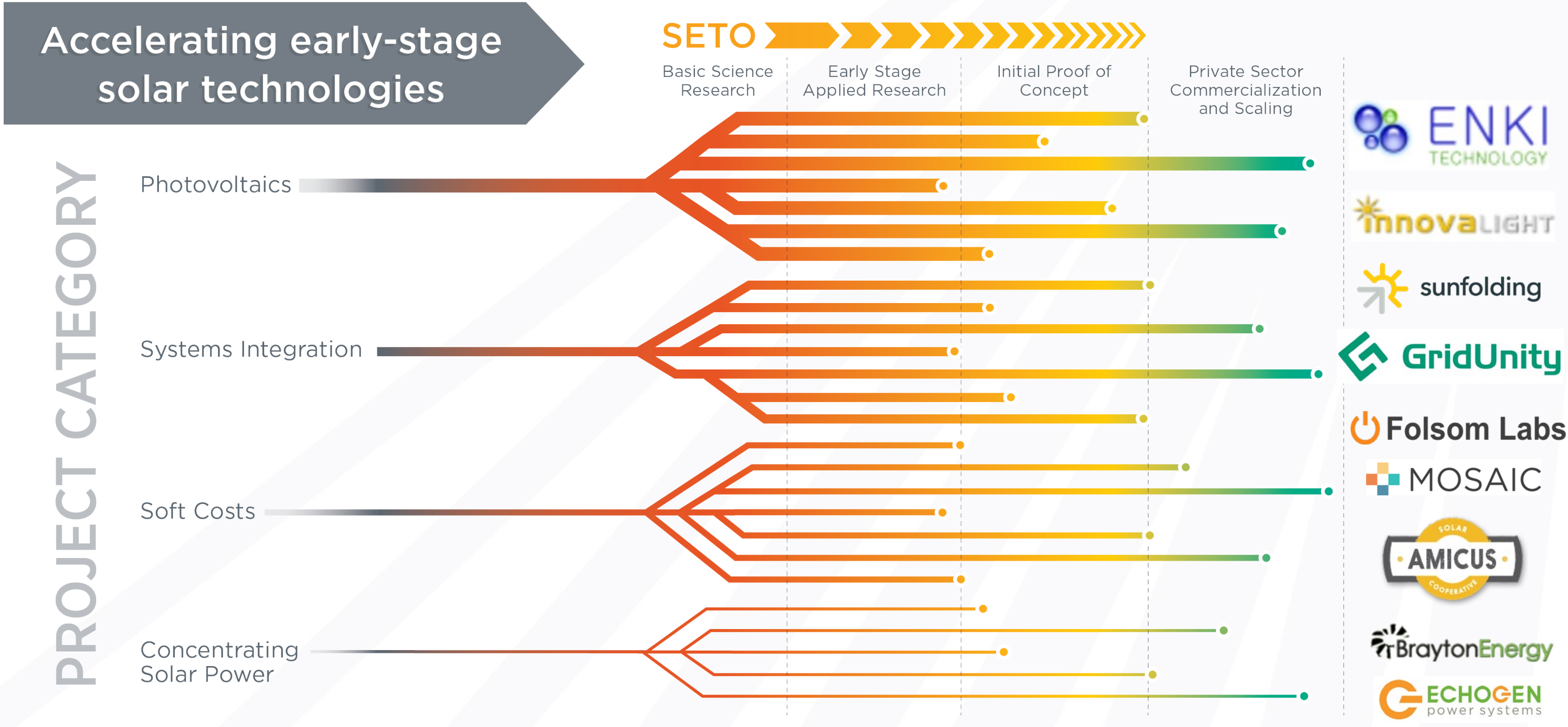
Manufacturing & Competitiveness: Working Toward 2025

New technologies enter U.S. manufacturing

U.S. solar manufacturing capacity increases across the value chain

- Supporting proof of concept, pilot production, technology transfer and scale-up of new products from US businesses
- Development of new technologies and business models

SETO Helps Ready Technologies for Market



AMERICAN MADE

SOLAR PRIZE

U.S. DEPARTMENT OF ENERGY

$3 million prize competition

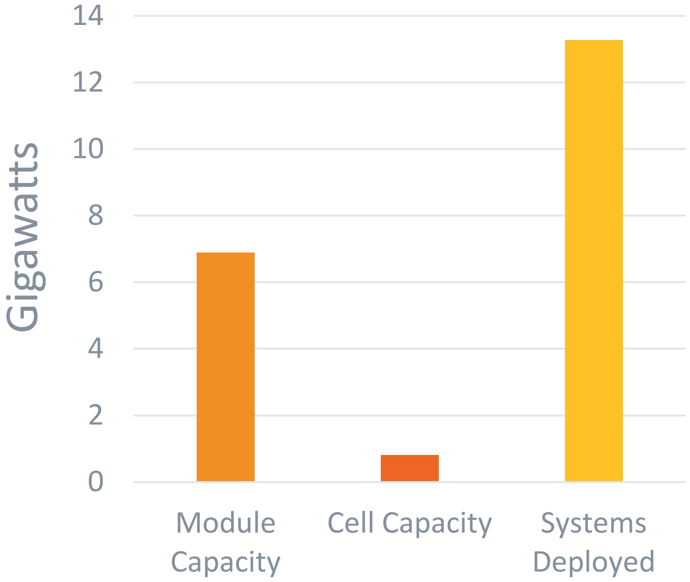
Ready!, Set!, and Go! Contests

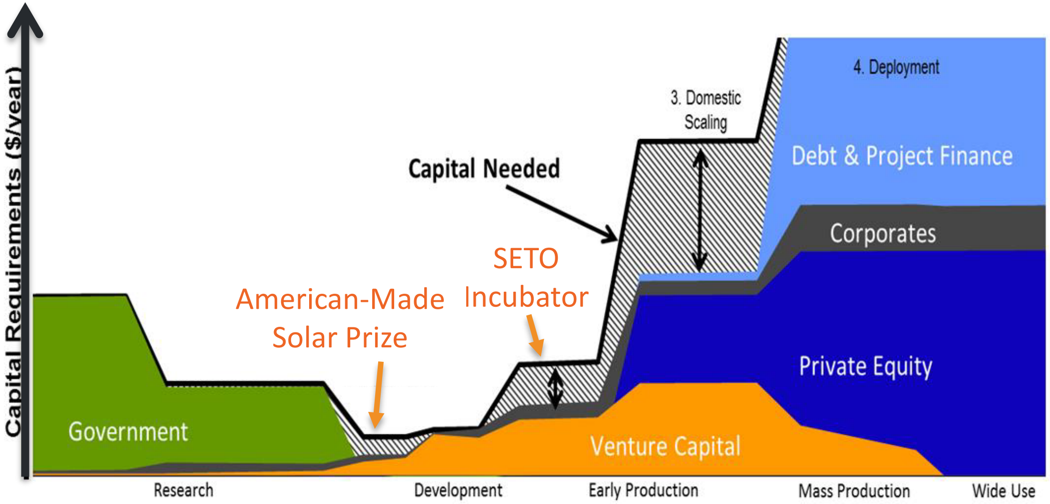
National network of support organizations

American-Made Network

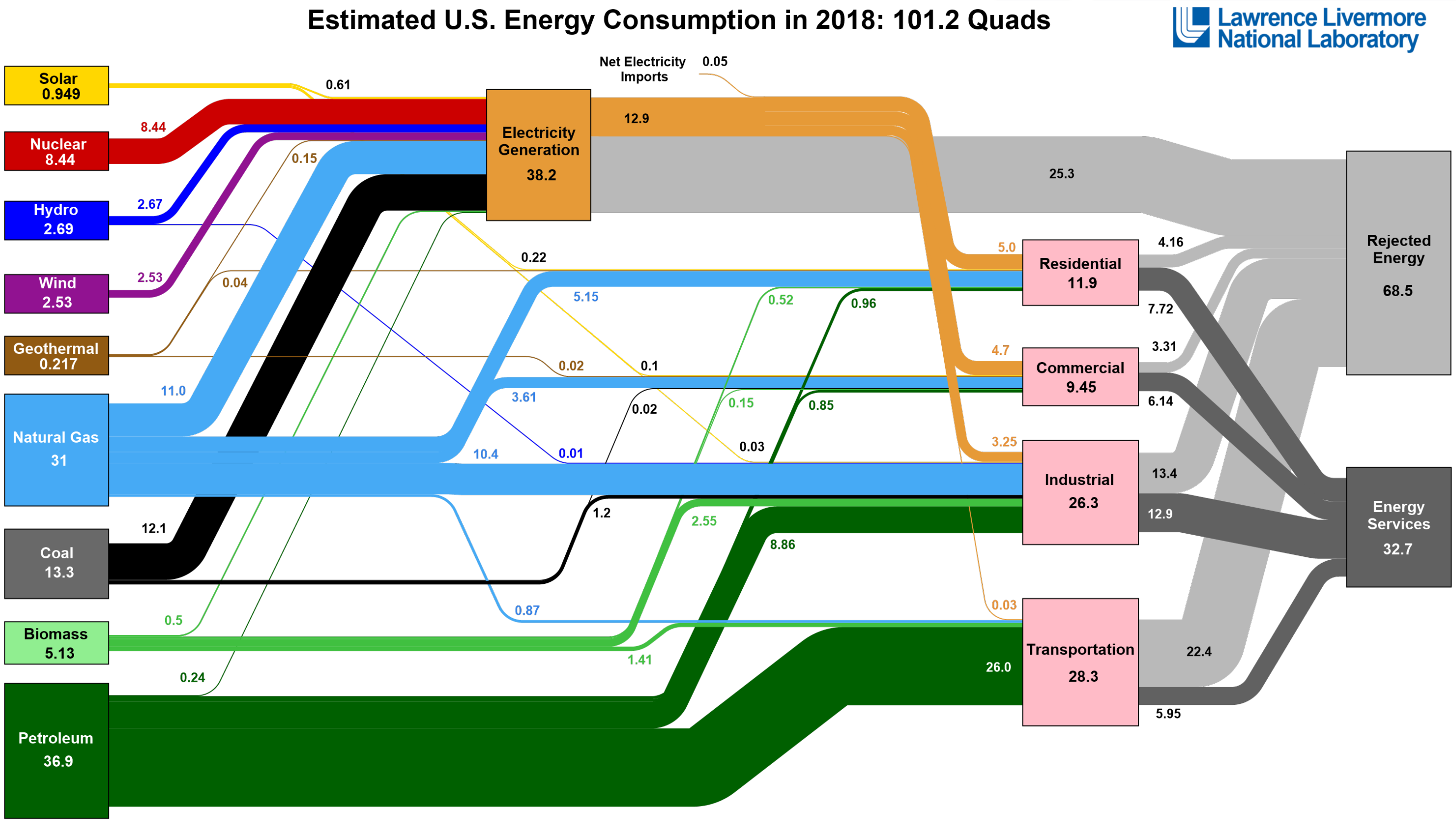
Manufacturing and Competitiveness Challenges

U.S. Manufacturing Capacity of PV Cells and Modules vs Total U.S. Deployment in 2019



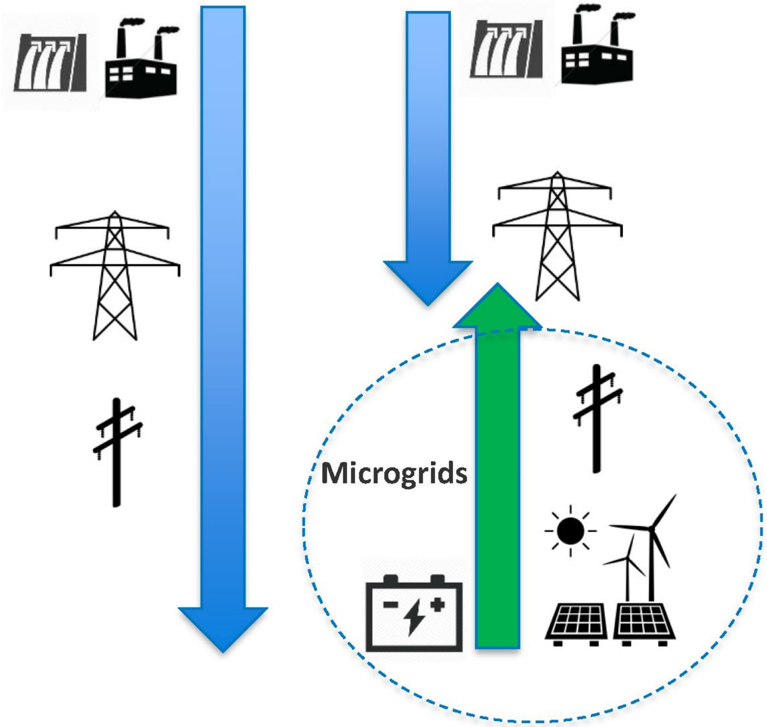


How Broad are the Applications for Solar Energy?



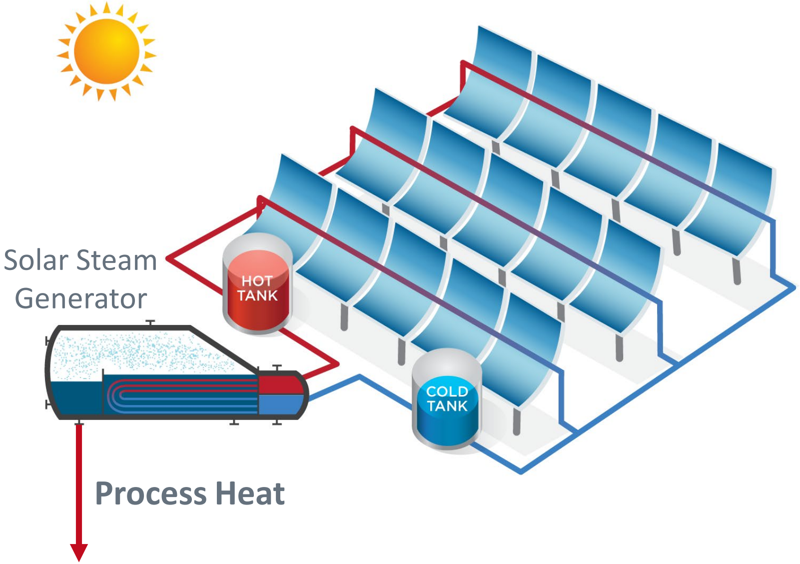
Source: LLNL March, 2019. Data is based on DOE/EIA MER (2018). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Beyond Grid-Tied Electricity Generation



Source: NREL 2019

SOLAR PROCESS HEAT



Thermally-Driven Industrial Processes:

- Desalination
- Enhanced Oil Recovery
- Agriculture and Food Processing
- Fuel and Chemicals Production
- Mining and Metals Processing

New Markets Example: Co-Location of Solar and Agriculture

Benefits to Solar Energy

- Improved solar PV efficiencies due to cooler microclimate underneath panels
- Reduced O&M costs
- Reduced construction and acquisition/permitting costs

Water Use Benefits

- Reduced evaporation
- Reduced runoff
- Improved water use efficiency of crops and pollinator habitat

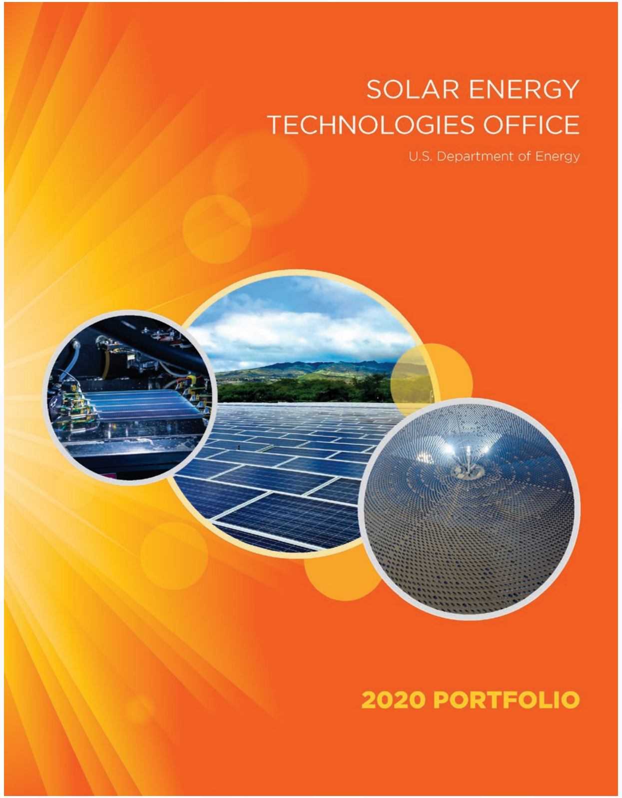
Agricultural Benefits

- Compatibility with crop production and livestock
- Pollinator habitat can improve local agricultural yields
- Improved soil health

Purpose of the Peer Review

Assessing Progress and Guiding the Future

- How effectively does our project portfolio address our goals?
- How well do our projects advance the solar industry?



SETO Teams

PHOTOVOLTAICS

R&D advancing photovoltaic technologies to improve efficiency and reliability, lower manufacturing costs, and drive down the cost of solar electricity.

CONCENTRATING SOLAR-THERMAL POWER

R&D to develop low-cost concentrating solar-thermal technologies, which incorporate thermal energy storage to provide electricity when the sun is not shining, and which can be utilized for desalination, process heat, and fuel production.

SYSTEMS INTEGRATION

R&D to enable solar energy to support grid reliability and security as well as coupling with energy storage and smart load management to provide new opportunities for enhanced resilience.

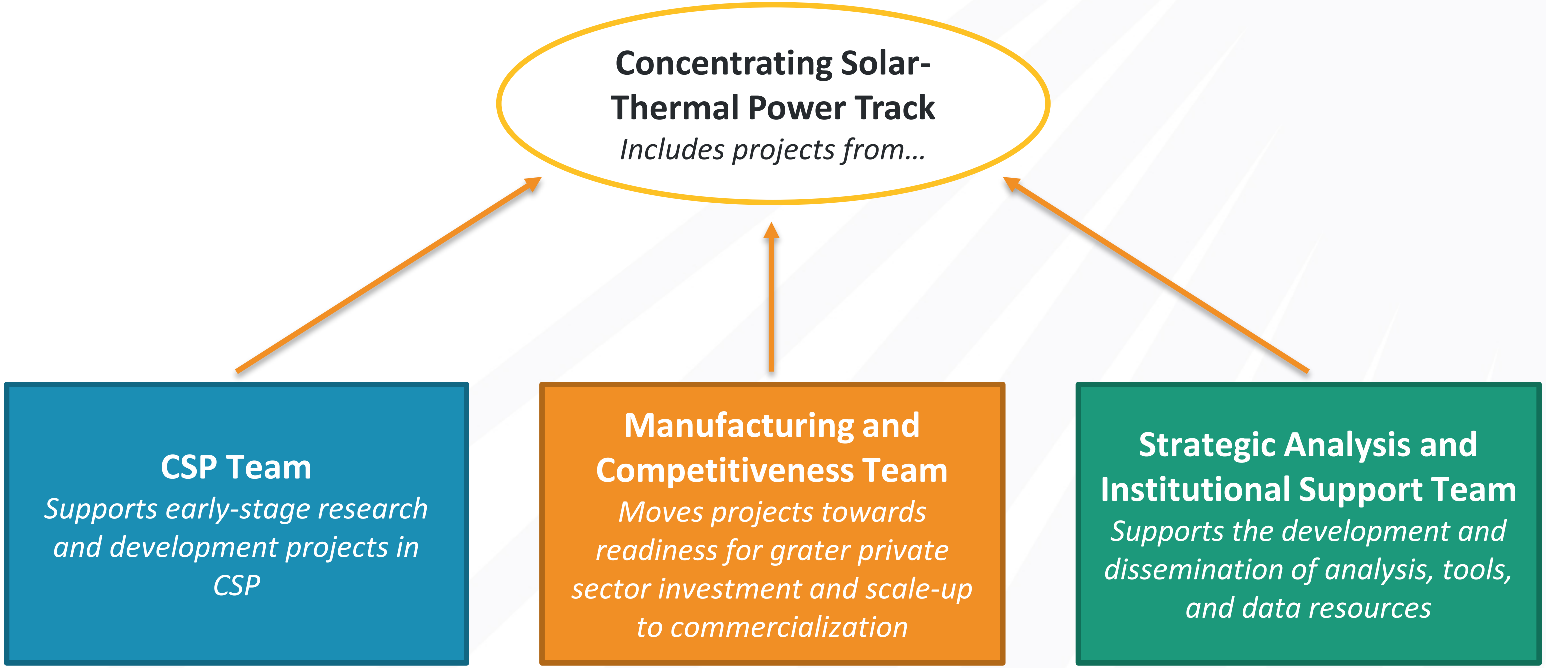
STRATEGIC ANALYSIS AND INSTITUTIONAL SUPPORT

Supports the development and dissemination of analysis, tools, and data resources related to the cost and value of solar technologies, and provides technical assistance to address specific challenges.

MANUFACTURING AND COMPETITIVENESS

Supports activities that amplify the impact of R&D projects and enable the private sector to develop and sustain new solar products with a focus on technologies with the strongest opportunities for manufacturing in the U.S.

Tracks Intersect with Multiple Teams



Topic Areas within Tracks

Photovoltaics

- Commercial PV Technologies
- Reliability and Standards Development
- System Design and Energy Yield
- New Cell and Module Structures, Designs, and Processes

Concentrating Solar-Thermal Power

- CSP Systems
- High Temperature Thermal Systems
- Power Cycles
- Solar Collectors
- Desalination and Other Industrial Processes

Systems Integration

- System Operation Reliability
- Power Electronic Devices and Control
- System Planning Models and Simulations
- PV for Resilient Distribution Systems

Soft Costs

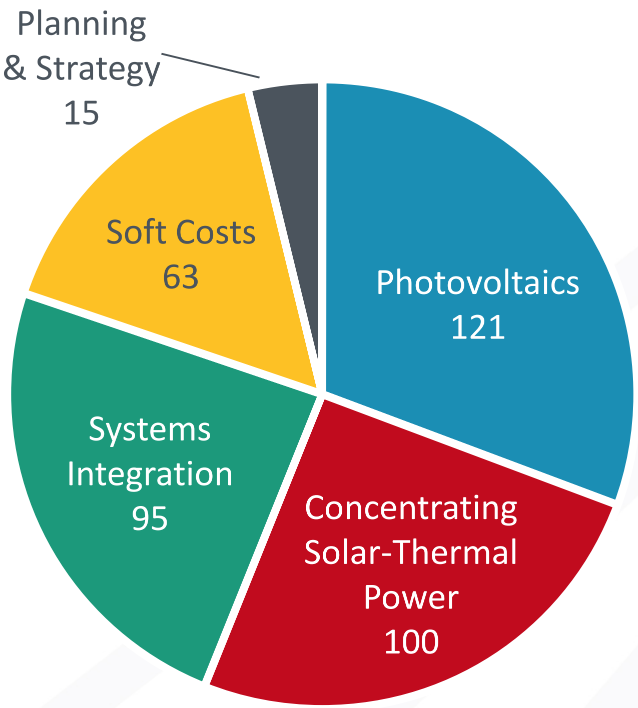
- PV Markets and Regulation
- Solar Energy Access
- Workforce

Planning and Strategy

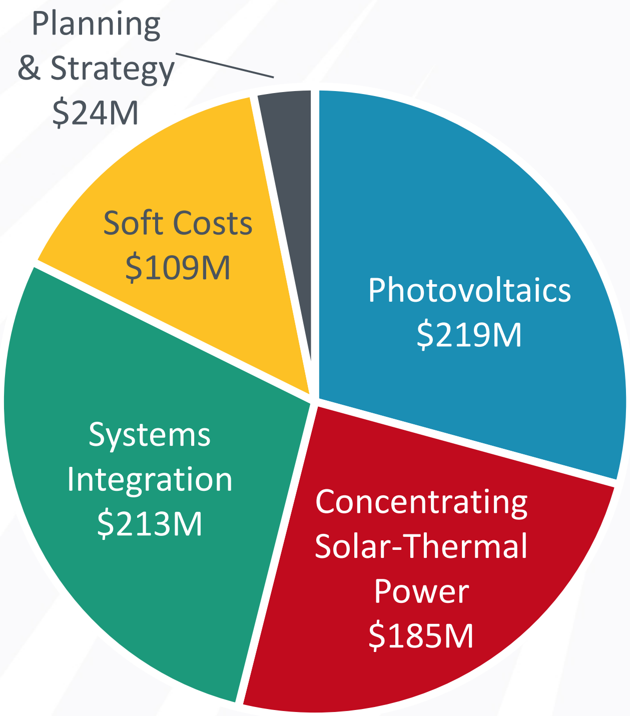
- Special Projects and Collaborations
- Visioning, Strategic Positioning, and Evaluation

Breakdown of Projects and Funding by Track

Projects by Track



Funding by Track



Challenge to You

STAY CONNECTED

Please stay connected with what we do: sign up for our newsletters, attend our Stakeholder Webinars, or just reach out and talk.

ENGAGE

If you are part of the peer review, let's push the limits of a virtual meeting to insure robust engagement.

GIVE FEEDBACK

Please continue to offer feedback – whether during the Peer Review or otherwise.

TRACK OVERVIEWS

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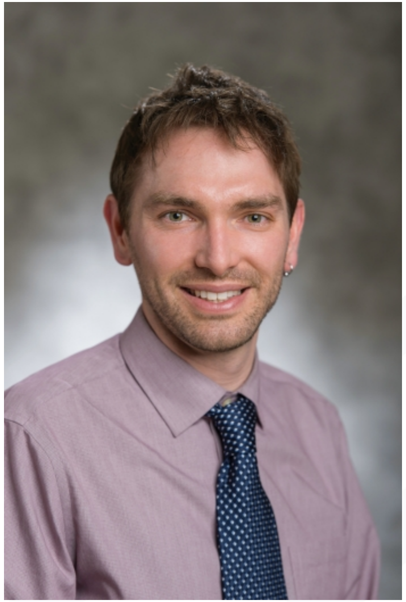
SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

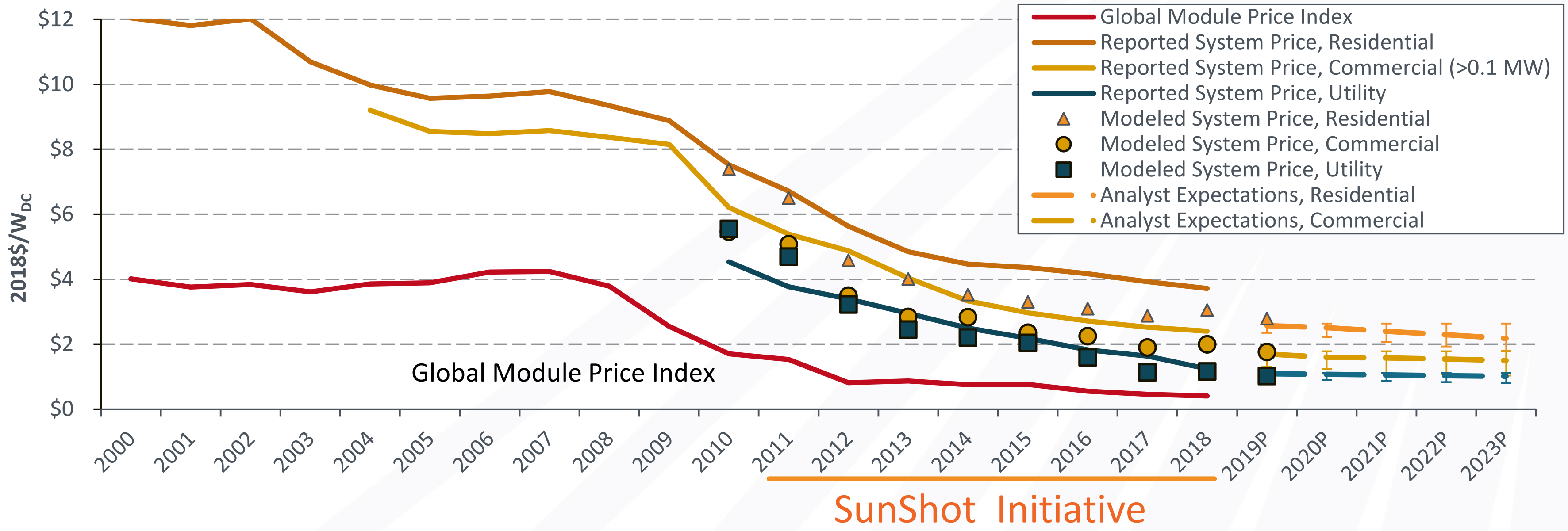


Photovoltaics

Dr. Lenny Tinker

Program Manager, Photovoltaics

A Brief Perspective on SETO PV R&D History

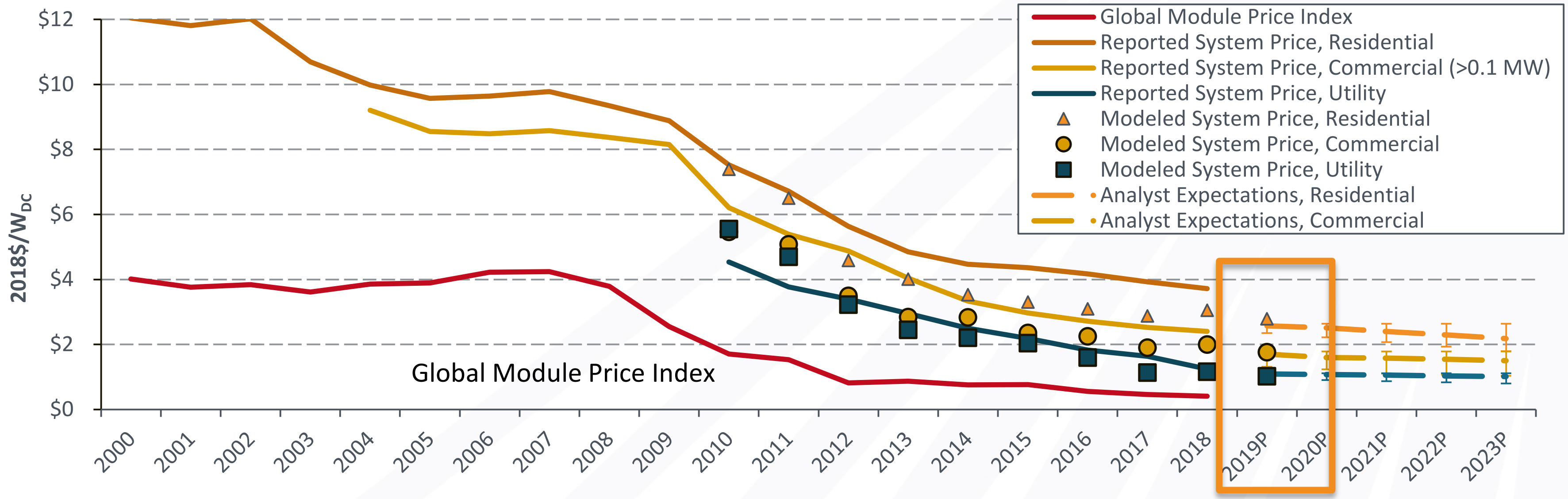


Where we've been: PV is prohibitively expensive… SunShot Initiative for $0.06/kWh

- Heavy R&D focus on thin films to get below silicon PV costs
- "3rd Gen PV" in hopes of something else (LSCs, QDs, IBSC…)

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).

A Brief Perspective on SETO PV R&D History

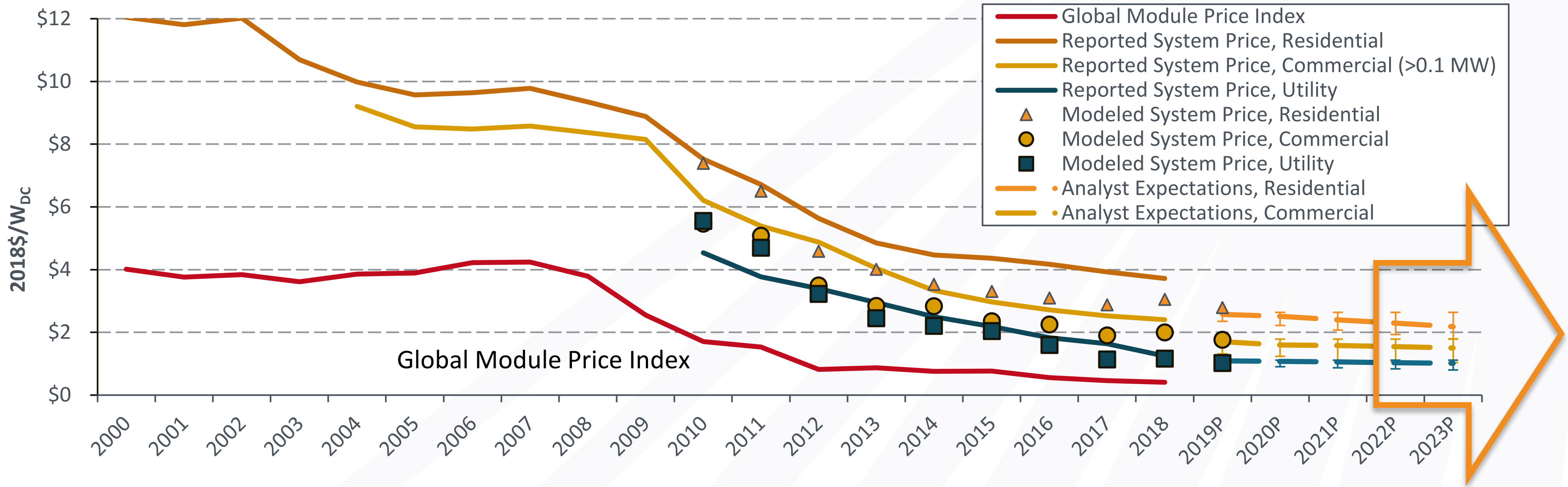


Where we are: Solar competes! 2% US electricity met by PV…Is $0.03 or 0.02/kWh possible!?

- Silicon dominates and costs from foreign manufactures are very low
- Need to better quantify real / bankable durability - can it be improved to 50yrs?
- Perovskites are efficient but can they be stable?
- Need to stay ahead of "new" modes of degradation (partial shading of thin films, PID..)

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).

A Brief Perspective on SETO PV R&D History

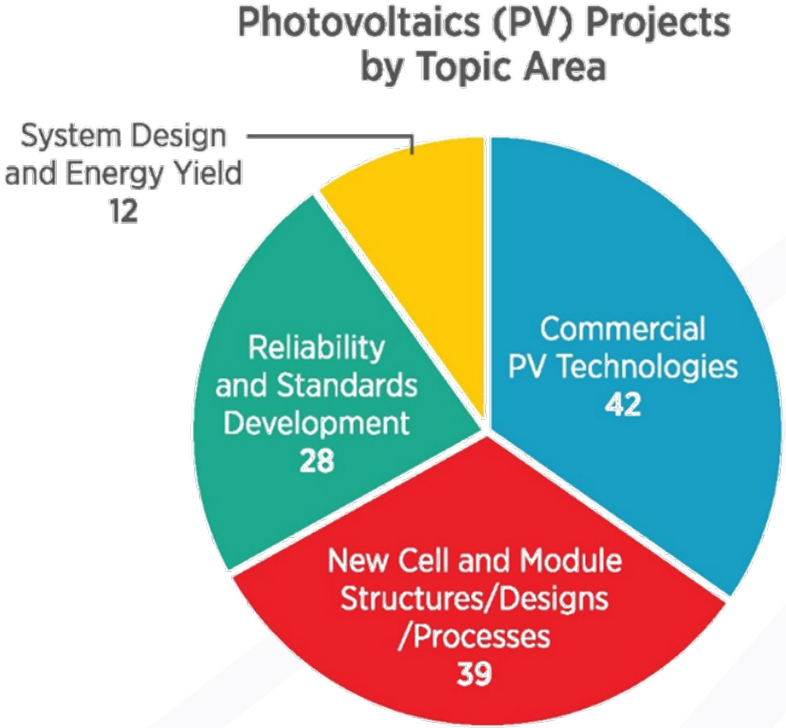


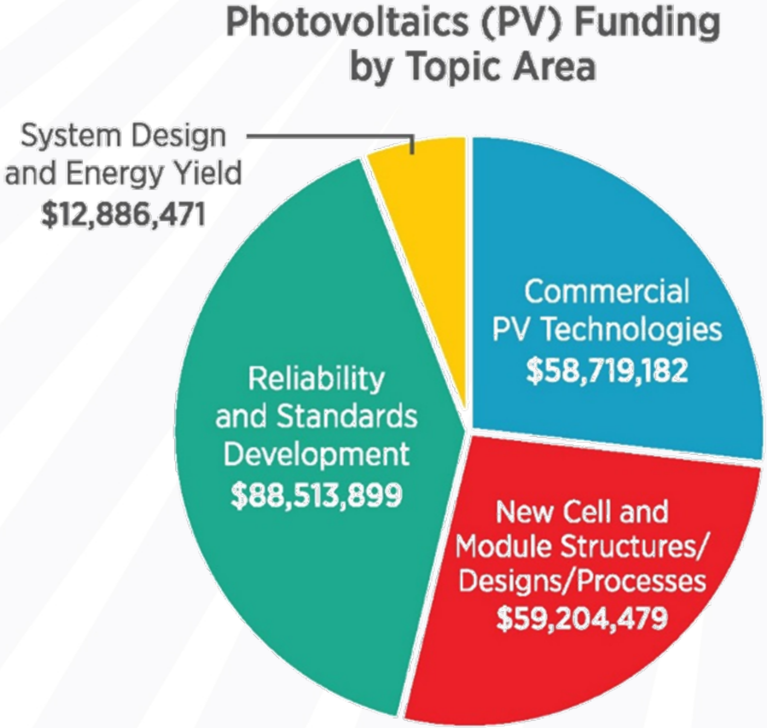
Where we're going: Low incremental value of PV at some times of day; TWyrs of US system data

- 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).

Active PV Projects (121 projects, $219M)



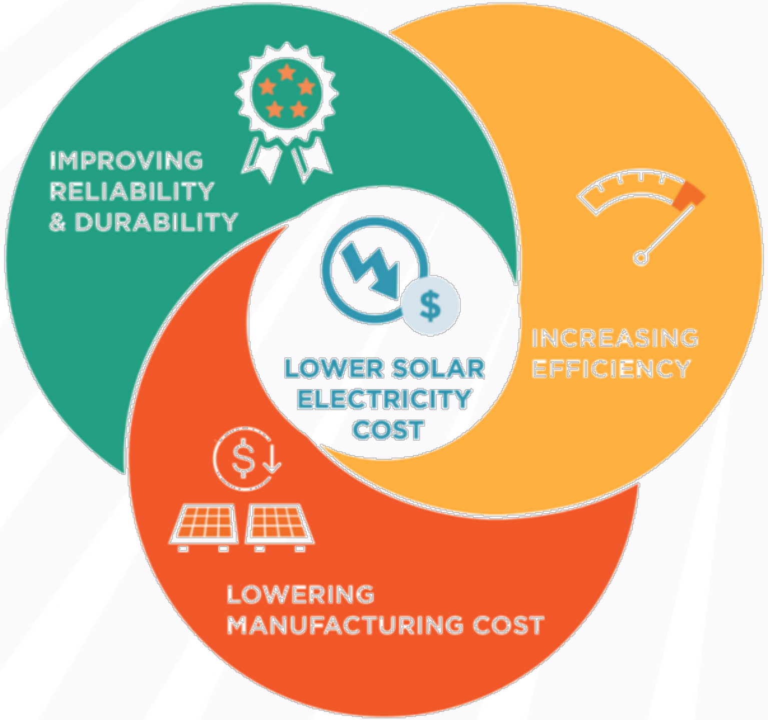


SETO Photovoltaics R&D Approach

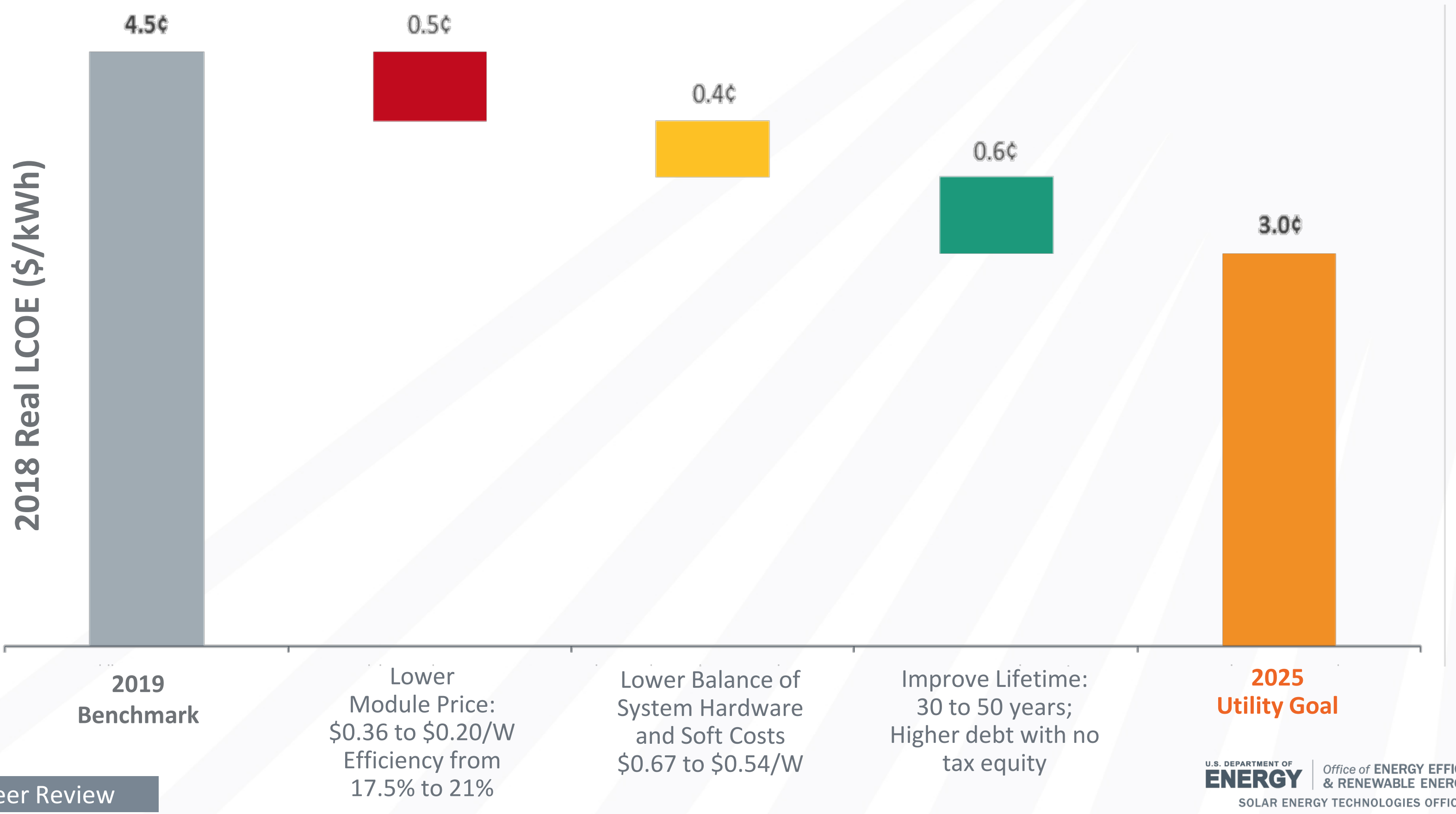
Funds research with a 3-15 year horizon, which is beyond industry focus or capabilities

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

Fosters the transition of research developments into the marketplace

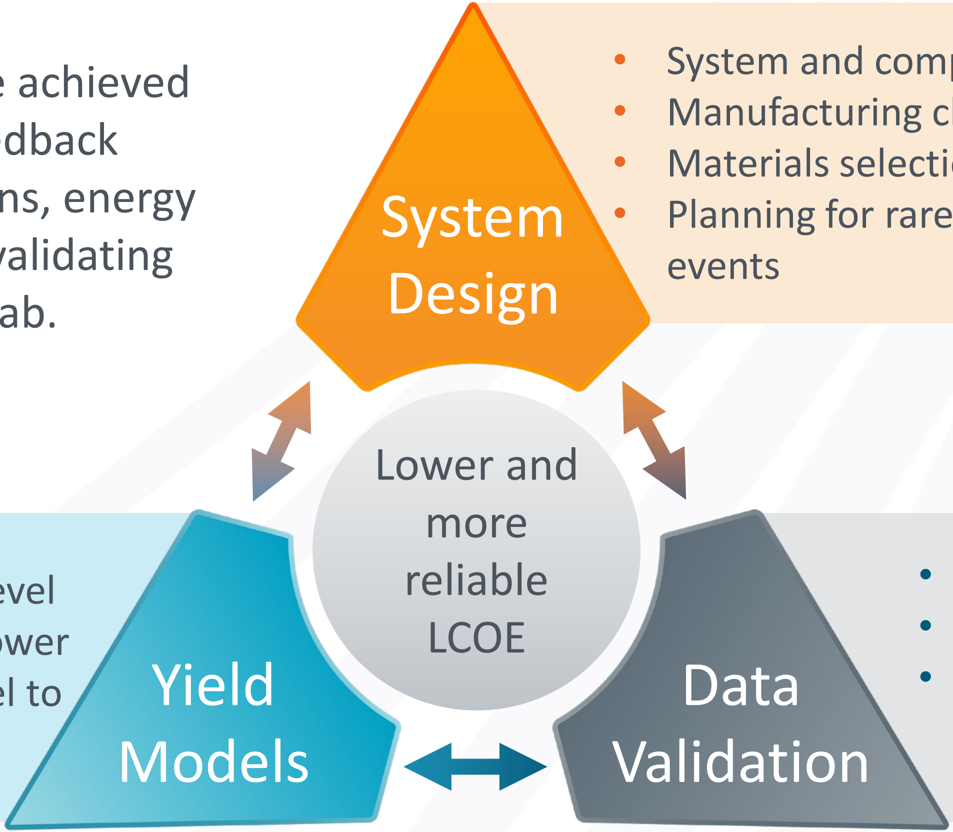


A Pathway to $0.03 per kWh for Utility-Scale PV



SETO PV Reliability Portfolio Approach

Improvement will be achieved through iterative feedback among system designs, energy yield modeling and validating data from field and lab.

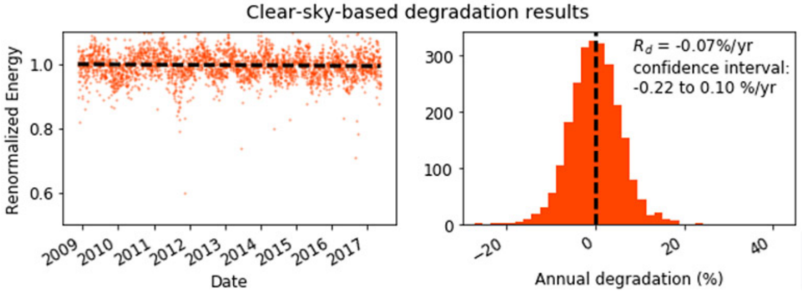


- System and component design
- Manufacturing choices
- Materials selections
- Planning for rare weather events

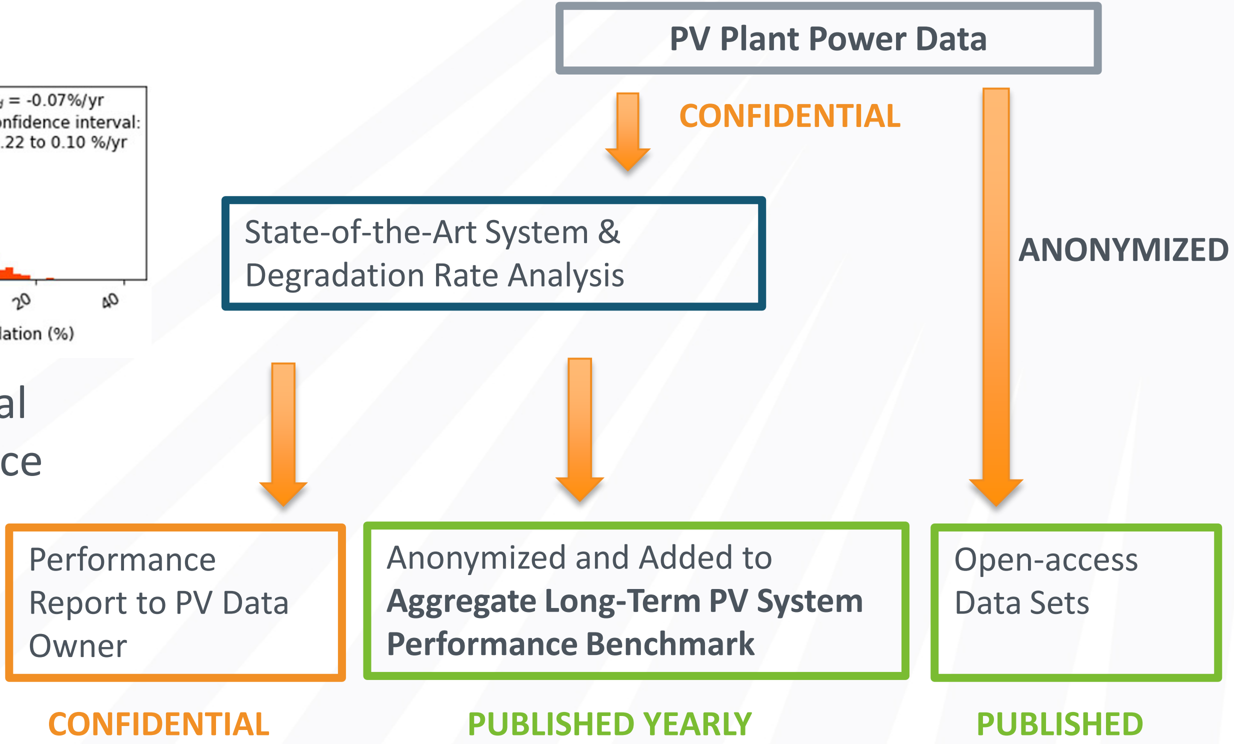
- Performance at fleet level
- System and module power
- Modeling at micro level to predict lifetime

- Outdoor long-tem data
- O&M experiences
- Laboratory validation and accelerated tests

DOE PV Fleet Performance Data Initiative



RdTools used to calculate annual degradation rates and confidence intervals from time-series performance data



www.nrel.gov/pv/fleet-performance-data-initiative.html

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SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

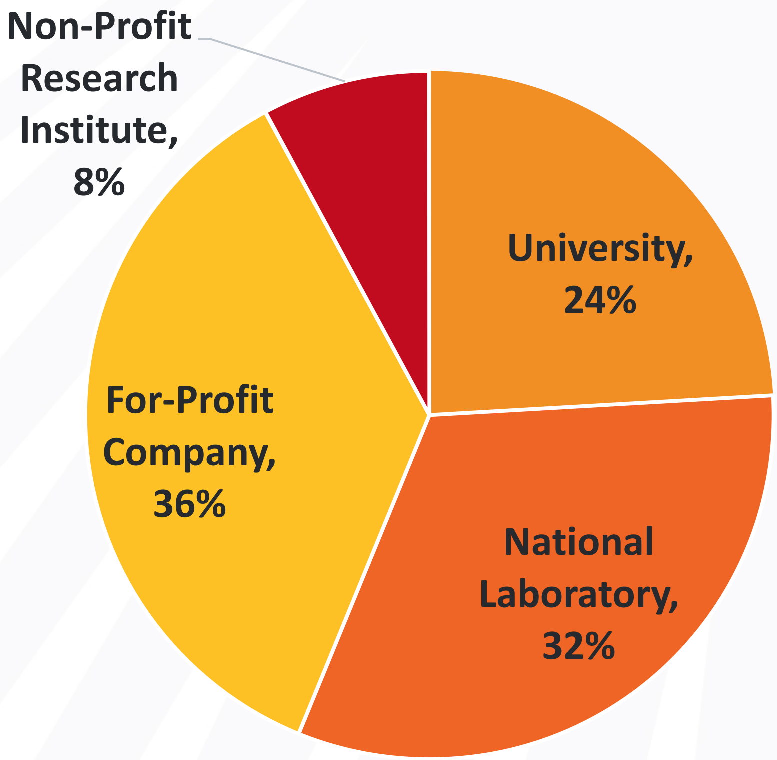
Concentrating Solar-Thermal Power

Dr. Avi Shultz

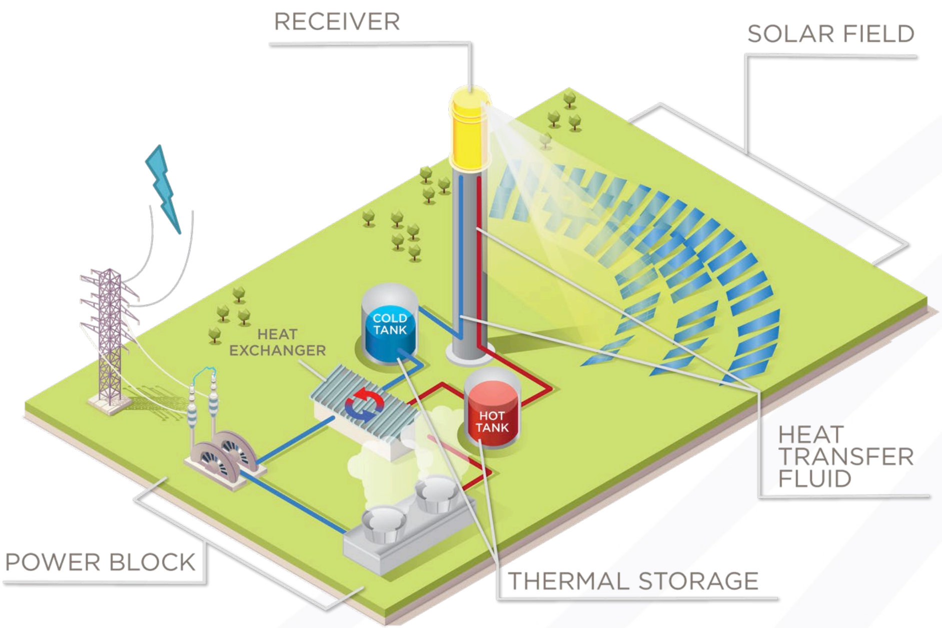
Program Manager, Concentrating Solar-Thermal Power

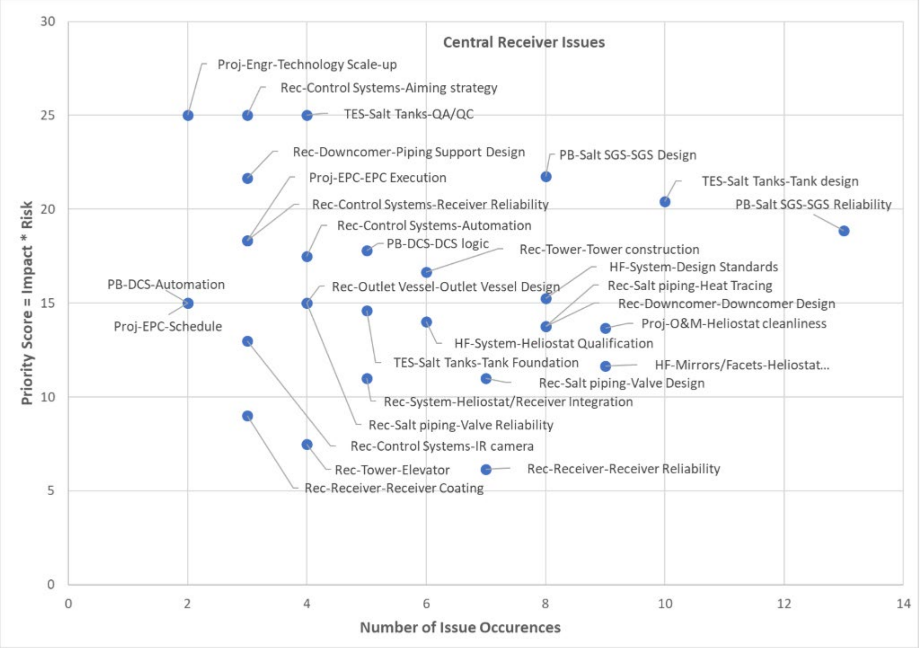
CSP Track Portfolio

- CSP Systems
- Power Cycles
- High-Temperature Thermal Systems
- Solar Collectors
- Desalination and Other Industrial Processes



Topic: CSP Systems

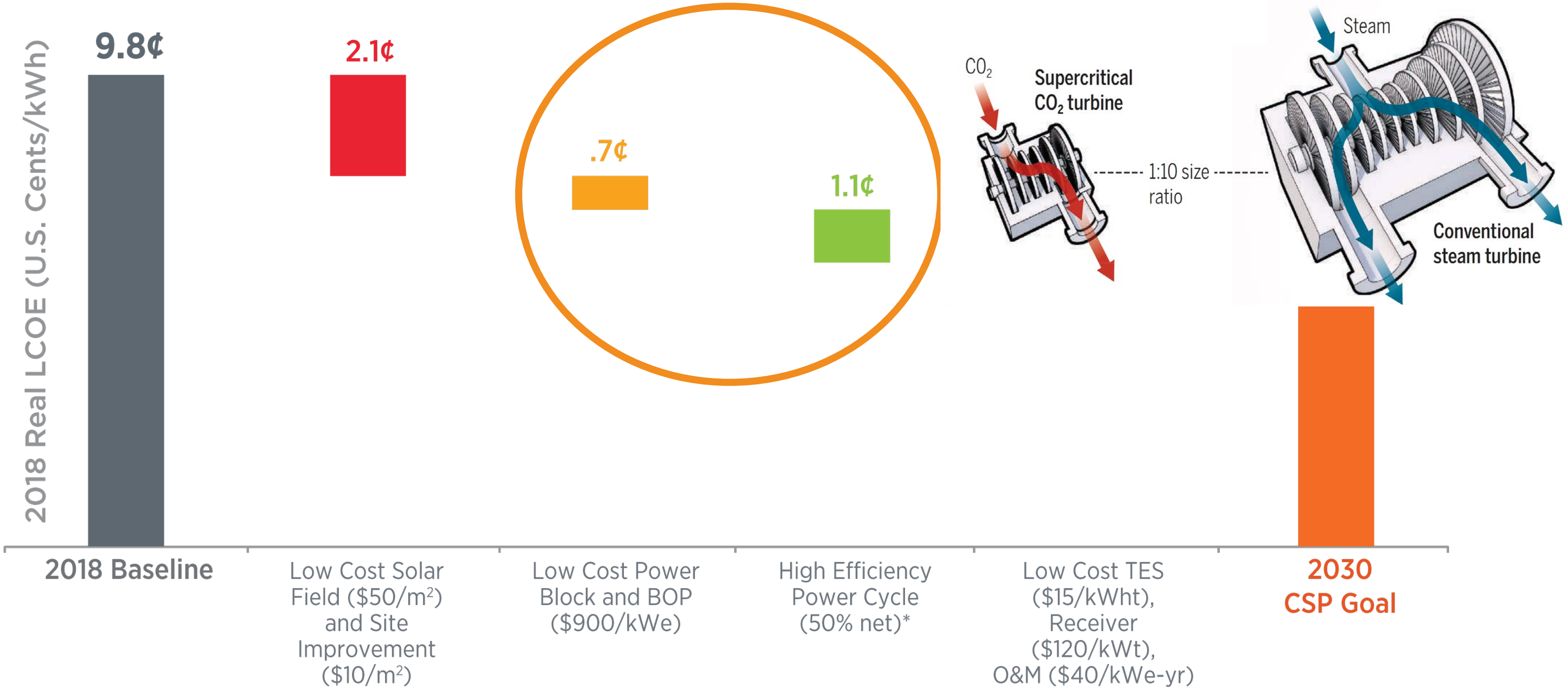




NREL; PI: Mark Mehos

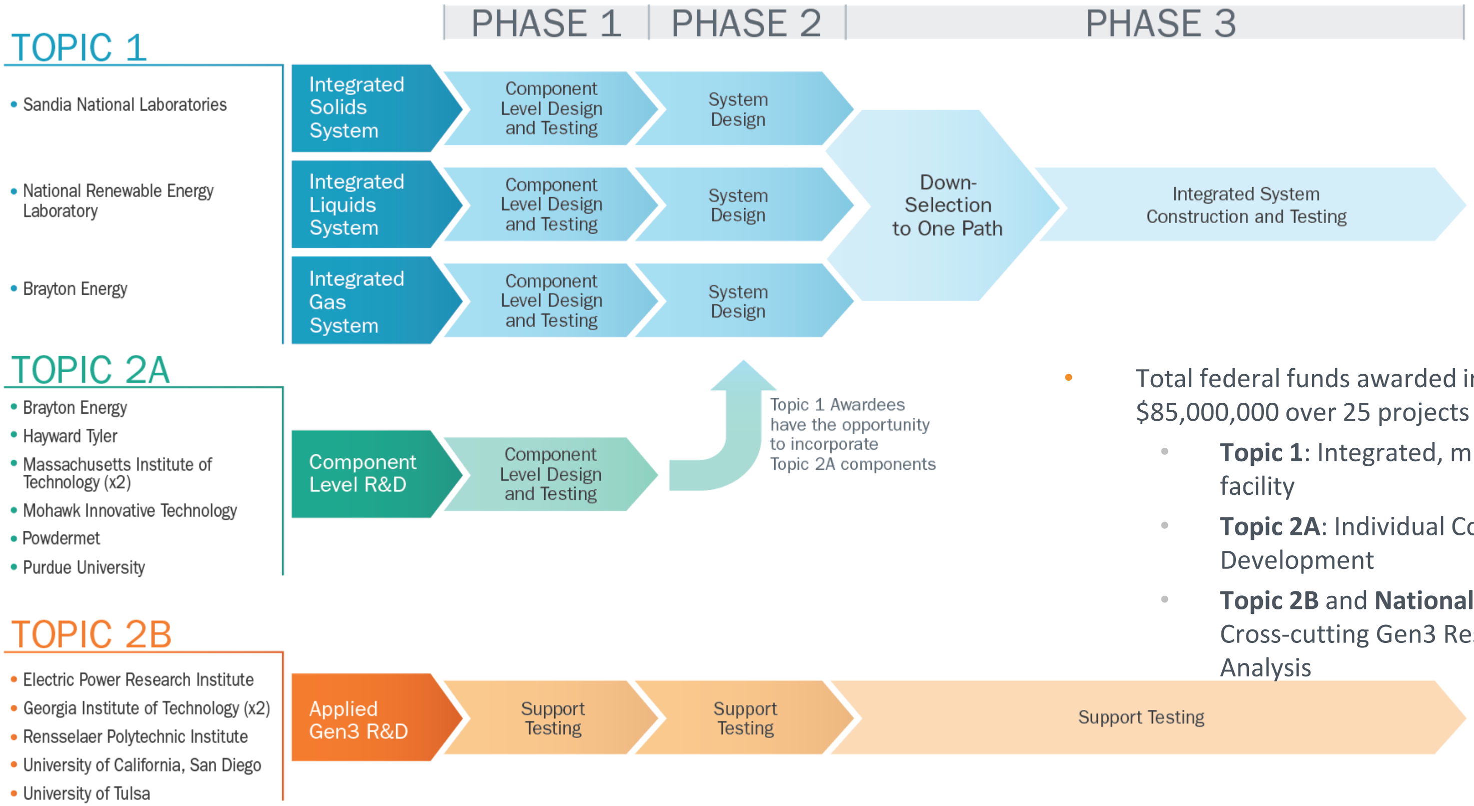
Report in preparation

Topic: Power Cycles



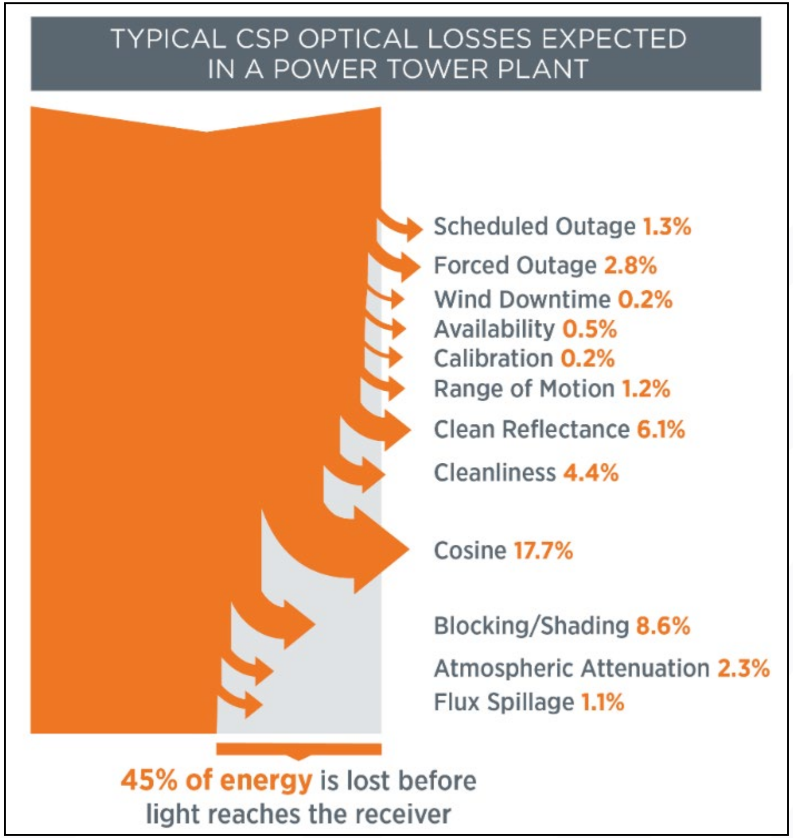
*Assumes a gross to net conversion factor of 0.9

Topic: High-Temperature Thermal Systems



- Total federal funds awarded in 2018: $85,000,000 over 25 projects in 3 Topics:
  - **Topic 1**: Integrated, multi-MW test facility
  - **Topic 2A**: Individual Component Development
  - **Topic 2B** and **National Lab Support**: Cross-cutting Gen3 Research and Analysis

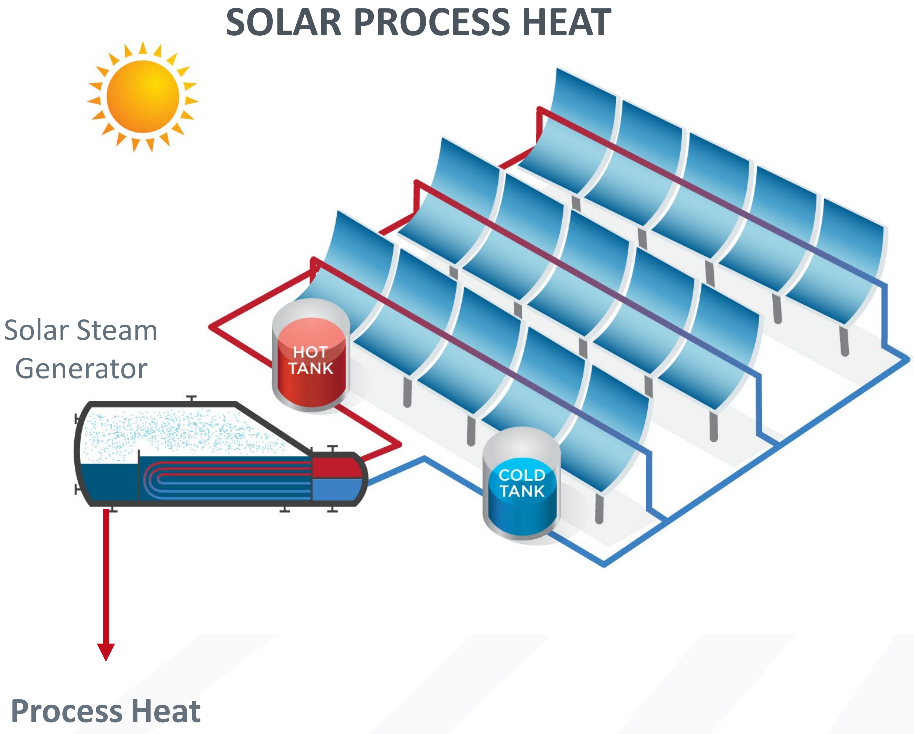
Topic: Solar Collectors



Priority Areas:

- Simplified designs for manufacturing and installation
- Lower costs through non-conventional materials
- Improved performance through autonomous operation

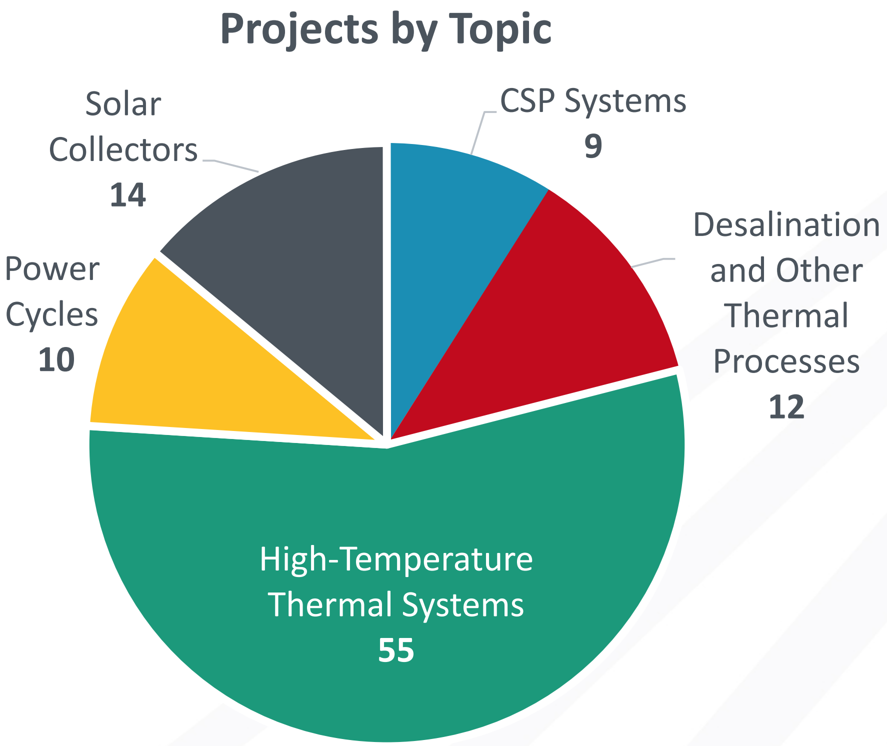
Topic: Desalination and Other Industrial Processes

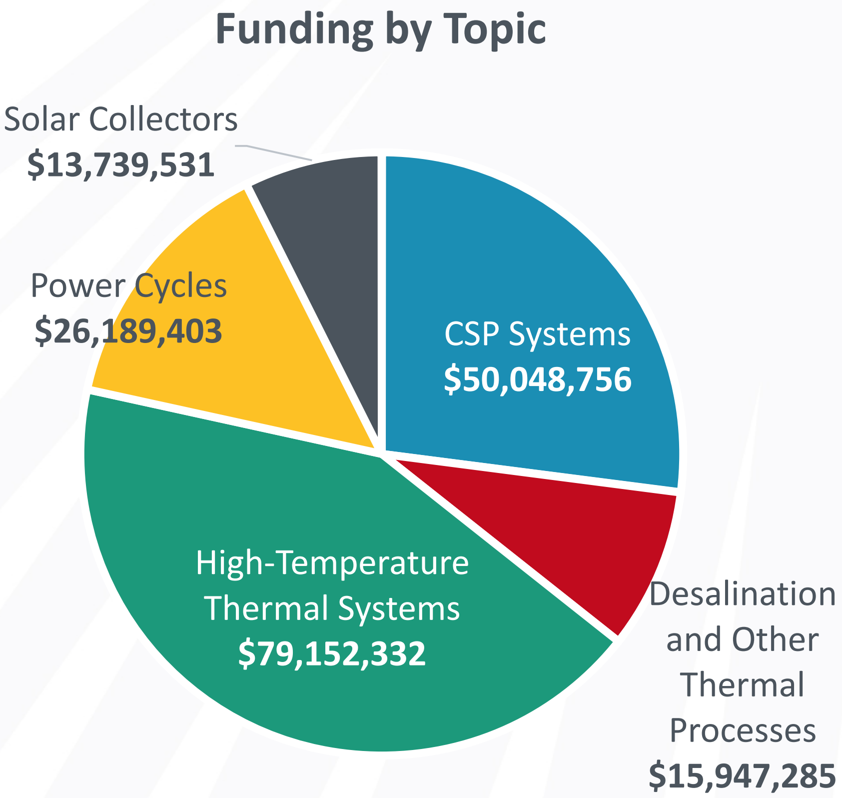


Priority Areas:

- Reduce the levelized cost of heat, **with thermal energy storage**, in temperature ranges of high priority to industrial processes
- Improve the **thermal efficiency** of solar-thermal-coupled processes
- Develop long-duration, thermochemical storage of solar energy (i.e. **solar fuels** and chemical commodities)

CSP Portfolio Breakdown by Topic





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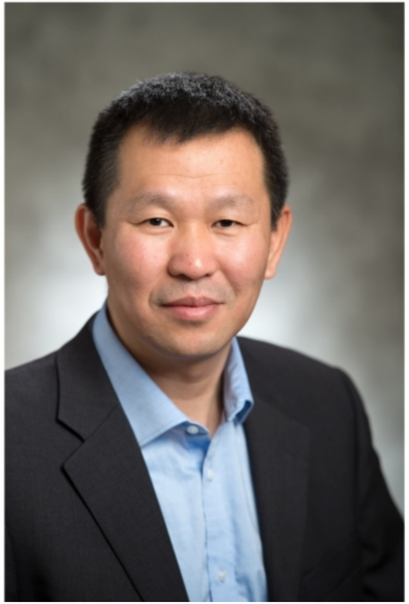


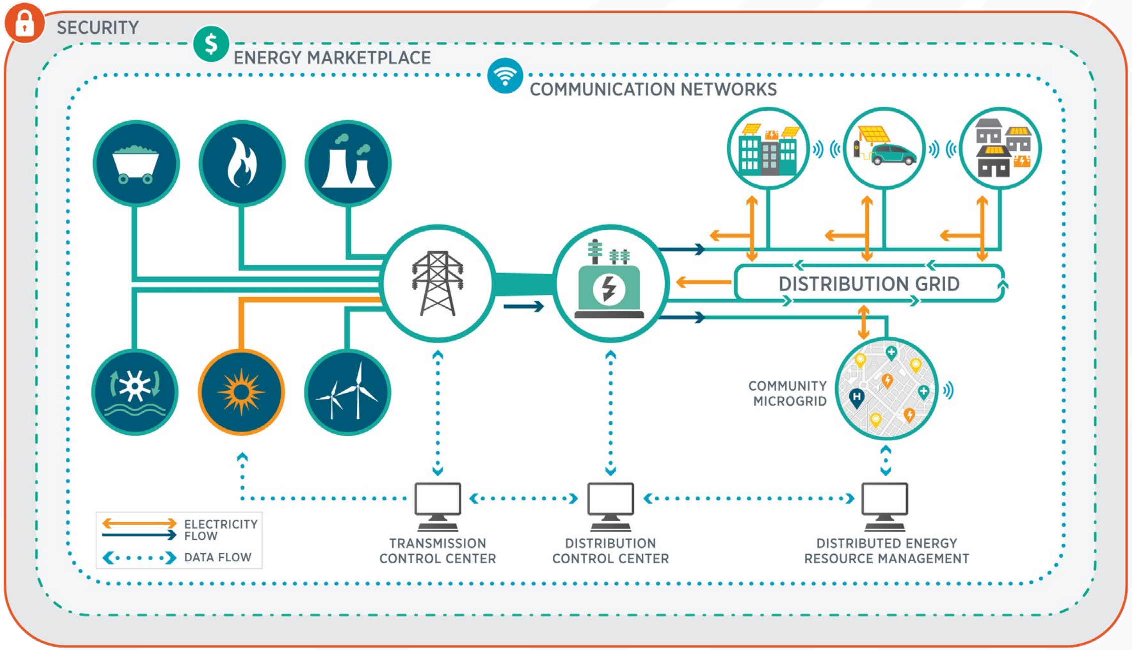
Systems Integration

Dr. Guohui Yuan

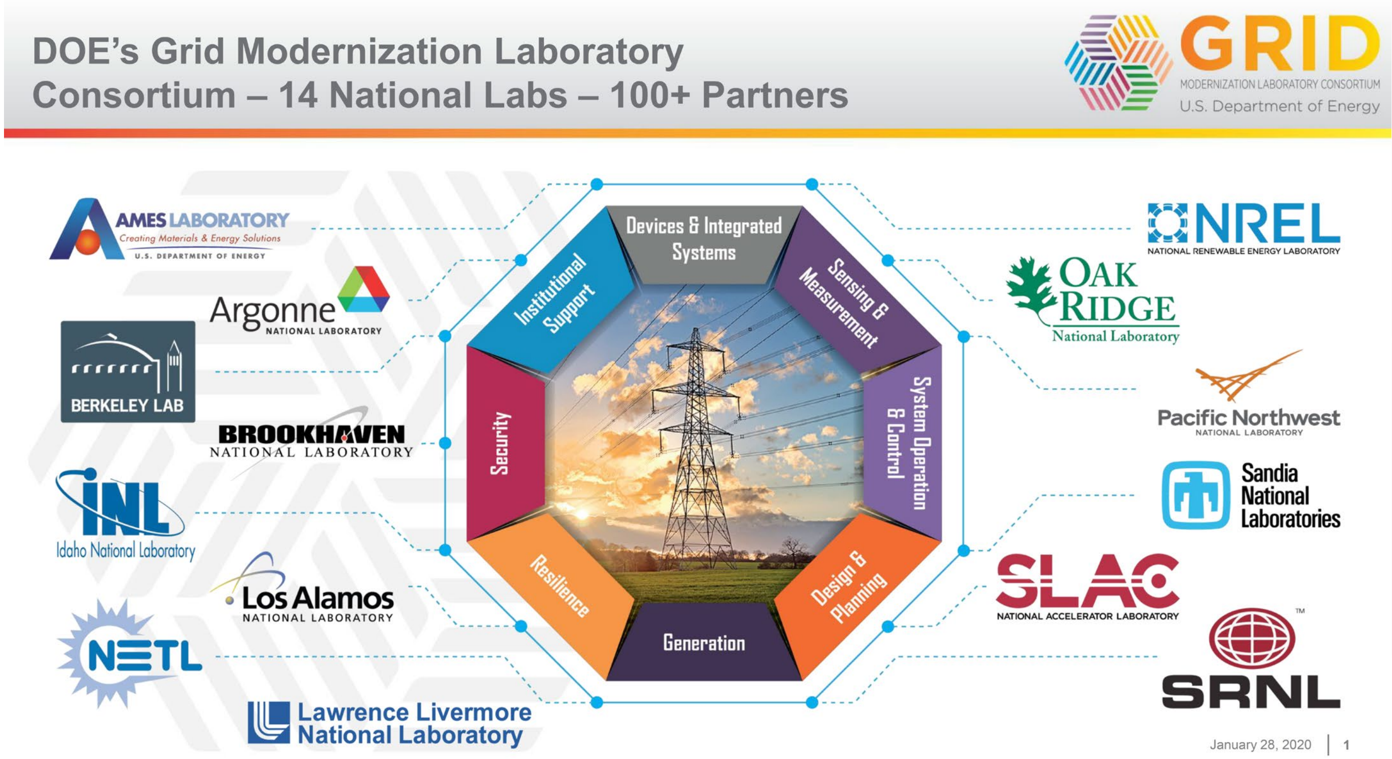
Program Manager, Systems Integration

SETO Systems Integration (SI) Program

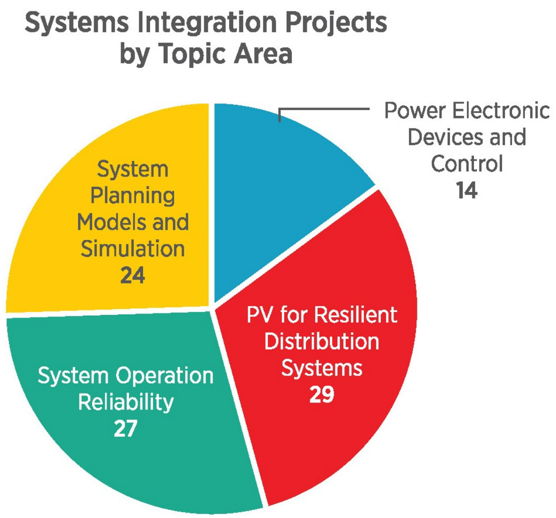
The Systems Integration (SI) subprogram supports early-stage research, development, and demonstration for technologies and solutions that advance the reliable, resilient, secure and affordable integration of solar energy onto the U.S. electric grid.

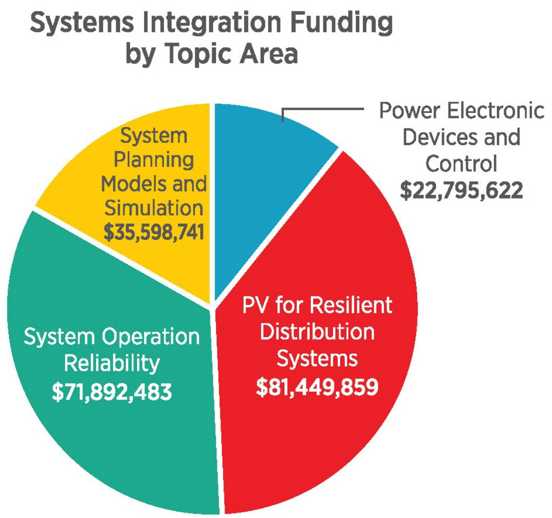


GMI – DOE-Wide Collaboration



SI Track Breakdown – 95 Projects and $213M Funding





- Projects include GMLC, and relevant projects under M&C, and SA programs
- Awardees represent national labs, universities, utility companies, and industry solution providers

SI Track Topic Areas

System Operation Reliability

- Real-time situation awareness and control that ensure system reliability with high penetrations of solar.
- Include sensing and communication, system protection, and optimal control algorithms.

System Planning Models and Simulations

- Modeling methodologies and software tools for short- and long-term system planning scenarios with PV.
- Include PV generation variability, system flexibility, grid stability, and interconnection requirements.

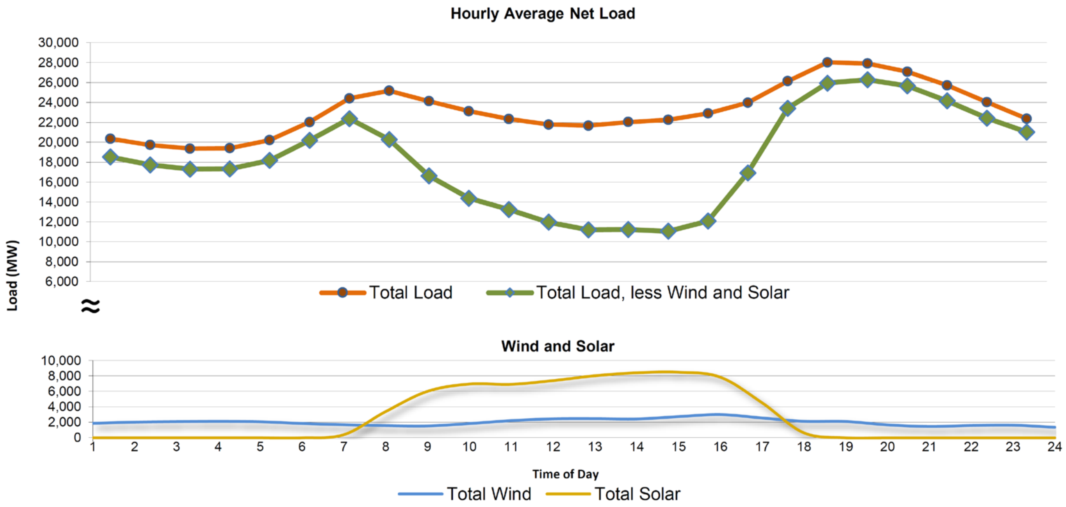
Power Electronic Devices and Control

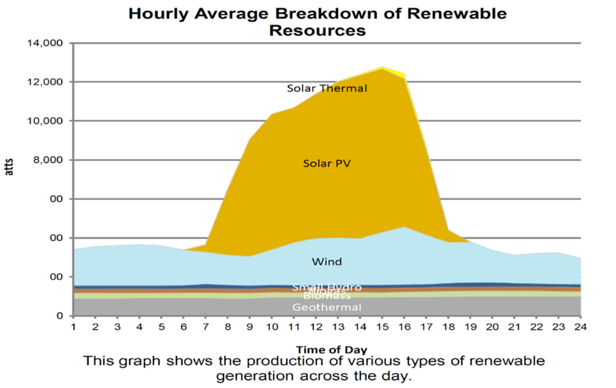
- Hardware technologies that serve as the critical link between solar PV and the electric grid.
- Include equipment efficiency and reliability improvement, cost reduction, and advanced grid control.

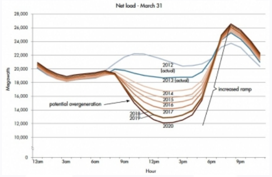
PV for Resilient Distribution Systems

- Distributed solar PV and DERs to provide service continuity during cyber and physical hazards
- Include blackstart capabilities, community microgrid, energy storage integration, for emergency response and faster recovery.

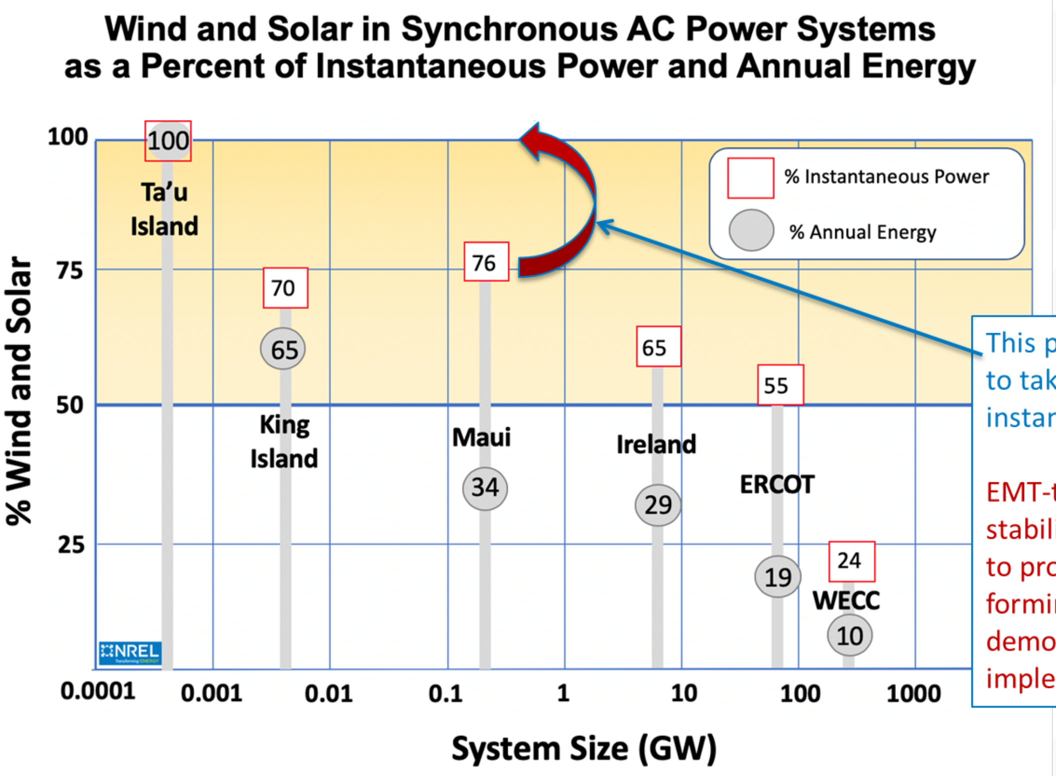
The Duck is Real (March 2, 2020)







Many Technical Challenges Ahead for Solar Grid Integration



This project focuses on how to take Maui to 100% instantaneous IBR.

EMT-type simulations of grid stability needs are expected to prove need for grid-forming inverters. Project will demonstrate in PHIL, then implement in field.

Source: Ben Kroposki / NREL

Solar Grid Integration Research Priorities

2010-2020	PV only contributes energy to the grid; PV doesn't support grid operation and reliability
Low->Medium Penetration	
2020-2030	Smart PV inverters contribute to essential reliability services in the legacy grid
Medium->High Penetration	
2030-	PV and advanced power-electronics provide capabilities to support reliable operation of the modernized grid

Solar generation has grown from less than 0.1 percent of the U.S. electricity supply to 2.6 percent per year and rapidly expanding. In five states, solar electricity already represents more than 10 percent of total generation.

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SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

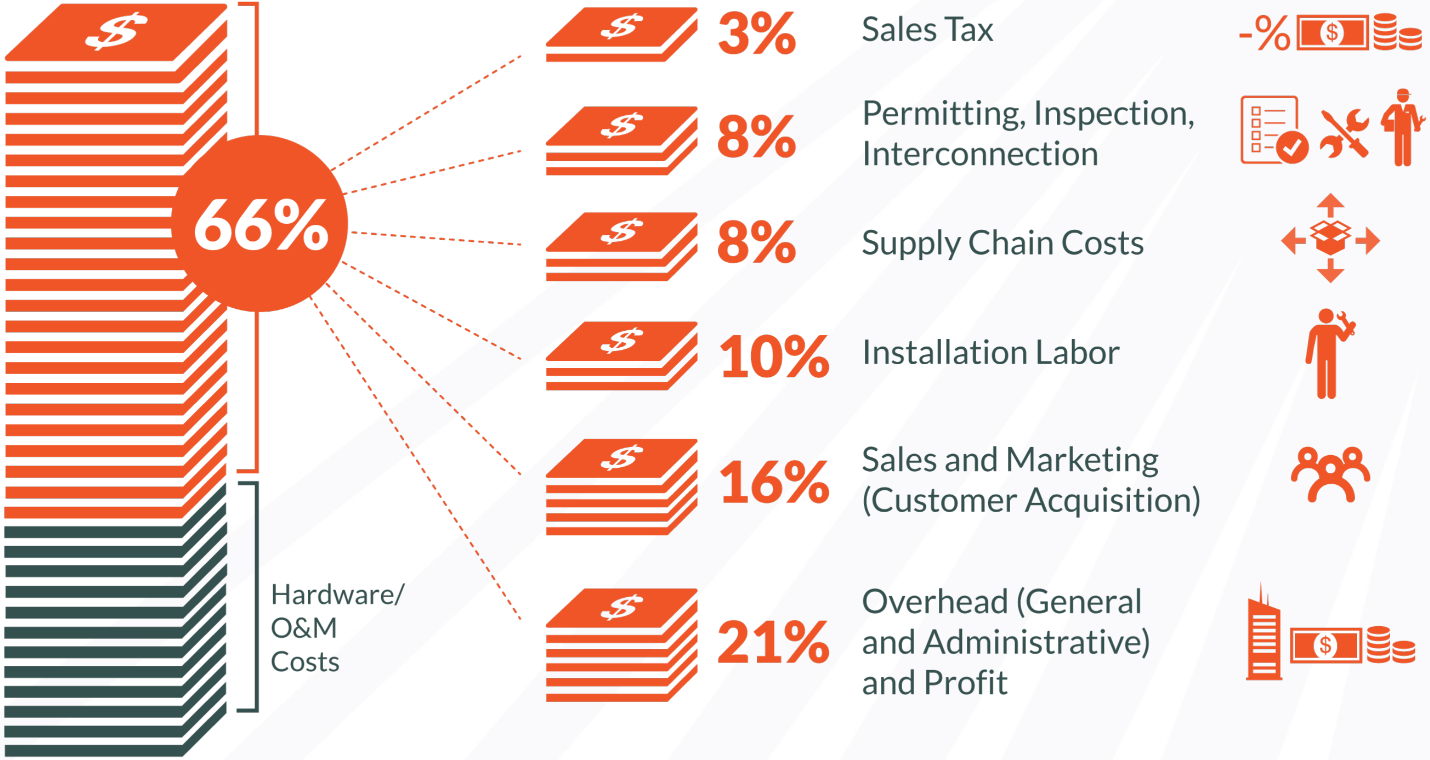
Soft Costs

Garrett Nilsen

Program Manager, Manufacturing and Competitiveness

Introduction to the Soft Costs Track

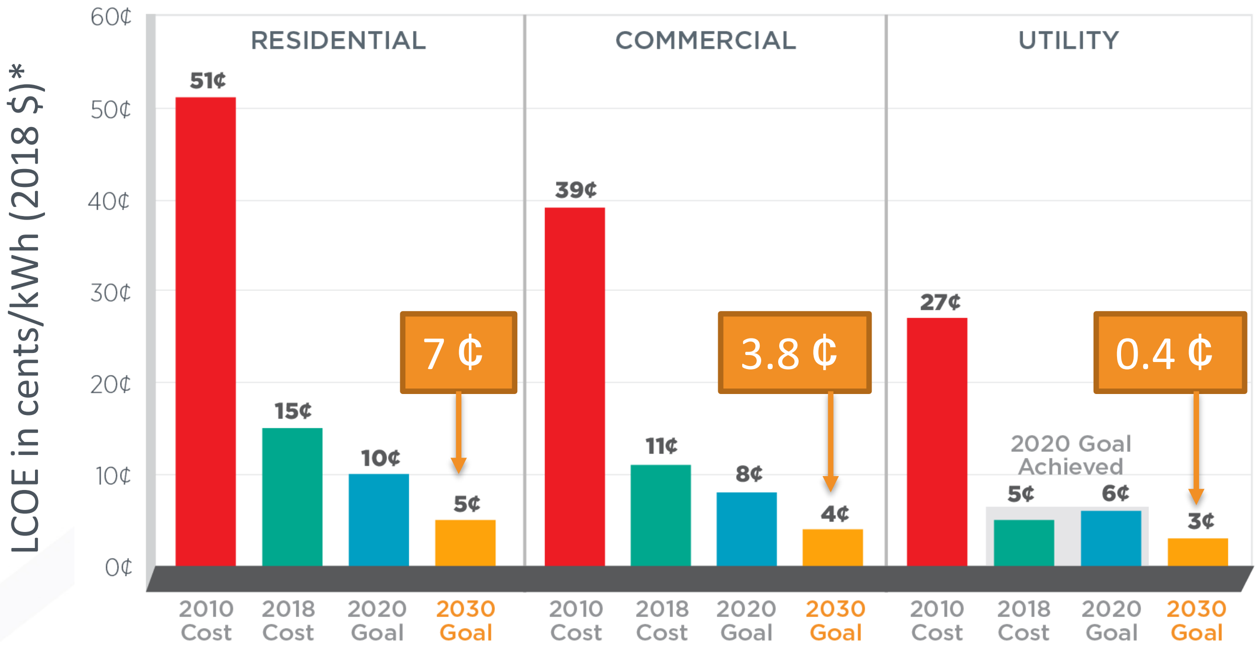
Summary of Solar Soft Costs (Residential)



Source: National Renewable Energy Laboratory (unpublished) "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2019."

Progress and Goals: 2030 Photovoltaics Goals

The office invests in innovative research efforts that securely integrate more solar energy into the grid, enhance the use and storage of solar energy, and lower solar electricity costs.



Potential reductions from soft costs

*Levelized cost of energy (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010-18.

Concentrating Solar-Thermal Power Soft Costs

- Location!
  - Location!
    - Location!

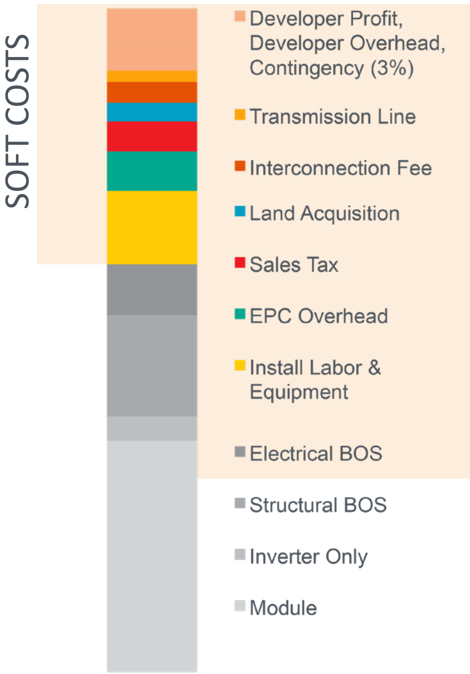
» .....the costs to control land and get approvals

- Environmental Permitting
- Land acquisition
- Interconnection
- And More!

New Markets: Defining and Addressing Soft Costs

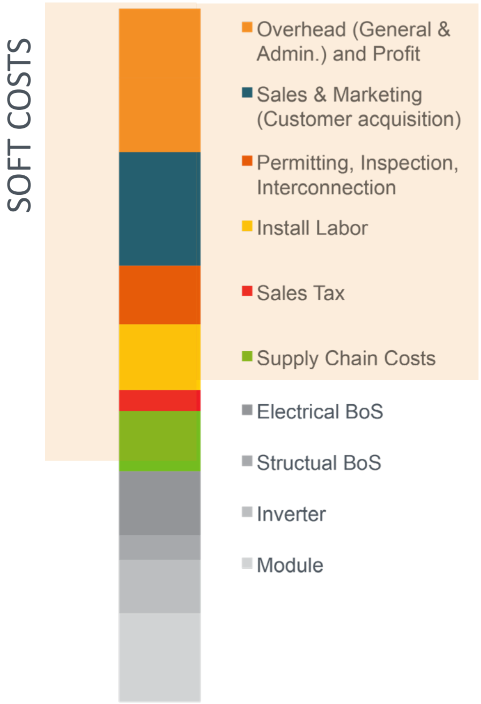
Utility-scale PV

Soft Costs = $.39/watt



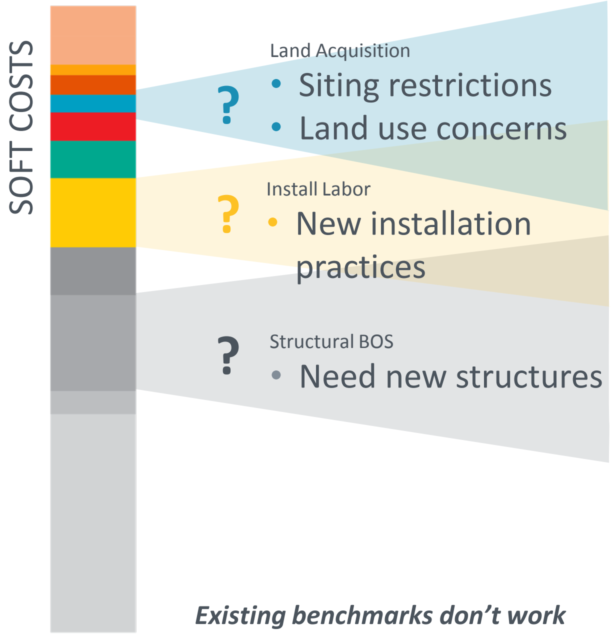
Residential/Commercial PV

Soft Costs = $1.86/watt



More Complex Applications (e.g.,Agricultural PV)

Costs are unknown



Existing benchmarks don't work

COMPLEXITY

Soft Costs Strategic Areas

Manufacturing & Competitiveness

BUSINESS INNOVATION

Developing solar finance and business solutions to expand access to capital and accelerate market growth

TRAINING

Training an innovative solar workforce to enable the solar industry to meet growing demand

NETWORKING AND TECHNICAL ASSISTANCE

Empowering state and local decision-makers through timely and actionable resources, peer networks, and technical assistance

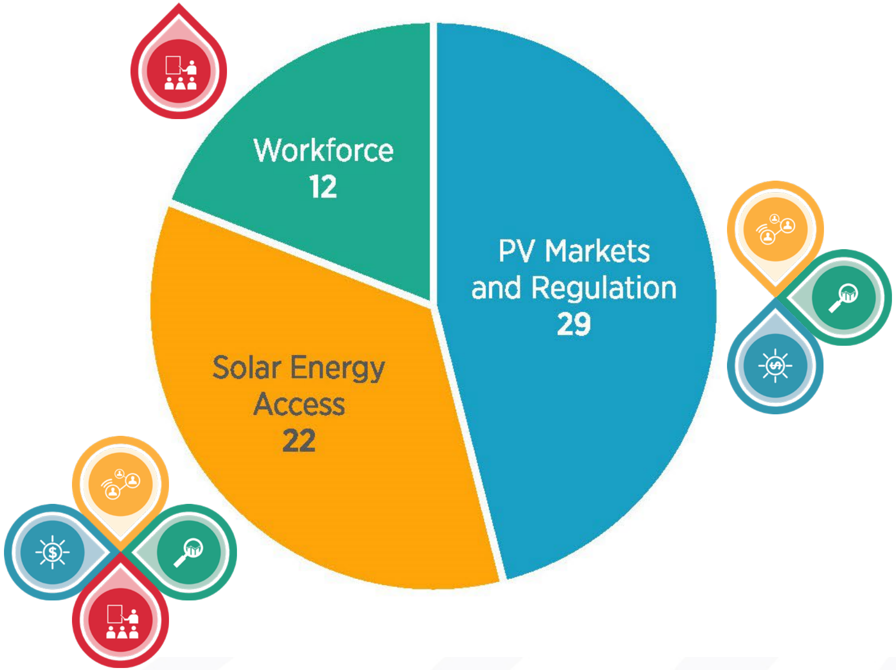
DATA ANALYSIS

Harnessing big data analysis and technical solutions to support the many stakeholders involved in solar deployment

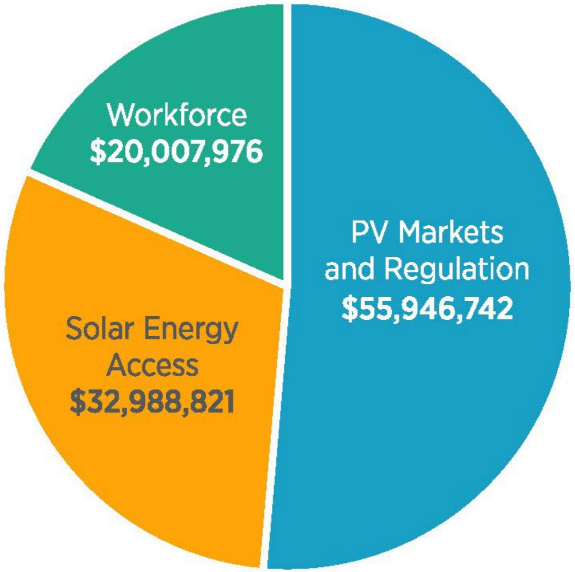
Strategic Analysis and Institutional Support

Soft Costs Track- Award Breakdown

Soft Costs Projects by Topic Area



Soft Costs Funding by Topic Area



Soft Costs Topic Area Scopes

PV Markets and Regulation

- Collecting data, developing tools and conducting analysis to help solar stakeholders navigate the U.S. solar energy markets and reduce soft costs

Solar Energy Access

- Increase access for solar to individuals, particularly individuals that do not have regular access to onsite solar, including low- and moderate-income individuals, businesses, nonprofit organizations, and states and local and tribal governments.

Workforce

- Providing solar energy and grid technology stakeholders with a trained and properly skilled workforce (installation, grid, cyber)

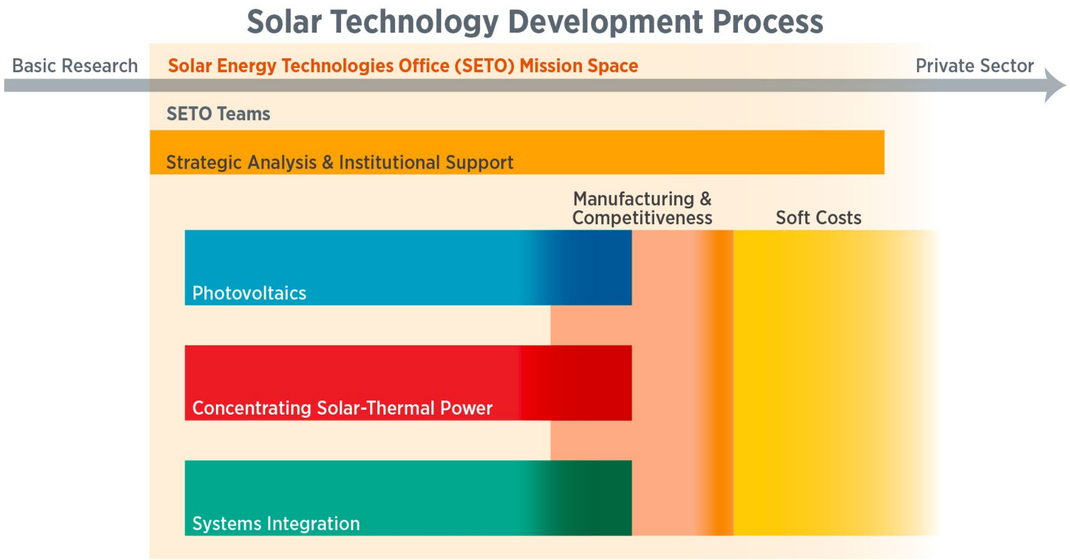
Manufacturing and Competitiveness Team

Manufacturing and Competitiveness Program

Engages in public-private partnerships to:

- Bring products out of the lab and closer to market
- Increase domestic manufacturing competitiveness
- Generate domestic value across the solar value chain
- Develop tools to lower costs and increase deployment

Focuses on 2-4 year horizon to augment short-term industry innovation:



Where you will find M&C projects?

- A **Full List of M&C Projects** can be found starting on ***Page 147 of the SETO 2020 Peer Review Book***

- In all of your tracks!!!
  - Projects were broken into Photovoltaics, Concentrating Solar-Thermal Power, Systems Integration and Soft Costs tracks
  - Goal: Allow you reviewers to see full spectrum of projects SETO funds in those areas

Tech-to-Market Project Approach

Promote activities that amplify the impact of R&D projects and enable technology transformations from prototypes to real-world, viable solutions.

Research & Development

↓

Market-relevant and self-sustaining technology

Plan

- T2M road-mapping
- IP strategy
- Product-market fit
- Path to scale

Validate

- Competition
- Standards
- Analysis
- External feedback

Engage

- Diversity
- Partnerships
- Follow-on funding
- Customer discovery

Annual Recurring Funding Programs

SETO Designed Programming

INCUBATOR

AMERICAN MADE SOLAR PRIZE

U.S. DEPARTMENT OF ENERGY

Congressionally Mandated Programming

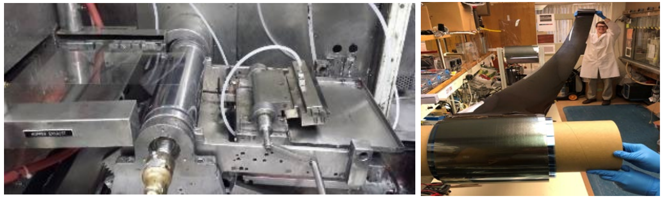
TECHNOLOGY COMMERCIALIZATION FUND

SBIR · STTR

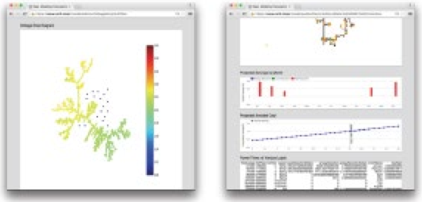
America's Seed Fund

Example Company Awardees

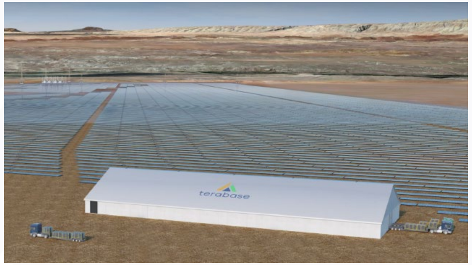
Energy Material Corp - Perovskites at scale



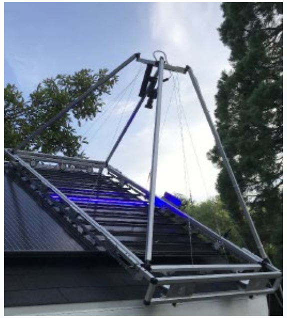
NRECA - Interconnection Automation



Terabase - Installation Automation

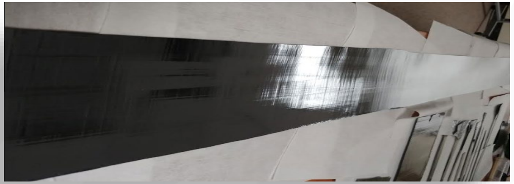


Tau Science - Field Characterization

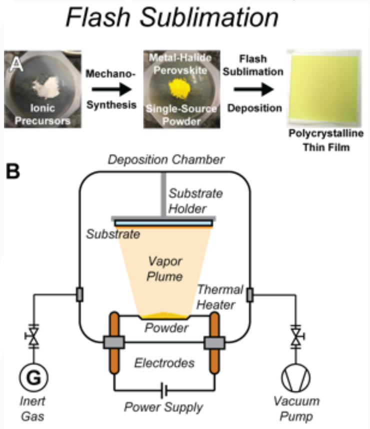


SpanIO - Solar/Storage/Load Integration

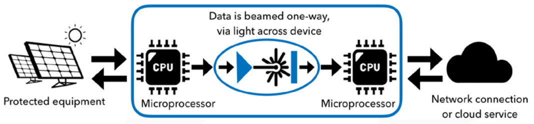
Leading Edge Crystal Technologies - Si wafers



Bluedot – Perovskite Deposition



Fend - Cybersecure Connectors



Fracsun - Soiling Measurement

Workforce Programming (active projects)

Expanding the Employee Pool

IGEN Illinois Green Economy Network — A Community College Partnership

The Great Tribal Seal of the Blue Lake Rancheria

SAFER FOUNDATION — A Road To A Better Future℠

PHILADELPHIA ENERGY AUTHORITY

mrea — midwest renewable energy association

Working with Veterans and Transitioning Military

SUNSPEC ALLIANCE

SOLAR READY VETS® NETWORK — U.S. DEPARTMENT OF ENERGY

Creating the Curriculum of the Future for Power Systems Engineers

EPRI — ELECTRIC POWER RESEARCH INSTITUTE

Cross discipline undergraduate competition

Strategic Analysis and Institutional Support Team

SAIS Team Goals or Mission

1. Support the development and dissemination of **analysis, tools, and data resources** related to the **cost and value of solar technologies alone and as they integrate with other technologies on the grid**
2. Provide public-sector institutions, in partnership with other solar industry stakeholders, with **technical assistance in applying these tools, data and information to address specific challenges**

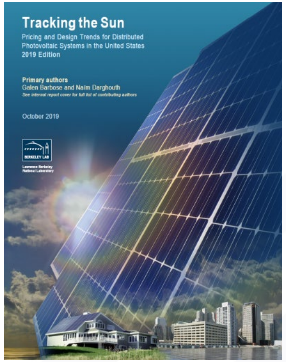
Current Areas of Emphasis in the SAIS Portfolio

- Solar Energy Data Ecosystem
- Grid Planning and Operational Analysis with High Penetrations of PV
- Integration of PV with Other Technologies (Behind the Meter)
- PV System Product Pricing and Costs
- Markets and Regulatory Analyses
- Analysis of Solar Access and Equity
- CSP System Costs and Value
- Technical Assistance

Examples of Awardees, Programs and Work Products

- Flagship Reports

BERKELEY LAB
Lawrence Berkeley National Laboratory



- Topical R&D: Avian and Solar

EPRI
ELECTRIC POWER RESEARCH INSTITUTE

Ucla

Argonne NATIONAL LABORATORY

- New Industry Analysis

- Technical Assistance for Decision Makers

SOLAR ENERGY INNOVATION NETWORK
U.S. DEPARTMENT OF ENERGY

Summing it Up

The Future for Solar is Bright

- Building on a successful decade
- Tremendous potential for the next decade
- Challenges and opportunities

We Have Important Goals to Achieve Together

- Peer review will help us to move forward

Thank You!