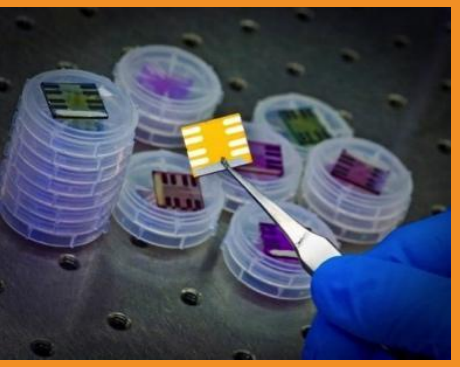
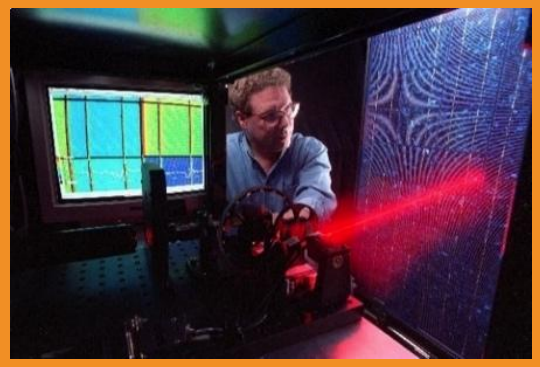
U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE




Agriculture and Solar

From competition to co-location

Zachary Eldredge, Technology Manager
Strategic Analysis and Institutional Support
zachary.eldredge@ee.doe.gov

energy.gov/solar-office

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

Solar Energy Technologies Office (SETO) Overview

MISSION

We accelerate the **advancement** and **deployment of solar technology** in support of an **equitable** transition to a **decarbonized energy system by 2050**, starting with a decarbonized power sector by 2035.

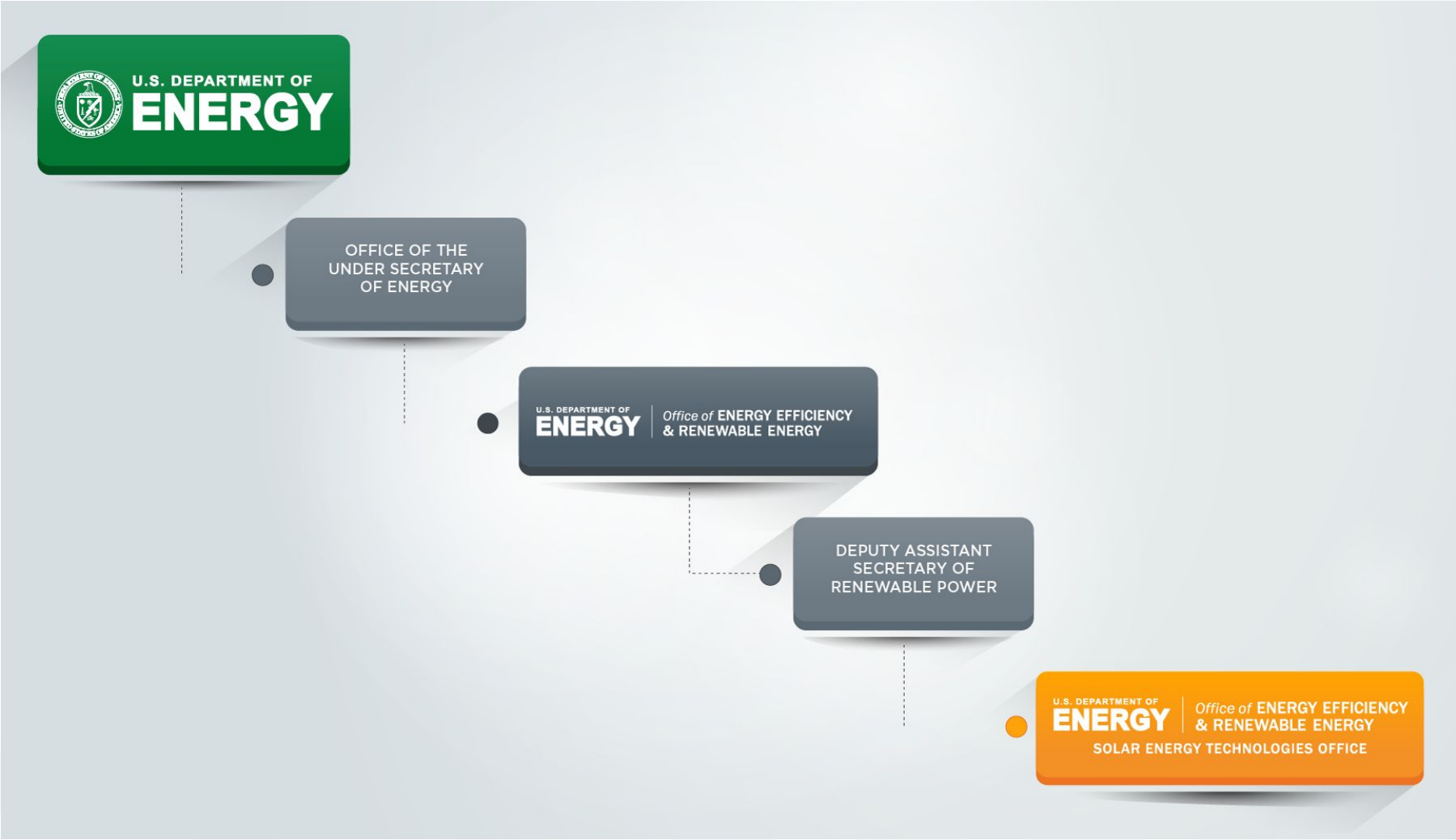
WHAT WE DO

Advance solar technology and drive soft cost reduction to make solar **affordable** and **accessible** for all Americans

Enable solar to **support grid reliability** and pair with storage to provide new options for **community resilience**

Support **job growth**, **manufacturing**, and the **circular economy** in a wide range of applications

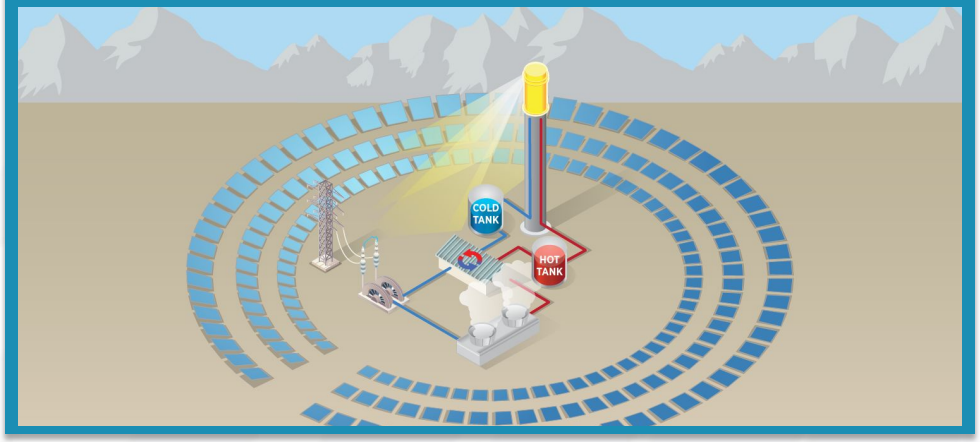
Where Does SETO Fit Within the Energy Department?



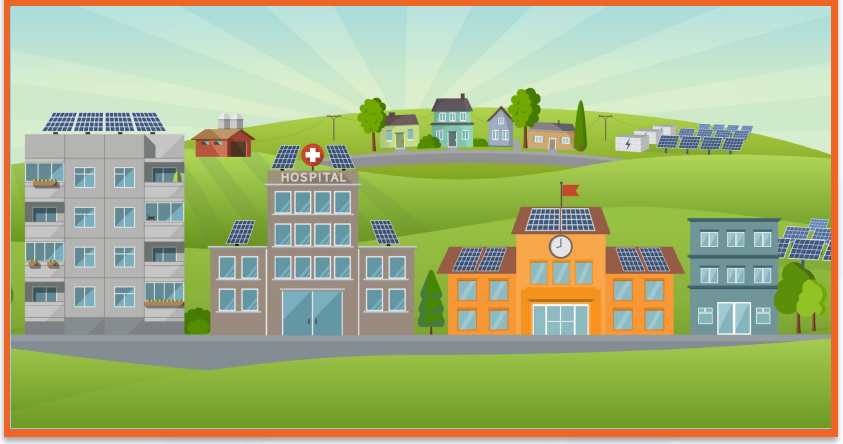
SETO Research Areas

PHOTOVOLTAICS

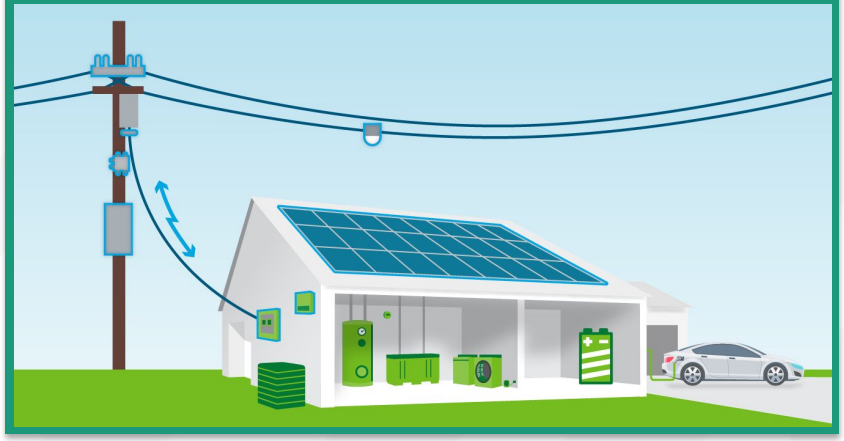
CONCENTRATING SOLAR-THERMAL POWER



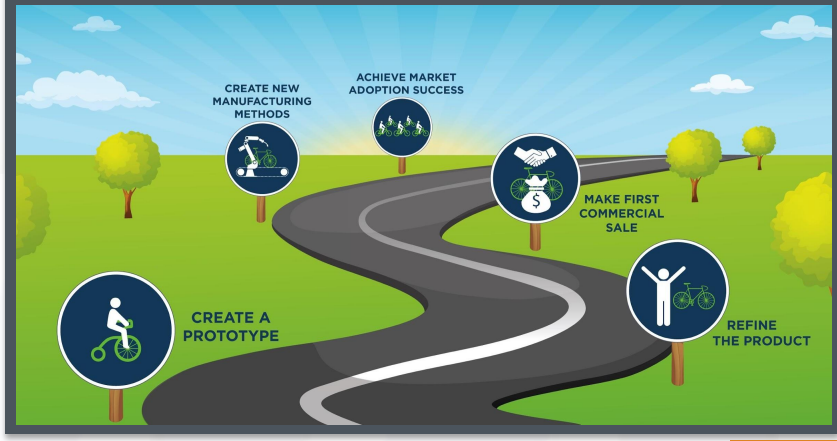
BALANCE OF SYSTEMS/ SOFT COST REDUCTION



SYSTEMS INTEGRATION



MANUFACTURING AND COMPETITIVENESS



EERE Programmatic Priorities

1. Decarbonizing the electricity sector.
2. Decarbonizing transportation across all modes: air, sea, rail, and road.
3. Decarbonizing the industrial sector.
4. Reducing the carbon footprint of buildings.
5. **Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water.**

Outline

Solar: Past, Present, Future

- Solar in the U.S. today
- Future scenarios; land-use impacts

Integrating Solar with Agriculture

- Possible technologies
- Open questions

Current SETO Projects

- InSPIRE
- Other projects

Opportunities to Engage

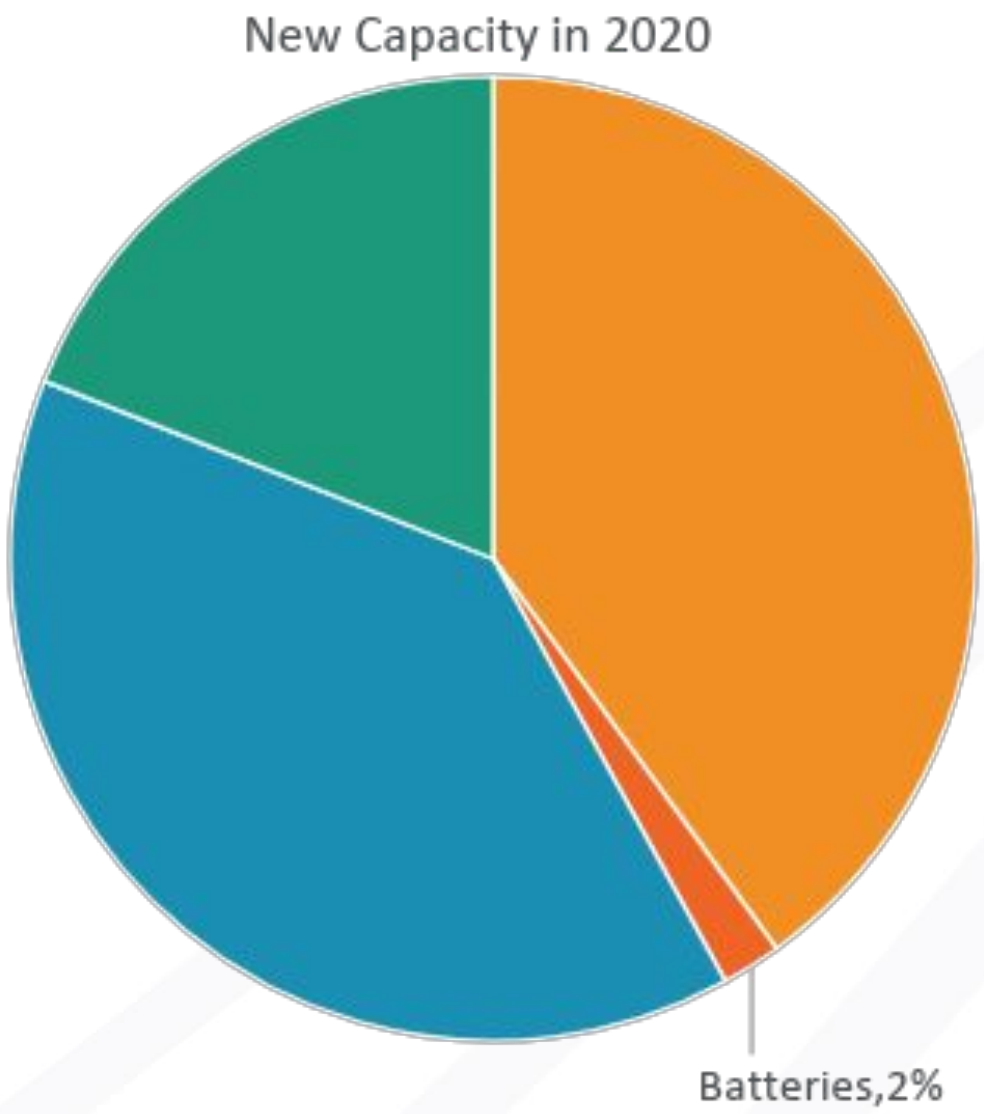
- Working groups
- Work with us!

U.S. Solar: Falling Costs, Rising Deployment

The solar energy industry is one of the fastest growing industries in the nation. Driven by falling costs and state and federal policy, total solar PV installed capacity is now **95 GW** and is **projected to grow to 118 GW** by the end of the year.

*Price is depicted as levelized cost of energy (LCOE)
Sources: National Renewable Energy Laboratory, "U.S. Solar Photovoltaic System Cost Benchmark: Q1 2019"; Wood Mackenzie Power & Renewables/SEIA U.S. Solar Market Insight.

Solar is One of the Fastest Growing Energy Sources in America

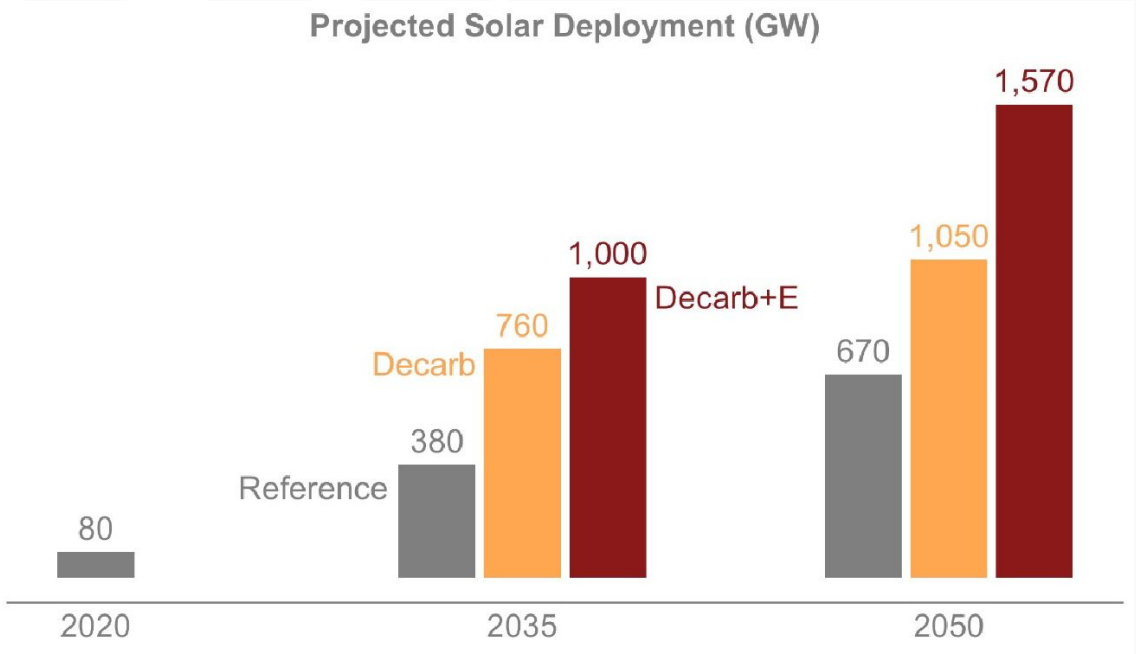


In 2020, solar PV represented **40%** of all new electricity capacity installed in the United States.

Solar energy represented **33%** of new capacity additions **over the past 5 years** and now supplies over 3% of the nation's annual U.S. electricity.

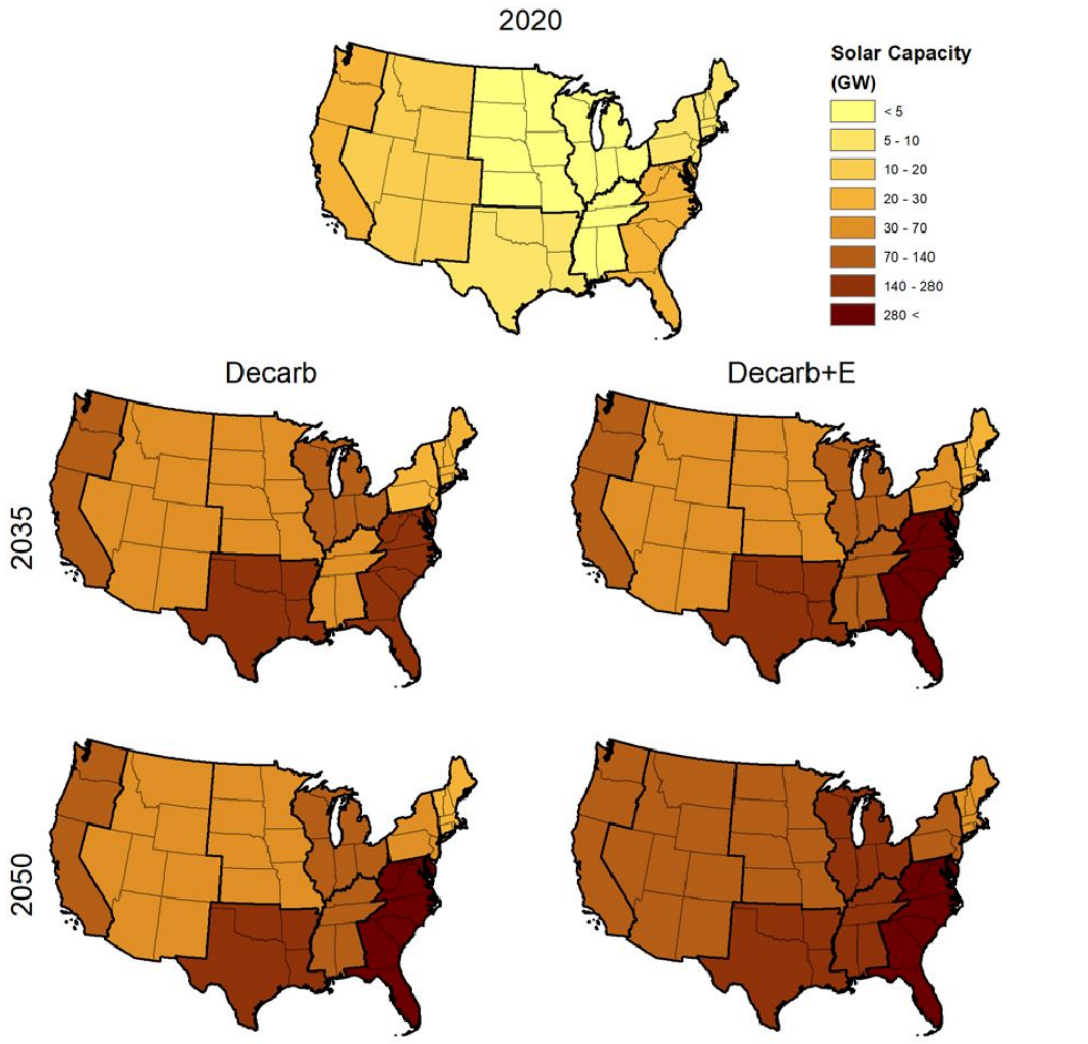
Solar Futures Study

- In early September 2021, DOE released the *Solar Futures Study*
- Charts a pathway to providing 45% of U.S. electricity through solar by 2050 (3% in 2020)
- Achieves 95% decarbonization by 2035



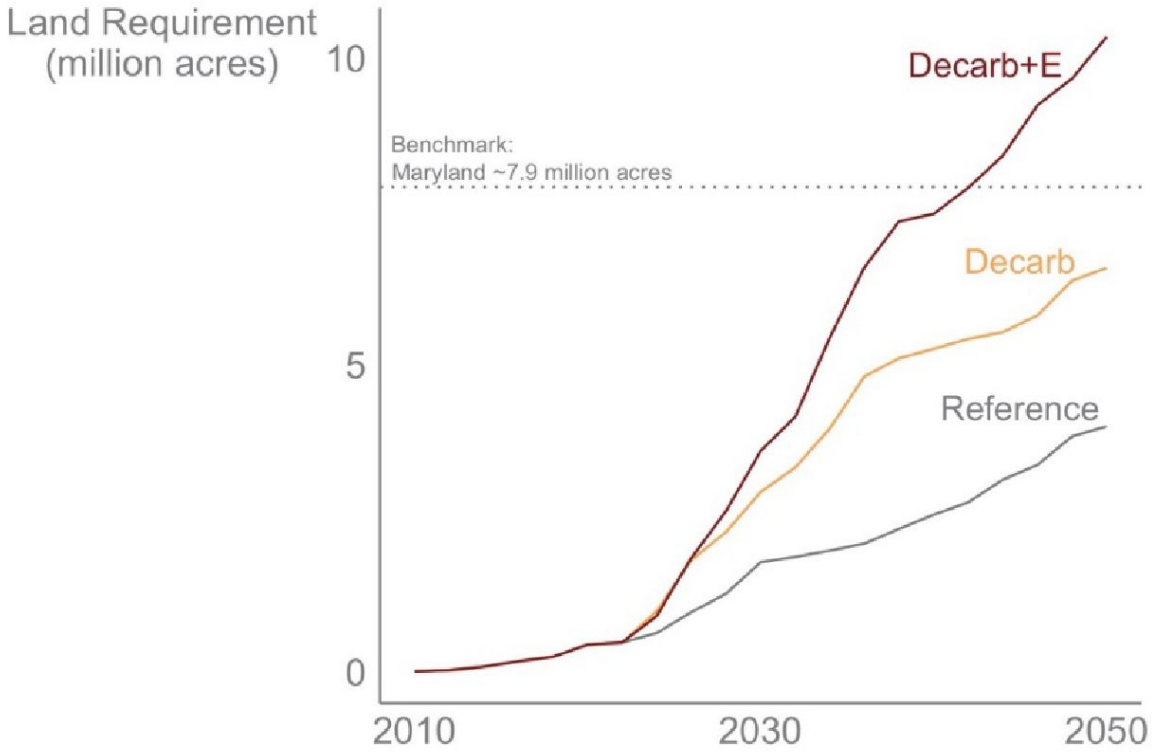
Solar Futures Study

- Solar capacity doesn't just increase but also comes to new places
- In *SFS,* every Census region has more solar in 2035 than anyone does today
- Lots of capacity deployed outside the usual suspects (CA, NV, AZ)
  - Texas is a major growth area (with transmission issues to solve)
  - So is Florida, Georgia

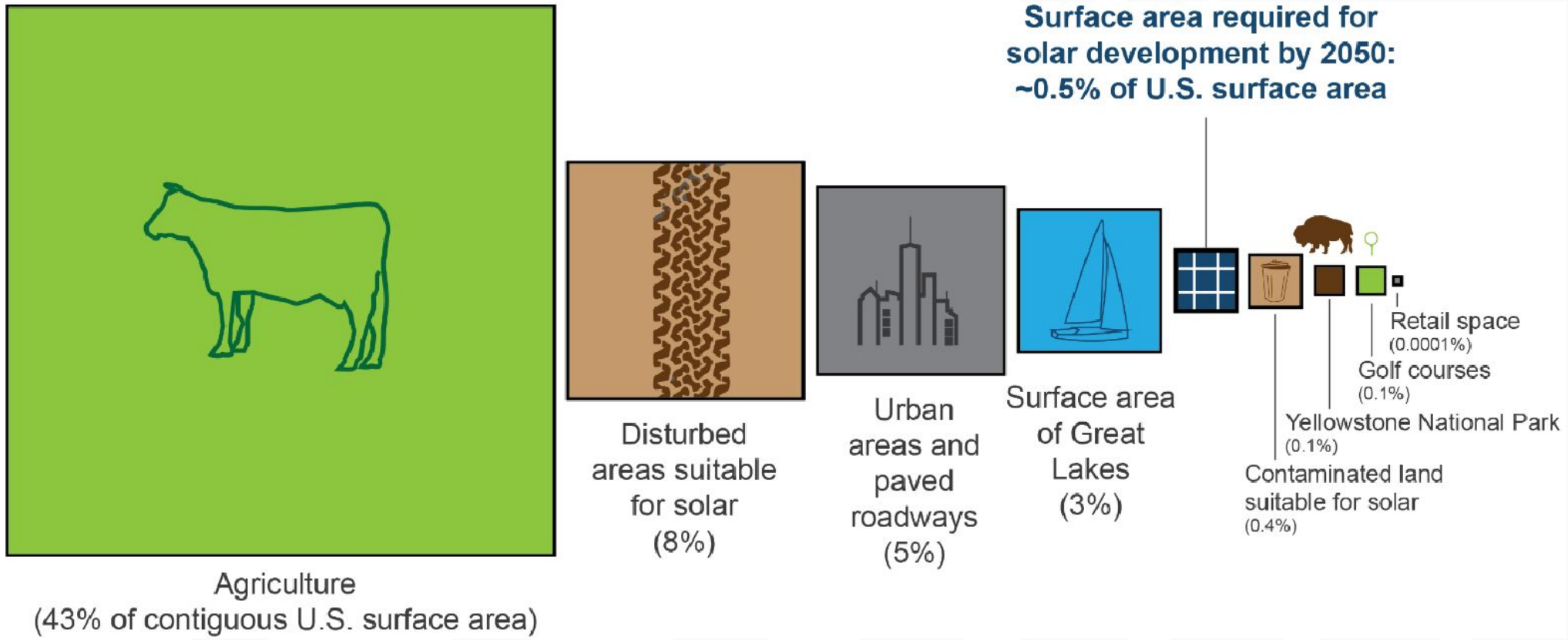


Solar Futures Study: Land-Use

- Estimates of land-use are generated by assuming 7.5 acres/MW for utility-scale PV
  - This is a rough estimate and in reality it varies by latitude, type of hardware deployed, etc
- Under the *SFS* scenarios land use in 2035 is roughly 5.7 million acres, increasing to as much as 10 million acres in 2050
- Larger than the state of



Solar Futures Study: Land-Use

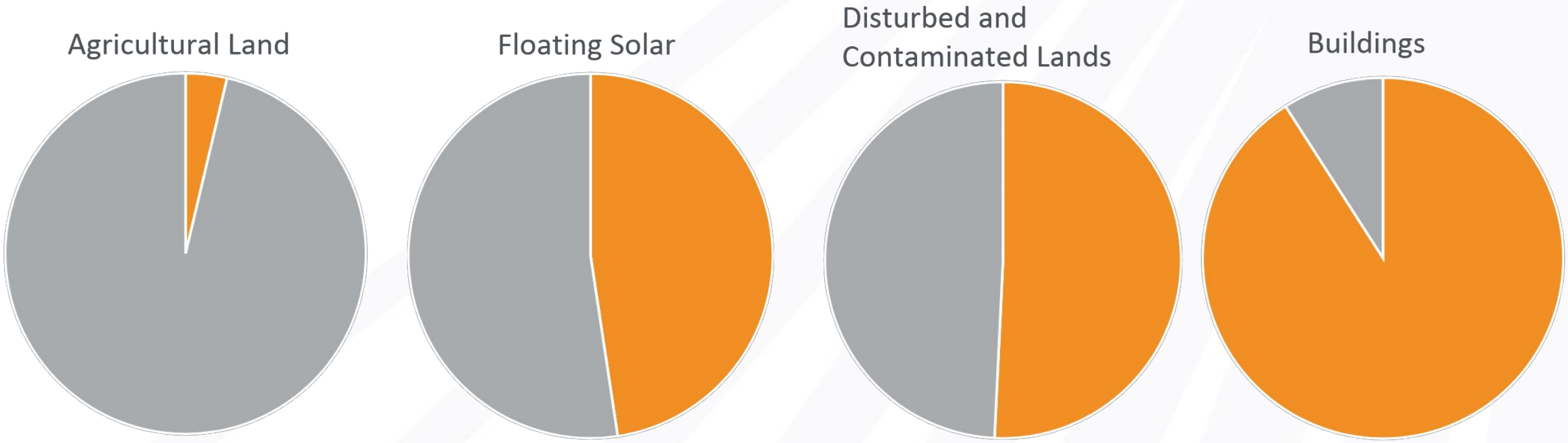


Solar land-use is not huge compared to total U.S. land available, but it will have impacts on local communities and some friction is to be expected

Achieving 1 TW of Solar by 2035: PV Potential

There are 115 TW of technical PV potential in the United States.

Each **orange piece** represents **1 TW** of potential.



Agrivoltaics: Harvesting the Sun Twice

“Traditional” Solar Development

- Removes existing vegetation
- Strips and grades topsoil
- Discourages habitat for insects, birds, or other animals
- Focus on minimizing need for mowing or vegetation management
- **Can we do better?**

Source: Lexington Herald Leader

Agrivoltaics: What Is It?

Agrivoltaics

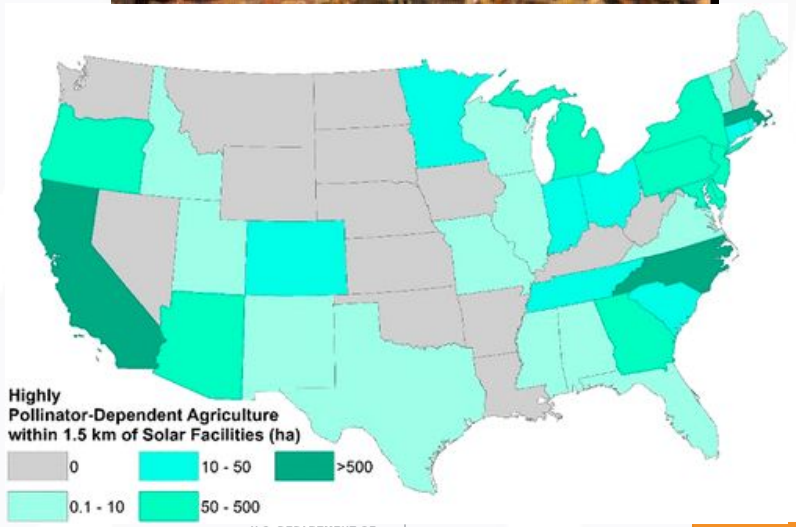
Agriculture (crop and livestock production, as well as pollinator habitat) underneath the panels, and/or in adjacent zones around the solar panels

Also called…

- Co-location of solar and agriculture
- Dual-use solar
- Ag-PV
- ….

Pollinators: The Birds and the Bees

- Plant flowers, grasses, etc which intentionally support pollinator habitat
- About 23% of U.S. crops depend on animals for pollination
- Solar fields with pollinators can provide significant benefits to surrounding ag communities



Grazing: Nature's Lawnmowers

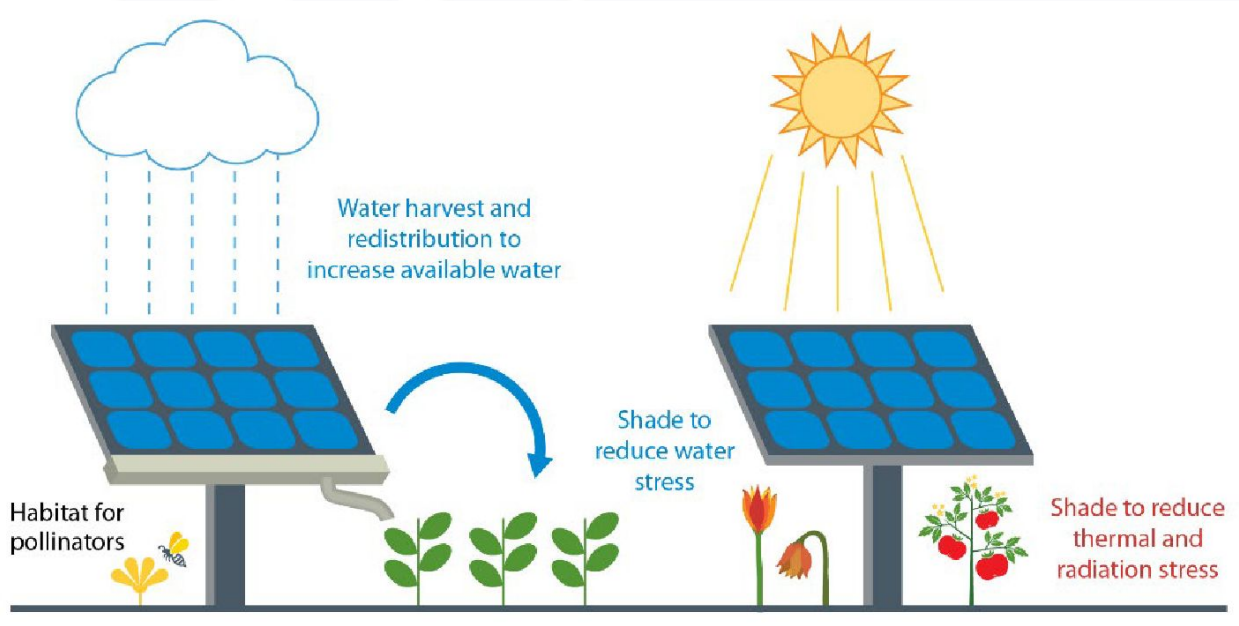
- Solar fields can be used as grazing sites for livestock
- Dual benefit:
  - Ranchers/shepherds get forage
  - Solar operators can avoid mowing, use of herbicides
- Check out the American Solar Grazing Association for more info!

Crops: Food and Energy Together

- Growing crops with solar panels requires careful attention to crop and solar design
- Crop questions:
  - How light-dependent is it?
  - How tall does it grow?
  - Can it be hand-harvested economically?
- Solar questions:
  - How are the panels spaced?
  - Are they high enough?
- Crop systems are of high interest to DOE but many open questions

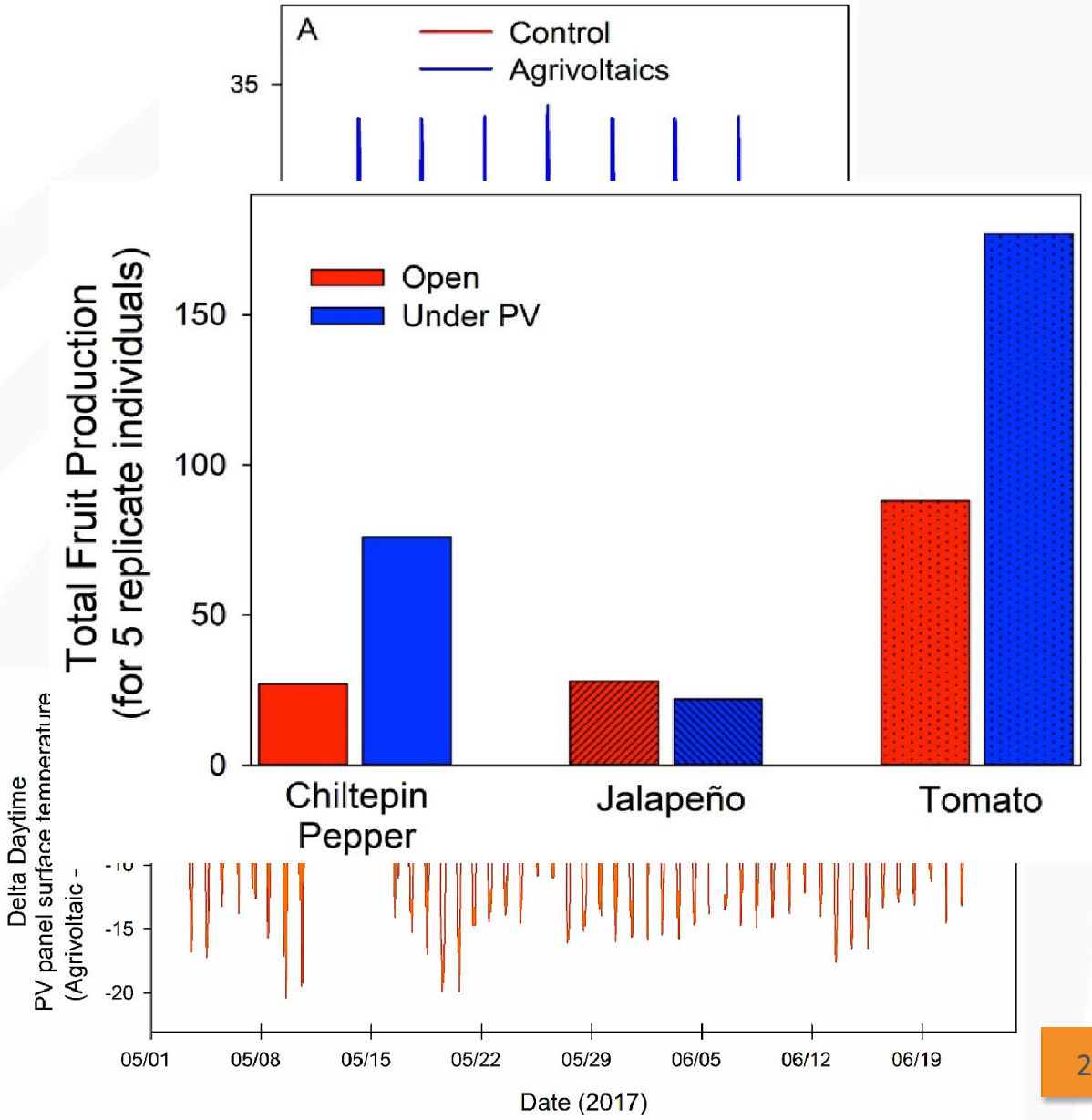
Potential Benefits of Agrivoltaics (to Farmers)

- Diversified revenue streams
- Shading to mitigate heat stress for animals and crops
- Potential water savings
- Pollination services for agriculture nearby the site
- On-farm energy production for resilience



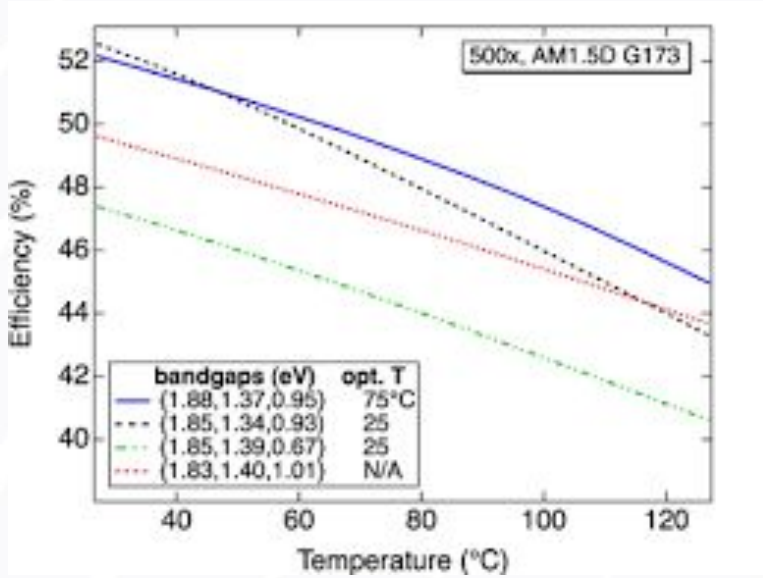
Case Study: U of Arizona Agrivoltaic Test Site

- University of Arizona researchers compared crop growth beneath panels and in an open control
- PV-shaded condition yielded 3x chiletin peppers, 2x tomato, similar jalapeno yield, with 30-50% less water needed
- This highlights possibilities for combined solar-ag production but is highly climate and crop specific



Potential Benefits of Agrivoltaics (to Solar)

- More efficient vegetation management
- Better micro-climate (lower temperatures) -> better energy production
- Siting in partnership with local communities



The New York Times

He Set Up a Big Solar Farm. His Neighbors Hated It.

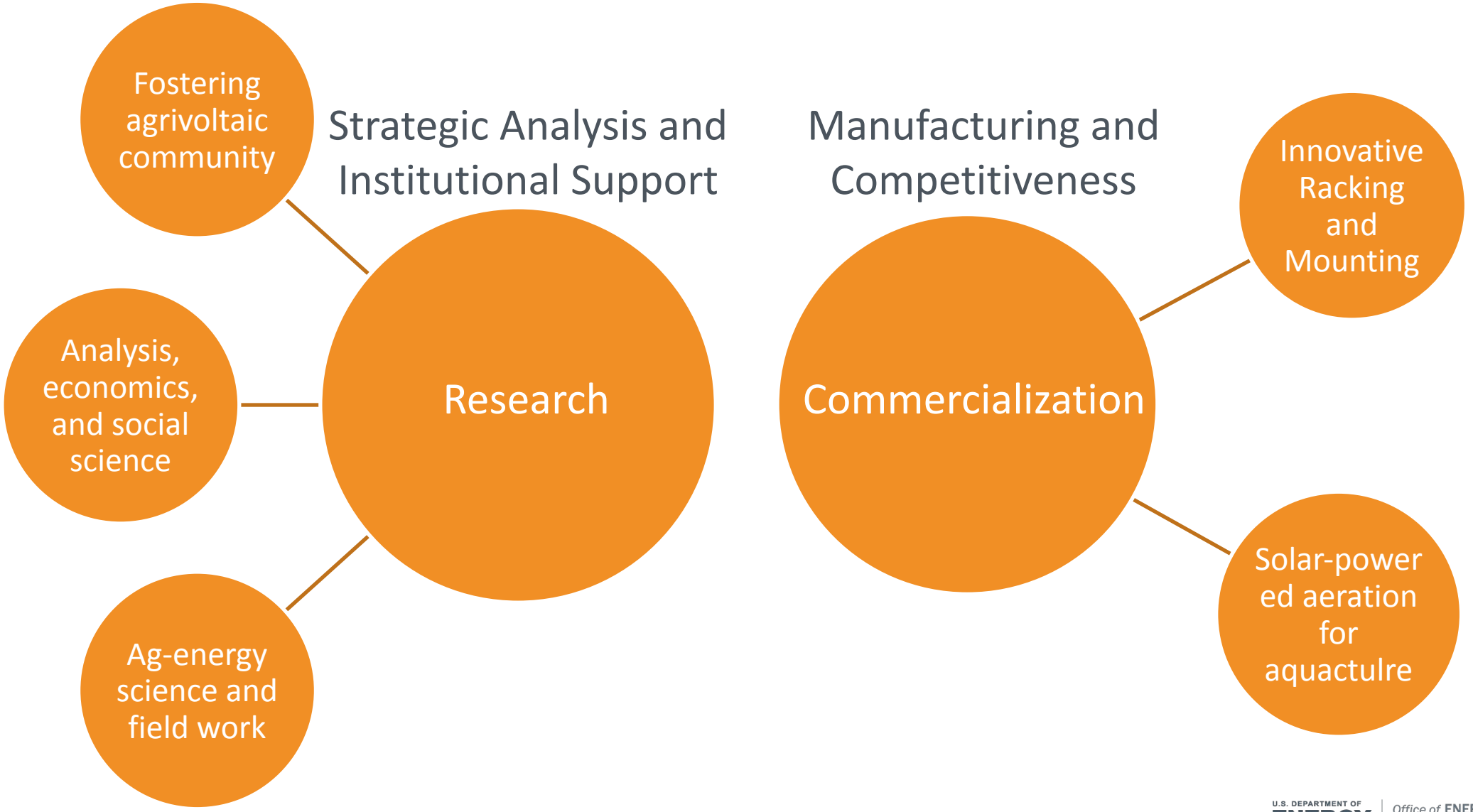
A push toward renewable energy is facing resistance in rural areas where conspicuous panels are affecting vistas and squeezing small farmers.

Open Questions in Agrivoltaics

- What are the long-term impacts of solar energy infrastructure on soil quality?
- What crops, in what regions, are best suited for agrivoltaic production?
- How can we co-optimize system design for maximum ag and energy yield?
- How will animals interact with solar energy equipment?
- What business/contractual arrangements should be used to bridge the gap between solar developer and agricultural producer or landowner?

Current SETO Agrivoltaics Projects

SETO Research and Commercialization Activities in Agrivoltaics



InSPIRE: DOE Agrivoltaics Flagship

- Meeting Solar Cost and Deployment Targets through **In**novative **S**ite **P**reparation and **I**mpact **R**eductions on the **E**nvironment (**InSPIRE**)
- Hosted by the National Renewable Energy Laboratory
- Works to build a network of research sites, companies, and universities with these interests
- Covers agrivoltaics, native vegetation, etc

InSPIRE 2.0 Activities - NREL

Field Research

- Economic viability of solar-agriculture co-location configurations
- Increasing ag yields in arid regions
- Energy, water, and food security in remote, off-grid areas.
- Pollinator and ecological services

Analytical Studies

- Satellite imagery analysis of current land groundcover practices
- Cost-benefit analysis of O&M ground cover practices at solar facilities.
- Quantification of ecological services of groundcover options

ASTRO Working Group

- Expert advisory group from multiple disciplines
- Provides feedback on project and experiment directions

Website Data Portal

- Wiki-style data portal

Start-End Date: 6/2018-9/2021
Funding: $1,889,928

InSPIRE 3.0: From Research to Real Scale

- Agrivoltaic configurations are no longer theoretical
- InSPIRE 1.0 and 2.0 demonstrated that agrivoltaics is viable
- InSPIRE 3.0 will map and address remaining knowledge gaps, preparing the sector to expand

Start-End Date: 10/2021-9/2024
Funding: $3,750,000

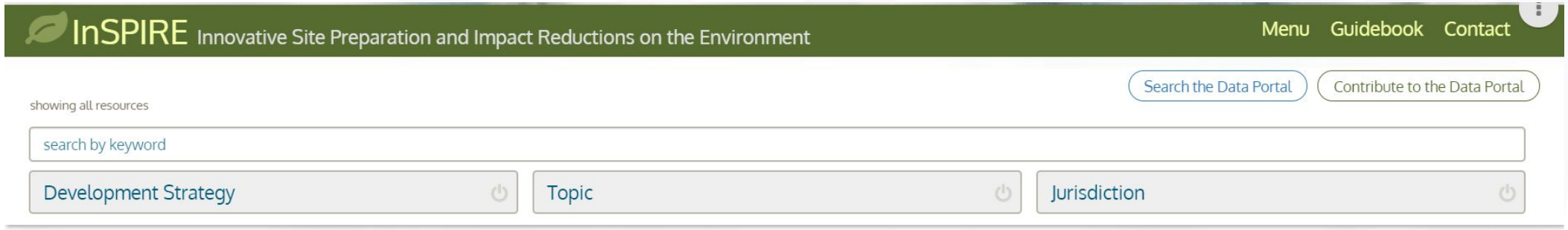
InSPIRE 3.0: Incubating the Agrivoltaic Community

- Maintain ASTRO network
  - Regular, consistent meetings between researchers, advocates, industry
- Fund seed projects
  - Provide grants of a few thousand dollars each to help students and ECRs get started in agrivoltaics
- Interagency collaboration
  - Work with USDA, DOI, NSF, or others as needed to provide data or technical advice related to agrivoltaics

InSPIRE research team on-site in Minnesota

InSPIRE 3.0: Foundational Agrivoltaics Research

- Site tracking
  - Establish a database of sites using agrivoltaics across the United States and make this public
  - Track growth of the sector and trends/patterns, for instance, in types of sites
- Research needs assessment and roadmap
  - Identifying current state of the science, questions that need to be answered
  - Laying out priorities for the next phase of research
- Economic analysis
  - Identifying challenges in scaling to multi-MW installations



InSPIRE 3.0: Field Work

- Evaluate agrivoltaics in many sites and conditions
  - States: WA, TX, CA, OR, CO, AZ, MA
  - Crops: Vegetables, cotton, traditional tribal crops
  - Goal: find and recommend optimal agrivoltaic systems
- Conduct ecosystem services analysis especially for pollinator habitat + solar (GA, MN, ID, OR, CA)
- Soil science and conservation impacts of agrivoltaics practices
- Pilot studies of agrivoltaics with bifacial PV panels

FY20 FOA Topic: *Solar and Agriculture: System Design, Value Frameworks and Impacts Analysis*

Summary

- Build upon and expand ongoing SETO projects related to the co-location of solar and agriculture by developing technology, evaluating practices to date, and conducting research and analysis that enable farmers, ranchers, and other agricultural enterprises to quantify and realize value from solar technologies while maintaining availability of land for agricultural purposes.
- Goal: To facilitate and expand the co-location of solar and agricultural activities where it is beneficial to both industries and to the local community.

Areas of Interest

Applications may address one or more of these areas:

- System design and technology development
- New frameworks for integrating solar and agriculture
- Research on ecological and performance impacts of co-location

Funding: $7 million total (4 awards)

Project Duration: 3 years per award

Impacts of Dual-Use Solar on Crop Productivity and the Agricultural Economy in Massachusetts and Beyond – UMass Amherst

BACKGROUND

- University of Massachusetts Amherst hosts a Clean Energy Extension Office
- MA has incentives in place for nontraditional solar siting that is driving significant commercial interest
- Lack of knowledge about impacts of agrivoltaics on farm economics

OBJECTIVES

- Conduct agricultural testing, evaluating yield and soil impacts, of agrivoltaic setups across the state of MA in several crop types (hay, cranberries, blueberries, grazing, etc)
- Conduct economic analysis on the impacts of agrivoltaic adoption on farm profitability and rural economies
- Use social science methods to test social acceptance of agrivoltaics to neighbors

Funding: $1.7 million

Partners: American Farmland Trust, Bluewave Energy, MA Departments of Energy and Ag, Hyperion Systems, Pinegate Renewables, SolAg

Integrated PV System Design and Management Platform for the Co-Optimization of Regenerative Cattle Grazing and PV Solar Generation – Silicon Ranch Corporation

BACKGROUND

- Silicon Ranch operates regenerative agriculture and solar plus grazing sites across the Southeast
- Solar grazing has been largely limited to sheep, but cattle are a much larger US market with more potential
- This project will tackle the engineering and scientific challenges needed to enable cattle grazing around solar panels.

OBJECTIVES

- Conduct animal welfare testing and soil science monitoring of a rotational grazing system with cattle in Georgia
- Project outputs:
  - Carbon inventory protocol
  - CattleTracker equipment and controls cheme
  - Publications on success

Funding: $2.3 million

Partners: NREL, Colorado State University

Evaluation of Economic, Ecological, and Performance Impacts of Co-Located Pollinator Plantings at Large-Scale Solar Installations – University of Illinois at Chicago (UIC)

BACKGROUND

- Pollinator plantings at large-scale solar facilities (10 MW or larger) face barriers to adoption due to uncertain costs, benefits, and operational risks
- UIC will study the PV performance impacts, installation and operational costs, and ecological benefits of pollinator plantings at large-scale solar facilities to inform decisions on if, when, and how to incorporate pollinator plantings into solar projects

OBJECTIVES

- PV performance, economic, and ecological data collection at 6 large-scale solar facility test sites in the Midwest
- Project outputs:
  - Pollinator planting implementation manual
  - Cost-benefit calculator
  - Solar site seed selection tool
  - Pollinator scorecard

Funding: $2.3 million

Partners: Cardno, University of Illinois at Urbana Champaign, Inoveteus, NextEra Energy, Lightsource BP, EDP Renewables, Argonne National Laboratory, National Renewable Energy Laboratory

The Agri-Solar Clearinghouse- National Center for Appropriate Technology (NCAT)

BACKGROUND

- Currently, there is no forum for agrivoltaics practitioners to communicate or find resources
- NCAT will create an information-sharing, relationship-building, public communications hub and professional network for the practice of co-locating agriculture and solar development

OBJECTIVES

- Four primary objectives:
  - Support co-location practitioners (farmers, landowners, solar developers, etc.) with an information-sharing network and technical assistance
  - Evaluate innovative financing options, tax incentives, funding sources, and ownership structures
  - Research key issues, identify barriers, and develop innovative solutions to enable co-location
  - Continue operating the clearinghouse after the period of performance
- Agri-Solar Clearinghouse features: user forum, technical assistance (TA) portal, informational resources, original publications, podcasts, videos, and a story-telling case study atlas
- Technical assistance: peer mentoring network, field trips to demonstration sites, and one-on-one TA

NCAT NATIONAL CENTER FOR APPROPRIATE TECHNOLOGY

Funding: $1.8 million

PARTNERS: University of Arizona, Smithsonian, Virginia Working Landscapes, Fresh Energy, Cal Poly, George Washington University, Helical Solar, Center for Rural Affairs, Renewable Northwest, Ridge to Reefs, Wexus Technologies, Montana Renewable Energy Association, Bozeman Greenbuild, Breezy Point Energy, Argonne National Lab, Oak Ridge National Lab, National Renewable Energy Lab

Small Business Innovation Research Portfolio

- Solar racking/mounting design optimized for co-location:
  - Blue Rock Solutions – suspended solar racking
  - FarmAfield Labs – solar integration with livestock feeding structures
  - Rute Foundation Systems – cable stayed solar racking
  - Soliculture – solar racking/mounting for greenhouse integration
  - Taka Solar Corporation – tube-based photovoltaic system
  - Tectonicus Constructs – irrigation canal spanning solar racking
  - TrackerSled – modular solar trackers for rural application
- Solar powered aeration systems with aquaculture applications:
  - Dissigno International
  - Epsilon Innovation Group
  - FarmAfield Labs
  - Floating Island International
  - Hawaii Fish Company

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SETO Opportunities

SETO FY22 Funding Opportunity: SolWEB

SETO is making **$10M available** for innovative solutions and strategies that maximize benefits and minimize impacts to wildlife and ecosystems from solar energy infrastructure.

FOA Issue Date:	3/1/2022
Informational Webinar:	3/8/2022 02:00pm ET
Submission Deadline for Concept Papers:	4/11/2022 5:00pm ET
Submission Deadline for Full Applications:	6/20/2022 5:00pm ET

- **Topic Area 1**: Wildlife-Solar Energy Interactions – 2-4 projects, $1-2M each
- **Topic Area 2**: Ecosystem Services from Solar Facilities – 2-4 projects, $500,000-$2M each

Contact solarwildlife@ee.doe.gov with questions

InSPIRE ASTRO Advisory Group (Agriculture and Solar Together: Research and Outreach)

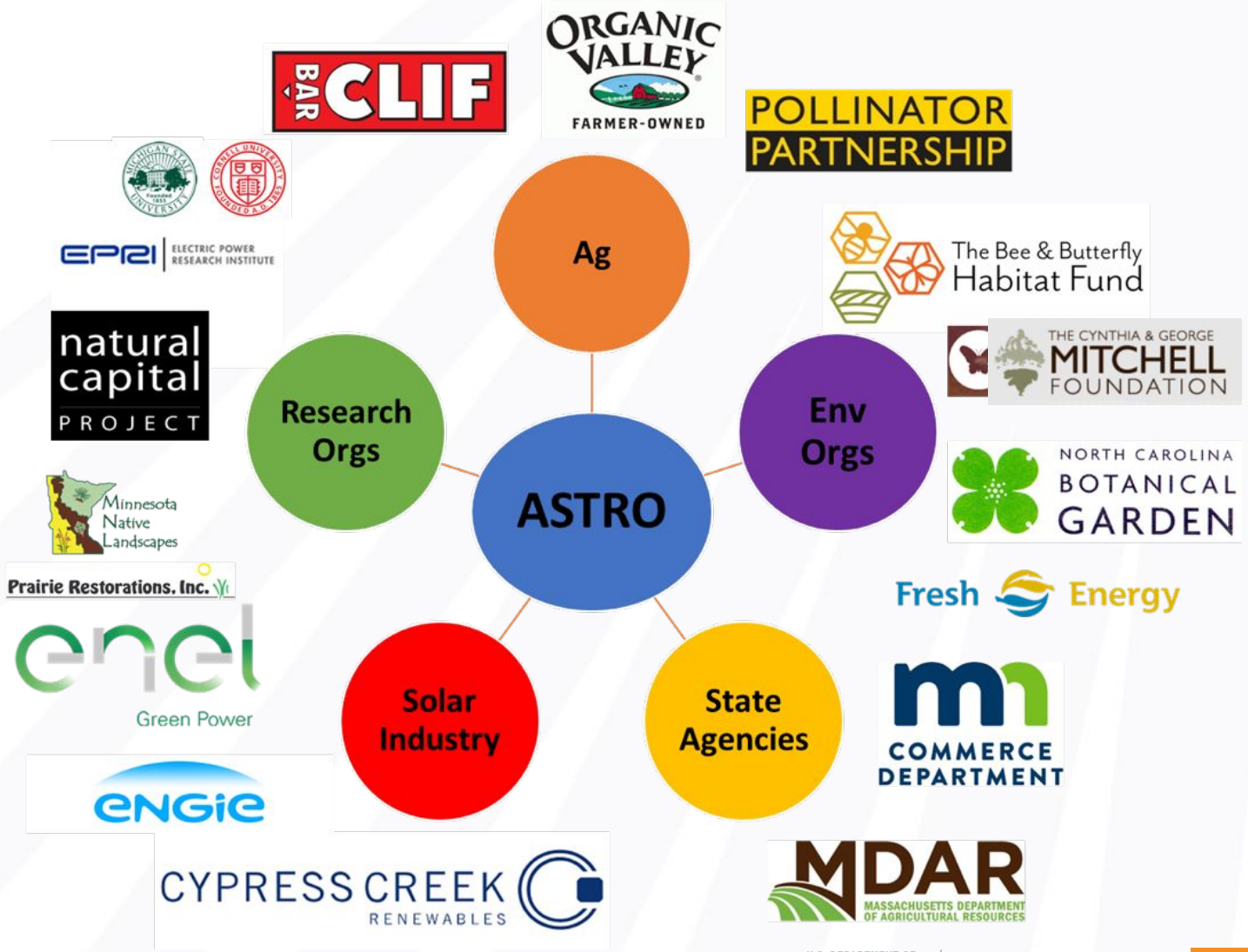
Research and Outreach Advisory Group

Feedback on research directions and study designs

Development of new InSPIRE research sites and activities

Coordinated outreach activities

Quarterly meetings



Interested in Joining Us?

Join our team. Design national R&D strategies across:

- Photovoltaics
- Systems Integration
- Manufacturing and Competitiveness
- Concentrating Solar-Thermal Power
- Soft Costs (Balance of Systems)

Email *ops.solar@ee.doe.gov* for more information.

ORISE Science & Technology Policy Fellowship

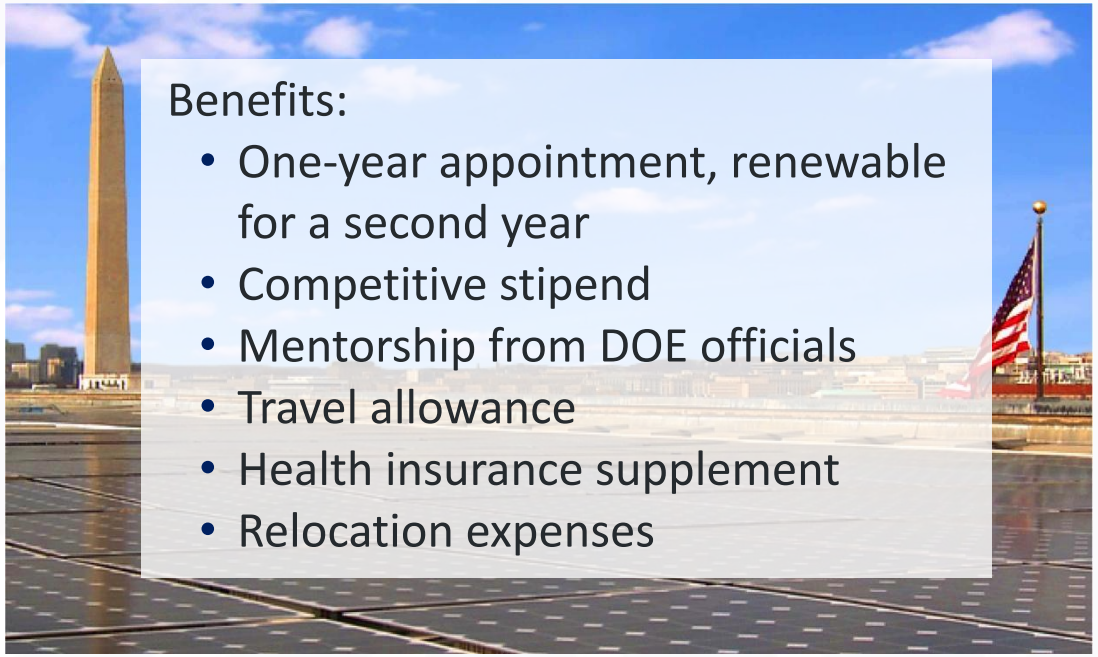
Develop leadership skills in science and technology policy by designing and implementing national research and development (R&D) programs

Strategic Areas:

- Photovoltaic technologies
- Concentrating solar-thermal power technologies
- Grid systems integration technologies
- Behavioral science, strategic analysis, and technical assistance
- Manufacturing and technology transfer
- Energy justice and community engagement

Eligibility:

Open to physical, natural, and social scientists, engineers, and entrepreneurs with bachelor's, master's, or doctoral degrees, and established professionals with post-degree experience. Must be a U.S. citizen or have Permanent Resident (Green Card) status.



Benefits:

- One-year appointment, renewable for a second year
- Competitive stipend
- Mentorship from DOE officials
- Travel allowance
- Health insurance supplement
- Relocation expenses

Applications are accepted on a rolling basis with two annual review dates: **January 15 | June 15**

VISIT: bit.ly/SETO-Fellowships • **EMAIL:** DOE-RPP@orau.org

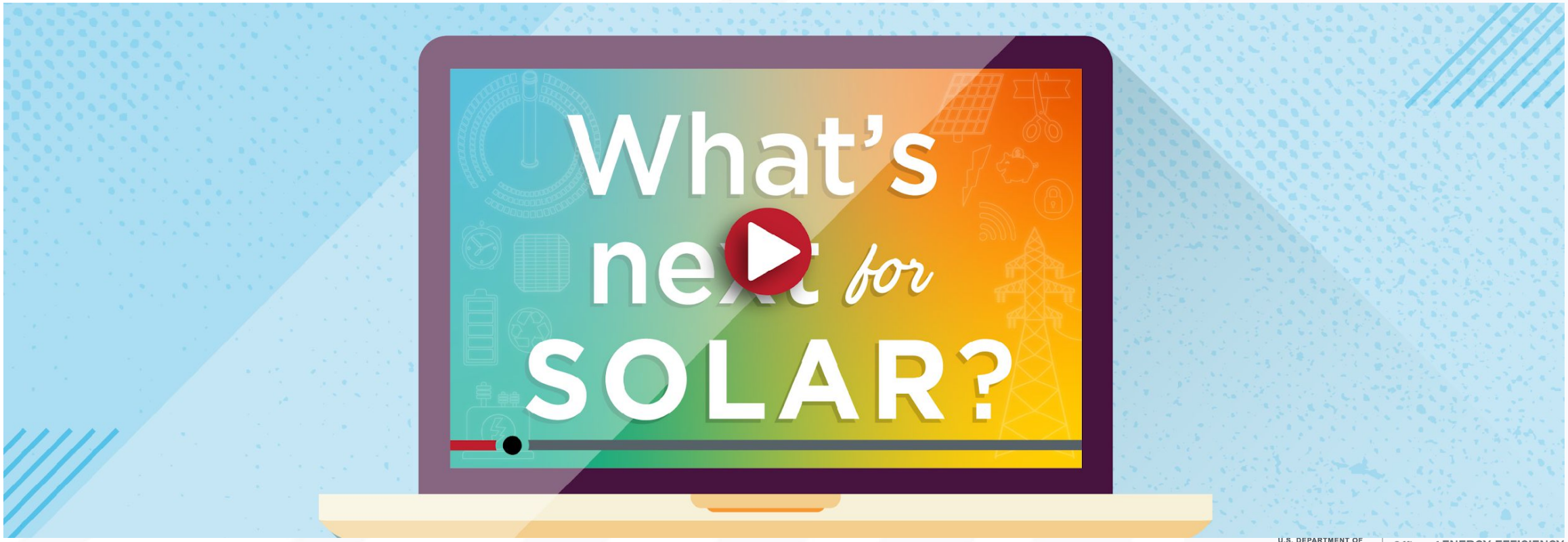
SETO Newsletter – Stay in Touch

The SETO newsletter highlights the key activities, events, funding opportunities, and publications that the solar program has funded.

SIGN UP NOW:
energy.gov/solar-newsletter

SETO Webinars

SETO hosts frequent webinars to provide updates on the office's work to our stakeholders. Led by SETO Director Dr. Becca Jones-Albertus, these webinars discuss SETO's priorities, as well as provide information on current and upcoming activities. Visit energy.gov/seto-webinars for more information!



QUESTIONS?