U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

DOE Solar Integration R&D Priorities and Recent Initiatives

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Systems Integration, SETO / EERE / DOE

Solar Energy Technologies Office 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

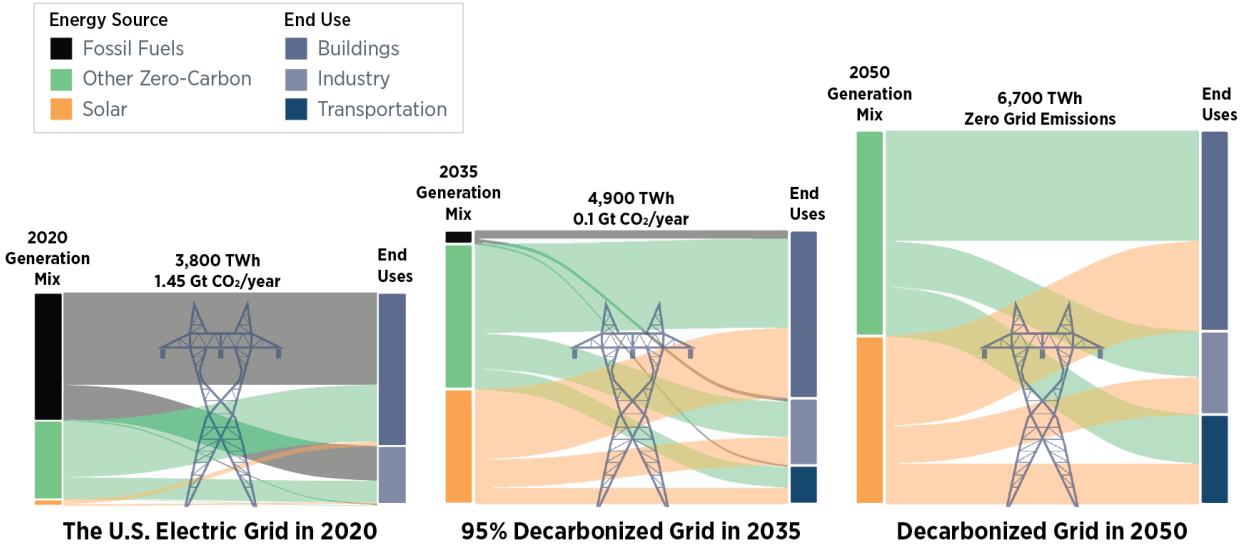
WHAT WE DO

Drive innovation in technology and soft cost reduction to make solar **affordable** and **accessible** for all Americans

Enable solar to support the **reliability**, **resilience**, and **security** of the grid

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

U.S. Energy Mix Scenarios 2020-2050



The U.S. Electric Grid in 2020

Solar: 3% of electricity demand, 80 gigawatts AC installed

95% Decarbonized Grid in 2035

Solar: 40% of electricity demand, 1,000 gigawatts installed

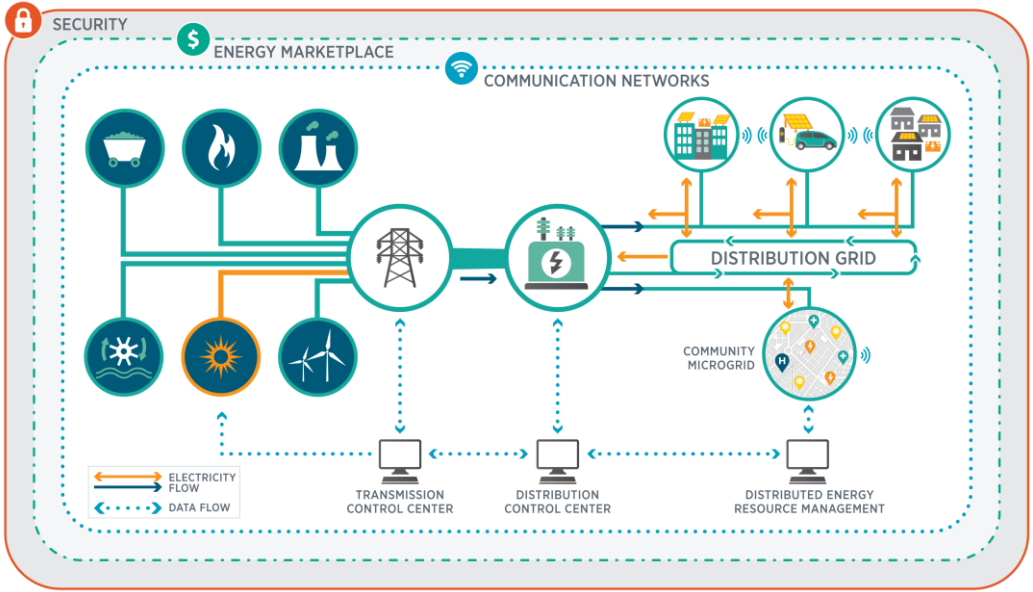
Decarbonized Grid in 2050

Solar: 45% of electricity demand, 1,600 gigawatts installed 3,000 GW in decarbonized energy system

https://www.energy.gov/eere/solar/solar-futures-study

SETO Systems Integration (SI) Program

The Systems Integration (SI) subprogram supports early-stage research, development, and demonstration (RD&D) of technologies and solutions – focusing on technical pillars **data, analytics, control, and hardware** - that advance the **reliable, resilient, secure and affordable** integration of solar energy onto the U.S. electric grid.

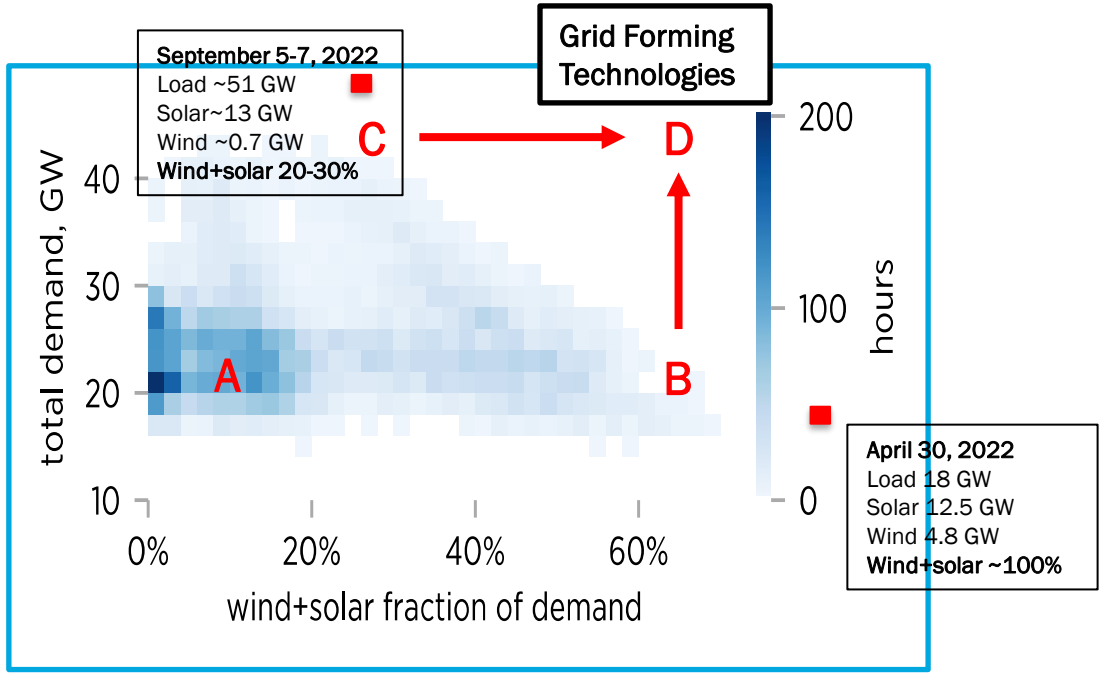


Challenges in Planning and Operations of a Decarbonized Grid

Operating a Power Grid with Extremely High IBR Contribution

Power system	System size	Peak solar + wind *power* contribution	Annual solar + wind *energy* contribution
U.S. WECC	163 GW	36%	13%
U.S. ERCOT	80 GW	58%	20%
U.S. SPP	51 GW	69%	28%
U.S. CAISO[4]	44 GW	70%	20%
Australia NEM	35 GW	50%	21%
Ireland	7 GW	84%	36%
Oahu	4 GW	58%	22%
Maui	0.5 GW	80%	37%

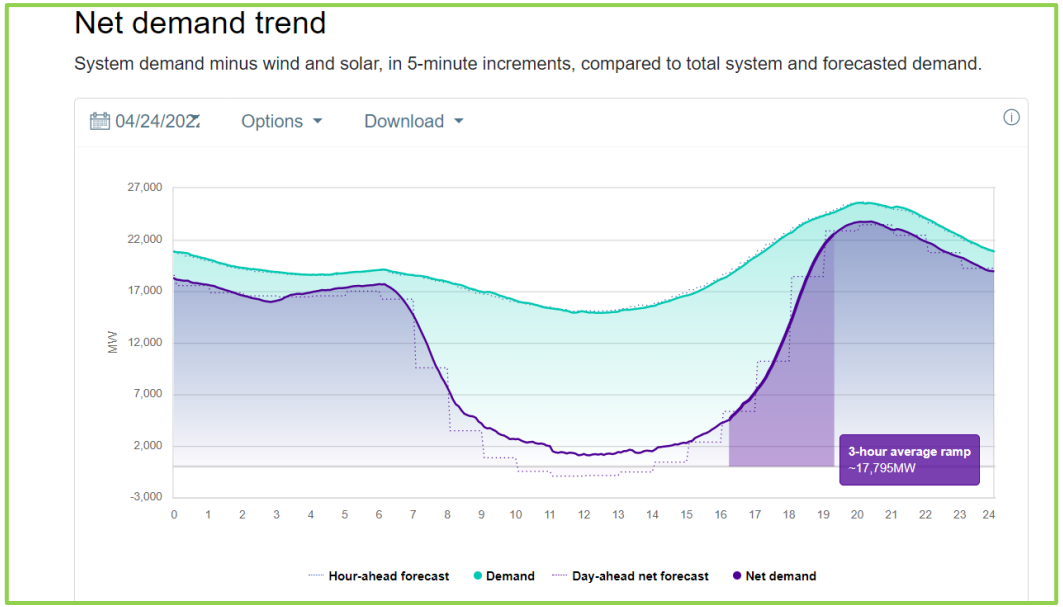
Solar Energy Technologies Office Multi-Year Program Plan | Department of Energy

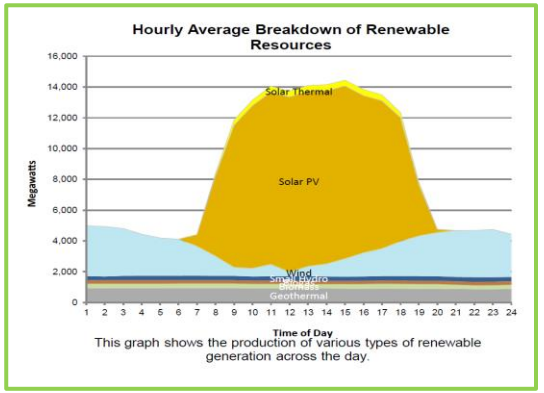


The frequency of occurrence of solar and wind power contributions at different demand levels in CAISO for 2019. For a vast majority of the operation periods, solar and wind penetration is low (Area A). Occasionally solar and wind provide a high contribution to the generation supply, with high percentage at low demand times (Area B), and lower percentage at high demand times (Area C). In the future, as solar and wind reach much higher deployment, the system will operate at high demand most of the times (Area D).

Managing Solar and Wind Generation Variability and Uncertainty

- *Daily renewable profile (CAISO Daily Outlook, April 24, 2021)*
- ***Served 94.5% of the load served by RE at 2:28pm for 4 seconds***





Ensuring Grid Reliability and Stability

- Major events in US, UK, and South Australia since 2016 Blue Cut Fire have shown
  - Significant “unexpected” loss of utility-scale solar PV, wind, and distributed generation (including DPV) due to transmission disturbances
  - Needs for improvements to NERC Reliability Standards, address modeling issues during interconnection studies and commissioning, and performance-based requirements for IBRs

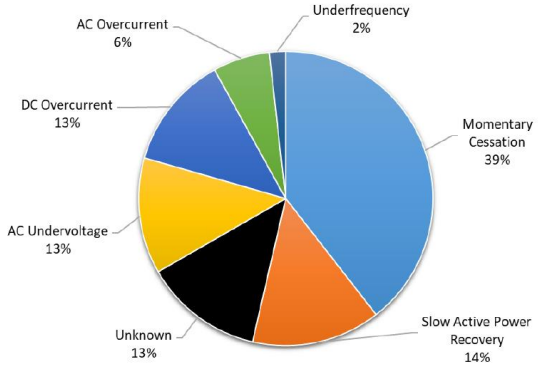
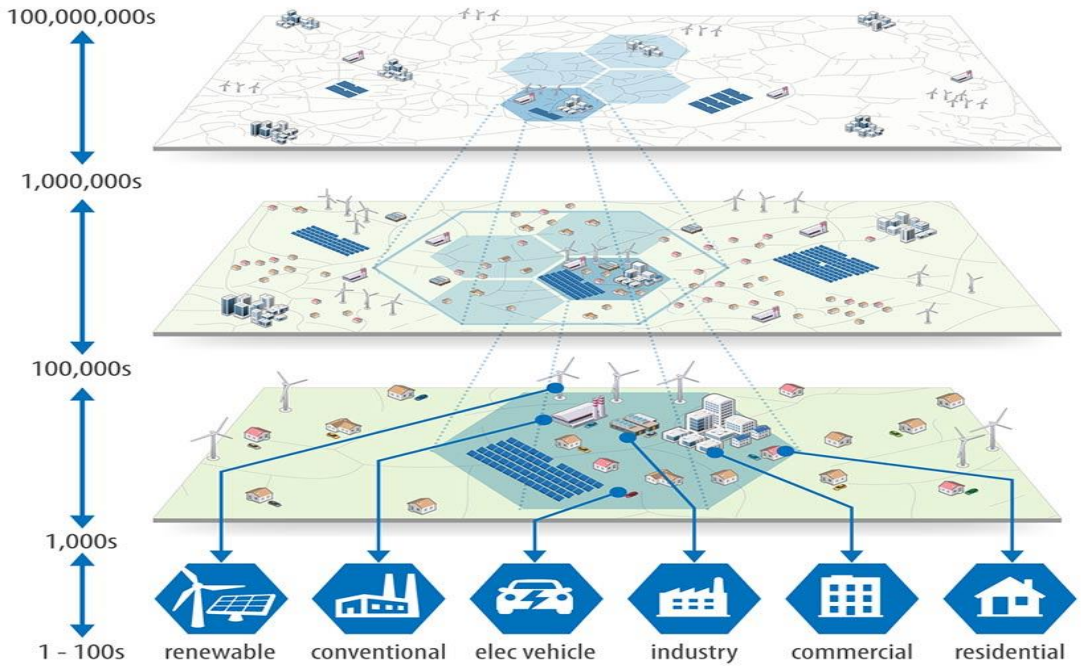


Figure 2.1: June 24 Disturbance Causes of Solar PV Reduction

Table ES.1: Overview of Disturbances

Disturbance and Name	Initiating Fault Event	Description of Resource Loss*
June 24, 2021 “Victorville”	Phase-to-Phase Fault on 500 kV Line	Loss of 765 MW of solar PV resources (27 facilities) Loss of 145 MW of DERs
July 4, 2021 “Tumbleweed”	Phase-to-Phase Fault on 500 kV Line	Loss of 605 MW of solar PV resources (33 facilities) Loss of 125 MW at natural gas facility Loss of 46 MW of DERs
July 28, 2021 “Windhub”	Single-Line-to-Ground Fault on 500 kV Circuit Breaker	Loss of 511 MW of solar PV resources (27 facilities) Loss of 46 MW of DERs
August 25, 2021 “Lytle Creek Fire”	Phase-to-Phase Fault on 500 kV Line	Loss of 583 MW of solar PV resources (30 facilities) Loss of 212 MW at natural gas facility Loss of 91 MW at a different natural gas facility

Achieving Scalability in a Complex Cyber-Physical System



Source: NREL Autonomous Energy Systems

Recent R&D Initiatives

SETO System Integration Key Research Areas

~$55M annual budget, ~90 active RD&D projects

System Planning	System Operation	Resilience & Cybersecurity	Enabling Technologies
• Power system modeling • PV plant and inverter modeling • Solar resource data & solar forecasting • Resource adequacy • Production cost modeling • Reliability and interconnection standards	• Real time situation awareness • State estimation and power flow • System and inverter control • System protection, stability, risk management • Grid services and system flexibility • DER integration and aggregation of PV, ESS, EV, and buildings • SW tools -EMS, ADMS, DERMS, MGMS	• Resilience planning and benchmark metrics • Resilient microgrids and DER-based solutions • Measurement & Verification, and cost/benefit analysis • Cybersecurity R&D and assessment tools for device, plant, and system • Cybersecurity standards • Stakeholder education and information sharing	• Power electronics • Energy storage • Data analytics and AI/ML • Sensing and communication • High performance computing and cloud-based tools • CHIL and PHIL testbeds

Latest Funding Programs (1)

FOA Issue Date: 4/20/2023	
Informational Webinar: 5/4/2023	3:00pm ET
Submission Deadline for Concept Papers: 6/5/2023	5:00pm ET
Submission Deadline for Full Applications: 8/15/2023	5:00pm ET
Expected Submission Deadline for Replies to Reviewer Comments: 9/13/2023	5:00pm ET
Expected Date for EERE Selection Notifications: December, 2023	
Expected Timeframe for Award Negotiations: December, 2023 – April, 2024	

- FOA announced on April 20, 2023
- $30 million to fund projects will develop new state-of-the-art **planning and operations tools** to enable solar energy to be more optimally and reliably integrated and utilized within the electric power grid

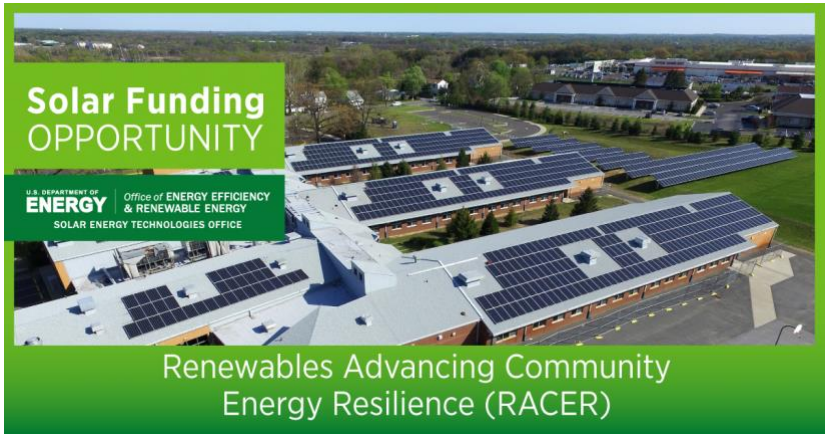
  - Topic 1: Planning Tools for Future Power Systems – 3-4 projects, $2-2.5 million each
  - Topic 2: Variability Management in Grid Operations – 3-4 projects, $2.5-3.5 million each
  - Topic 3: Rapid System Health and Risk Assessment Tools for Grid Operators – 3-5 projects, $2.5-4 million each

Latest Funding Programs (2)

- Selections announced in May 2023
- $26 million IIJA funding for projects that can demonstrate an electric grid that runs on 100% solar, wind, and battery storage.
  - Topic 1: Wind and Solar Grid Services Design, Implementation, and Demonstration
  - Topic 2: Protection of Bulk Power Systems with High Contribution from Inverter-Based Resources

- Topic 1: Wind and Solar Grid Services Design, Implementation, and Demonstration (4 projects)
  - Electric Power Research Institute
  - GE Renewable Energy
  - Portland General Electric Company
  - Veritone
- Topic 2: Protection of Bulk Power Systems with High Contribution from Inverter-Based Resources (4 projects)
  - Con Edison Company Of New York
  - National Renewable Energy Laboratory
  - Pacific Gas And Electric Company
  - University Of Illinois At Chicago

Latest Funding Programs (3)



- Selections announced in November 2022
- $27 million for projects to enable communities to utilize solar and solar-plus-storage in Topic Areas 1 & 2
- Kickoff meeting June 6 & 7 in DC

- Topic 1: Innovative Community-Based Energy Resilience Planning (11 projects)
  - City Of Duluth
  - Electric Power Research Institute
  - Groundswell
  - Kansas State University
  - Lawrence Berkeley National Laboratory
  - National Renewable Energy Laboratory
  - Navajo Technical University
  - North Carolina State University
  - University Of Central Florida
  - Virginia Department Of Energy
  - Wayne State University
- Topic 2: Automation Strategies for Rapid Energy Restoration (6 projects)
  - GE Research
  - National Renewable Energy Laboratory
  - National Rural Electric Cooperative Association
  - Slipstream
  - University Of Connecticut
  - Washington State University

UNIFI: Grid-Forming Technology Consortium

- SETO-Funded, NREL-Led, $25M, 5-Year Program (2022-2026)
- Year 1: Published “Specifications for Grid-forming Inverter-based Resources, Version 1” (Open for Comments)

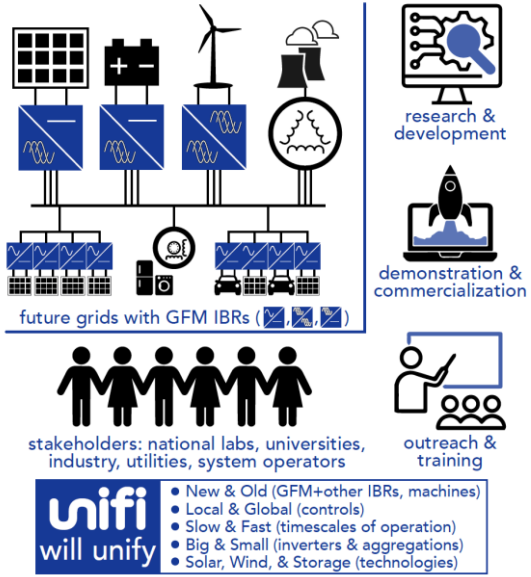
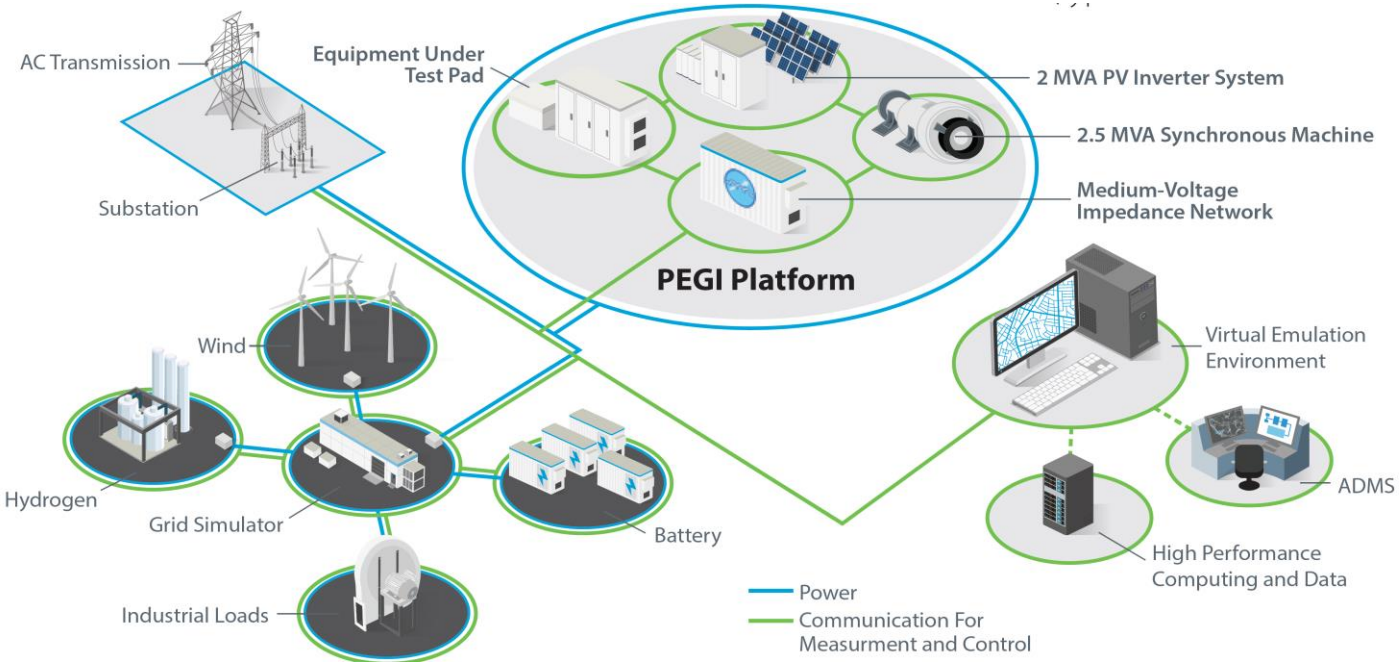


Figure 1: Mission, Vision, Goals, and Thrusts of UNIFI.

Power Electronics Grid Interface (PEGI) at NREL



Industry Workshop, May 24th and 25th, 2023, https://www.nrel.gov/grid/power-electronics-grid-interface-workshop.html

Unlocking the Value of Solar Forecasting

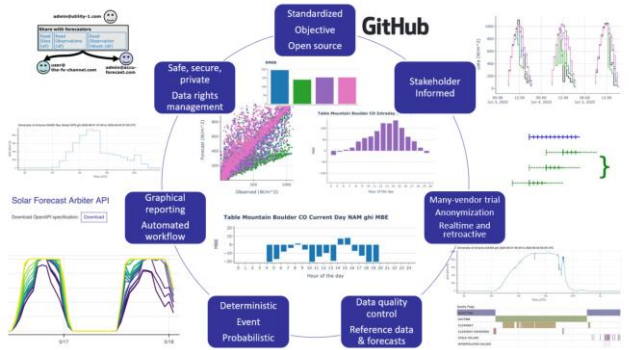
Round 1: October 2021, Solar Forecasting Prize
https://www.energy.gov/eere/solar/american-made-solar-forecasting-prize
Round 2: February 2023, Net Load Forecasting Prize (Open)
https://www.energy.gov/eere/solar/american-made-net-load-forecasting-prize

Solar Forecasting Funding Programs (2013 & 2017)

- Improve irradiance forecast
- Improve power forecast & utility integration
- Create benchmarking tools

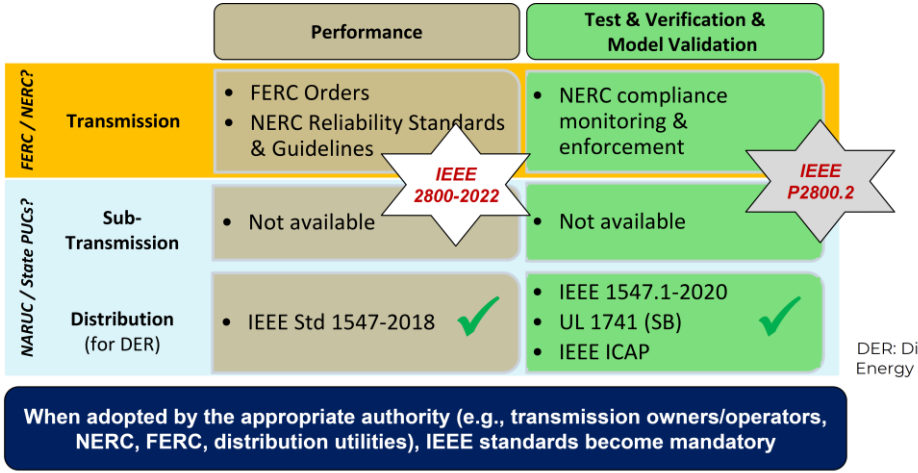
Solar Forecast Arbiter

A paradigm shift in forecast evaluation



(Source: University of Arizona/EPRI)

Interconnection Standards for Inverter-Based Resources



DER: Distributed Energy Resource

(Source: IEEE P2800 WG, Jens C. Boemer, Andy Hoke, et al)

INTERCONNECTION INNOVATION e-XCHANGE
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Stakeholder Engagement
Establish and foster working groups to solve interconnection challenges

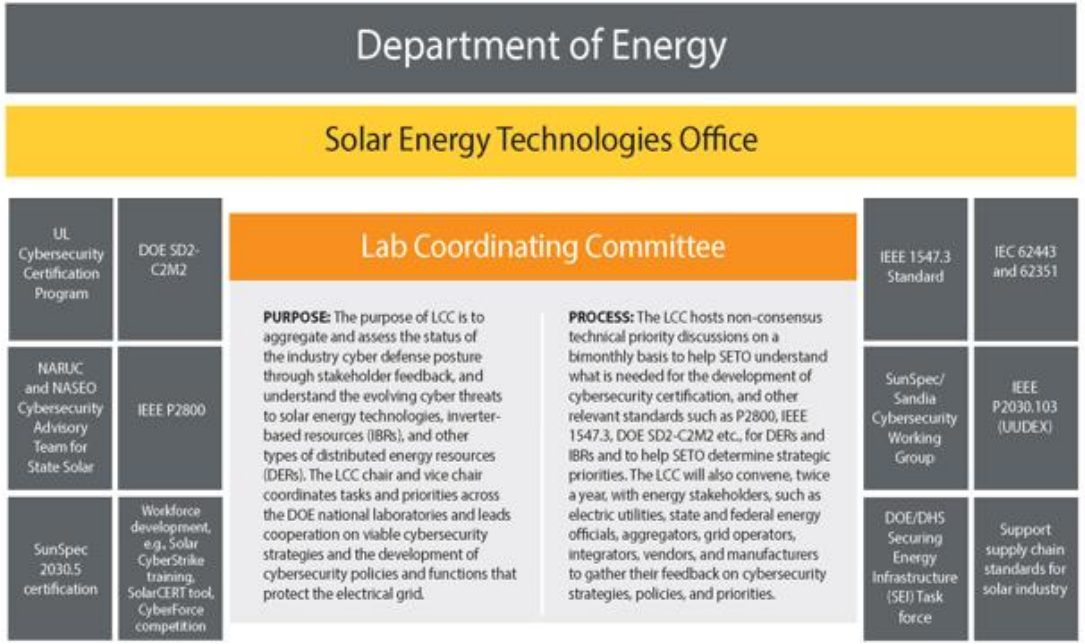
Data Collection and Analysis
Collect and analyze interconnection data to inform solutions development

Strategic Roadmap Development
Create roadmap to inform interconnection process improvements

Technical Assistance
Leverage DOE laboratory expertise to support stakeholder roadmap implementation

Securing Solar for Grid (S2G) Program Activities

- Regularly meet to assess current industry trends and facilitate non-consensus discussion and debate on project priorities.
- Coordinate activities and promotes collaboration with CESER and EERE offices.
- Facilitate Industry Advisory Board meetings.
- Facilitate periodic informational webinars, led or supported by the national labs.



Sandia National Laboratories

Idaho National Laboratory

NREL Transforming ENERGY

Pacific Northwest National Laboratory

Solar Cybersecurity Research Areas

STANDARDS DEVELOPMENT & BEST PRACTICES

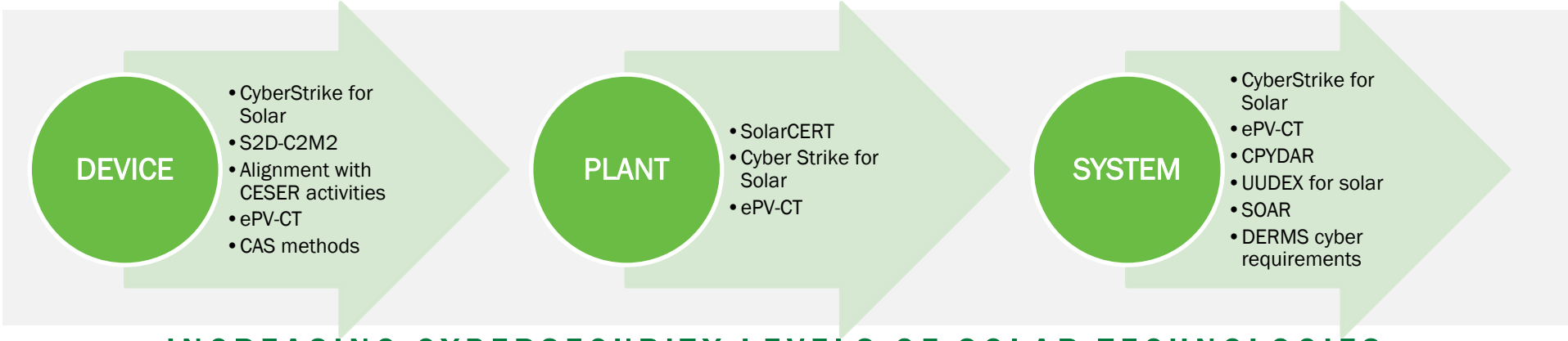
Stakeholder engagement to investigate gaps and develop best practices that can become standards to enable the secure integration of inverter based resources and DERs.

EDUCATION & WORKFORCE DEVELOPMENT

Development of educational modules and training to increase cybersecurity awareness and knowledge within solar stakeholders.

CYBERSECURITY TOOL KIT & SUPPLY CHAIN

R&D of tools to understand cybersecurity posture, risk assessment to inform investments, and device design security & maturity model for cyber supply chain.



INCREASING CYBERSECURITY LEVELS OF SOLAR TECHNOLOGIES

THANK YOU

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