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

SOLAR ENERGY TECHNOLOGIES OFFICE

DOE Solar Grid Integration Research Overview

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Systems Integration

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

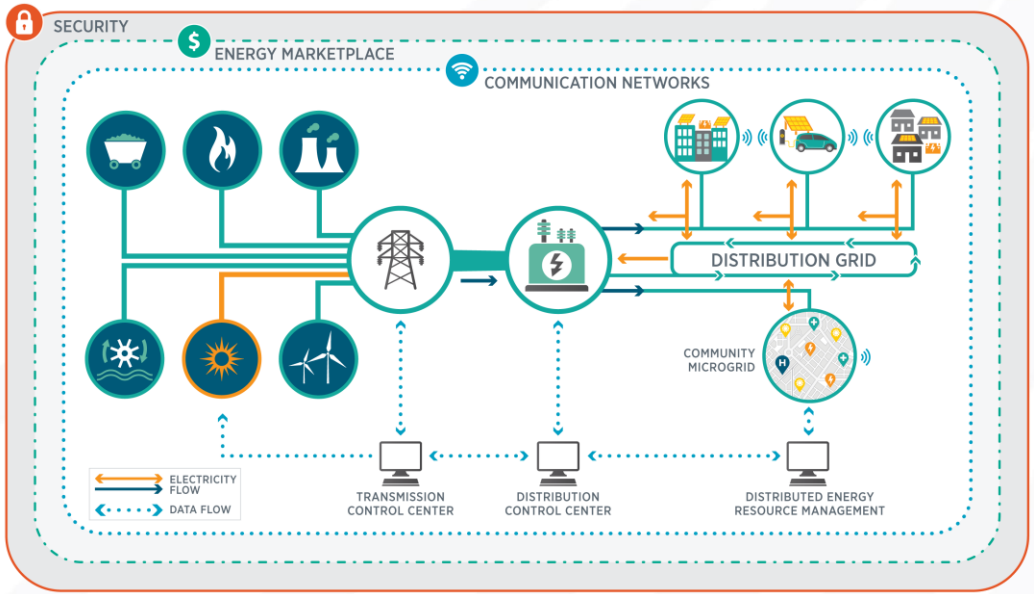
Drive innovation in technology and soft cost reduction to make solar **affordable** and **accessible** for all Americans

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

SETO Systems Integration (SI) Program

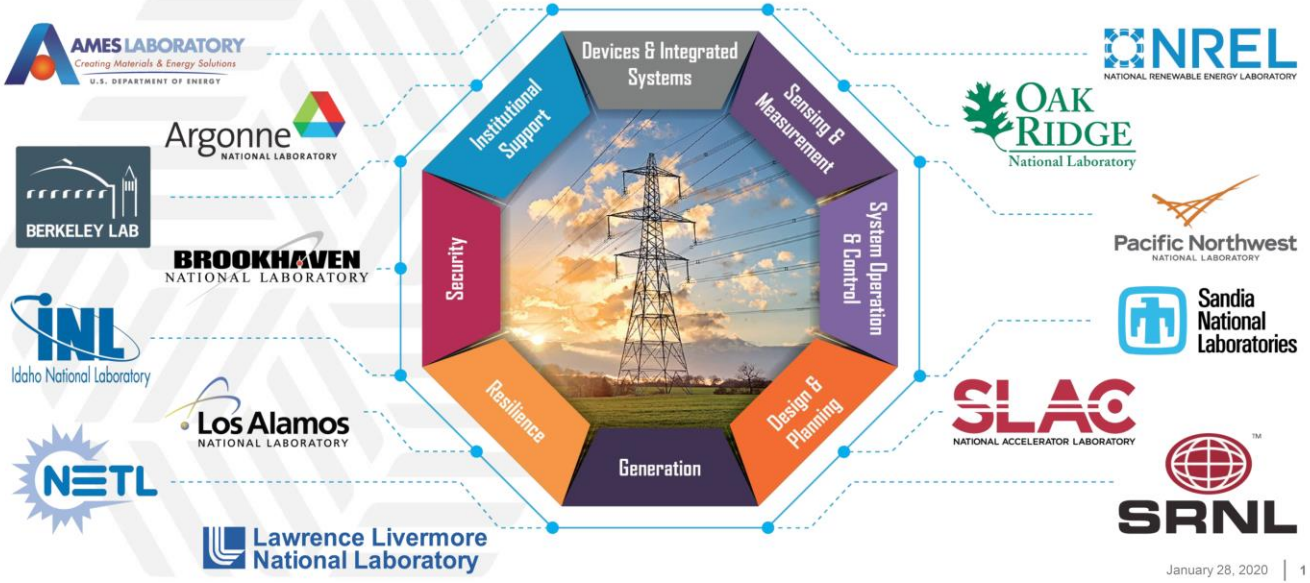
The Systems Integration (SI) subprogram supports early-stage research, development, and demonstration (RD&D) of technologies and solutions – focusing on technical pillars **data, analytics, control, and hardware** - that advance the **reliable, resilient, secure and affordable** integration of solar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



GMI – DOE-Wide Collaboration

DOE's Grid Modernization Laboratory Consortium – 14 National Labs – 100+ Partners

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy



Systems Integration Team

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SETO System Integration Research Areas

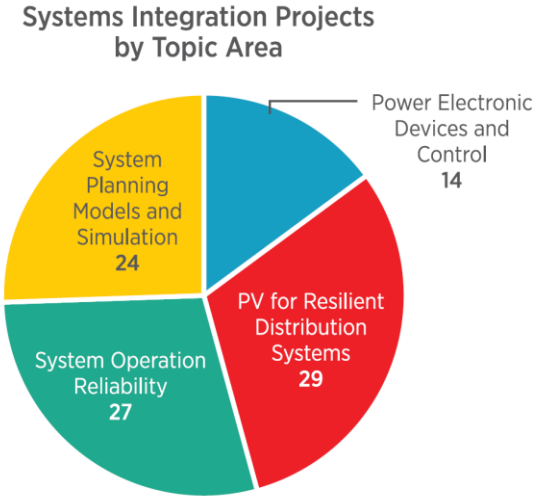
- **Grid Planning with High Solar**
  - Power system modeling
  - Solar resource data
  - Codes and standards
  - Scenario analysis
  - Integration studies

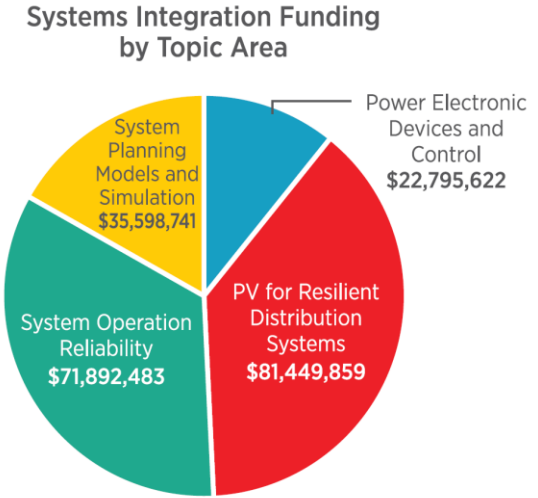
- **Grid Operation with High Solar**
  - Solar Forecasting
  - Situation awareness
  - Grid services
  - Control and protection
  - Sensing and communication

- **Resilience and Cybersecurity with Solar PV and DER**
  - Community microgrids
  - Design for cybersecurity
  - Testing, validation, & supply chain
  - Value analysis and info sharing
  - Regional partnerships

- **Power Electronics and Other Enabling Technologies**
  - Hardware and software design
  - Cost reduction and reliability
  - Control and grid support
  - Testing, validation, & field demonstration

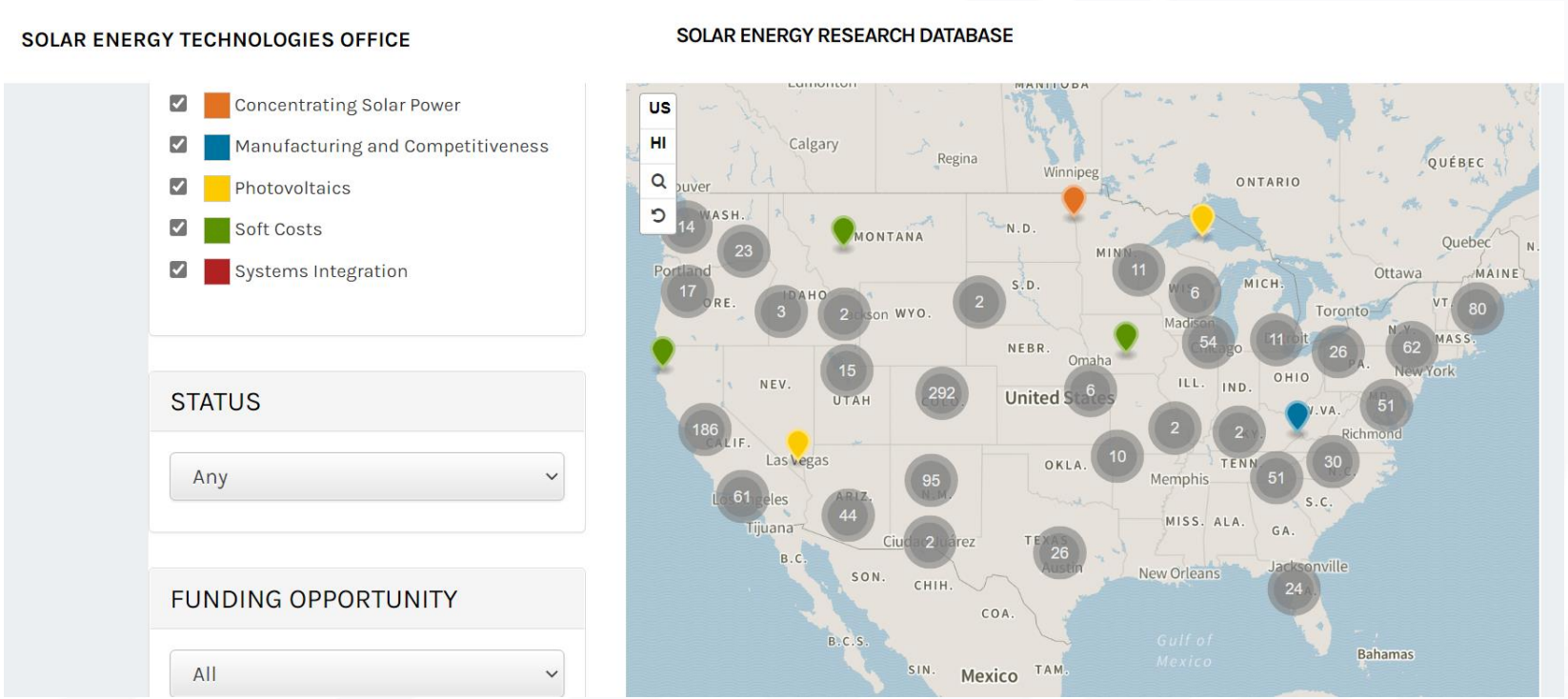
SI Track Breakdown – 95 Projects and $213M Funding





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

Solar Energy Research Database



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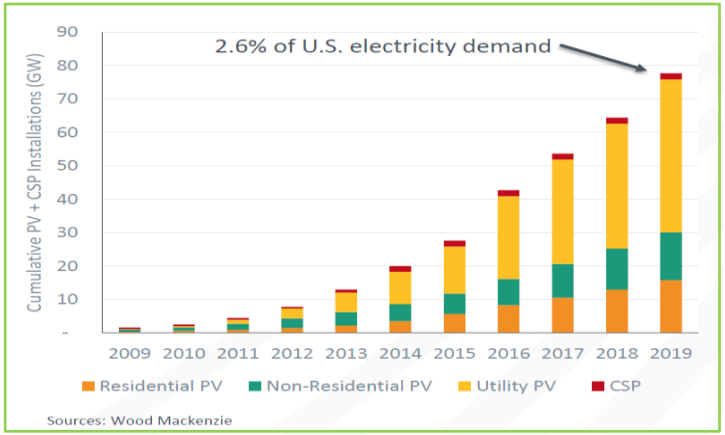
Many Challenges for Solar Grid Integration

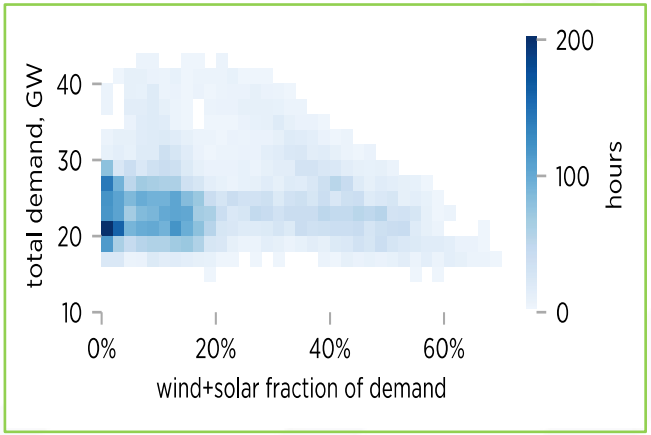
Rapid solar growth

- *~60% utility-scale*
- *~40% distributed*



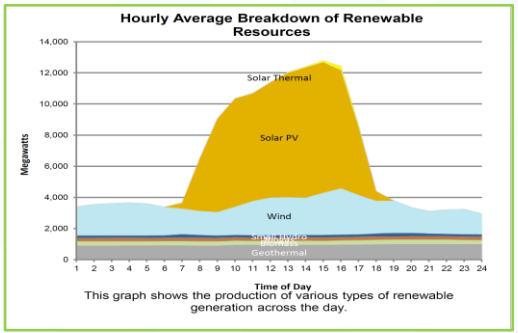
Supply and demand

Wind/solar meet >60% demand sometimes (EIA, CAISO 2019)



Variable in time and location

(CAISO daily renewable profile)



- Weak grid and Low inertia
- Fast dynamics of IBR
- Variability and uncertainty
- Protection
- Situation awareness
- BTM DER control
- T&D interdependence
- Cybersecurity
- Resilience
- Cost/benefit
- Institutional challenges
- And others …

Emerging Challenges from Distributed Solar

- CAISO installed solar capacity:
  - Utility-scale: ~14,000MW
  - BTM Rooftop/small solar: ~5,000 MW (GTM)
- Contingency event:
  - Palo Verde: 2,750 MW (largest in WECC)
  - DOE/NERC reportable events
    - loss of 300MW firm load for 15 minutes
    - system-wide voltage reductions > 3%
- Challenges from DERs
  - DER cybersecurity standard underdevelopment
  - Customer owned devices
  - Vast numbers of devices
  - Complex interconnectivity
  - Knowledge gap between IT and OT

Source: NERC IRPTF Technical Report
BPS-Connected Inverter-Based Resource Modeling and Studies May 2020

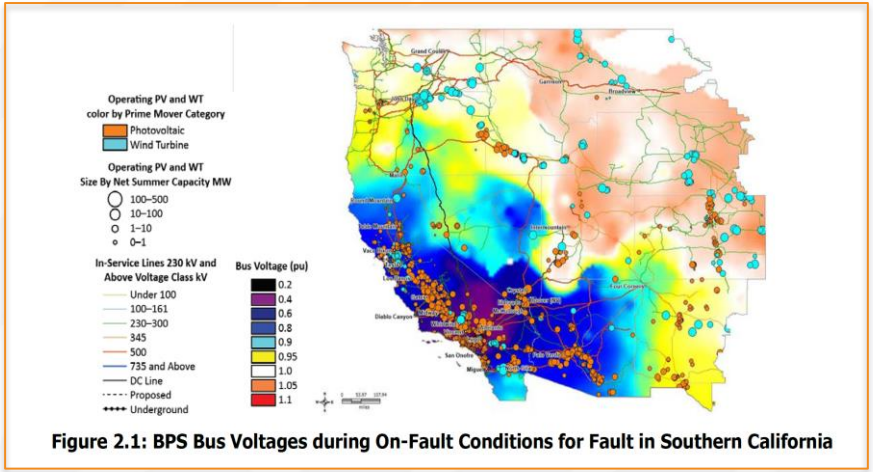


Figure 2.1: BPS Bus Voltages during On-Fault Conditions for Fault in Southern California

Renewable Integration and Grid Stability

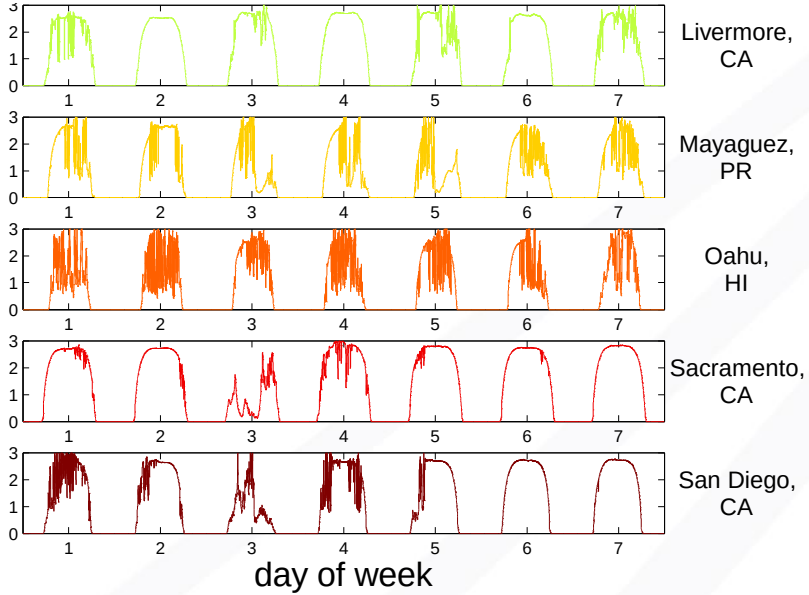
Major Events

- February 2021, TX winter storm power outage
- August 2020, CA rolling blackout
- 8/09/2019, UK blackout
  - lightening strike
  - 150MW of small embedded generation disconnected; further 350MW of embedded generation disconnected
  - 737MW offshore windfarm output reduction
  - 45 minute outage for 1.1 million customers
- 10/09/2017, Southern CA Canyon 2 Fire
  - transmission fault;
  - 900 MW of solar PV resources lost; PV inverters trip off due to momentary cessation in response to voltage transients
- 9/28/2016, South Australian blackout
  - Extreme weather (high wind, high temperature)
  - 456 MW wind generation reduction
  - 850,000 customers lost power for hours
- 8/16/2016, Southern CA Blue Cut fire
  - transmission fault
  - 1200 MW of solar PV resources lost; PV inverters trip off due to frequency during transients

NERC/DOE/Industry Response

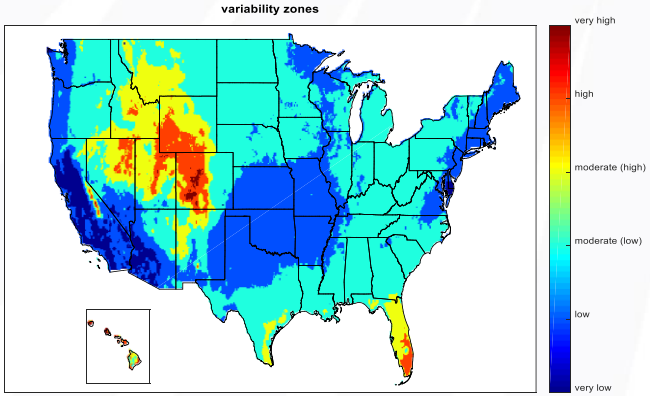
Variable Solar Generation

Sample measurements (1 min)



Short-Term and Long-Term Resource data are critical:

- Historical = NSRDB
- Real time = sensors
- Future = forecast

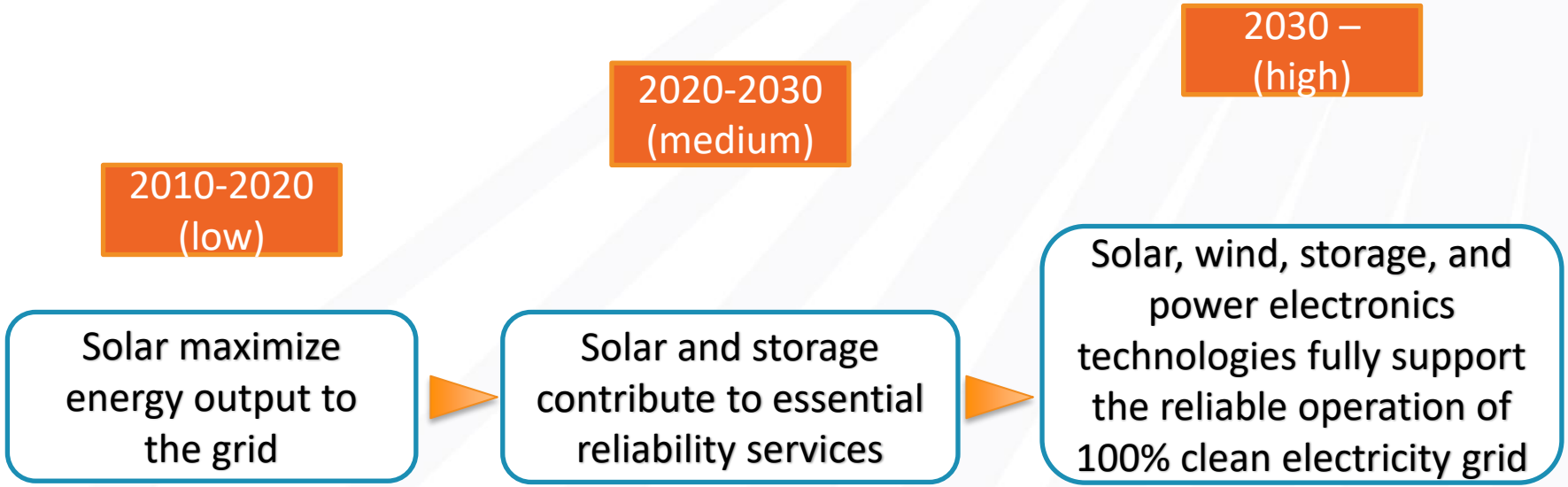


In Conclusion: The Grid is Rapidly Evolving

- **Low Inertia:** Power electronics-connected generation and consumption reduce the mechanical inertia in the system.
- **More Uncertain:** Uncertainties increase due to variable generation, smart loads, electric vehicles, generation and network contingencies, weather and cyber events, and hidden failures.
- **More Distributed:** The grid trends to having many small active resources such as rooftop PVs, smart appliances, and electric vehicles.
- **Responsive:** The high-speed control capabilities of power electronics present new opportunities for achieving a more ***responsive*** power grid.
- **Adaptive:** The solutions can and should make the grid more ***adaptive*** – ramping requirements, network reconfiguration, AC/DC hybrid operation and islanding at various granularities.
- **Scalable:** Small resources are more ***scalable*** through various combinations as needed, e.g. against cyber or physical disturbances and during outage recovery.

Solar Grid Integration Research Priorities

Solar generation has grown from less than 0.1 percent of the U.S. electricity supply 2010 to 3 percent per year in 2020 and rapidly expanding. In five states, solar electricity already represents more than 10 percent of total generation.



For Questions:

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