SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

Future System Impact of DOE Solar Grid Integration Research

2019 SETO Workshop

Washington DC

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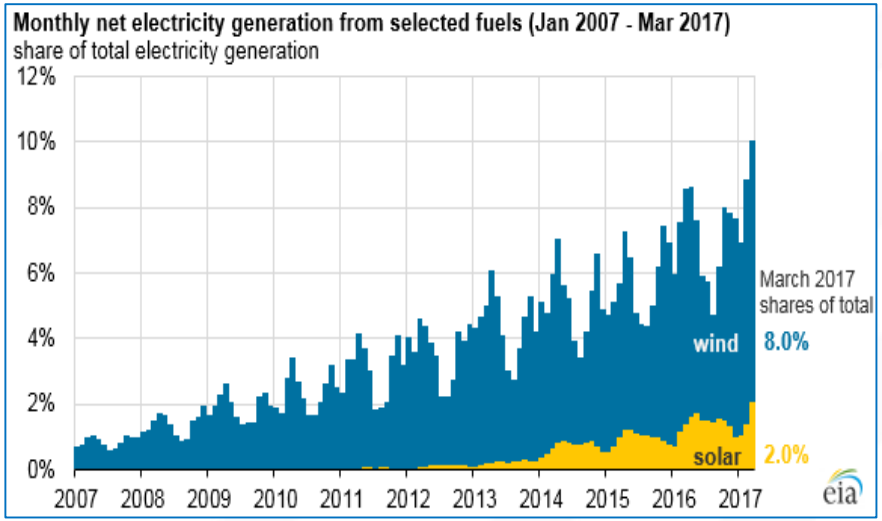
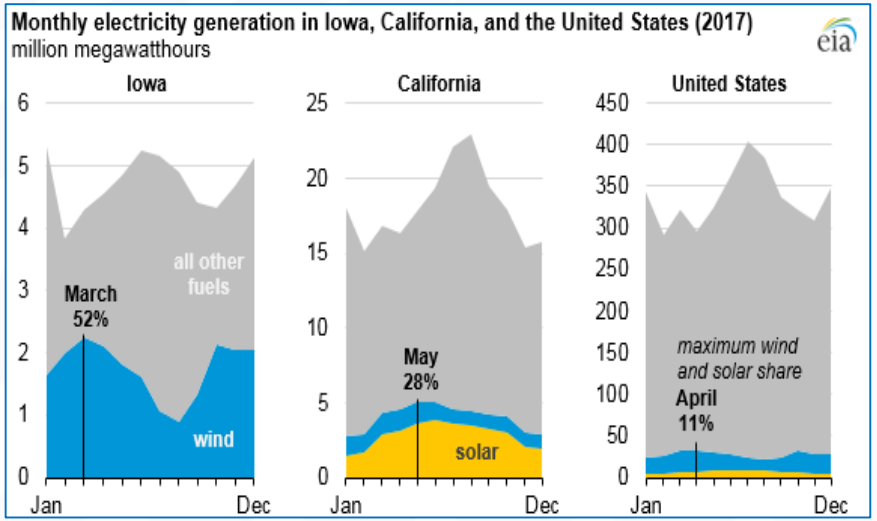
Wind and Solar Generation in the U.S. (EIA, 2017)

- United States in 2017 reached 8% for the year and peaked at 11% in April.
- California's annual solar share was 15.6%
- Wind and solar made up at least 20% of electric generation in 10 states in 2017

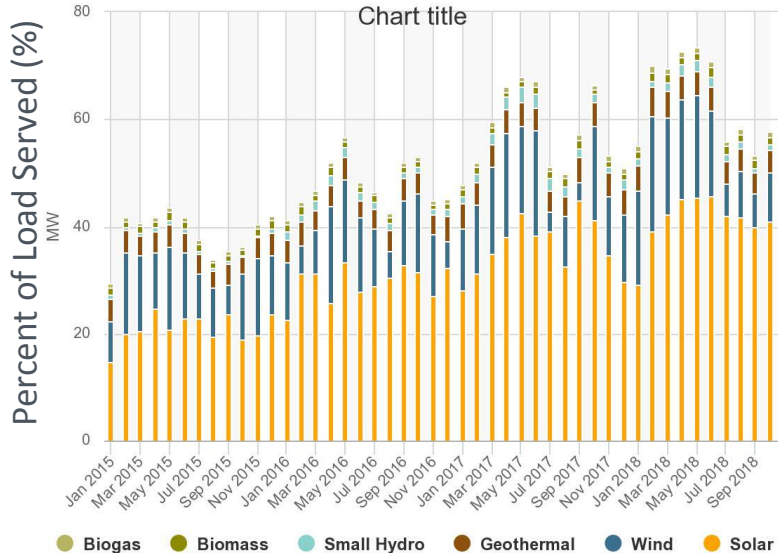




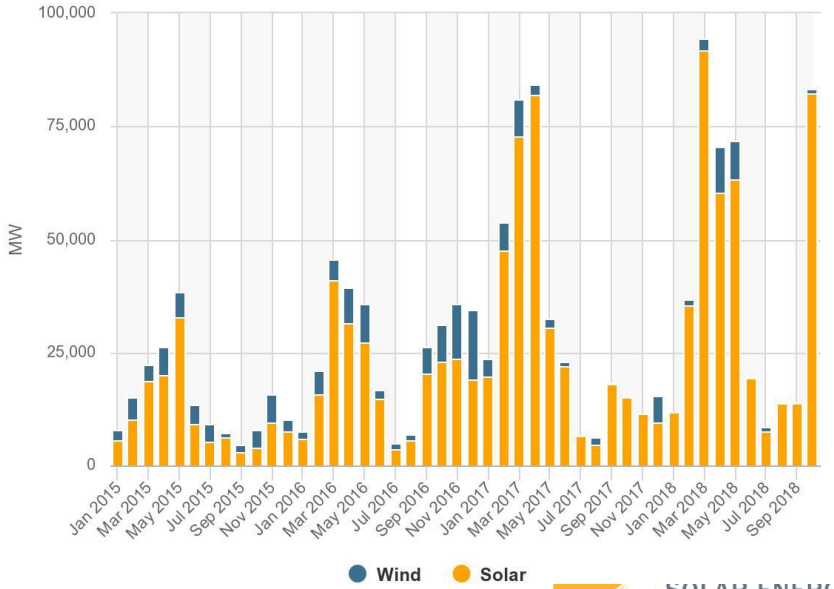
Real-Time Wind and Solar Penetration (CAISO)

- Maximum 5-min solar penetration level (utility-scale only): *45.6% in September 2018*
- Maximum 5-min renewable serving load at all time: 73.95%
- Solar curtailment 82,391MWh in October *2018*

Monthly Maximum Percent of Load Served by Renewables

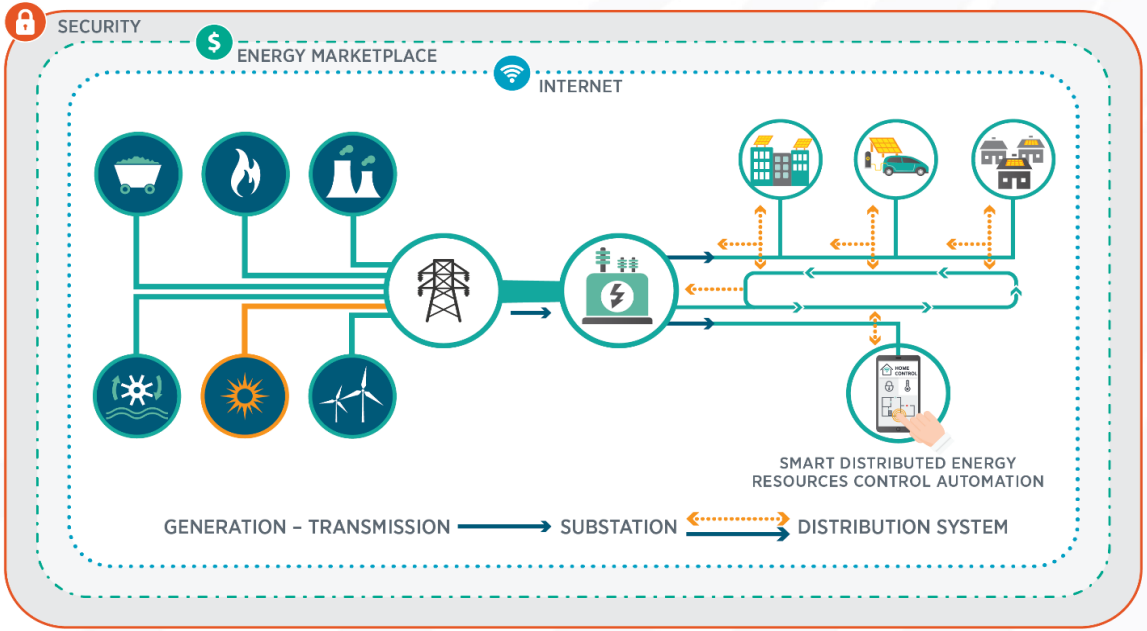


Economic Curtailment

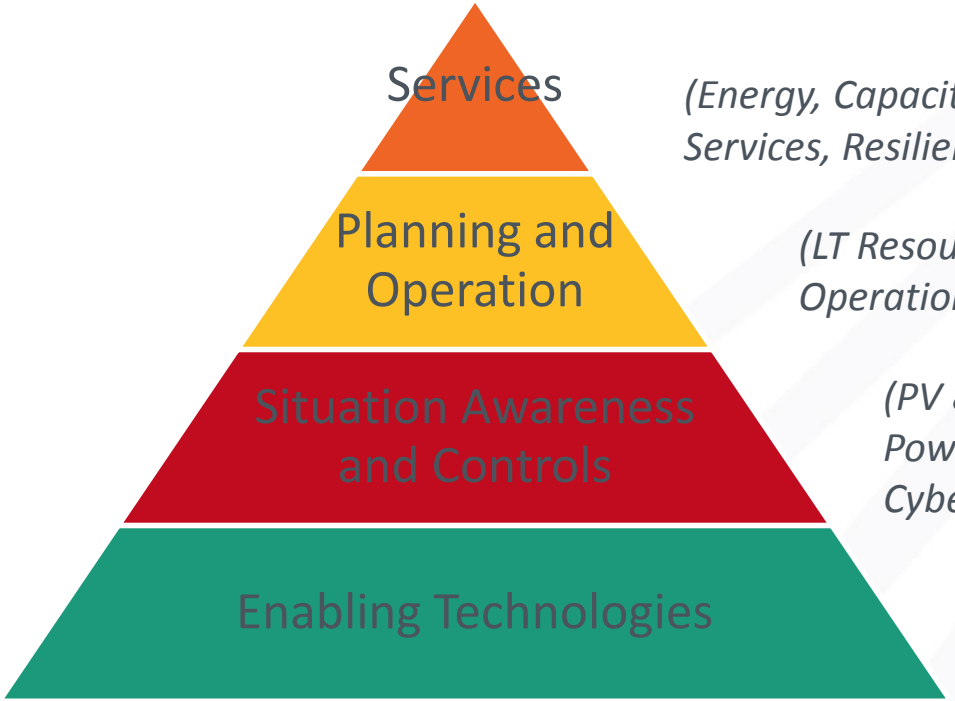


DOE/SETO Systems Integration Research

The Systems Integration (SI) subprogram supports early-stage research, development, and field validation that advances the reliable, resilient, secure and affordable integration of solar energy onto the U.S. electric grid.



A System Approach for Solar Grid Integration Research



(Energy, Capacity, Ancillary Services, Essential Reliability Services, Resilience)

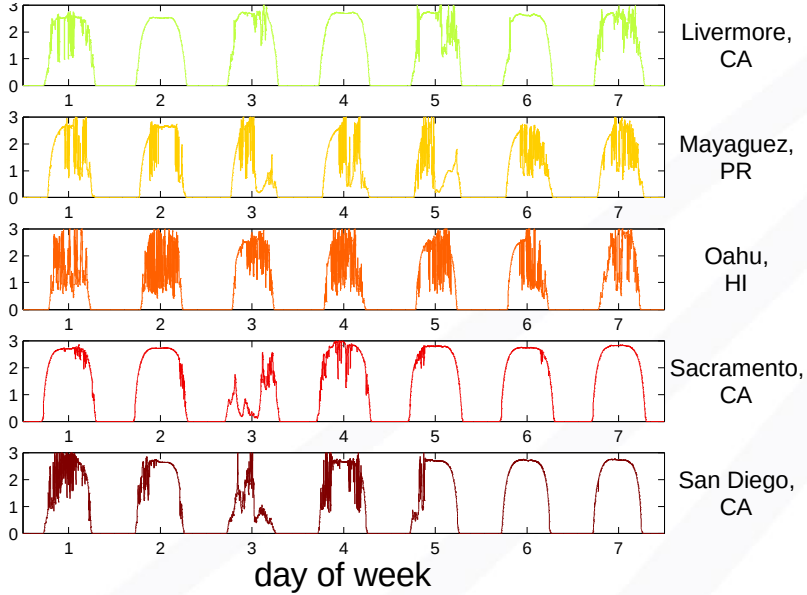
(LT Resource Planning, Day-Ahead Operation, Real-time Operation, Emergency Event Operation)

(PV & Power System Models, State Estimation, Optimal Power Flow, Data Ingestion, Interoperability, Cybersecurity, Visualization)

(Power Electronics, Solar Forecasting, Energy Storage, Data Analytics & Machine Learning, Communication, Control, Sensors, Computing)

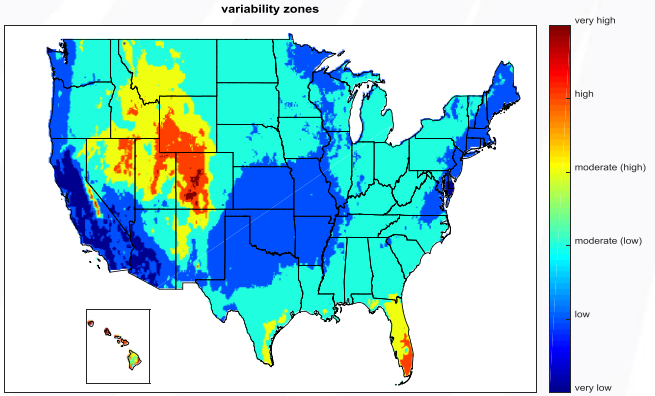
Challenges: Solar Generation Variability

Sample measurements (1 min)



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

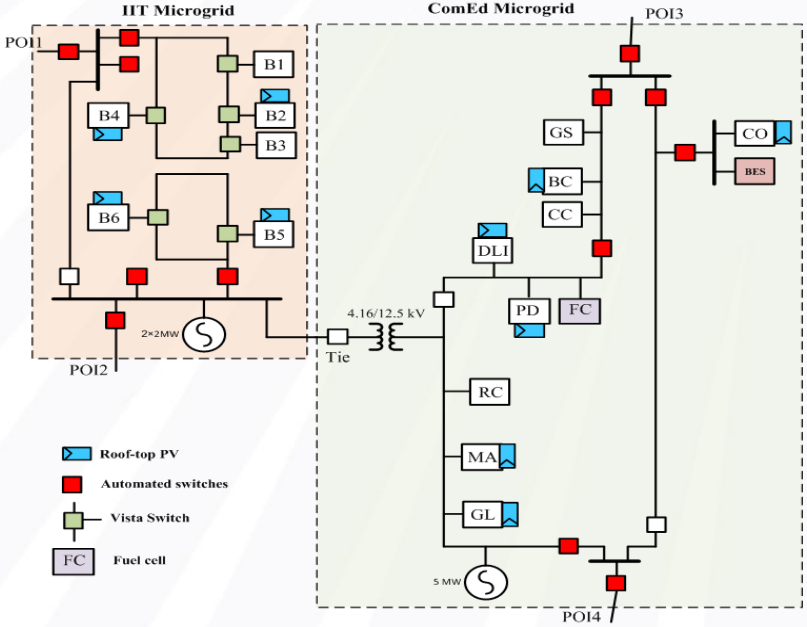
- Historical = NSRDB
- Real time = sensors
- Future = forecast



PV + Storage (SHINES)

- **Objective:** Sustainable and Holistic Integration of Energy Storage and Solar PV
- SHINES solutions should:
  - Be grid connected;
  - Consist of solar PV and energy storage;
  - Utilize smart inverters;
  - Be capable of operating in conjunction with load controls;
  - Incorporate solar and load forecasting into decisions; and
  - Be interoperable internally and externally using standard protocols
- Projects:
  - **CMU** – agent-based control
  - **ComEd** – community microgrids
  - **EPRI** – 2-level optimized control
  - **Fraunhofer CSE** – global scheduler for PV, ES, and load
  - **HECO** – integrated into EMS
  - **Austin Energy** – comprehensive DER management

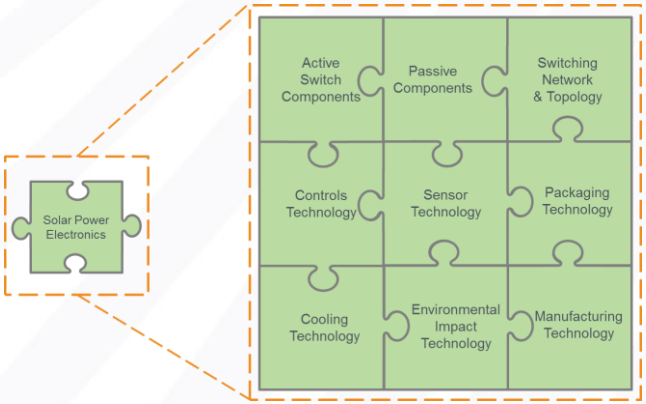
Brownsville Microgrids



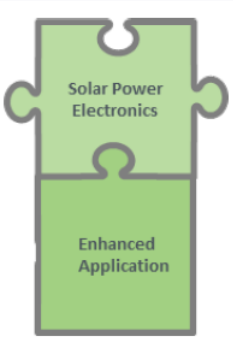
Solar Power Electronics Research

- Objectives:
  - significant reductions in the lifetime costs of power electronics (PE) for solar photovoltaic (PV) energy, and
  - enable versatile control functionalities to support grid integration of solar PV for enhanced grid services.
- Projects

Georgia Institute of Technology
North Carolina State University
University of Arkansas
University of Maryland at College Park
University of Washington
Virginia Tech
Flex Power Control
Oak Ridge National Laboratory
University of Texas at Austin



Topic Area 1: Optimization of constituent technologies for reduced lifetime costs



Topic Area 2: Conceptual modular PE for enhanced grid services

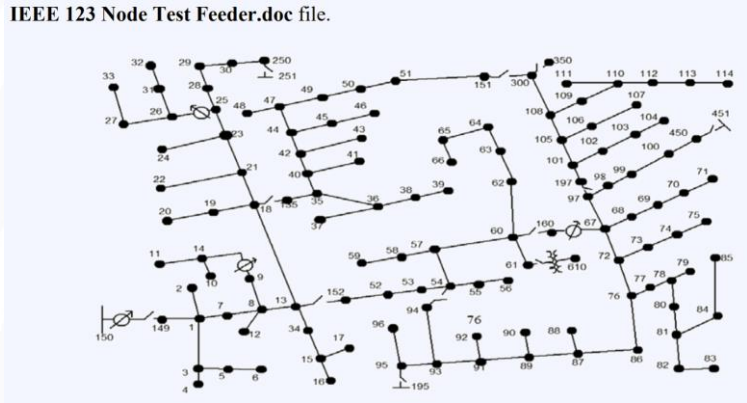
Real-Time System Operation (ENERGISE)

- **Objectives:** Develop and validate near-term (2020) and long-term (2030), highly scalable system planning and real-time operation solutions that seamlessly interconnect and integrate high penetration (>100% of distribution peak load) solar generation in distribution in a cost-effective, secure, and reliable manner.
- **Projects:**

University of Vermont	University of Southern California	UC Berkeley
NREL 1	NREL 2	UC Riverside / RPU
SCE	PPL	OpusOne
Northeastern University	University of Central Florida	Sandia

Solution Set:

- Distribution System State Estimation (DSSE)
- Optimal Power Flow (OPF)
- Real-time data
- Machine Learning
- Real time Voltage and Frequency Control w/ DERs
- DERMS integration
- Large number of node and computing

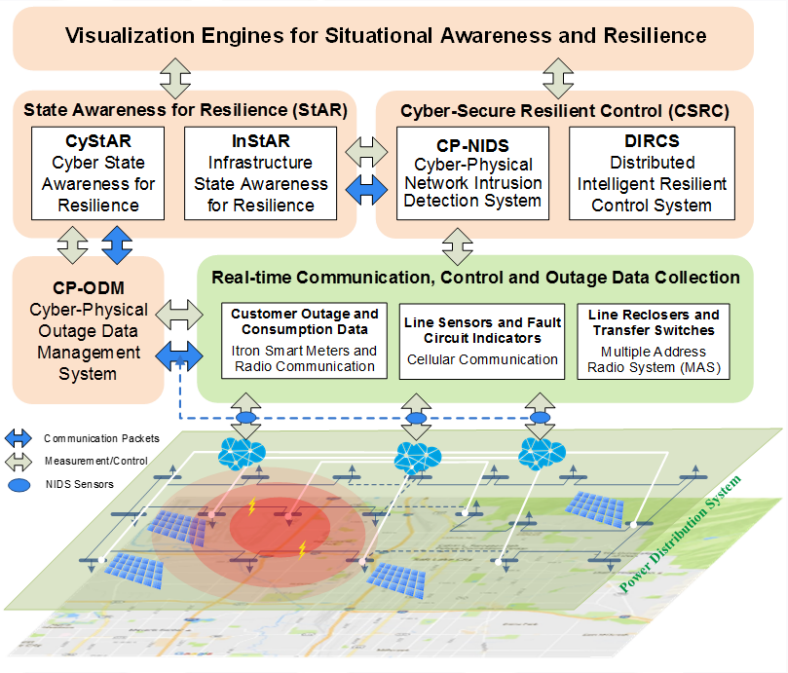


Situation Awareness and Energy Assurance for Critical Infrastructure (ASSIST)

- **Objectives:** To improve situational awareness of solar energy systems, especially at critical infrastructure sites, increase resilience to cyber and physical threats, and strengthen solar integration on the grid.

Projects:

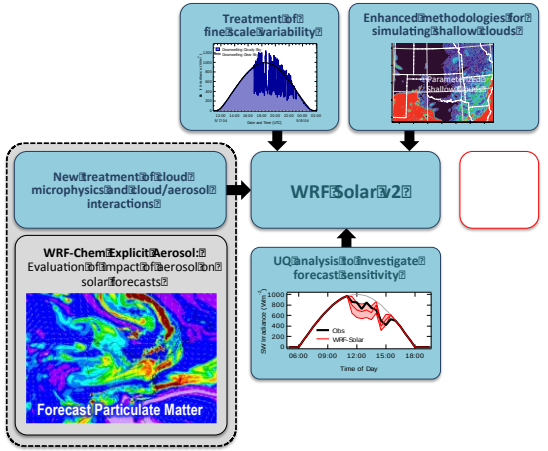
University of Utah	UNC Charlotte	University of South Florida
University of Oklahoma	Arizona State University	Kansas State University
EDD	EPRI	NCSU
Siemens		



Solar Forecasting Research

- Objectives:
  - Topic 1: Develop a uniform test Framework
  - Topic 2: Develop solar irradiance forecasting models
  - Topic 3: Develop solutions that integrate improved solar power forecasts with ISO/RTO and utility energy management systems.
- Projects

University of Arizona	PNNL	UCSD	NREL-1
Johns Hopkins University	ERPI	BNL	NREL-2



solar irradiance forecasting

integration with utility and ISO operation

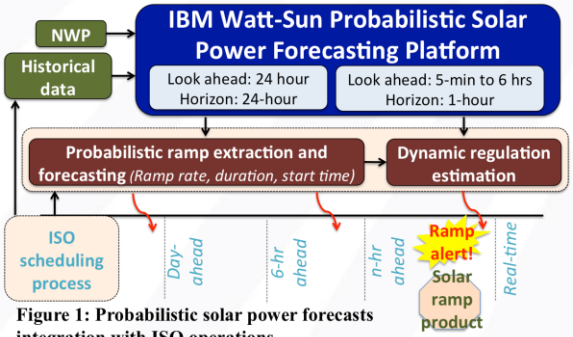


Figure 1: Probabilistic solar power forecasts integration with ISO operations

Cybersecurity Research

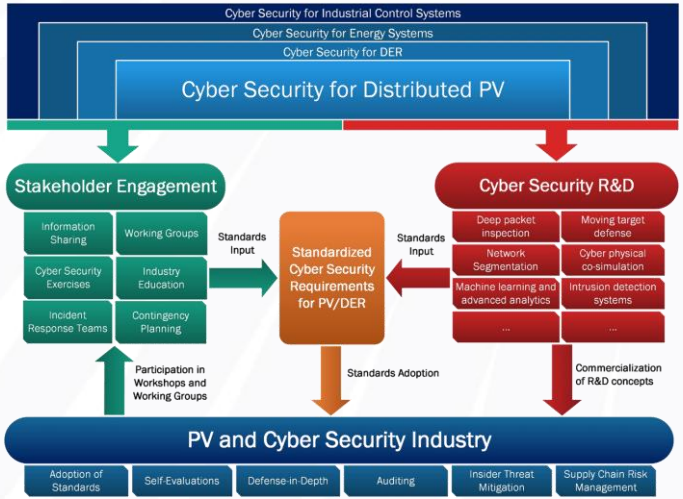
Objectives

- Align with DOE and EERE cybersecurity crosscut initiatives
- Identify system- and device-level cybersecurity vulnerabilities
- R&D in cybersecurity measures and mitigation strategies, hardware, software, firmware, supply chain
- Creating consensus DER cyber security standards and testing/verification methodologies

Activities

- Developed "Roadmap for PV Cybersecurity" (Sandia)
- Collaboration with CESER on NREL/HECO project
- EERE Cybersecurity MYPP

PV Cybersecurity Roadmap (Sandia)

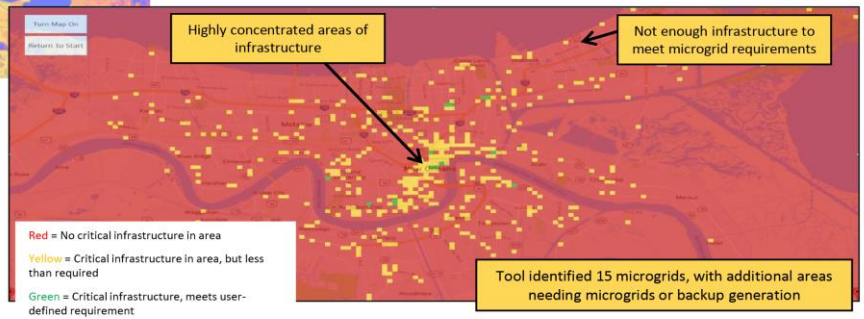


GMLC Resilience Distribution System (RDS) Program

- **Objectives:** develop and validate the integration of DERs, such as solar PV, storage, and emerging grid technologies to enhance the resilience of distribution grids.

Results of Hurricane Inundation Modeling for New Orleans and surrounding regions

Area size of 1000 ft x 1000 ft | minimum of 4 buildings per microgrid



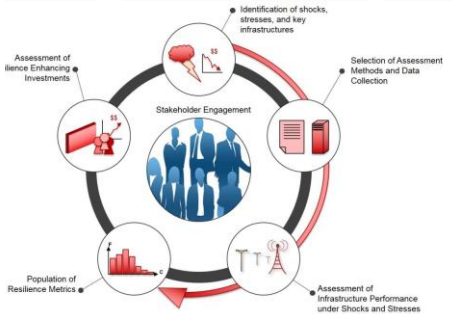
- Applying grid and infrastructure modeling to determine grid investments that will improve community resilience.
- **Resilience metric:** use microgrid designs to maximize the number of people with access to key services during flooding scenarios.

Demo projects:

- SLAC
- SNL
- PNNL
- ORNL
- LLNL
- INL

Valuation Analysis project

- LBNL



Building Resilient Power System in Puerto Rico

Objective: DOE Office of Electricity and SETO have tasked national laboratories to perform near-, medium-, and long-term modeling activities to support the rebuilding of a more resilient electric power grid system in Puerto Rico after the devastation of Hurricane Maria in late September 2017.

Phase 2 Approach:

1. Build on insight from research in Hawaii and elsewhere
2. Develop integrated portfolio
3. Rigorous modeling and analysis
4. Broad stakeholder engagement (federal, state, local community, and industry)

Fuels/Interdependencies
- LNG Infrastructure
- Telecom Infrastructure
- Solar Resource and Supply Curves

Bulk Power System
- Investment Support Tools
- Capacity Expansion Modeling (AURORA)
- Production Cost Modeling (FESTIV)
- System Stability Modeling (Epfast)
- Dynamic Modeling (MAFRIT)

Transmission
- Protection and R/T Info
- Risk-Based Contingency Analysis
- Grid Asset Benefit-Cost Evaluations

Distribution & Edge
- System Advisory Model & PVWatts
- DER Interconnection Standards
- DER Feeder Hosting Methodology
- Contingencies, Operations, and Storage Sizing for Islandable Sections
- GIS Resiliency Improvement Tool

Lead Lab Key:
- ANL
- NREL
- ORNL
- PNNL
- SNL

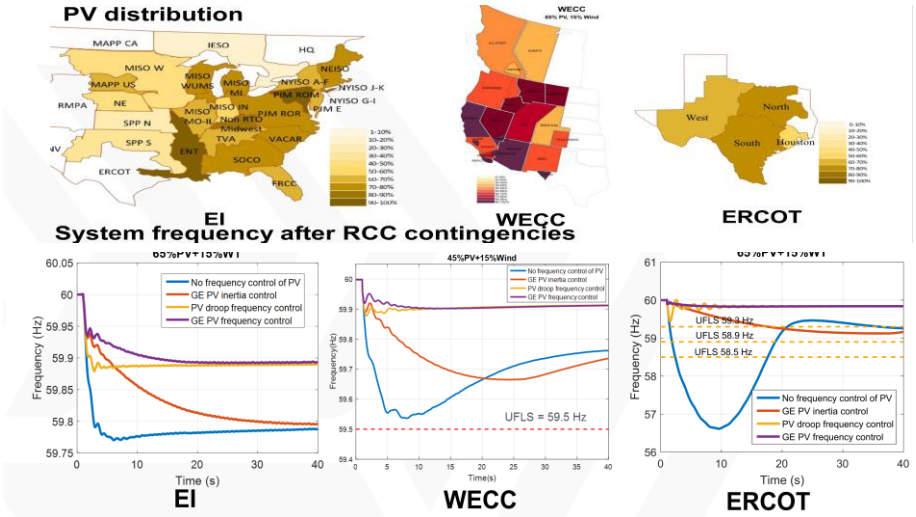
GMI/GMLC Crosscut

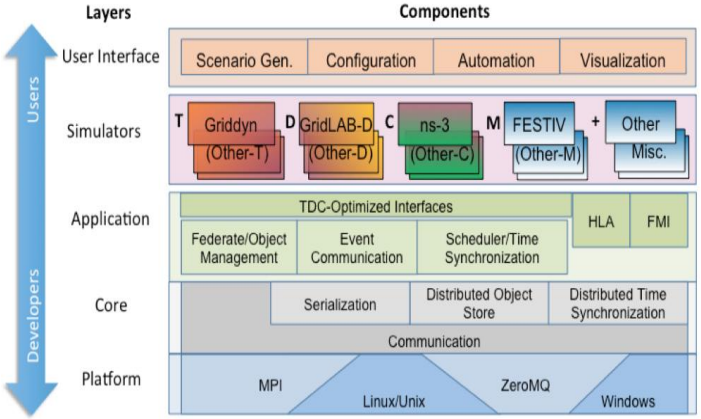
Objective: Improve grid reliability and resiliency through the strategic goals of the Grid Modernization Initiative and encourages the Department to include **all applied energy programs** to ensure broad energy system resilience and modernization.

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Collaboration:

- With OE, CESER, EERE offices
- With labs, industry, and universities





Examples: (left) frequency at 20%, 40%, 60%, and 80% renewable penetration, (right) Transmission-Distribution-Communication (TDC) co-simulation platform

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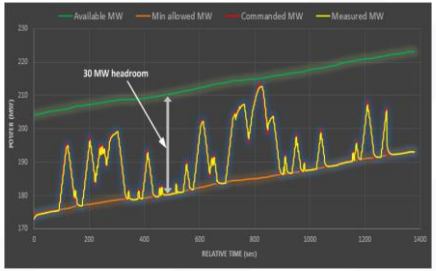
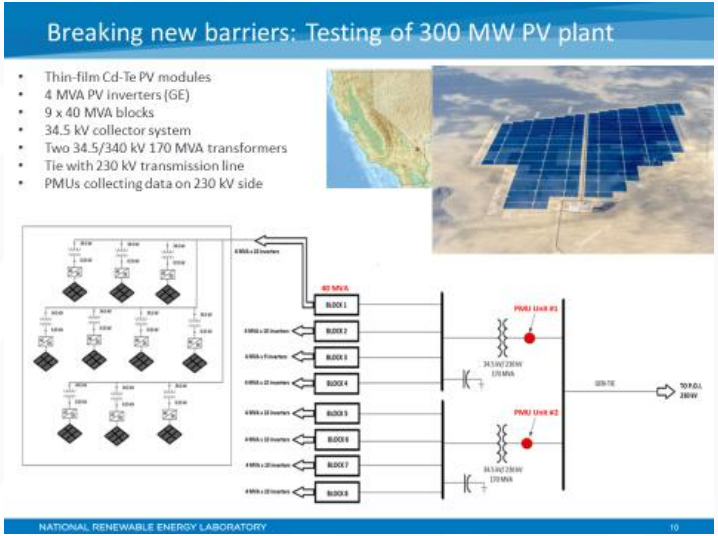
Demonstration of Essential Reliability Services from Solar PV

- NREL/CAISO/First Solar partnering in the 300-MW PV System Commissioning Test
- Winner of NARUC Innovation Award in 2017

- 4-sec AGC signal provided to PPC
- 30 MW headroom
- Tests were conducted for 30 minutes at:
  - Sunrise
  - Middle of the day
  - Sunset
- 1-sec data collected by plant PPC





Courtesy: NREL, Vahan Gevorgian
http://www.nrel.gov/docs/fy17osti/67799.pdf

"These data showed how the development of advanced power controls can enable PV to become a provider of a wide range of grid services, including spinning reserves, load following, voltage support, ramping, frequency response, variability smoothing, and frequency regulation to power quality."

New DOE Solar Energy R&D Initiatives

Announced in March 2019

(https://www.energy.gov/eere/solar/funding-opportunity-announcement-solar-energy-technologies-office-fiscal-year-2019)

- NEW funding opportunity to advance solar energy technologies:
  - $130M ($44M for Advanced Systems Integration)
  - To support a wide range of R&D topics: protection, PV modeling, grid services, cybersecurity, and advanced inverter controls, etc.
  - **Concept paper deadline: May 14, 2019**

Science & Technology Policy Opportunity

- Play an integral role in establishing and implementing new projects and initiatives to make solar energy more affordable and reliable.
- Learn about the federal government and its role in advancing science and technology.

Design and implement national R&D strategies for:

- Photovoltaic Technology
- Concentrated Solar Power Technology
- Technology to Enable better Solar Integration with the Grid

Eligibility:

- The opportunity is available to highly talented scientists and engineers holding bachelor's, master's, or Ph.D. degrees of all quantitative backgrounds as well as applicants with relevant post-degree experience.

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

For additional information or to apply:
VISIT: https://www.zintellect.com/Posting/Details/3603
EMAIL: DOE-RPP@orau.org

Thank You!

& Let’s Work together!