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

SOLAR ENERGY TECHNOLOGIES OFFICE

2022 SETO PEER REVIEW

Systems Integration
Program Overview

January 31, 2022

Guohui Yuan, Program Manager

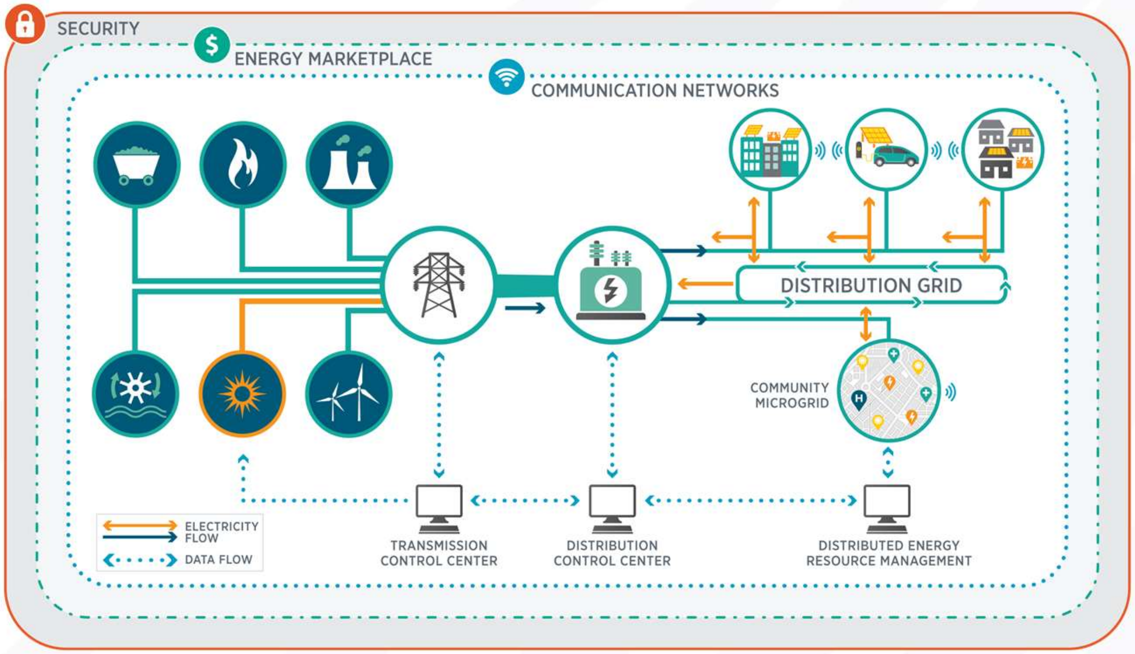
energy.gov/solar-office

What is System Integration?

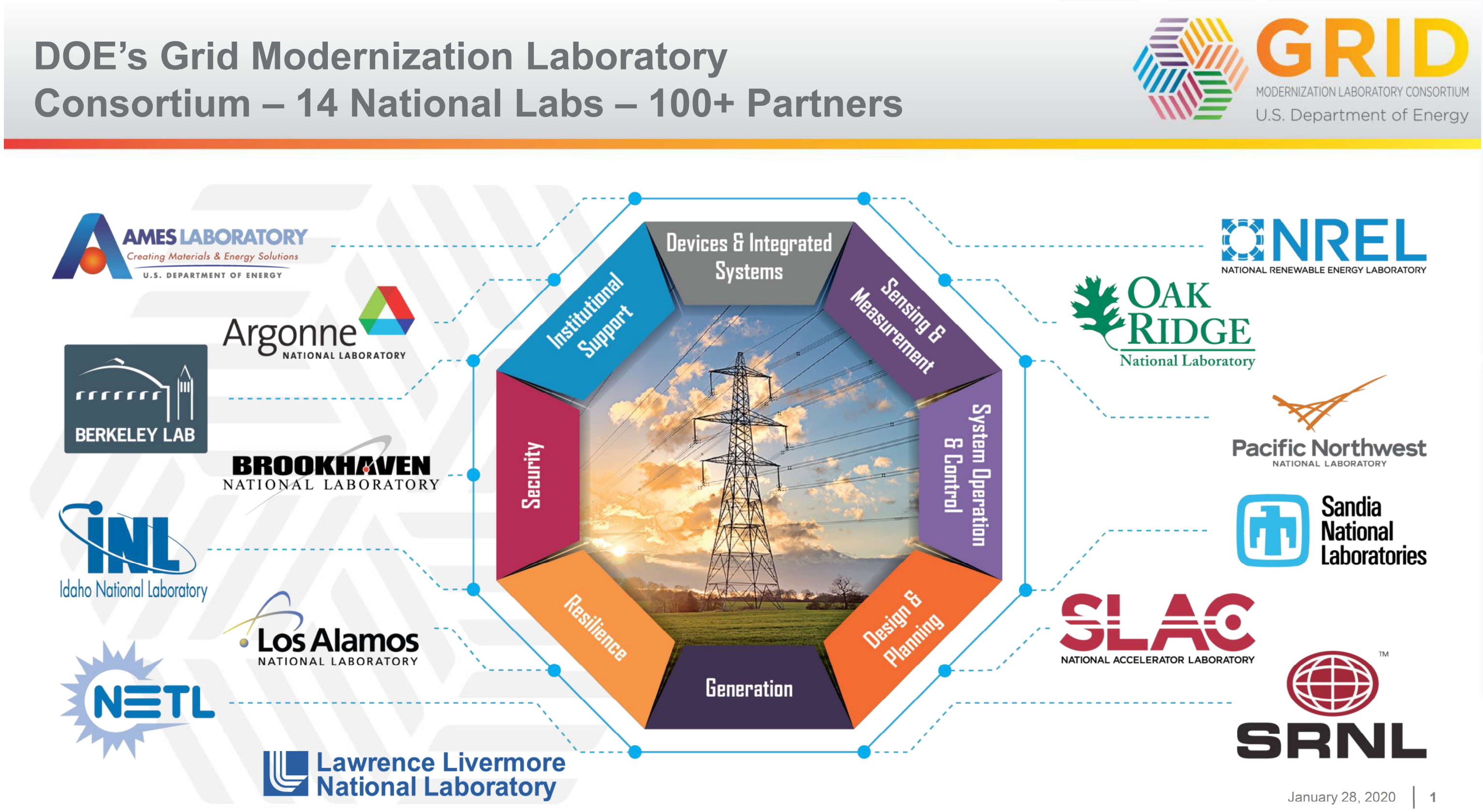
[Next-Generation Inverters Enable Solar Energy Integration - YouTube]

SETO Systems Integration (SI) Program

The Systems Integration (SI) subprogram supports **research, development, demonstration, and deployment** (RDD&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



Systems Integration Team

Guohui Yuan

Shay Banton

Bishnu Bhattarai

Kemal Çelik

Patricia Clark

Tiffany Jones

Rebecca Glaser

Rodney Kizito

Marissa Morales-Rodriguez

Robert Reedy

Yi Yang

Thomas Rueckert

John Seuss

David Walter

System Integration Key Research Areas

System Planning

- Develop methods and tools for short- and long-term power system planning with high solar contribution.
- Address issues in system reliability, resource adequacy, generation variability, system flexibility.
- Include power system modeling, solar and load forecasting, and interconnection standards.

System Operation

- Develop real time situation awareness and control solutions for high-level solar integration
- Address operation issues for both bulk power and distribution systems
- Include operation data integration, grid services, system stability and protection, power flow analysis, and control optimization.

PV for Resilience & Cybersecurity

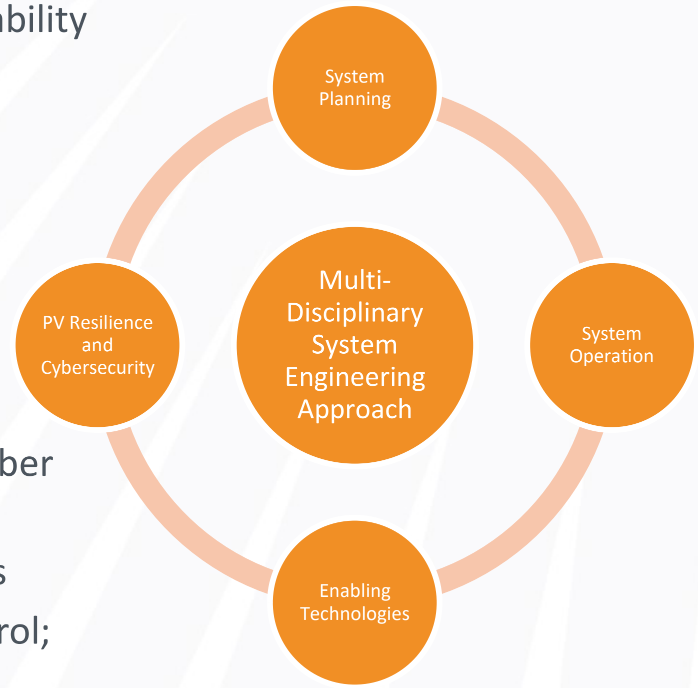
- Develop solutions to ensure the continuity of electric power service and faster recovery during grid disruptions.
- Address physical weather-related hazards as well as cybersecurity threats
- Include integrated solutions with solar PV, energy storage, and other DER.

Power Electronics & Enabling Technologies

- Develop new foundational hardware, software, and system technologies to enable solar grid integration.
- Include power electronics, AI/ML and data analytics, sensing and communications, computing, and advanced testbeds.

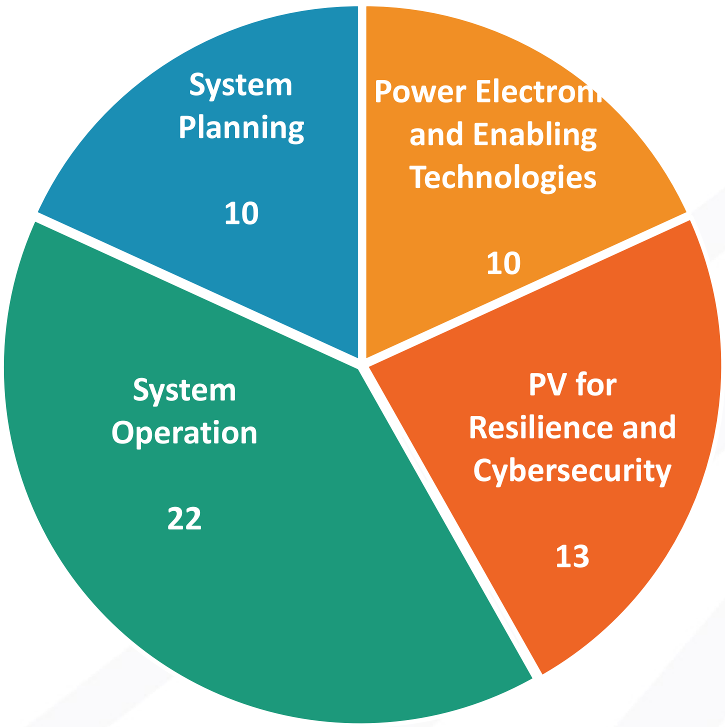
Research Programs

- FY22 SETO Lab Call – transient/dynamic modeling, open data, NSRDB, reliability and cybersecurity standards
- FY21 SI & Incubator FOA – grid-forming consortium, BTM solar integration
- FY20 SETO FOA – resilient community microgrids, cybersecurity, hybrid PV plants
- FY19 SETO Lab Call – all SI topics
- FY19 GMLC Lab Call - resilience models, sensing and measurement, cyber security
- FY19 SETO FOA - grid services, system protection, grid-forming inverter, cyber security
- ASSIST FOA – situation awareness, and resilience for critical infrastructures
- Advanced Power Electronics FOA - Improving PE efficiency, reliability, control; WBG devices
- GMLC-RDS Lab Call - Resilient distribution system design, demonstration, and value analysis

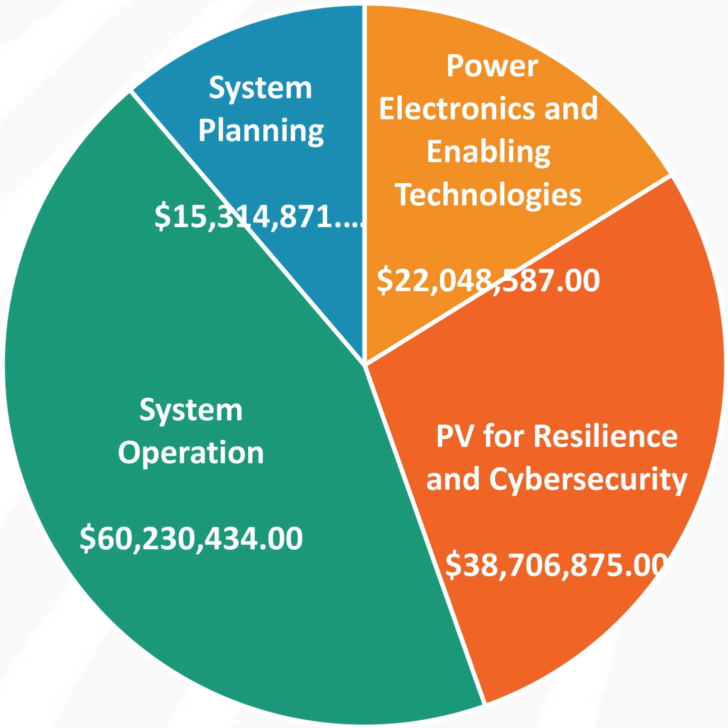


Systems Integration (SI) Peer Review Portfolio

SI Projects by Topic Area



SI Funding by Topic Area



Justice, Equity, Diversity & Inclusion (JEDI)

JEDI Strategy for SI:

- Diversify Merit Reviewer pool
- Diversify selection of Awardees
- Include DEI requirements in program designs
- Enhance community resilience through Technology demonstrations

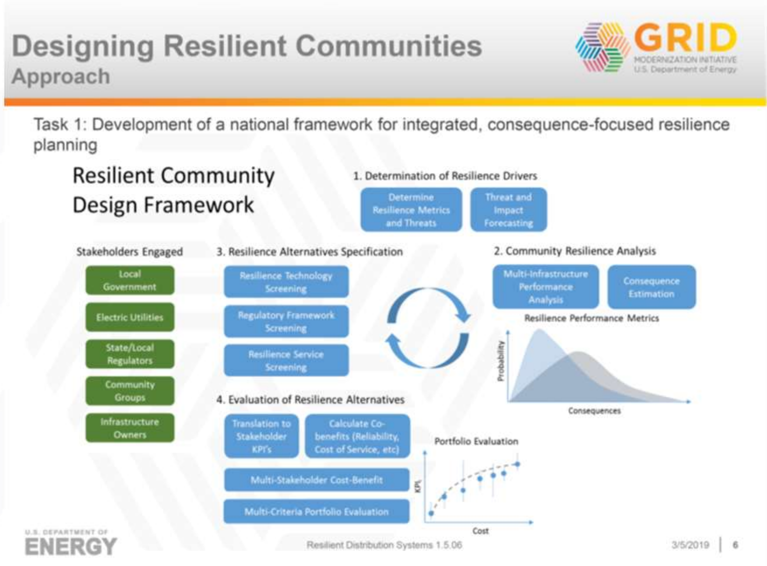
Recent JEDI Successes for SI:

- Bronzeville, Chicago microgrid project successfully completed final testing (January 2022)
- Diversity of SI subprogram team
- 14 applications for SI focus area of MSI STEM Research and Development Consortium (MSRDC)

7.7 MW community microgrid that will provide service to approximately 770 customers in the historically Black neighborhood of Bronzeville, Chicago. Photo courtesy of ComEd

Stakeholder Engagement

- Program-level
  - Actively listening
  - Stakeholder workshops and webinars
  - Technical workshops
- Project-level
  - Include TRCs, IABs, SAGs, surveys to solicit diverse stakeholder voices to guide research
  - Build in stakeholder engagement tasks and milestones.
  - Transparency in research methodologies
  - Disseminate results in public reports, online content, training webinars, and demonstrations



Source: Bobby Jeffers & Robert Broderick)

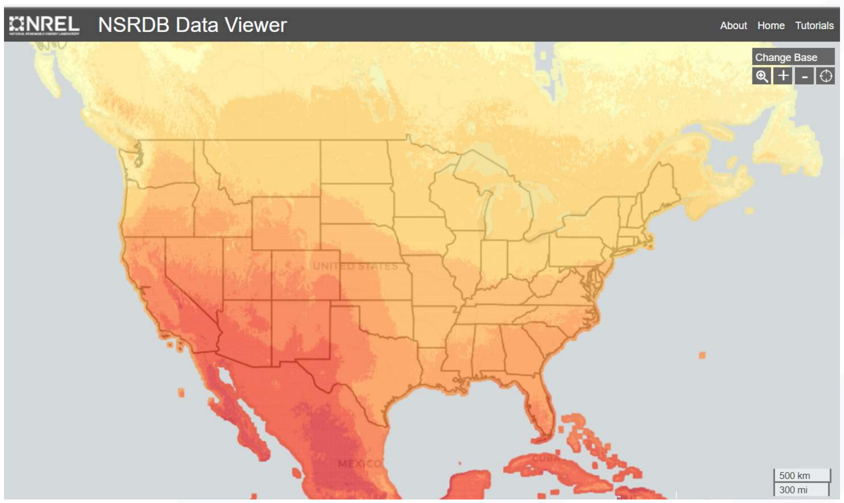
DOE-led Stakeholder meeting in Puerto Rico

Challenges

Solar Generation Variability and Uncertainty

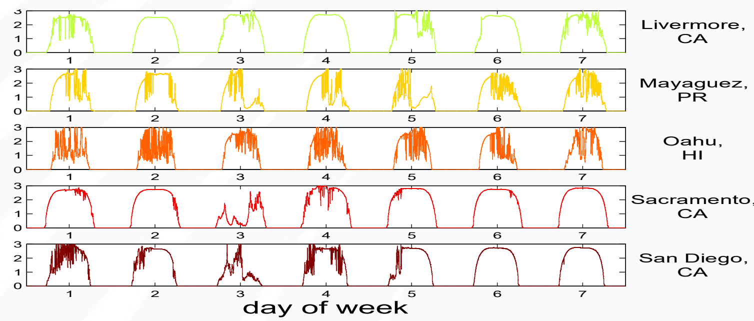
Solar Irradiance Data (GHI, DNI):

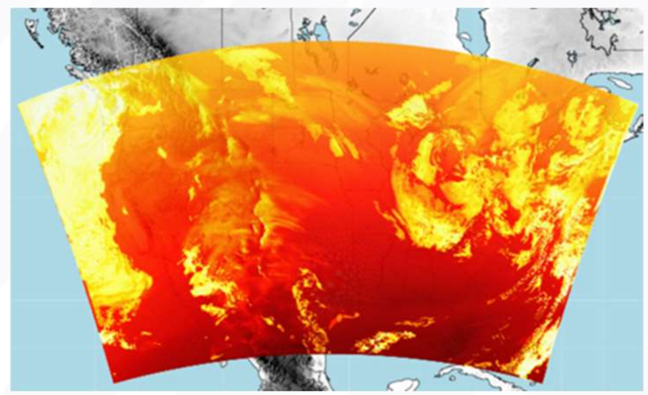
- Historical = NSRDB
- Real time = satellites and ground sensors
- Future = forecast



2019 Annual Mean of GHI from NSRDB (2km x 2km, 5 min, Terabytes) [Home - NSRDB (nrel.gov)]

Sample measurements (1 min)

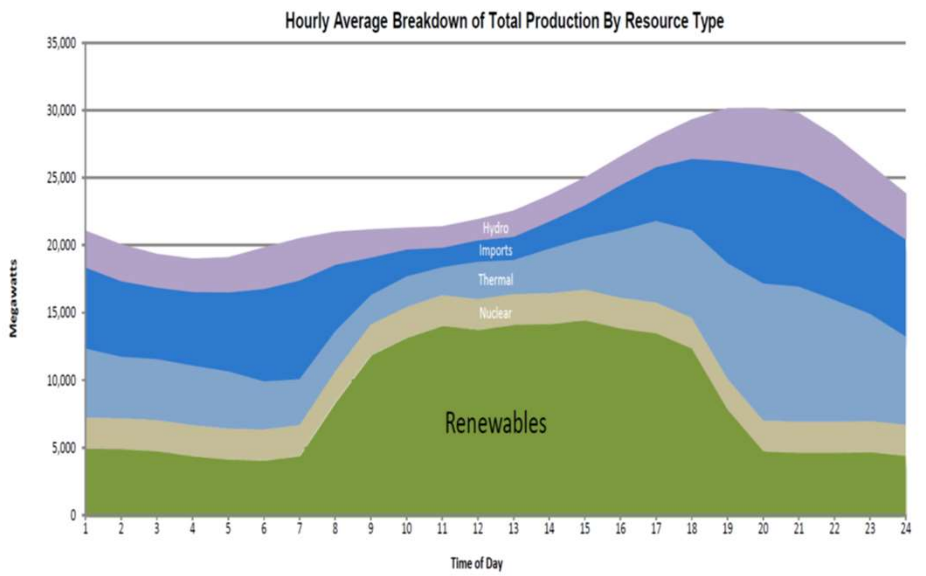




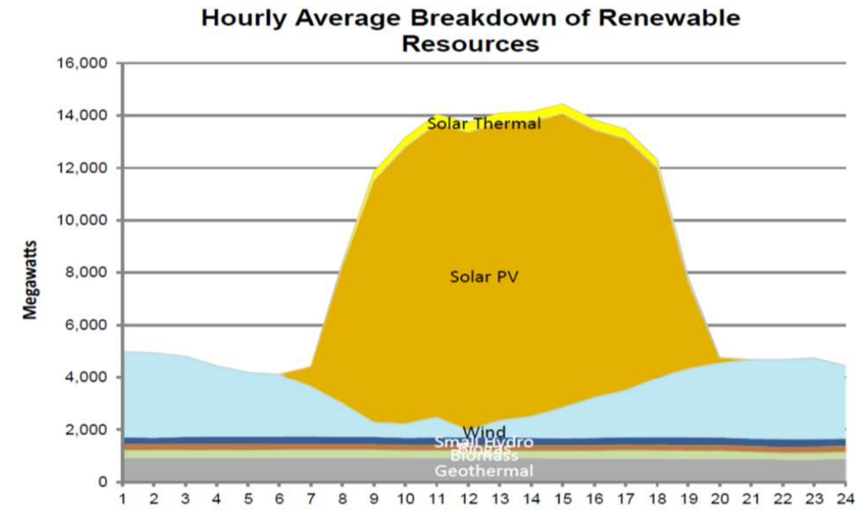
[WRF-Solar® | NCAR Research Applications Laboratory | RAL (ucar.edu)] ***Run on HPC***

Operating a Decarbonized Electricity Grid

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



This graph depicts the production of various generating resources across the day.

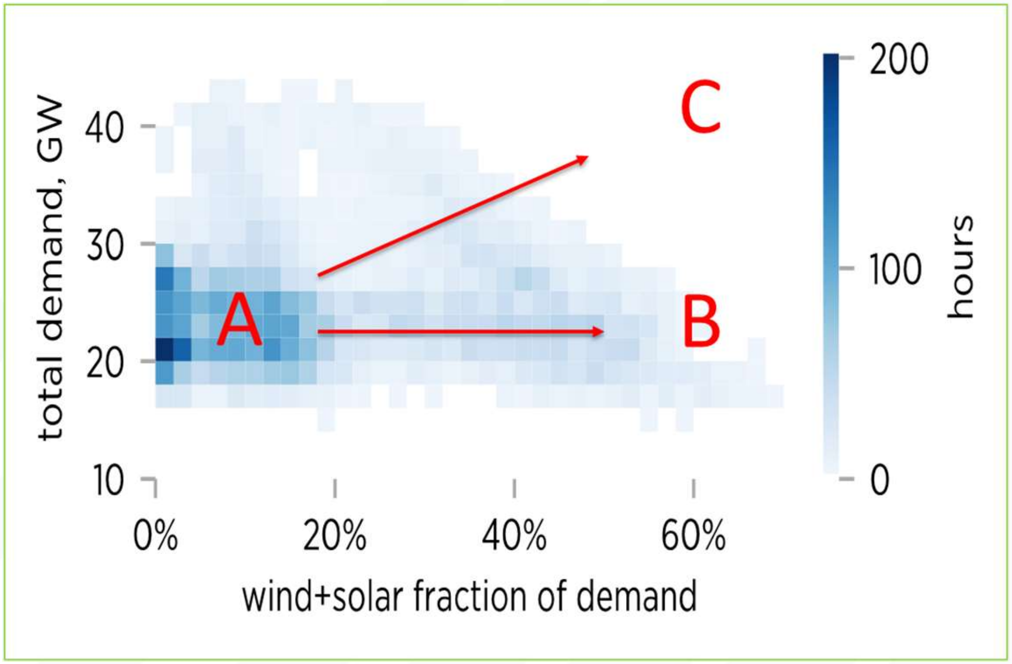


This graph shows the production of various types of renewable generation across the day.

Operating a Decarbonized Electricity Grid (continue)

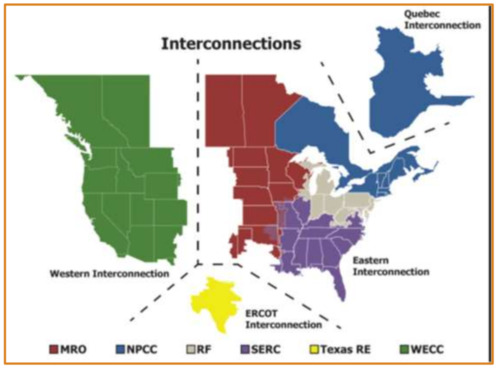
Power system	System size	Peak solar + wind *power* contribution	Annual solar + wind *energy* contribution
U.S. WECC	163 GW	36%	13%
U.S. ERCOT	80 GW	58%	20%
U.S. SPP	51 GW	69%	28%
U.S. CAISO[4]	44 GW	70%	20%
Australia NEM	35 GW	50%	21%
Ireland	7 GW	84%	36%
Oahu	4 GW	58%	22%
Maui	0.5 GW	80%	37%

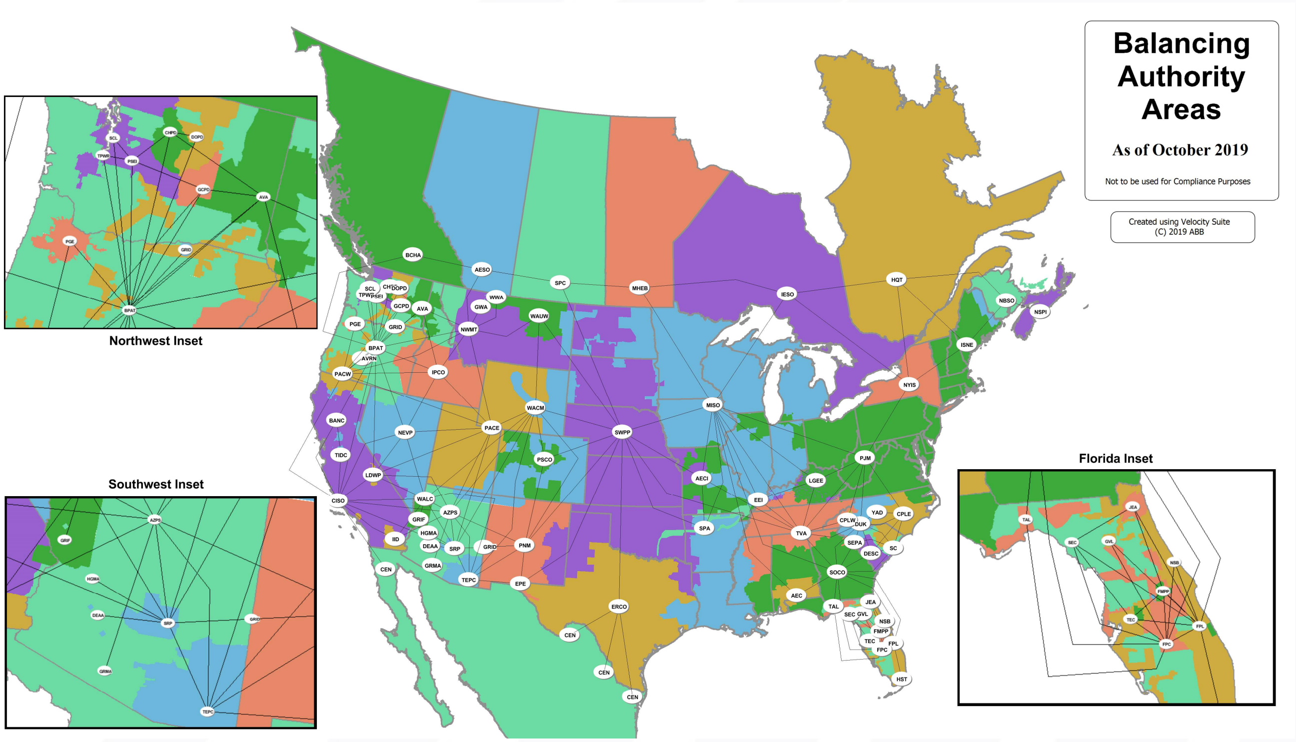
[Solar Energy Technologies Office Multi-Year Program Plan | Department of Energy]



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 higher contribution to the generation supply but only at lower demand levels. (Area B). In the future, as solar and wind reach much higher deployment, the system will operate at high demand most of the times (Area C).

Scalability of Solar Integration on U.S. Electric Grid





Source: NERC

Natural Disasters and Cybersecurity Threats

Grid Stability and Resilience

Major Events

- May 2021, Odessa disturbance
  - Transmission fault
  - ERCOT solar output drops from 4.5GW to 3.5 GW in <1 min
- February 2021, TX winter storm power outage
- August 2020, CA rolling blackout
- 8/09/2019, UK blackout
  - lightening strike, 45 minute outage for 1.1 million customers
  - 737MW offshore windfarm output reduction
  - 150MW of small embedded generation disconnected; further 350MW of embedded generation disconnected
- 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

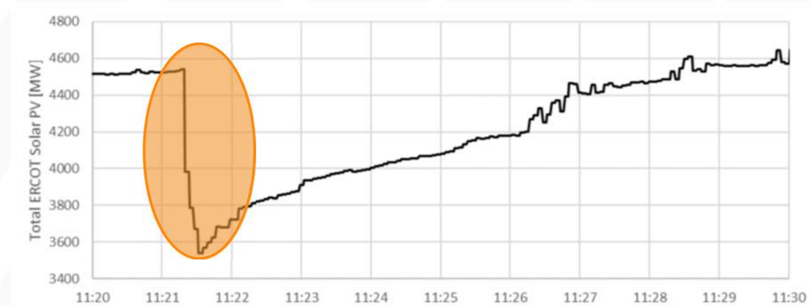
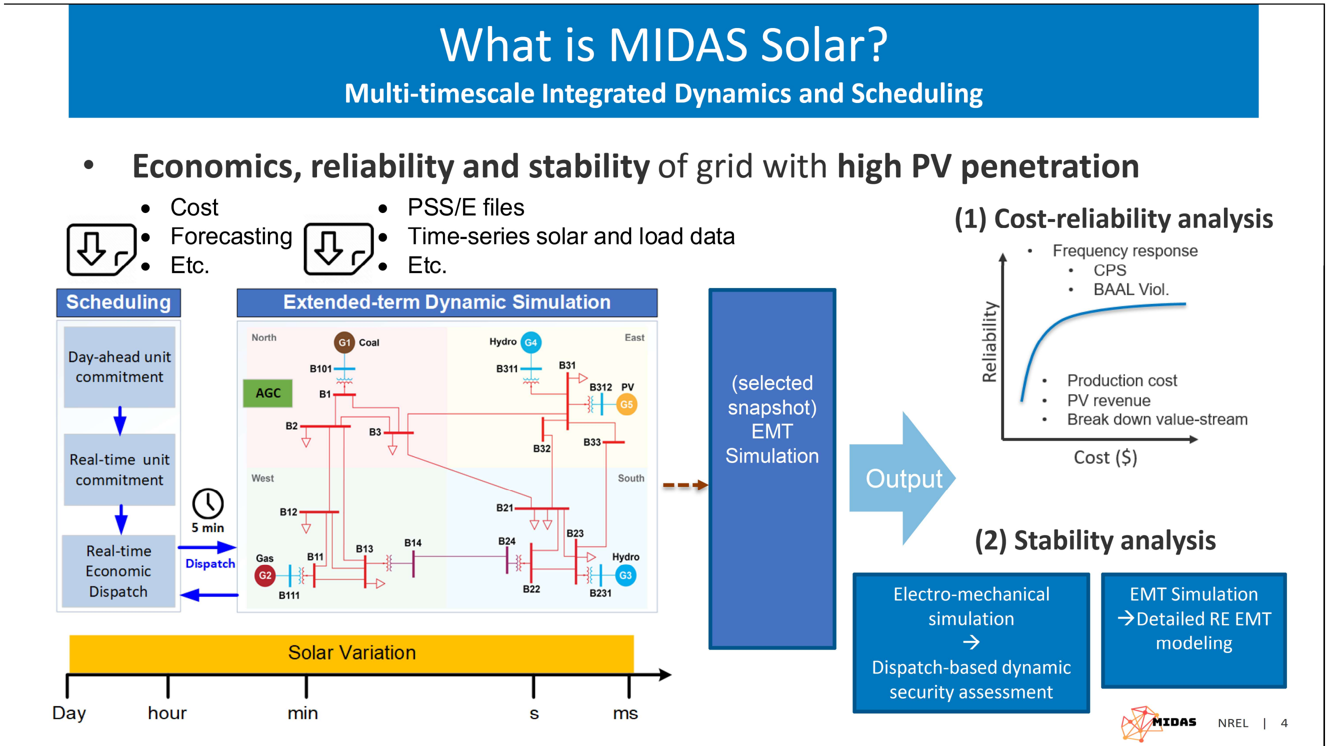


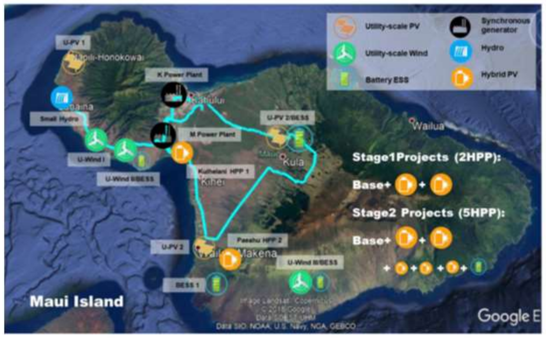
Figure I.5: ERCOT BPS-Connected Solar PV during Disturbance [Source: ERCOT]

System Planning

Modeling 100% Renewable Grid



Maui Grid

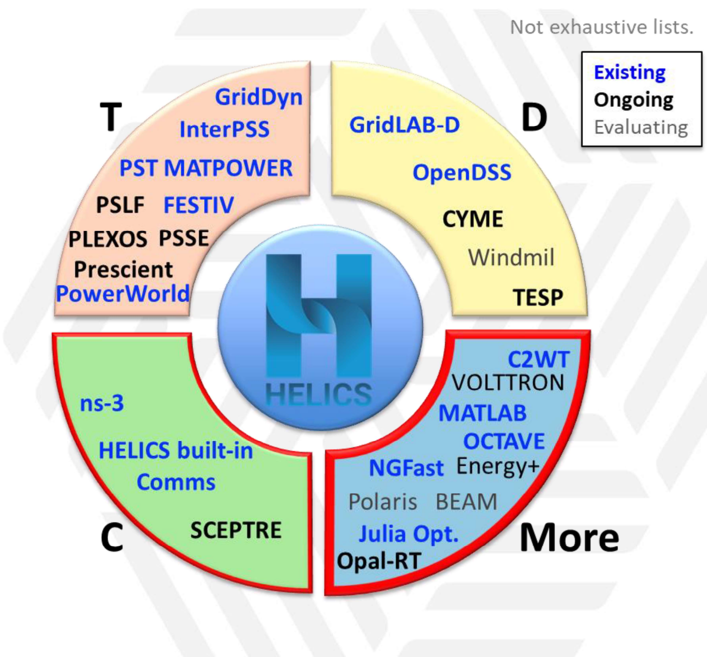


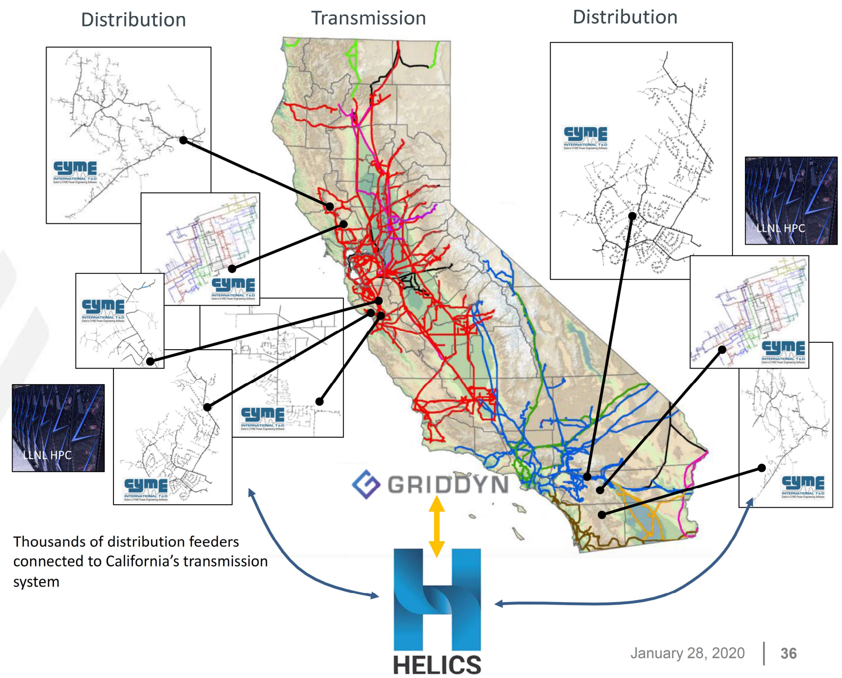
(Source: Jin Tan, NREL)

Multi-Domain Co-Simulation Platform

HELICS middleware enables coupling of transmission, distribution, communications and other models

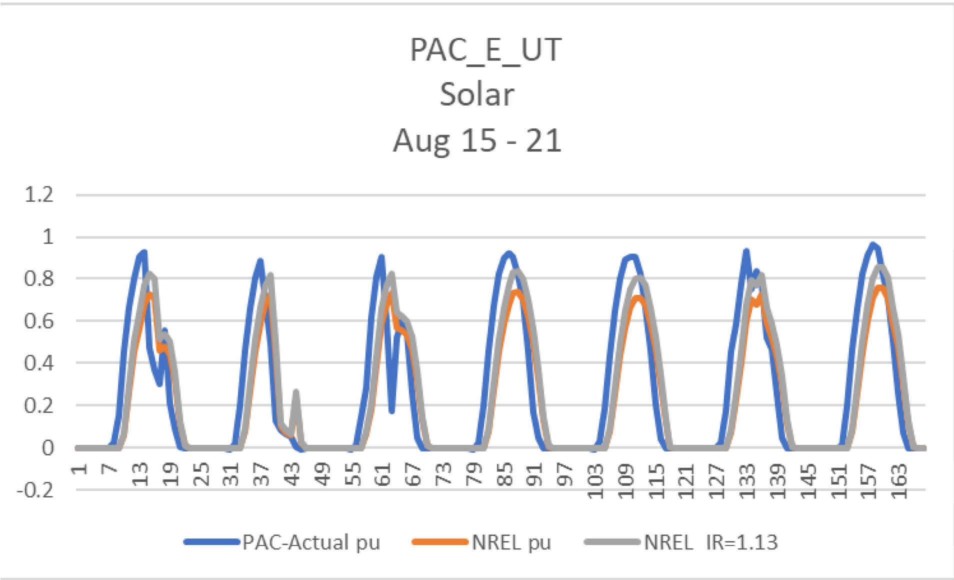
GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy



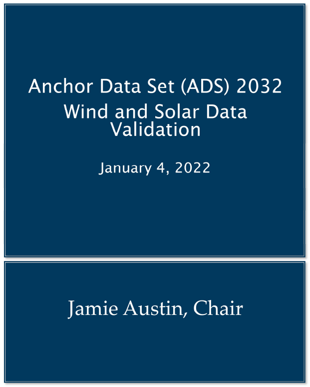


Develop and Validate 2032 WECC-ADS Solar Datasets

- Use existing NREL models and historic wind/solar data to create utility-scale and BTM solar datasets for the entire WECC region
- Validate with actual plant-specific data
- Support long-term system planning and wind/solar development
- Close collaboration between DOE, NREL, PNNL, and WECC staff



WECC


Anchor Data Set (ADS) 2032
Wind and Solar Data Validation

January 4, 2022

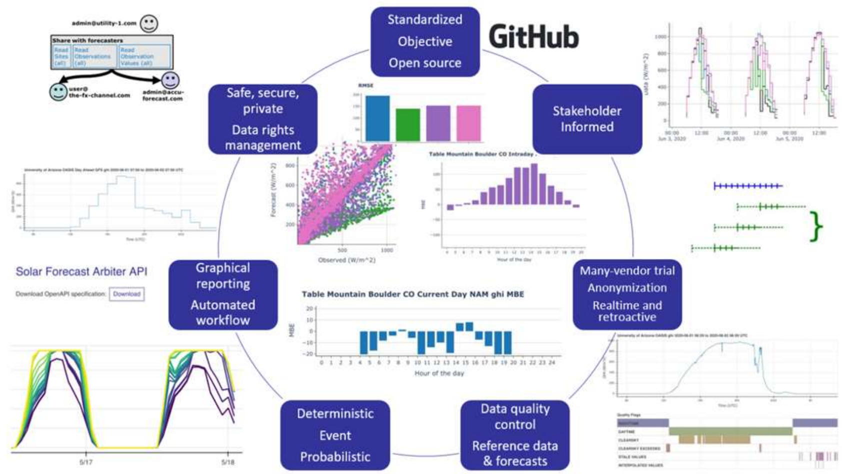
Jamie Austin, Chair

Unlocking the Value of Solar Forecasting

- Solar Forecasting Prize
  - Bringing together forecast providers a

Solar Forecast Arbiter

A paradigm shift in forecast evaluation



(Source: University of Arizona)

Interconnection Standards Development

		Performance	Test & Verification & Model Validation
FERC / NERC?	BES[1] / BPS[3] – Transmission	• FERC Orders • NERC Reliability Standards & Guidelines	• NERC compliance monitoring & enforcement
NARUC / State PUCs?	BPS[3] – Sub-Transmission	• Not available IEEE P2800	• Not available IEEE P2800.1
NARUC / State PUCs?	DER[2]	• IEEE Std 1547-2018 ✓	• IEEE 1547.1-2020 • Ul 1741 (SB) • IEEE ICAP ✓

[1] NERC definition of Bulk Electric System: ≥100 kV with gross individual / aggregate nameplate rating greater than 20 MVA / 75 MVA

[2] DER connected at typical (radial) primary and secondary voltage levels

[3] transmission and meshed sub-transmission

IEEE standards are voluntary industry standards and must be adopted by the appropriate authority to become mandatory (e.g., Transmission Owners, NERC, FERC).

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

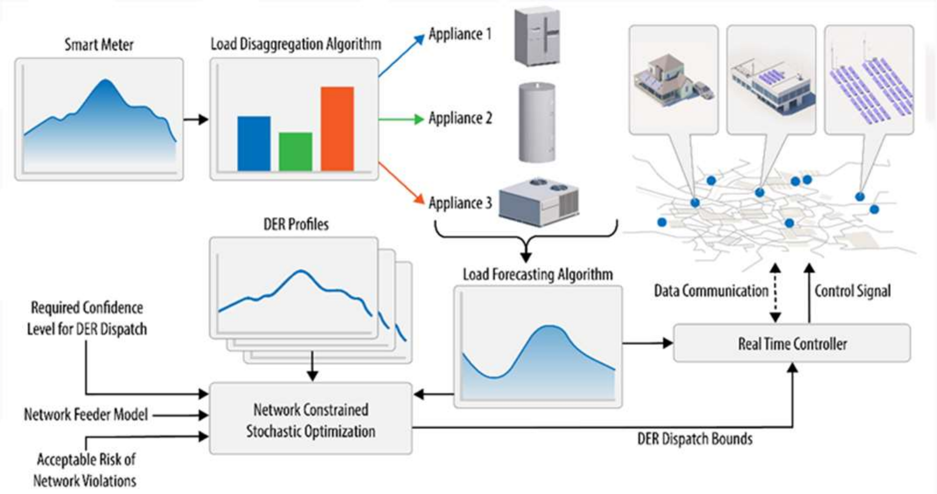
System Operation

Control of behind-the-meter DERs with AMI Data Integration

Project Description

- **Goal:** Develop and field-validate a control technology to enable optimal provision of grid services from BTM solar PV and other DERs.
- **Innovation:** 1) Smart meter as a controller with improved controllability and observability of BTM DERs for utilities. 2) Hierarchical control architecture with careful consideration towards data communication and computational complexity tradeoffs.
- **Approach:** 1) Leverage ground truth whole house consumption data to develop and validate load disaggregation and control algorithms. 2) Parallel hardware development. 3) integration, lab validation, field demonstration.

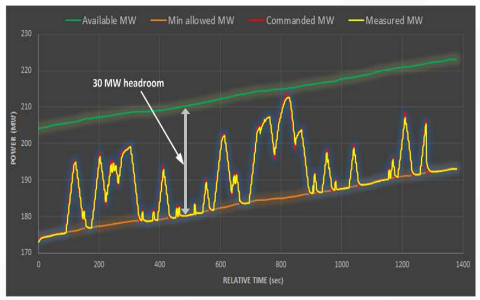
Solution Architecture (Eaton)

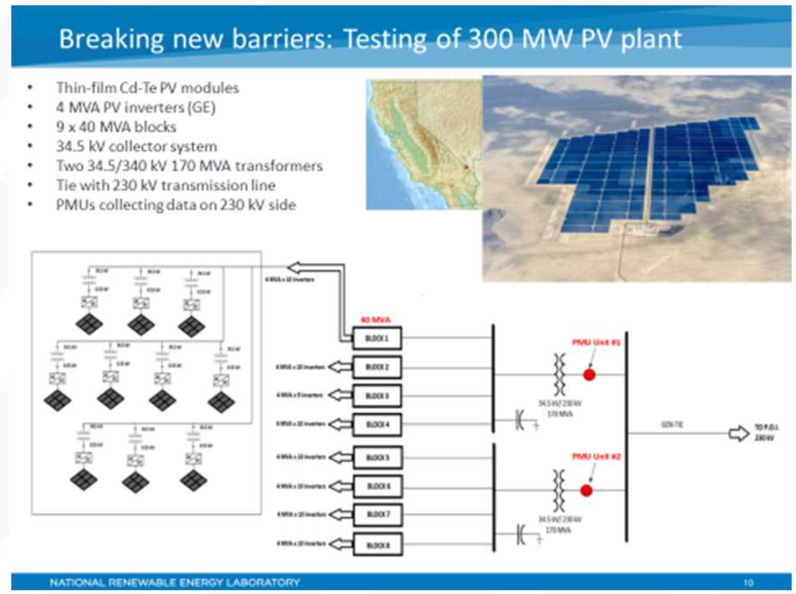


Demonstration of Essential Reliability Services from Solar PV

- 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."

UNIFI Grid-Forming Technology Consortium

NREL-Led, 5-Year, $25M Program

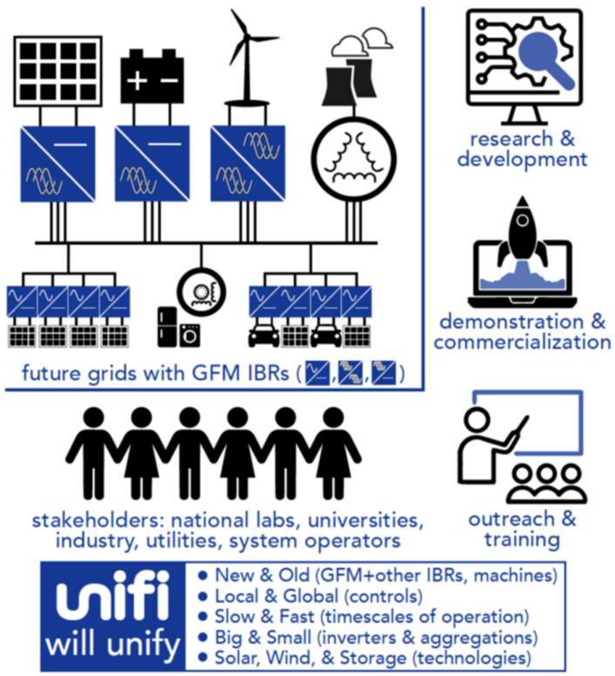


Figure 1: Mission, Vision, Goals, and Thrusts of UNIFI.

□ Project Co-leads, ● Project Team

National Labs

- □ *National Renewable Energy Laboratory (NREL)* B. Mather, Y. Lin, A. Hoke, G.-S. Seo, J. Wang
- ● *Pacific Northwest National Laboratory (PNNL)* W. Du, T. McDermott, Q. Huang, M. A. Elizondo
- ● *Sandia National Laboratories (Sandia)* A. Ellis, J. Flicker, M. Reno, B. Pierre
- ● *Lawrence Berkeley National Laboratory (LBNL)* C. Roberts, J. Eto

Universities

- □ *University of Washington (UW)* B. Johnson
- ● *University of Minnesota (UMN)* S. Dhople
- ● *Georgia Tech (GT)* D. Divan
- ● *Arizona State University (ASU)* V. Vittal, R. Ayyanar
- ● *North Carolina State University (NCSU)* I. Husain, S. Lukic, D. Lubkeman
- ● *University of Alaska Fairbanks (UAF)* M. Shirazi
- ● *University of California Berkeley (UC Berkeley)* D. Callaway
- ● *Temple University* X. Lu
- ● *University of Illinois at Urbana-Champaign (UIUC)* A. Domínguez-García, O. Ajala
- ● *University of Puerto Rico, Mayagüez (UPRM)* E. I. O. Rivera
- ● *University of Wisconsin-Madison (UW-Madison)* D. Gross
- ● *Virginia Tech (VT)* A. Mehrizi-Sani

Inverter Manufacturers

- ● *General Electric (GE)* R. Legg, S. Achilles, P. Arsuaga, R. Dutta, M. Bowman
- ● *Enphase Energy (Enphase)* D. Zimmanck, P. Chapman
- ● *Siemens Corporate Technology (Siemens)* U. Muenz
- ● *Hitachi ABB Power Grids (HAPG)* D. Das
- ● *Danfoss* D. Isaksson, M. A. Awal, L. D. Flora
- ● *Eaton* A. Rockhill

Industry Labs, Utilities, & System Operators

- □ *Electric Power Research Institute (EPRI)* A. Tuohy, D. Ramasubramanian, E. Farantatos, A. Huque, B. Seal, W. Wenzong, J. Boemer
- ● *Hawaiian Electric Company (HECO)* C. Ching, D. Ishimura
- ● *Southern California Edison (SCE)* J. Castaneda
- ● *Pacific Gas & Electric Company (PG&E)* S. Xu
- ● *Portland General Electric (PGE)* L. Bekkedahl
- ● *New York Power Authority (NYPA)* G. Stefopoulos
- ● *Commonwealth Edison (ComEd)* A. Vukojevic
- ● *Southern Company* C. R. Black
- ● *PacifiCorp* S. Wang
- ● *ISO New England (ISO-NE)* X. Luo
- ● *Midcontinent ISO (MISO)* J. Harrison

Real-time Simulation & Software Vendors

- ● *Typhoon* I. Celanovic
- ● *OPAL-RT* S. Chakraborty
- ● *Electranix* A. Isaacs

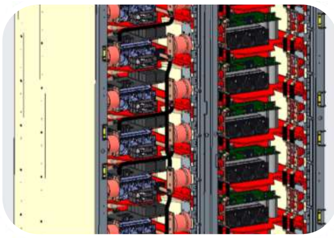
Additional Industry Partners

SEL, Manitoba Hydro International, plexim, terabase, California ISO, NRECA, Rte, TMEIC, SPP Southwest Power Pool, CenterPoint Energy, Global PST Consortium, Xcel Energy, FREEDM Systems Center, Carrier, PowerAmerica, PGSTech, DERlab, WECC, Schneider Electric, SMA, Powertech, PSERC, Fraunhofer, PowerWorld Corporation, ercot, Kaua'i Island Utility Cooperative, Beckwith Electric Co. Inc.

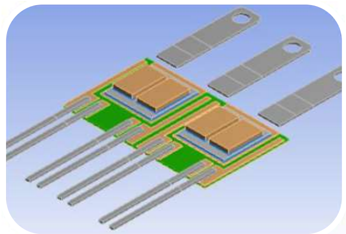
This document contains confidential, proprietary, or privileged information exempt from public disclosure.

Power Electronics

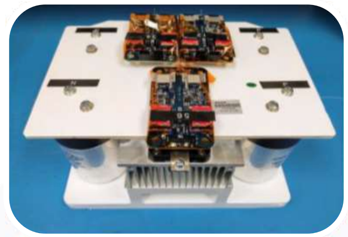
Power Electronic Hardware Technologies



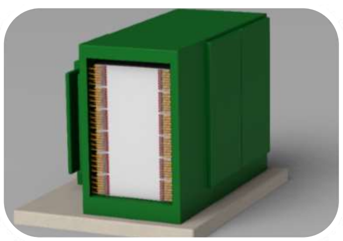
MV SiC PV inverter (UT Austin)



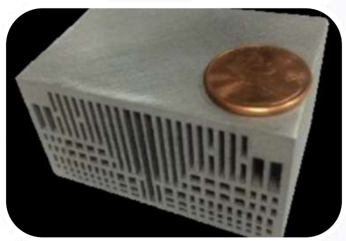
BiDFET based PV Inverter (NCSU)



Transformer-less MV PEBB (University of Arkansas)



Multiport DC Transformer (GTech)

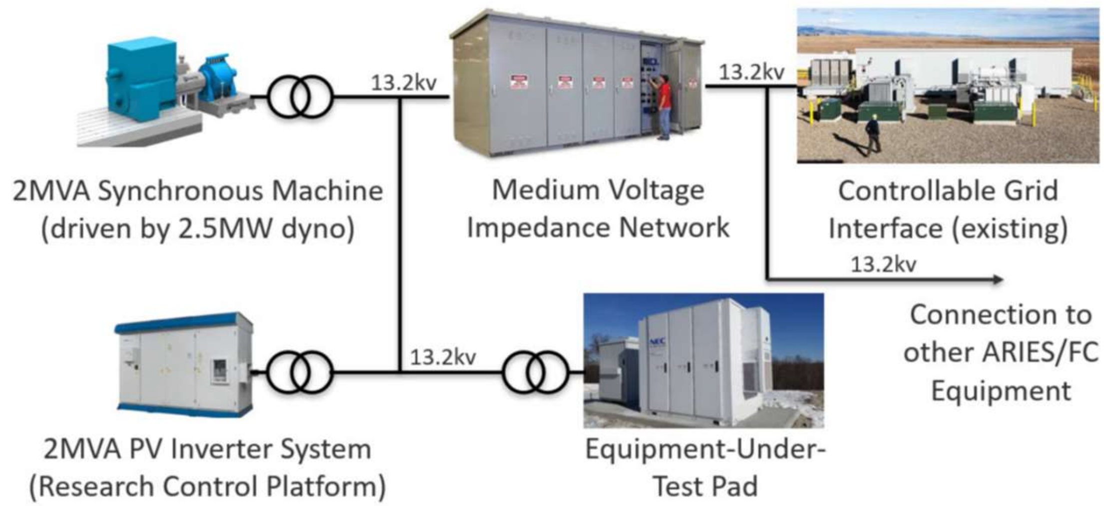


Heat Sink design with Additive Manufacturing (ONRL)

Highly-Reliable Residential PV Inverter (UMD)

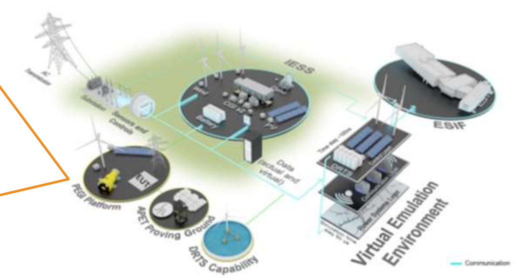
a) reductions in the lifetime costs
b) improve device reliability
c) enable versatile control functionalities

Power Electronics Grid Interface (PEGI)



Power Electronic Grid Interface (PEGI) Platform

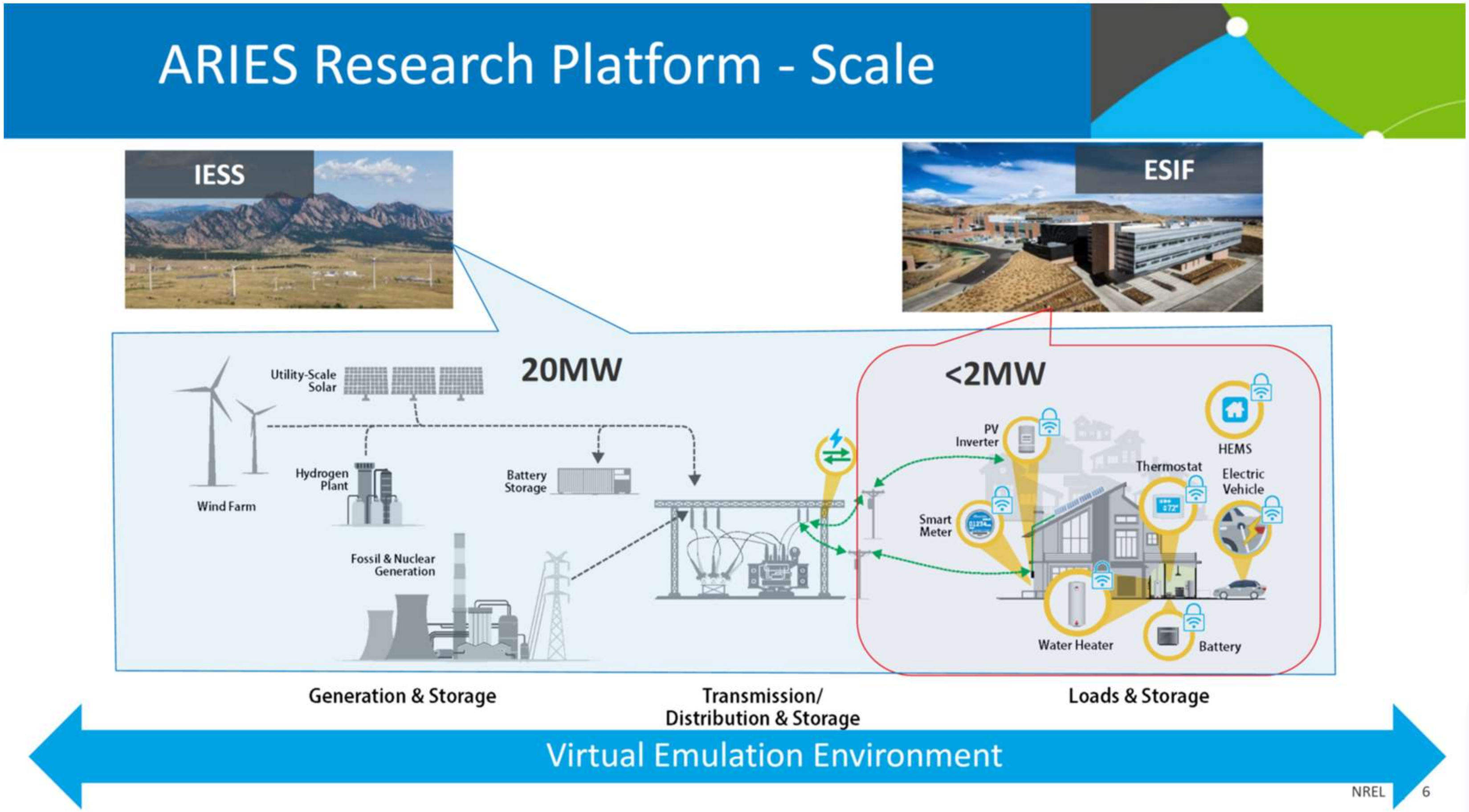
ARIES Campus



Power Electronics R&D Focused Capabilities

(Source: Barry Mather, NREL)

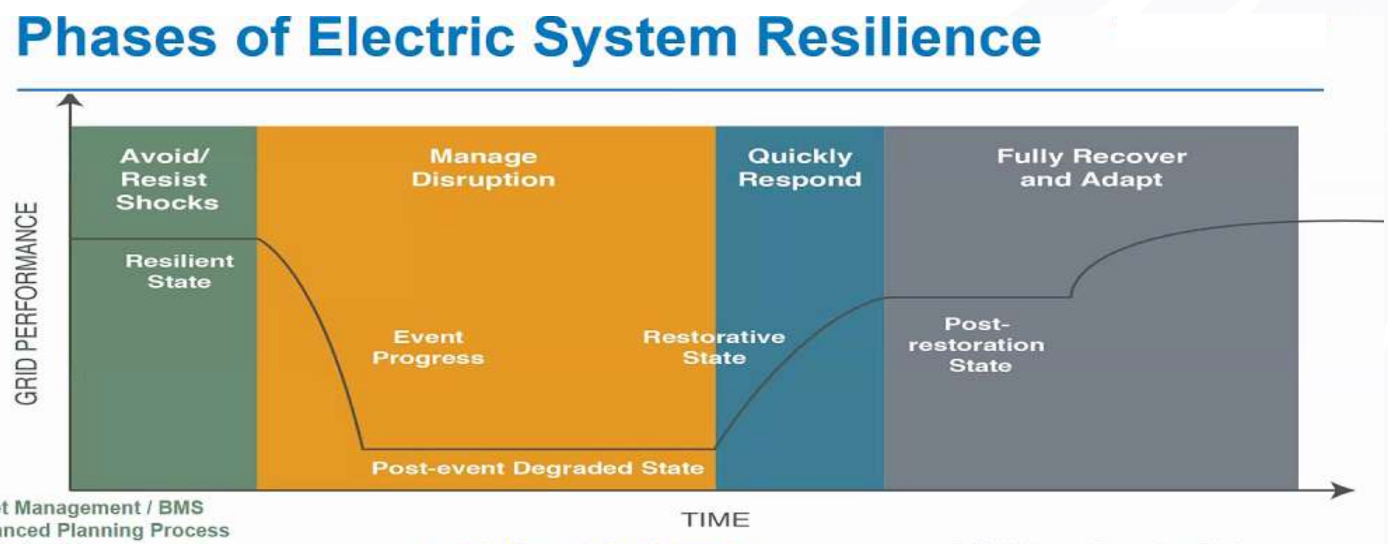
Investing in World Class Test Facility



(Source: Barry Mather, NREL)

PV for Resilience

Consequence-Based Resilient System Design



- Asset Management / BMS
- Advanced Planning Process
- Vegetation Management & EAB Focused Tree Trimming
- Distribution Standards Including Storm Hardening
- Inspection & Maintenance Program
- Targeted Minor Storm Hardening
- Flood Mitigation
- Side Tap Fusing
- Substation Perimeter Fence
- Intrusion Detection
- Cyber Security

- Sub-Transmission Automation
- FLISR
- Recloser Loops Scheme Programs
- Remote Terminal Units
- Line Sensors
- Mobile Transformer Fleet
- Critical Spares
- Damage Appraisal & iPads
- Emergency Response Plan
- Outage Management System
- Mutual Aid agreements

- Reliability and Emerging Risk Assessments
- Event Analysis
- Event Forensics
- Reliability Guidelines and technical reference documents
- System Operator Certification and Credential Maintenance
- System Operator Training
- Periodic Review

SNL (Jeffers, Broderick)

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

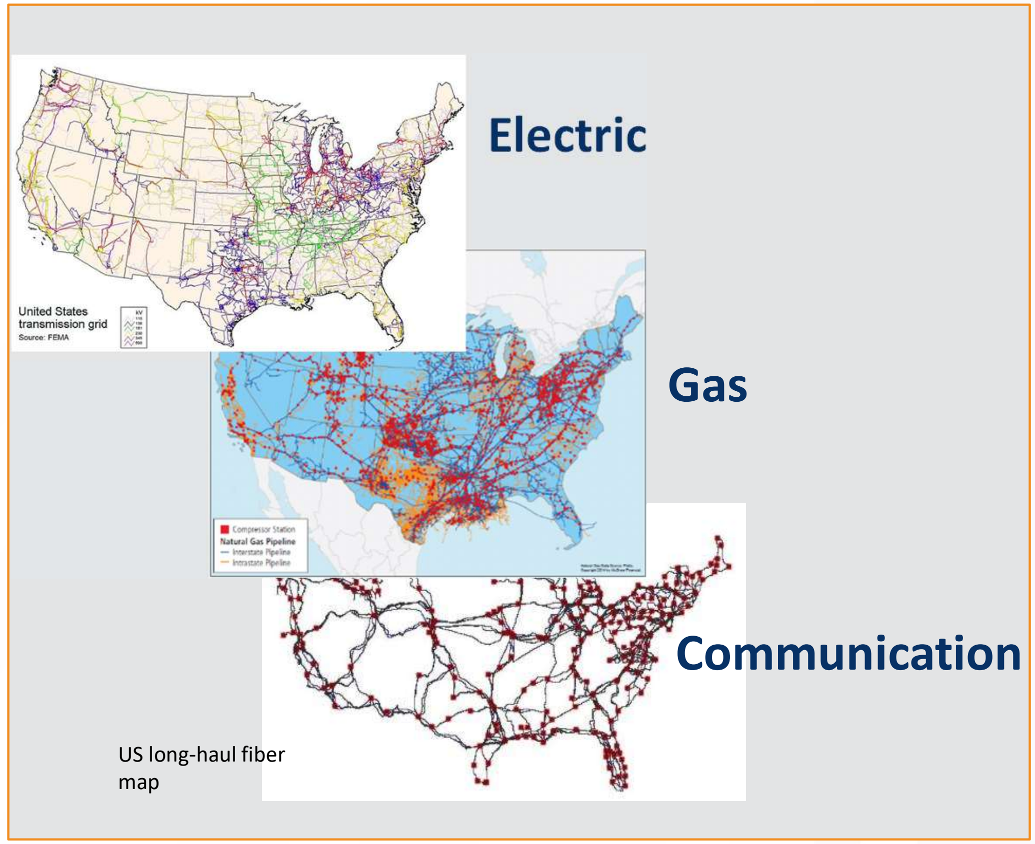
Distribution & Edge
- System Advisory Model & PVWatts
- DER Interconnection Standards
- DER Feeder Hosting Methodology
- Contingencies, Operations, and Storage Sizing for Islandable Sections
- GIS Resiliency Improvement Tool

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

North American Energy Resiliency Model (NAERM)

Goal: To identify electric critical infrastructure throughout North America and to **understand vulnerabilities and interdependencies with the interconnected system** to allow DOE to partner with industry, national labs, and other federal agencies to develop strategic initiatives to protect from cyber and physical threat while furthering energy dominance for the United States.

Collaboration with OE, Wind, and Water Technology Offices



Grid Resilience with a 100% Renewable Microgrid

Project Description

- **Goal:** Advance the state of the art in grid resilience demonstrating a 100% renewable microgrid
- **Innovation:** 1) optimize distributed energy resource operations, 2) enable islanding operations powered only by renewable energy, 3) reduce PV curtailment from islanding operations.
- **Approach:** 1) Install **grid-forming inverters + ESS** to support seamless islanding and blackstart without diesel backup generators. 2) **Field test and validate** an enhanced microgrid control system. 3) enhance the Real-Time Digital Simulator (RTDS) model for the Borrego Springs Microgrid; leverage power hardware in the loop **(PHIL) simulation**.

SDG&E Borrego Spring Microgrid

(~40MW solar, 1.5MW/3MWh BESS, fuel cell, electrolyzer, backup diesel gensets)

Cybersecurity

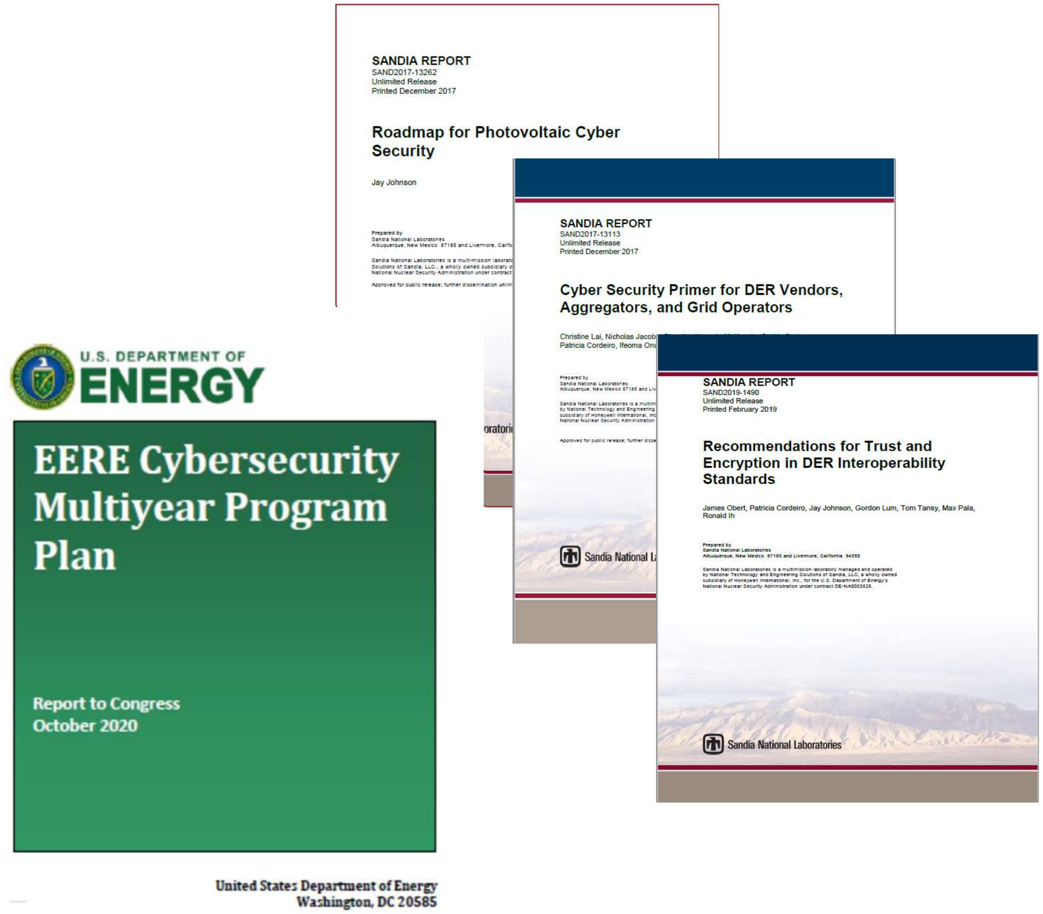
Cybersecurity a Key Challenge and an EERE Priority

Goal 1: Accelerate Cyber Resilience R&D of EERE Operational Technologies

- **1.1 Improve cybersecurity defenses and resilience.**
- **1.2 Mitigate vulnerabilities**
- **1.3 Next-generation cyber resilient technologies.**

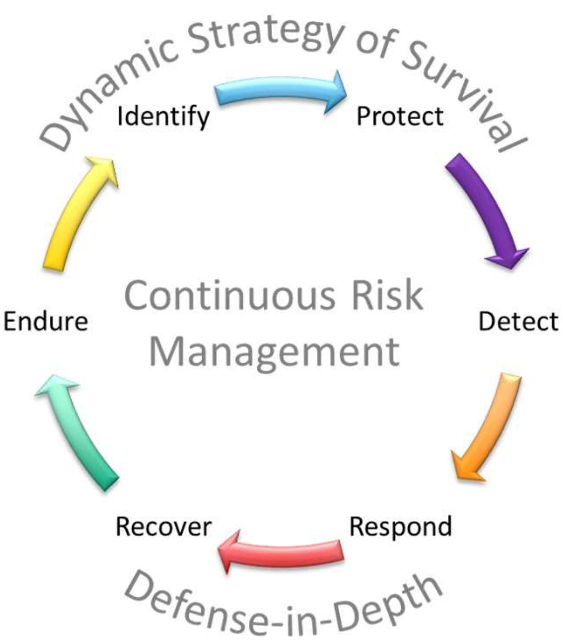
Goal 2: Increase EERE Stakeholder Cybersecurity Awareness

- **2.1 Improve situational awareness.**
- **2.2 Enhance EERE technology cybersecurity maturity.**
- **2.3 Identify opportunities for EERE stakeholder participation in cyber incident response exercises.**



Cybersecurity Strategy for Solar Integration

- Develop a **holistic approach** in information technology (IT) and operation technology (OT) risk management
  - Apply NIST Cyber Security Framework (CSF) and DOE's cybersecurity maturity model (ES-C2M2)
  - moving from a cybersecurity approach that focuses primarily on utility companies to one that includes endpoint device manufacturers and third-party system integrators.
- Build community awareness and **information sharing** mechanisms
  - equipment standards and vigorous testing, validation, and certification
  - supply chain cybersecurity, e.g. solar inverters and control software
- Leverage **DOE and national labs** technical expertise, research and testing facilities, and funding resources
- **Collaboration** within DOE and with other federal agencies, state and local, and industry
  - November 2021 : SETO-SEIA Cybersecurity Summit: Securing Our Solar Future Today
  - SETO funded project to work with NARUC and NASEO to develop state solar cybersecurity toolkits.
  - Ongoing INL-SEIA partnership



. Adapted from Jovanna Helms at LLNL

https://www.nist.gov/programs-projects/cybersecurity-framework

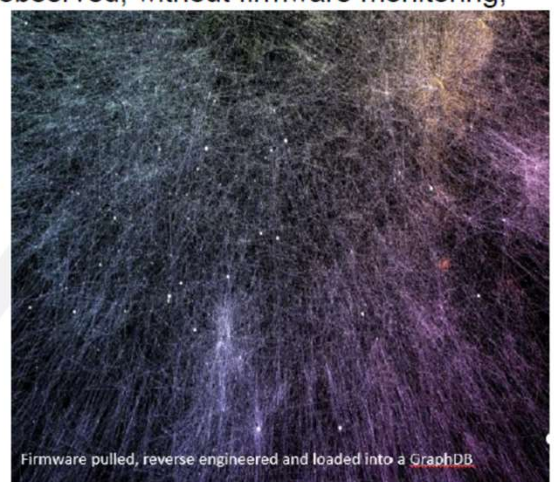
https://www.nist.gov/document/2018-04-16frameworkv11core1xlsx

Firmware Cybersecurity Analysis Tools and Capabilities

5.1.1 Firmware Command and Control Innovation and Impact

GRID MODERNIZATION LABORATORY CONSORTIUM U.S. Department of Energy

- ✓ **Innovation:** ML based firmware baselines show all functions used; agile embedded response integrated with bi-directional sharing of structured threat to security operations enable the protection of the electric grid critical functions
  - ✓ Current state of the art: reloading firmware when unexplained behavior is observed; without firmware monitoring; manual sharing of static indicators with field device operations
- ✓ **Contributions Advancing the State of the Art:**
  - ✓ Insight into embedded systems operations
  - ✓ Operate through detection and remediation vs offline reloads of firmware;
  - ✓ In-situ response; Detection based on ML firmware code behaviors;
  - ✓ Connectivity to Upstream Data Analytics
- ✓ **Impact:**
  - ✓ Visualized Firmware for Analysis provides insights previously unknown
  - ✓ Agile Embedded Detection and Response

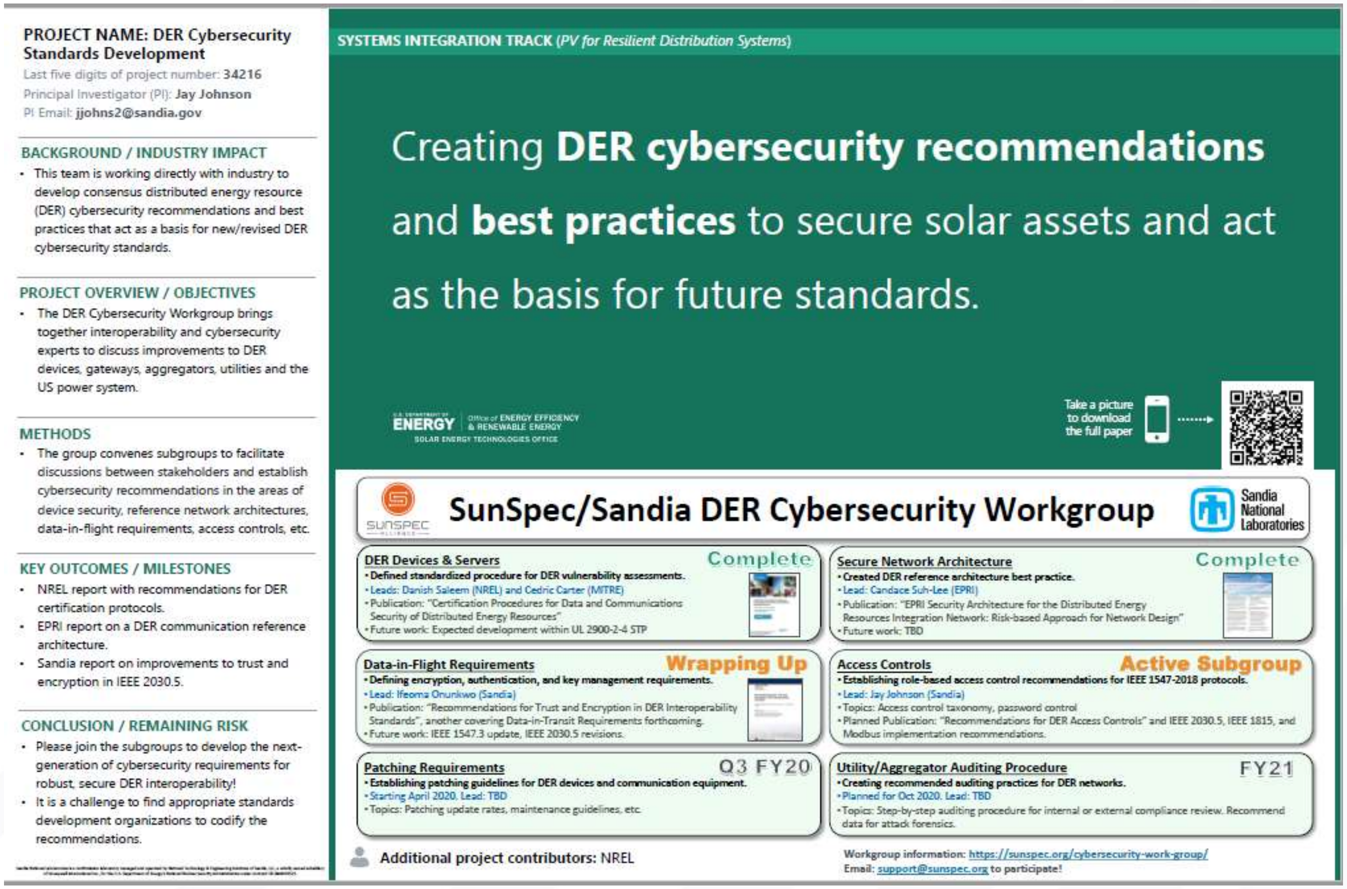


Firmware pulled, reverse engineered and loaded into a GraphDB

- ✓ **Firmware C2 will share indicators locally and remotely with upstream energy security operations centers; identify adverse conditions indicating a cyber attack with response while maintaining operational functionality**

(Source: Rita Foster, INL)

DER Cybersecurity Standards Development



(Source: Jay Johnson, SNL)

AI/ML and Data Analytics

Apply Data Science and Advanced Computing Technologies

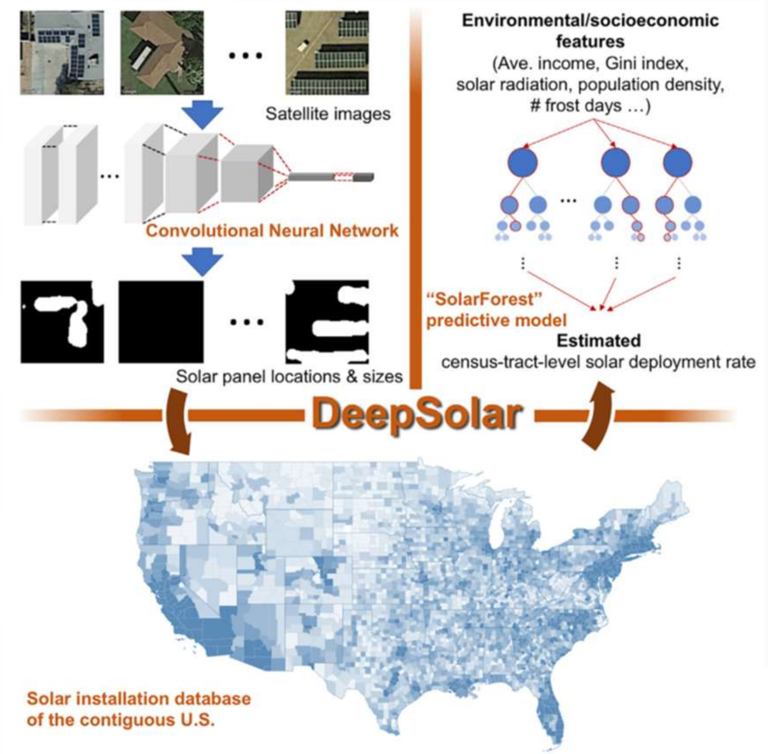
- **Don't lose sight of the problems to solve**
  - Solar forecasting, control optimization, threat detection
  - Data science and AI/ML as enabling technologies
  - Energy system is a cyber-physical system with IT/OT
- **Leverage multiple computing platforms**
  - high performance computing (HPC)
  - public and private cloud
  - edge computing, embedded computing, quantum computing
- **Practical consideration**
  - Balance complexity with practicality
  - Combine data- and physics-based techniques
  - Transition from lab research to real world
  - Standard data interfaces for interoperability
- **Data management**
  - Respect data privacy and security
  - Education and collaboration
  - Collaboration: OE, AITO, NSF, NOAA, industry, Office of Science/ASCR

DeepSolar

Stanford is currently working on a SETO-funded project to apply CNN techniques to public and multi-modal data, including satellite imagery and street views, to develop a high-fidelity database which maps solar energy resources (including temporal and subtype information) and the associated infrastructure. This is built on the previous DeepSolar deep learning framework to automatically localize solar photovoltaic panels from satellite imagery and estimate their sizes.

By the numbers

Typical image tile size	15 m – 22 m
Typical image resolution	15 cm
Training set	~370,000 images
Validation set	~13,000
Test set	93,500
Total Installations in U.S.	1,470,000
Prediction accuracy	~90%



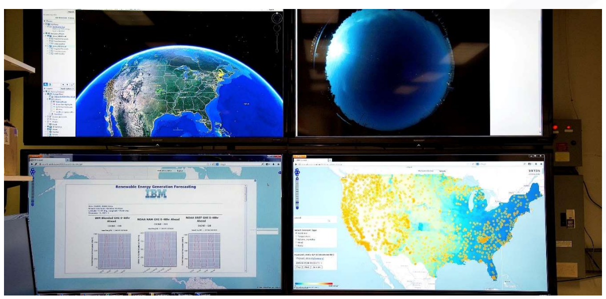
Jiafan Yu, Zhecheng Wang, Arun Majumdar, and Ram Rajagopal, ***Joule*** *2, 2605–2617, December 19, 2018*

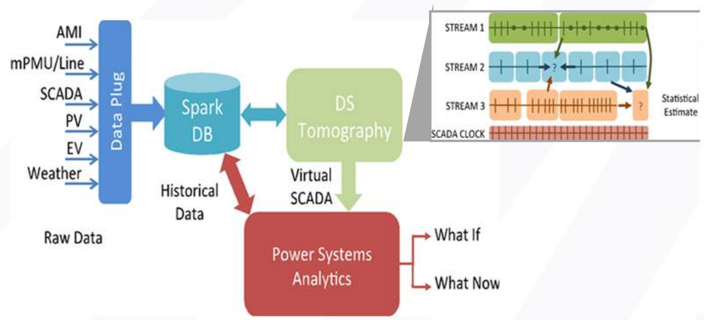
Apply AI/ML Technologies in Solar Grid Integration

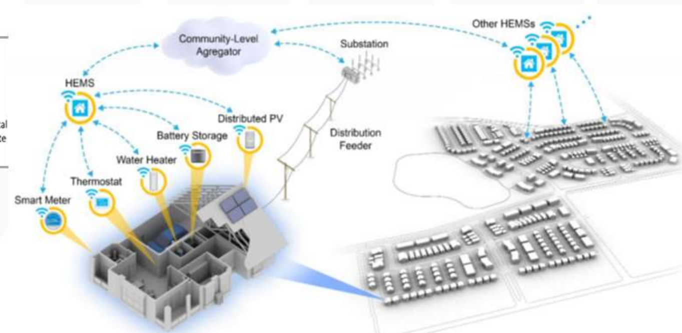
- **IBM Watt-SUN** Using machine-learning, the same technology behind the Jeopardy! playing robot Watson, IBM improved solar forecasting accuracy by as much as 30%.

- **SLAC** Developing a suite of open-source software tools to enable utilities to **anticipate, absorb and recover** from extreme events, applying AI and ML for distribution grid planning and monitoring (i.e. ML-based power flow, switch detection, solar disaggregation, forecasting, topology detection, network re-configuration)

- **NREL** Using smart meter data and AI techniques, the team develops algorithms that can learn to identify homeowner preferences and enable day-ahead load schedules. The algorithms evaluate how to best use variable solar energy to pair with flexible building loads like electric water heating or electric vehicle charging.







In Summary

- Key SI programmatic goal:
  - Develop technologies and solutions to enable the **reliable, resilient and secure operation of a 100% clean energy grid.**
- Top priorities
  - Advance inverter-based technologies to provide essential grid reliability services.
  - Develop cybersecurity tools to protect solar assets and electricity grid.
  - Apply ML/AI and data analytics methods in system planning and operation
- Support DOE's implementation of **Infrastructure Investment and Jobs Act (IIJA))** provisions

(Source: NREL Image Gallery)