U.S. DEPARTMENT OF
ENERGY

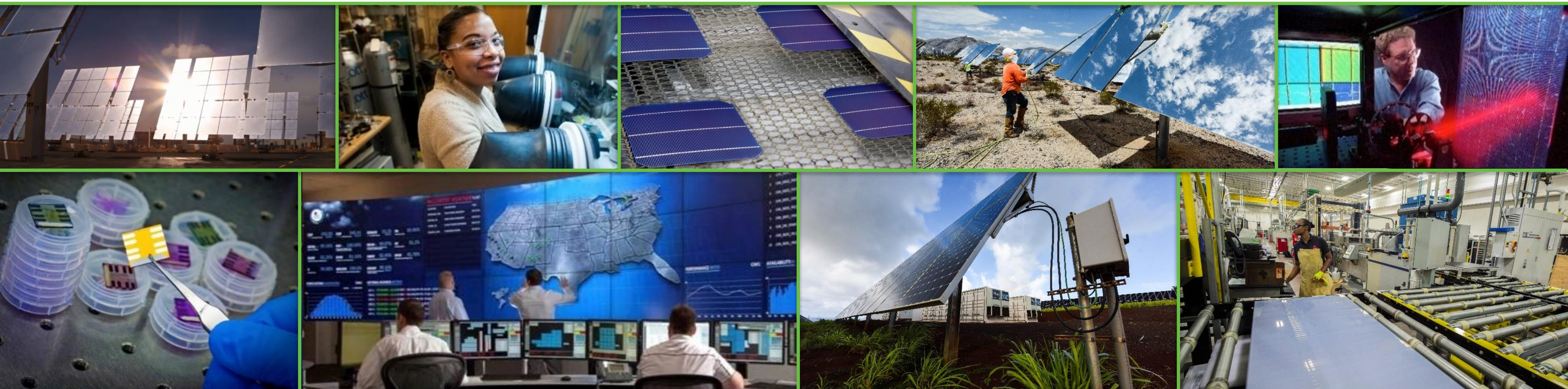
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

2024 Workshop: Solar and DERs for Community Energy Resilience

Garrett Nilsen, Deputy Director

Solar Energy Technologies Office, U.S. Department of Energy

November 14, 2024



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 economy no later than 2050**, starting with a decarbonized power sector by 2035.

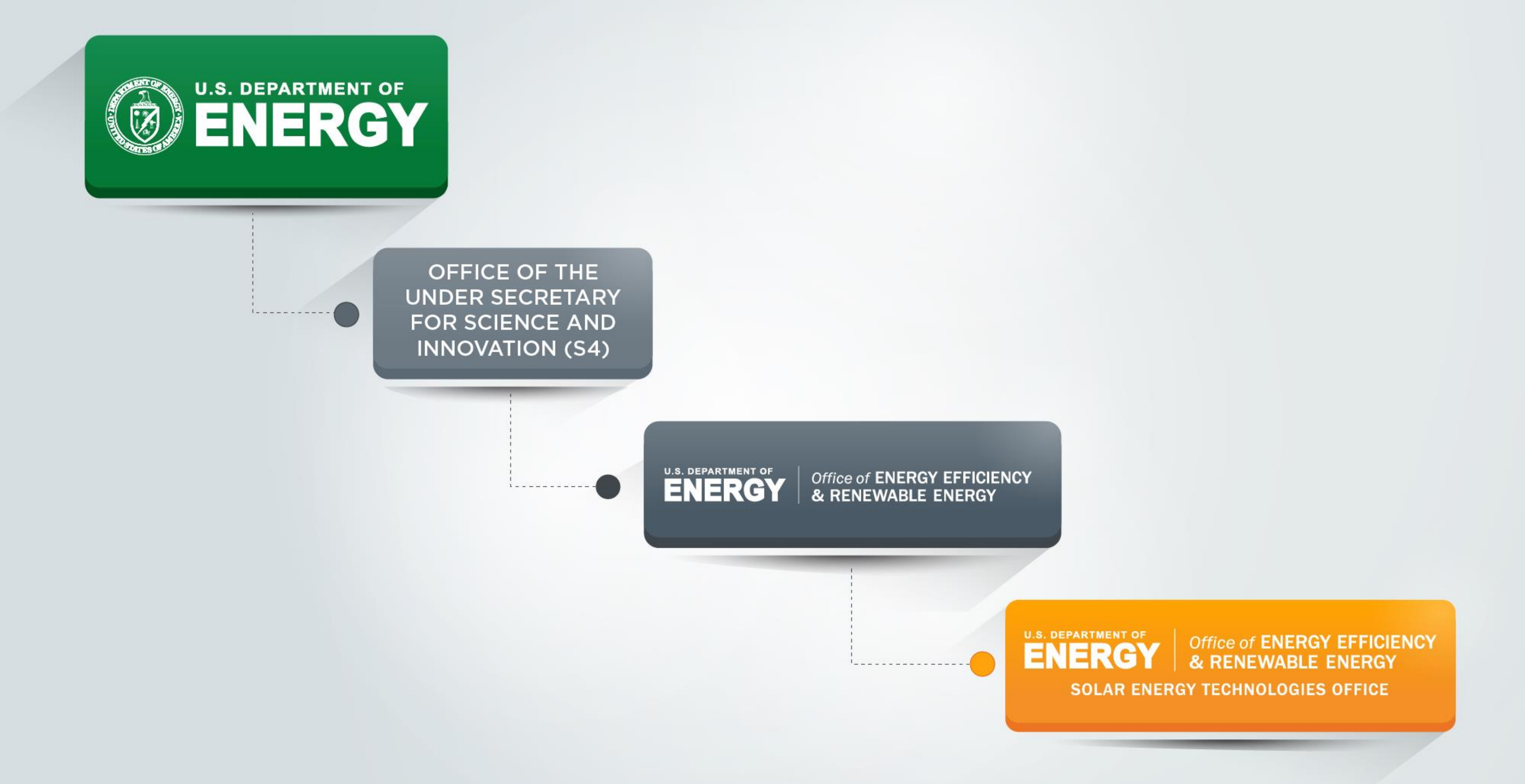
WHAT WE DO

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

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

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

Where Does SETO Fit Within the Energy Department?



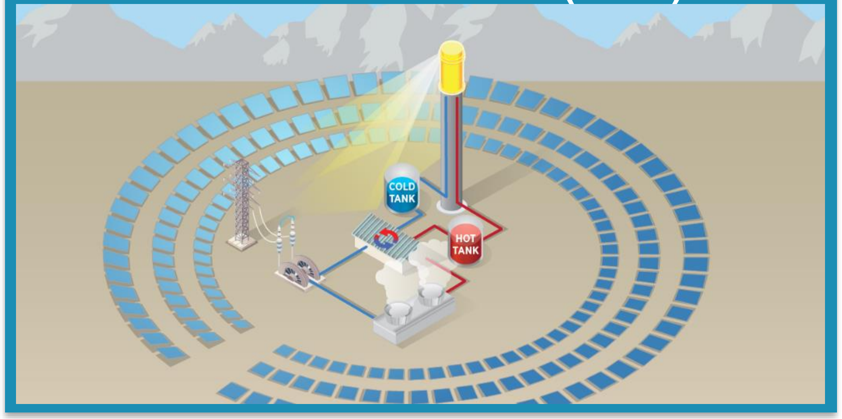
Driving Toward Administration Decarbonization Goals

- **Reduce hardware and soft costs** of solar electricity **for all Americans** to enable an affordable carbon-free power sector by 2035.
- Enable inverter-based technologies to provide essential grid services and black start capabilities while demonstrating the **reliable, resilient and secure operation of a 100% clean energy grid**.
- **Accelerate solar deployment and associated job growth** by opening new markets, reducing regulatory barriers, providing workforce training, and growing U.S. manufacturing.
- **Center energy justice** by reducing environmental impacts, removing barriers to equitable solar access, and supporting a diverse and inclusive workforce.
- **Support a decarbonized industrial sector** with advanced concentrating solar-thermal technologies and develop affordable renewable fuels produced by solar energy.

SETO Subprograms

PHOTOVOLTAICS (PV)

CONCENTRATING SOLAR-THERMAL POWER (CSP)



MANUFACTURING AND COMPETITIVENESS

SYSTEMS INTEGRATION

STRATEGIC ANALYSIS AND INSTITUTIONAL SUPPORT *

WORKFORCE AND EQUITABLE ACCESS *

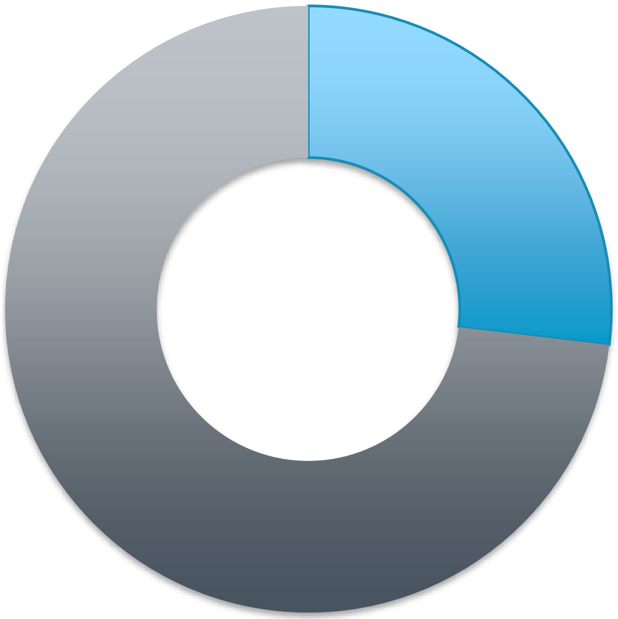
*Funded from the Soft Costs Budget Line

DOE Solar Office Funds 600+ Active Projects

Projects and partners in 43 states plus the District of Columbia

36% of projects led by national labs

25% of projects led by universities

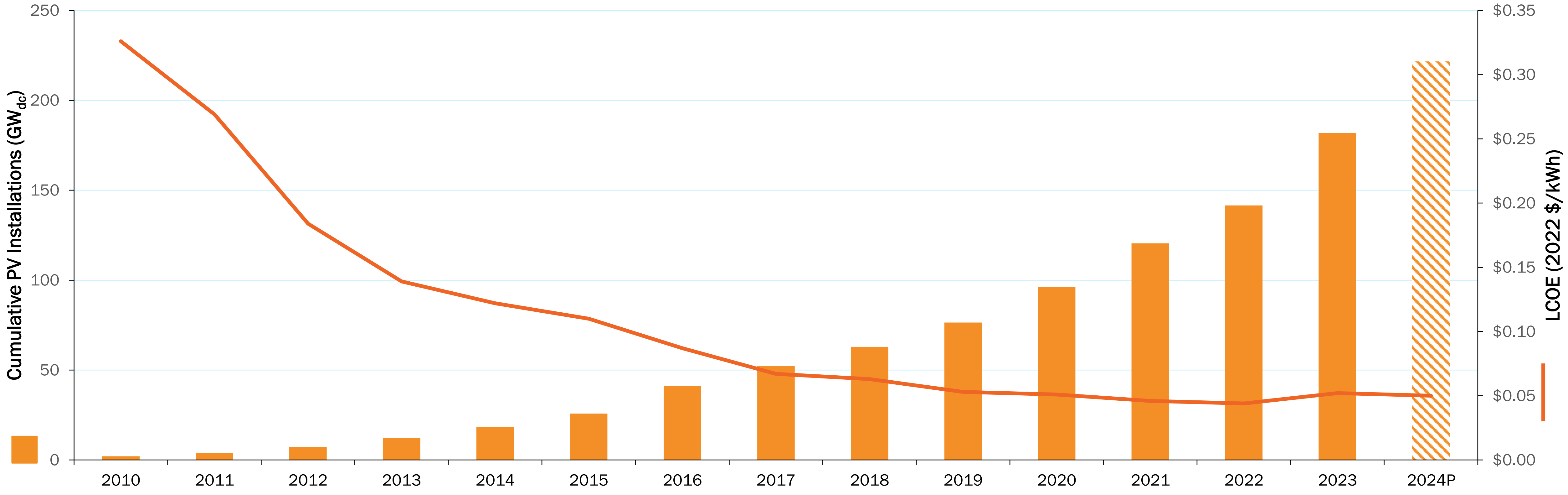


39% of projects led by businesses, non-profits, and state and local government

U.S. Solar: Falling Costs, Rising Deployment

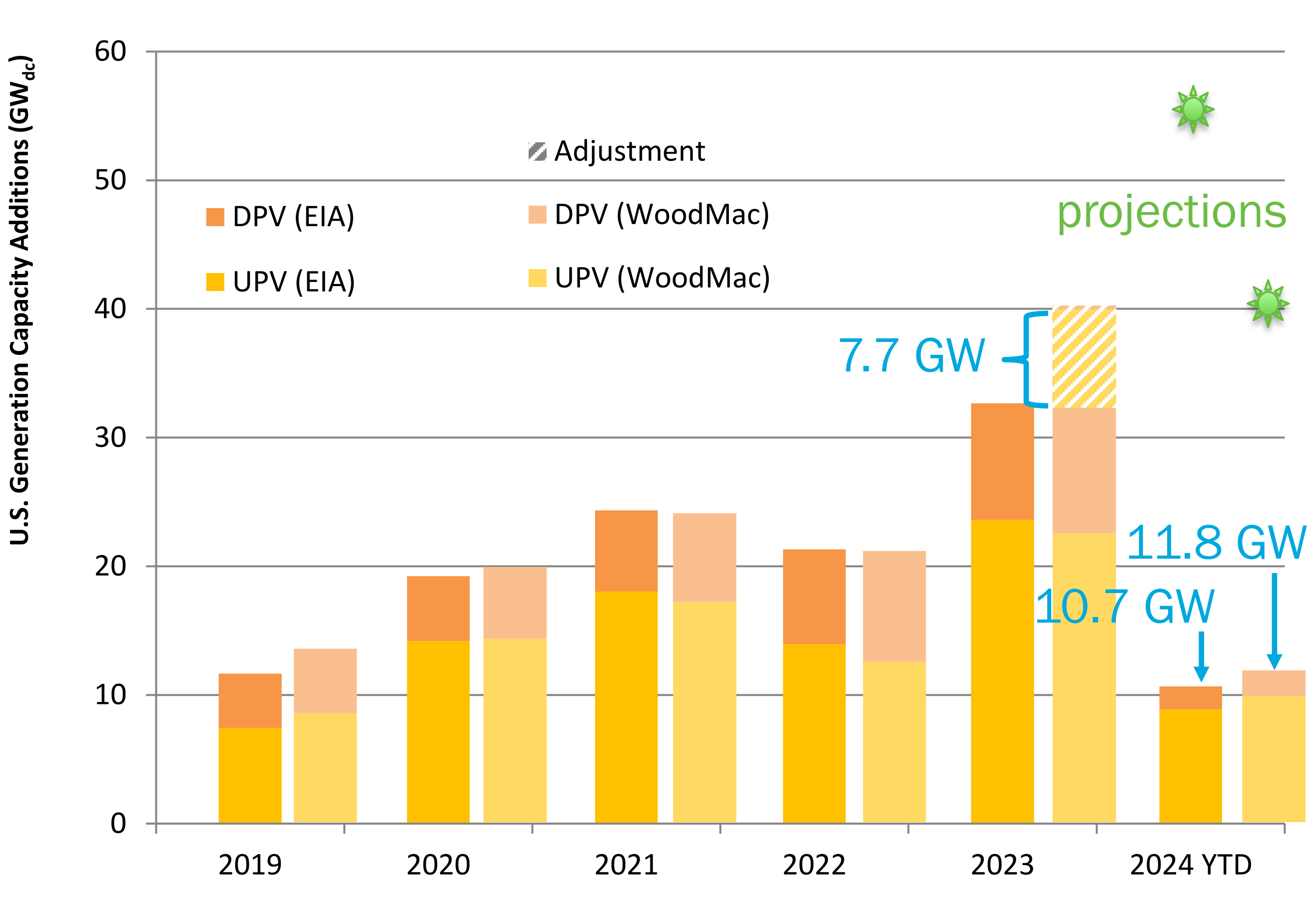
The solar energy industry is one of the fastest growing industries in the nation. Driven by falling costs and state and federal policy, total solar PV installed capacity is now over **180 GW and is projected to grow to about 220 GW by the end of the year.**

PV Deployment and System Price in the U.S. (2010–2023, 2024 Estimate)



Sources: Wood Mackenzie/SEIA: Solar Market Insight Report 2023 Year in Review. National Renewable Energy Lab System Advisor Model was used to depict electricity costs as the levelized cost of energy (LCOE) for a utility-scale system in a mid-America location with average solar resource, without benefit of tax credits

Record-breaking Installation Volumes!



Sources: Energy Information Administration (EIA) Electric Power Monthly, Wood Mackenzie (WoodMac) US Solar Market Insight: Q2 2024. All 2023 and 2024 data is preliminary and different data sources update at different times.

*DPV = distributed photovoltaics, UPV = utility-scale photovoltaics, YTD = year-to-date

**Inverter loading ratio = 1.15 for DPV and 1.3 for UPV

At the beginning of May, WoodMac revised their **2023 annual installations upwards from 32 GW_{dc} to 40 GW_{dc}**. This was the result of a modification to how they determined the installation date for UPV projects in Texas (which represented 29% of installs in 2023 and was 5.2 GW higher in 2023 after the adjustment), plus data from developers that they received after the deadline for their earlier report (including AZ, VA, LA, and NC).

Installation data for **Q1 2024** is *preliminary*, however, estimates range from **10-12 GW_{dc}** of installs. This is nearly double Q1 2023 installations, which is notable because Q1 installations are usually the lowest volume of the year (with Q4 being the highest, often by a substantial margin).

WoodMac's most recent projections (released June 6) for 2024/2025 were revised upwards by a few GW, but they are still projecting nearly flat installation growth for the next several years due to ongoing labor and high voltage equipment constraints plus the trade policy uncertainty.

Research Areas: Systems Integration

The goal for SETO's system integration research is to achieve high-solar grid integration by supporting the reliability of the power system, enhancing resilience and security, and increasing system flexibility to reduce grid integration costs.

Where we are now:

- Inverter-based solar and wind resources pose challenges to system reliability and stability
- Solar generation variability and uncertainties
- System operators have no visibility or control over most distributed solar

Priority R&D Topics:

- Develop long-term planning models and tools for solar integration
- Develop advanced control capabilities for power electronics
- Enhance grid services to operate high-solar grid
- Advance communications and sensing for situation awareness
- Improve solar forecasting
- Integrate storage to add flexibility
- Enhance resilience and security in system design
- Accelerate grid codes and standards development

Find our latest Peer Review feedback here: https://www.energy.gov/eere/solar/2024-seto-peer-review

Thank you for being here today!

Introduction to SETO's Resilience Portfolio

- **Marissa Morales-Rodriguez, PhD** Technology Manager, Systems Integration
- **Allie Robins**, Technology Advisor, Workforce and Equitable Access (WEA)

SETO's Resilience Portfolio:

Workforce & Equitable Access Team

Alexandria Robins (CONTR)
Task Lead, Solar Energy Technologies Office
U.S. Department of Energy

The National Community Solar Partnership+

NCSP+ is a coalition of stakeholders working to expand access to affordable, distributed solar to every U.S. household

NCSP+ Supports:

- Community Solar
- Community-benefitting commercial solar
- LMI residential rooftop solar + storage
- Microgrids
- Distributed solar + storage aggregations such as Virtual Power Plants

NCSP+ Provides Participants:

- No-cost technical assistance
- Funding opportunities
- Research and analysis
- Peer-to-peer networking
- Online courses and training
- Tools and resources to support equitable scaling

Join the National Community Solar Partnership+

>2000
PARTNERS

>1000
ORGANIZATIONS

50
STATES

Scan the QR Code to join NCSP+!

Join the National Community Solar Partnership:
https://ncsp.solarinyourcommunity.org/

or email community.solar@ee.doe.gov

Meaningful Benefits of Distributed Solar

EQUITABLE ACCESS & CONSUMER PROTECTIONS

- Contract terms that support strong consumer protections
- Inclusive outreach and engagement
- Financial products that are accessible to all households

Justice40 Priority 3:
Increase Clean Energy Parity

MEANINGFUL HOUSEHOLD SAVINGS

- Guaranteed bill and/or household savings
- Wealth building opportunities
- Indirect multifamily affordable housing tenant benefits

Justice40 Priority 1:
Reduce Energy Burden

RESILIENCE, STORAGE, AND GRID BENEFITS

- Household and community level resilience strategies
- Grid strengthening strategies
- Improved health outcomes through reduced or shortened power outages

Justice40 Priority 7:
Increase Energy Resiliency

COMMUNITY-LED ECONOMIC DEVELOPMENT

- Opportunities for community ownership
- Community benefits agreements
- Support for entrepreneurship and local and minority and women-owned businesses

Justice40 Priority 8:
Increase Energy Democracy

SOLAR WORKFORCE DEVELOPMENT

- Strategies that ensure jobs are accessible to workers of all backgrounds, offer competitive wages and union membership
- Training and apprenticeship programs

Justice40 Priority 6:
Increase Clean Energy Jobs

Technical Assistance

NCSP has provided **163 direct technical assistance engagements - totaling over 2,737 hours -** since its launch

- Recipients in 35 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.

NCSP+ members can apply for

free, on-demand technical assistance

for project development, markets, and regulation:

01 **Join** the National Community Solar Partnership+

02 **Identify key questions** for your project or program

03 **Fill out the application** for technical assistance pinned at the top of the NCSP+ online community

Equitable Solar Communities of Practice

Project Overview:

- Officially launched in early 2024
- Supporting the expansion of equitable benefits of solar through stakeholder-led process
- Landscape and gap analysis
- Public convening over the summer
- Report to be published this fall

Solar United Neighbors
Equitable Access and Consumer Protections

Clean Energy States Alliance
Meaningful Household Savings

Clean Energy Group
Resilience, Storage, and Grid Benefits

Cooperative Energy Futures
Community-led Economic Development

Midwest Renewable Energy Association
Solar Workforce

Learn more at https://www.energy.gov/communitysolar/equitable-solar-communities-practice

Community Power Accelerator - Resources

Community Power Accelerator
U.S. DEPARTMENT OF ENERGY

The **Community Power Accelerator** connects solar developers building projects in low-income and disadvantaged communities to **training, technical assistance** and **capital providers**

Accelerator Lab

- A community solar 101 training and a longer 10-week instructor-led intensive course
- A **new free-of-charge, self-paced, online course.** Open to all interested in solar development.

Marketplace

Developers and Investors have access to an online match-making platform

- Now **accepting expanded business models** beyond community solar!

Credit-ready Checklist

Helps developers complete all the requirements to pitch robust, credit-ready projects

- A **revamped credit-ready** checklist to encompass expanded business models **built with meaningful benefits**!

Technical Assistance

Resources and direct technical assistance from DOE, National Labs, and other experts

- Now supporting those interested in developing **community-benefiting distributed solar projects.**

Community Power Accelerator Prize

Two rounds of $10M prizes provides pre-development funding to 50 new developers

- A **new $10M round** of the Community Power Accelerator Prize to **support innovative solar business models in pre-development**

Scan to join!

Community Power Accelerator Prize, Round 3

The Community Power Accelerator Prize is a **$10 million, three-phase prize.**

The prize is designed to **fast-track the efforts of new, emerging, and expanding solar developers** to grow projects that deliver meaningful benefits and are prepared to **engage with capital providers.**

Scan to visit the prize!

Community Power Accelerator Prize

(Photo Credit: ICAST, Round 2 Winner)

Important dates

- Open: September 9, 2024
- Submission deadline: December 17 at 5 p.m. ET
- Winner announcement: February 2025

Read the Rules

- The official rules can be found at: herox.com/CommunityPowerAcceleratorRound3

Enter your Phase 1 submission

- The Phase 1 submission form can be found on HeroX by clicking on:

SOLVE THIS CHALLENGE

(Photo Credit: Minneapolis Climate Action, Round 2 Winner)

Join the National Community Solar Partnership+!

Our membership is growing! Join NCSP+ to access our technical assistance, networking, events, resources, and to also **share your expertise** with our community!

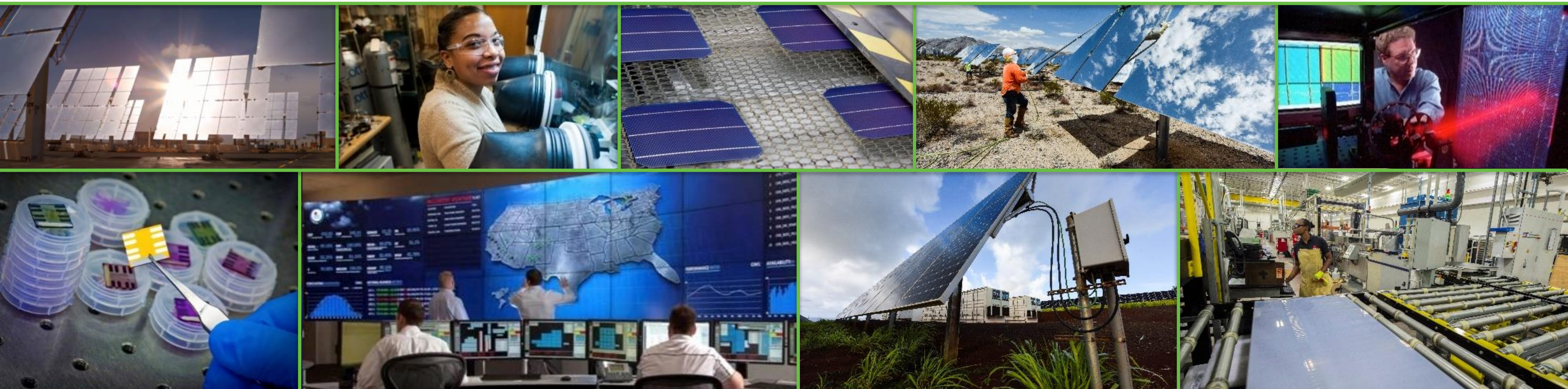
Please send questions to community.solar@ee.doe.gov.

Scan the QR Code to join NCSP+!

SETO's Resilience Portfolio: Systems Integration

Marissa E. Morales-Rodriguez, Ph.D.
Technology Manager, Solar Energy Technologies Office
U.S. DOE-Energy Efficiency and Renewable Energy

October/2024



Motivation

Extreme Events

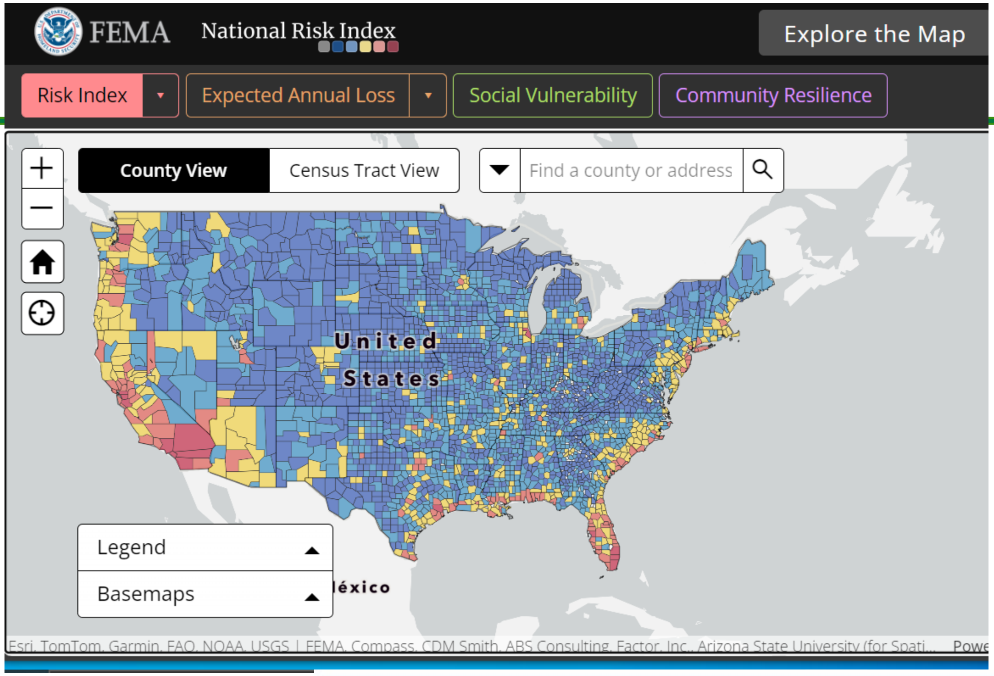
- Natural hazards
- Cyber-physical security threats

Energy Transition

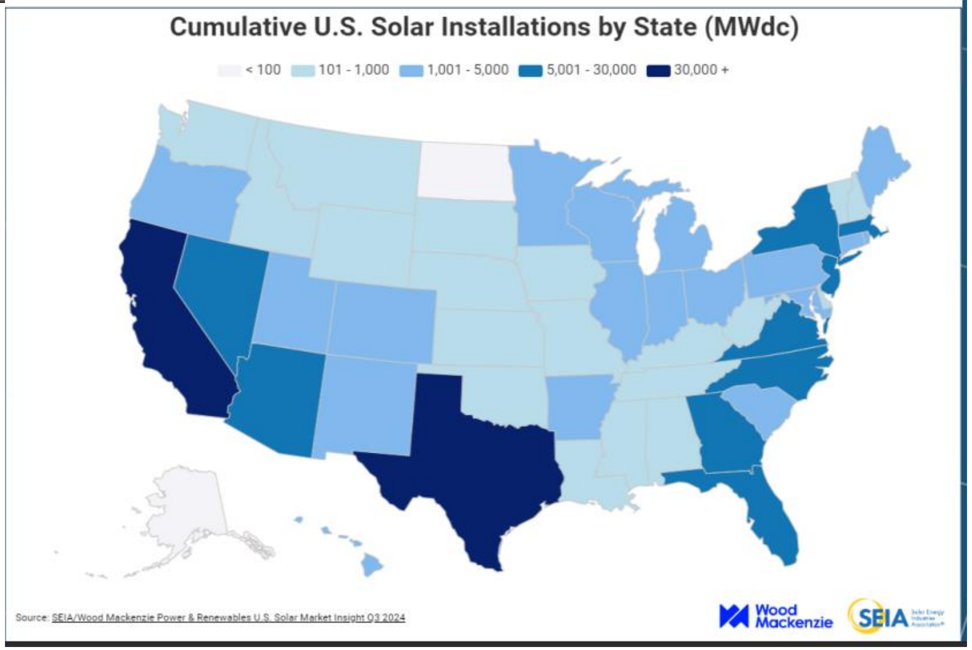
- Decarbonized electricity sector by 2035
- Reliable, resilient and secure electricity

Energy Justice and Equity

- Equitable access to solar energy resources
- Availability and affordability to all customers

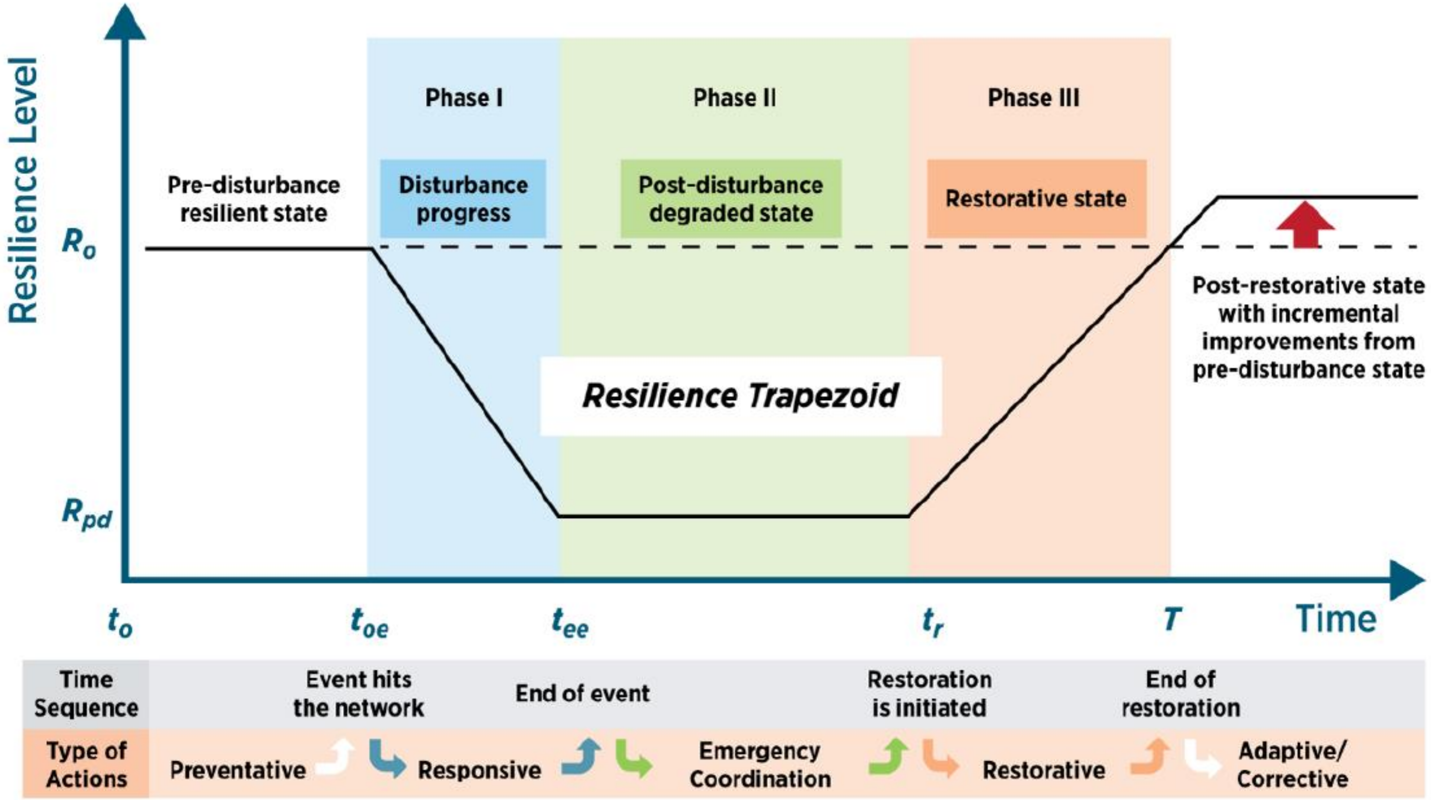


Source: Map | National Risk Index



Source: SEIA

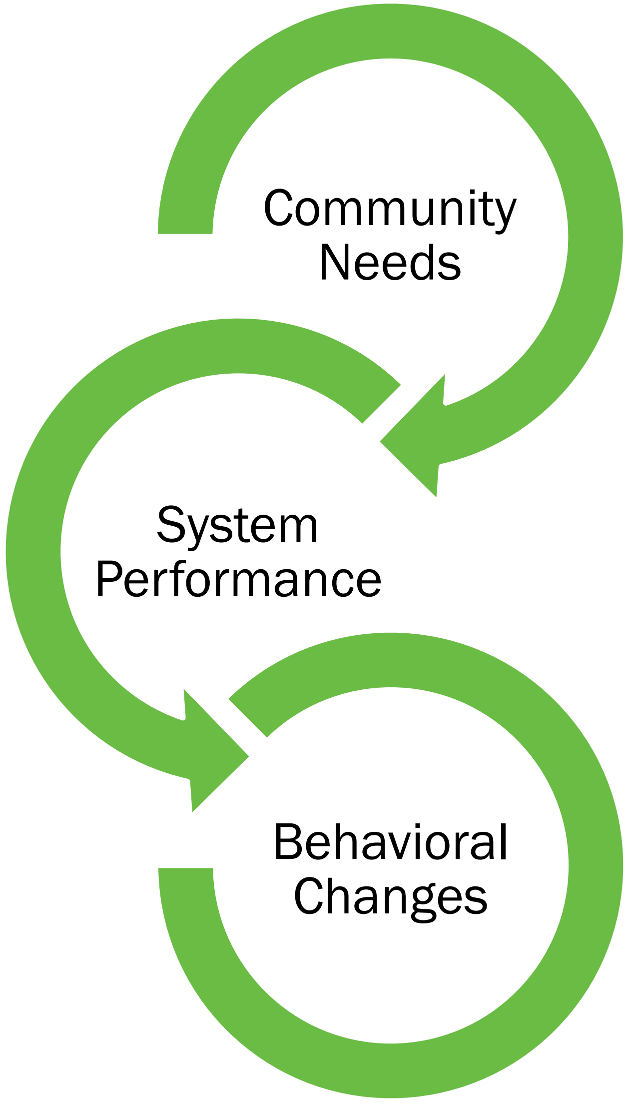
Resilience Stages



"Ability [of a system] to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions, e.g., deliberate physical and cyberattacks, accidents, or naturally occurring threats or incidents."

Context to understand solar resilience benefits

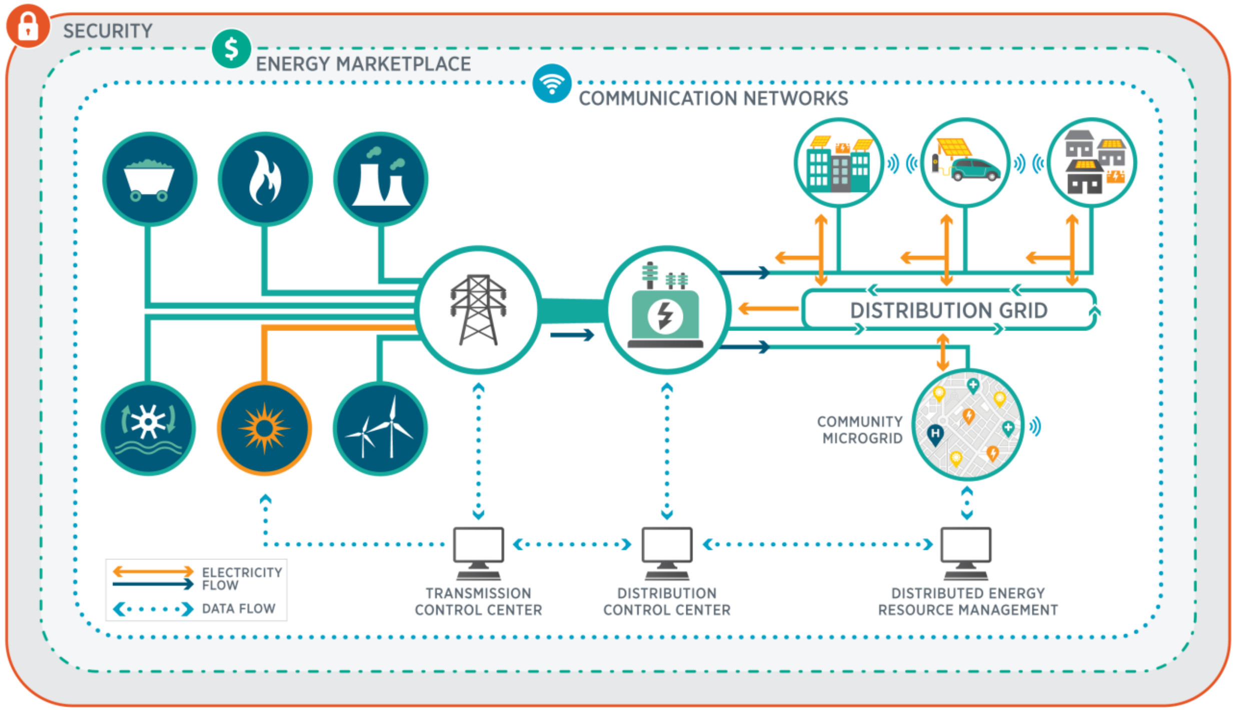
- Outcome or End State
- Asset or System Properties (Community and Energy System)
- A process



SETO Systems Integration 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.

- System Planning
- System Operations
- System and Community Resilience
- Solar and DER Cybersecurity



Achieving 100% Decarbonized Power System

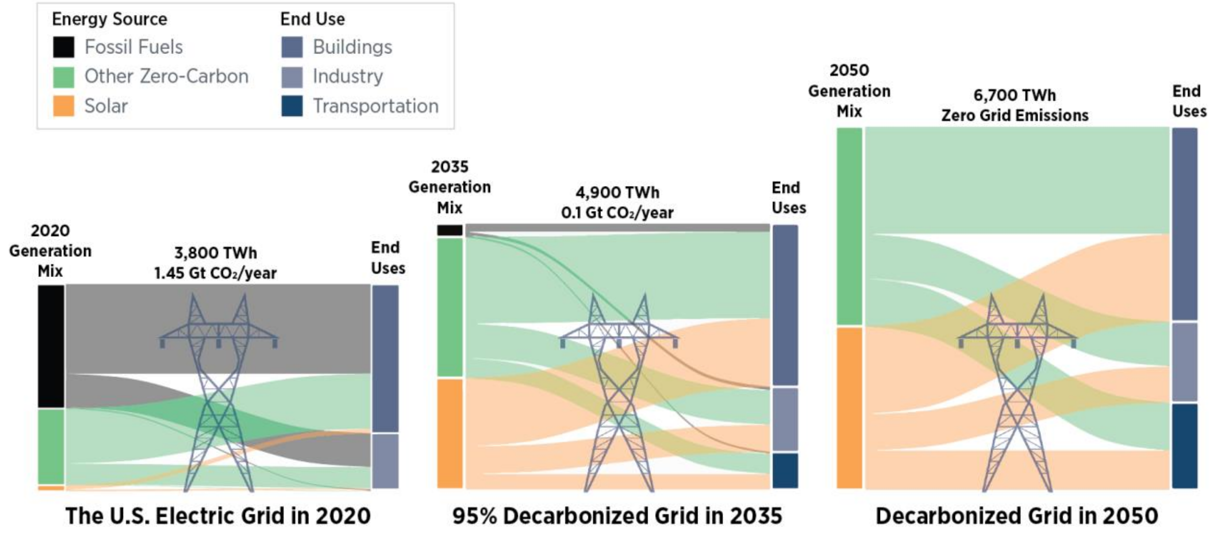
Changing Energy Landscape

Regional operation nearing 100% IBR operation

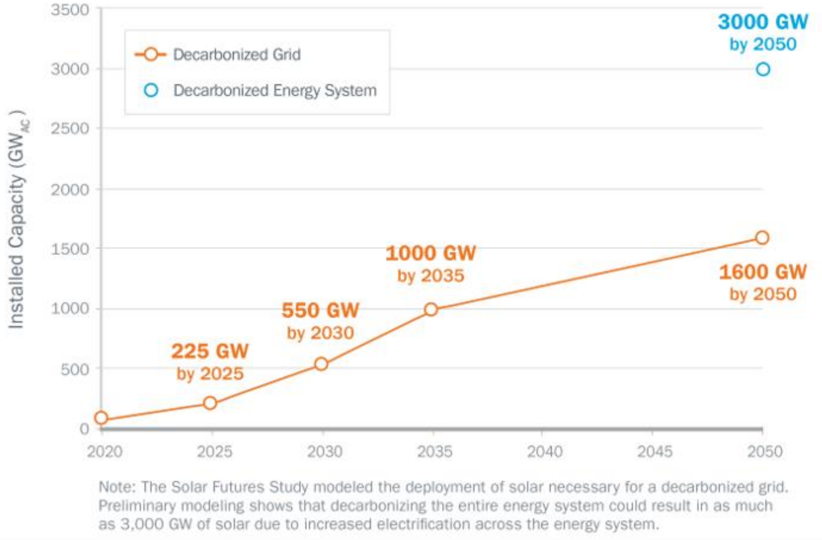
Diurnal changes in resource mix and varying source dynamics

Increased uncertainty in operations

Inadequate operator tools to handle increased need for flexibility



- Need rapid, sustained growth over next decade+.
- Simplified analysis of 100% energy decarbonization shows solar capacity reaching 3,000 GW by 2050.



Source: Solar Futures Study (energy.gov)

SETO/SI Resilience Efforts

2015 - 2016

- **SHINES**: Connect PV + Storage → Dynamic Load Management → Advanced Forecasting Techniques → Utility Communications and Controls
- **ENERGISE**: HW/SW Tools for Grid Operations → Resilient Hierarchical Controls → Coordination and Management of Flexible Resources

2017 - 2018

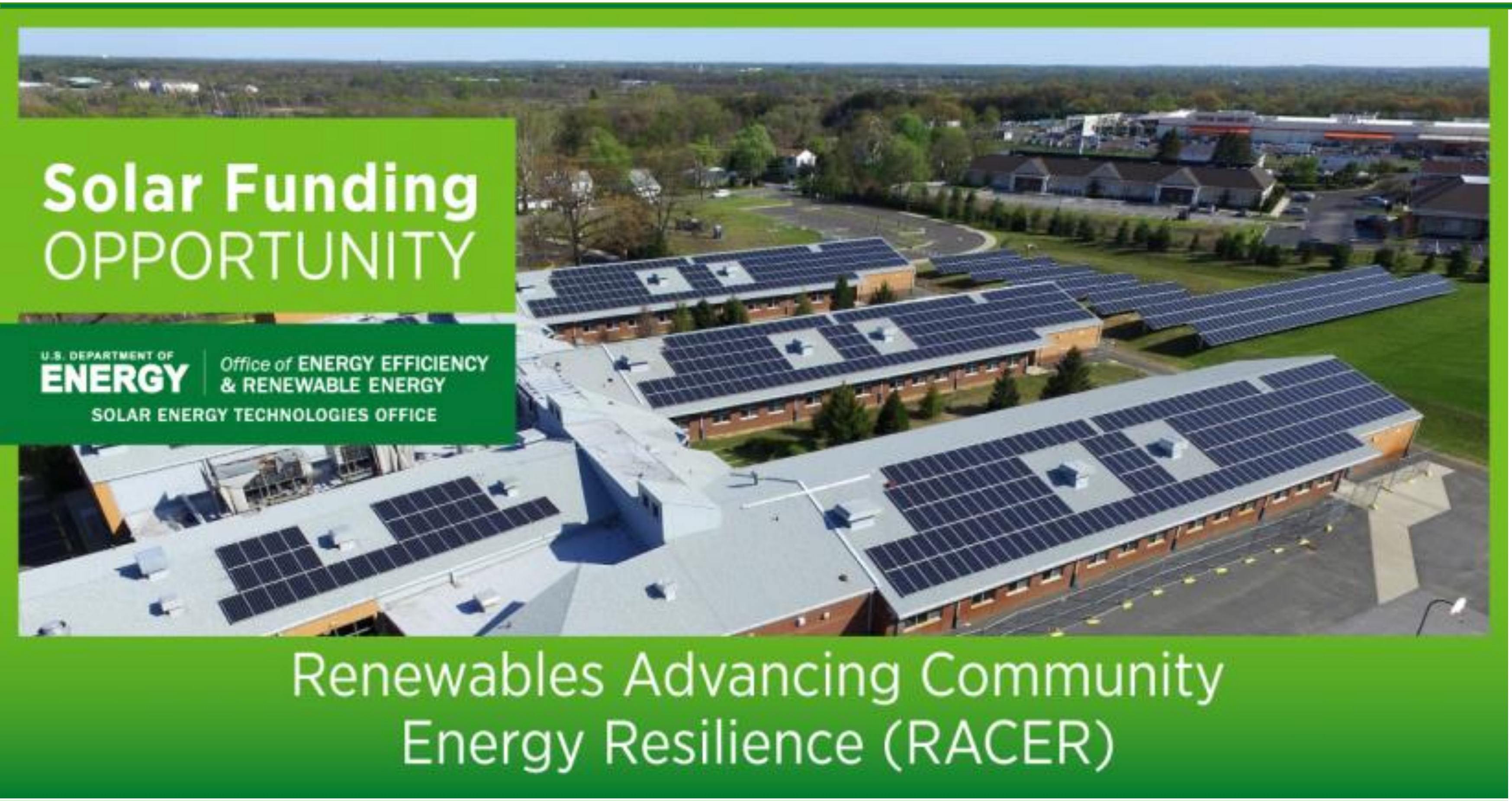
- **GMLC Lab Call**: Resilient Distribution Systems → Planning Metrics Consortia → Microgrids Systems & DERMS
- **ASSIST**: Controls Monitoring Communication → Situational Awareness → Autonomous & Resilient Operations → Network Reconfiguration → PV + Storage for Critical Loads → Cybersecurity

2019 - 2021

- **GMLC Lab Call***: Resilience Modeling & Metrics
- **FOAs**: 2019 → Adaptive Protection & Resilience → Resilient Inverter Controls → 2020 → Resilient Community Microgrids → MG's Orchestrator & Cellular Grids

2022 - 2023

- **RACER**: Topic 1: Planning → Topic 2: Restoration → GMLC → Report: Desing Resilient Communities



$25 million in funding for projects to enable communities to utilize solar and solar-plus-storage to **prevent disruptions in power caused by extreme weather** and other events, and to **rapidly restore electricity** if it goes down.
Aug 2022

RACER Topic Areas

Topic Area 1: Innovative Community-Based Energy Resilience Planning
11 projects,
$500,000–1M each

Topic Area 2: Automation Strategies for Rapid Energy Restoration
6 projects, $2–3M each

Topic Area 3: Innovative Solutions to Increase the Resilience and Hardening of PV Power Plants
3 projects, $1.5–3M each

Learn more: energy.gov/eere/solar/articles/funding-notice-renewables-advancing-community-energy-resilience-racer

FY20 FOA: Microgrid Orchestrator Development for Resilient Operation, Adjuntas Puerto Rico

Networked Community Microgrids with High Solar Penetration

- **Network Microgrids Orchestrator**

-Distributed Optimization
-Agent-Based Architecture

- **ML-based Forecasting**

-ML-based load and generation Forecasting
-3-use cases:
    Full-comms
    Partial Comms
    No-comms

- **Microgrid Dynamic Boundaries**

-Maximize PV utilization by expanding MG boundaries
-Consider load-generation unbalance

- **Network Microgrid protection**

-Negative-admittance protection
-Inverter-modifications to increase sequence contributions

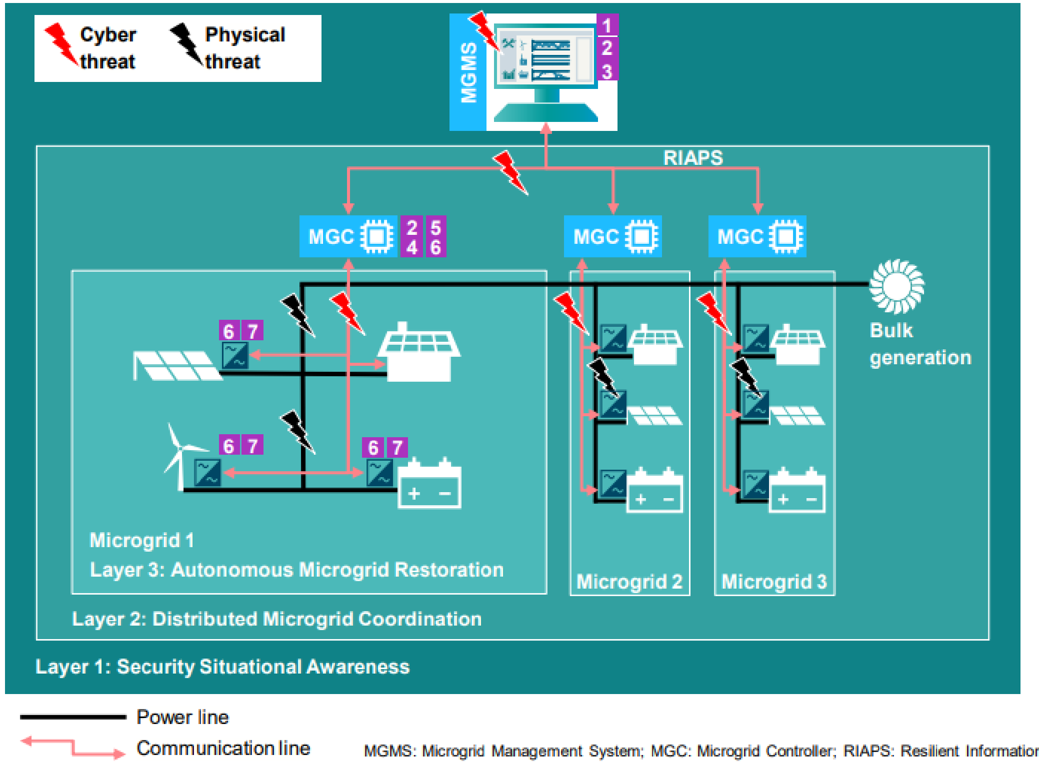
Success Story—New Tool Connects Multiple Microgrids to Increase Community ... Energy

ASSIST FOA SIEMENS- AUtonomous and Resilient Operation of energy systems with RenewaAbles (AURORA)

In AURORA, we develop and demonstrate a 3-layer protection scheme for Networked Microgrids against cyber and physical threats

SIEMENS
Ingenuity for life

Networked Microgrids



Project objectives

Layer 1: Security Situational Awareness
1 Short-term PV forecasting
2 Fast reconfiguration after physical events
3 Detect and localize cyber attacks

Global restoration ↑ ↓ Loss of MGMS / Loss of communication

Layer 2: Distributed Microgrid Coordination
4 Peer-to-peer Energy Management
5 Communication-free Energy Management

Local restoration ↑ ↓ Blackout

Layer 3: Autonomous Microgrid Restoration
6 Autonomous restoration after blackouts
7 Robust parallel grid-forming inverters

MGMS: Microgrid Management System; MGC: Microgrid Controller; RIAPS: Resilient Information Architecture Platform for the Smart Grid

Siemens Technology

Success Story—Using Renewable Microgrids to Keep the Lights On | Department of Energy

Research Questions

- Is the energy resilience definition comprehensive?
- What is the state of the art when implementing community and power systems energy resilience?
- How energy resilience benefits provided by solar and DERs are quantified?
- How solar and DERs can change energy restoration processes?
- Do we understand risks related to climate and cyber threats to a decarbonized grid?

Thank you!

marissa.morales-rodriguez@ee.doe.gov

SIGN UP NOW:
energy.gov/solar-newsletter

Grid and community resilience: The role of the utilities now vs the future

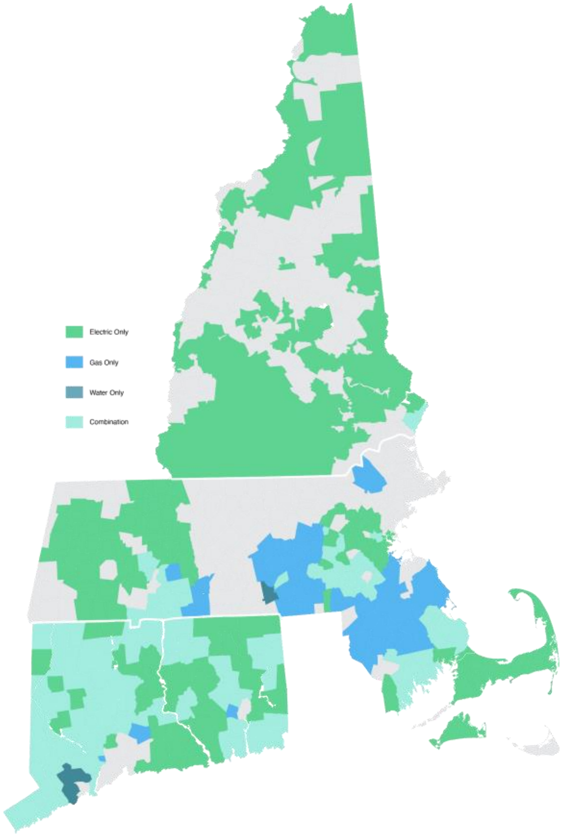
Dr. Elli Ntakou

Eversource Energy

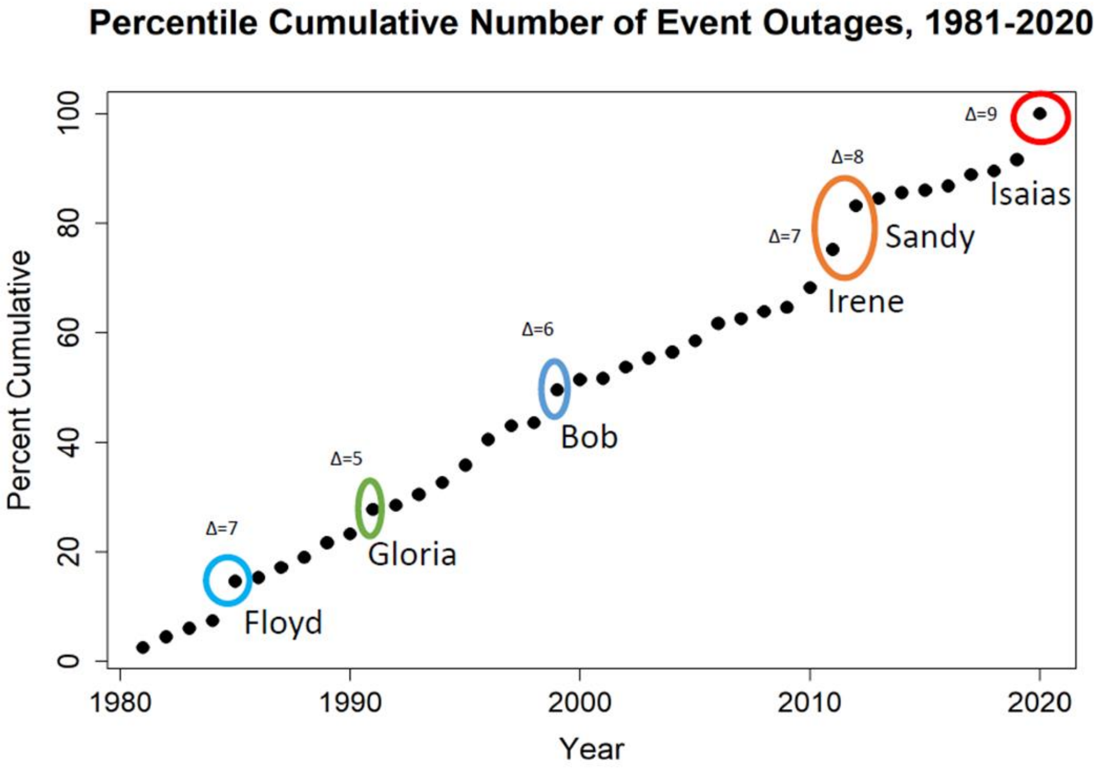
November 14, 2024

What’s Going On In The Northeast?

Safe, reliable and sustainable energy for 4.4M customer meters in CT, MA and NH.



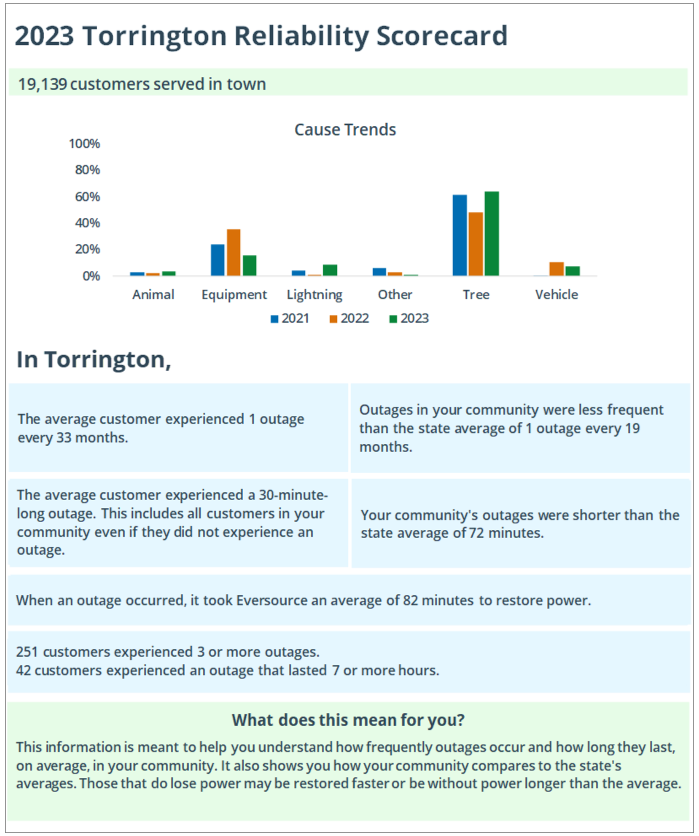
Climate intensification is already observed in the Northeast.



Utilities Are Adapting

EVERSOURCE ENERGY

Customer Empowerment & Transparency



2023 Torrington Reliability Scorecard

19,139 customers served in town

In Torrington,

The average customer experienced 1 outage every 33 months.	Outages in your community were less frequent than the state average of 1 outage every 19 months.
The average customer experienced a 30-minute-long outage. This includes all customers in your community even if they did not experience an outage.	Your community's outages were shorter than the state average of 72 minutes.

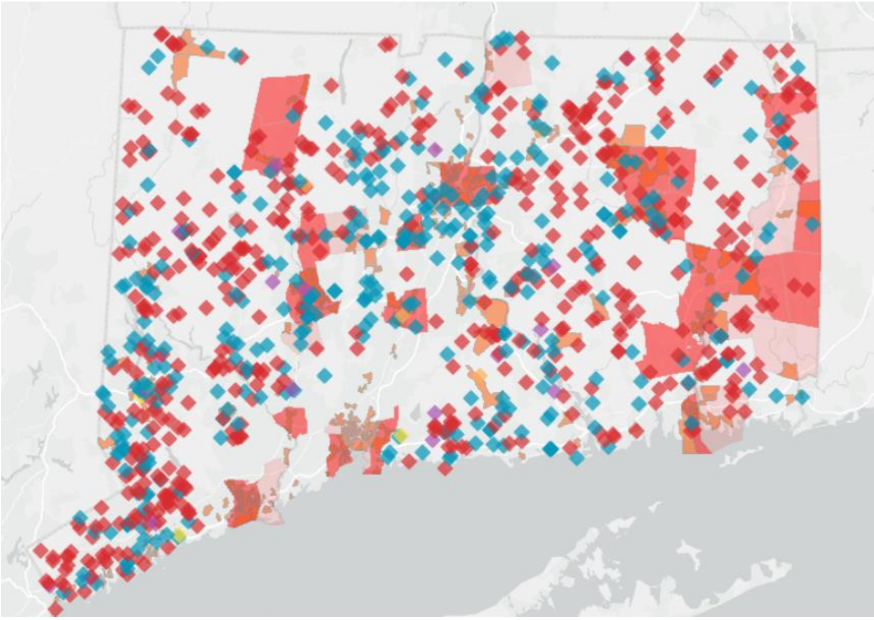
When an outage occurred, it took Eversource an average of 82 minutes to restore power.

251 customers experienced 3 or more outages.
42 customers experienced an outage that lasted 7 or more hours.

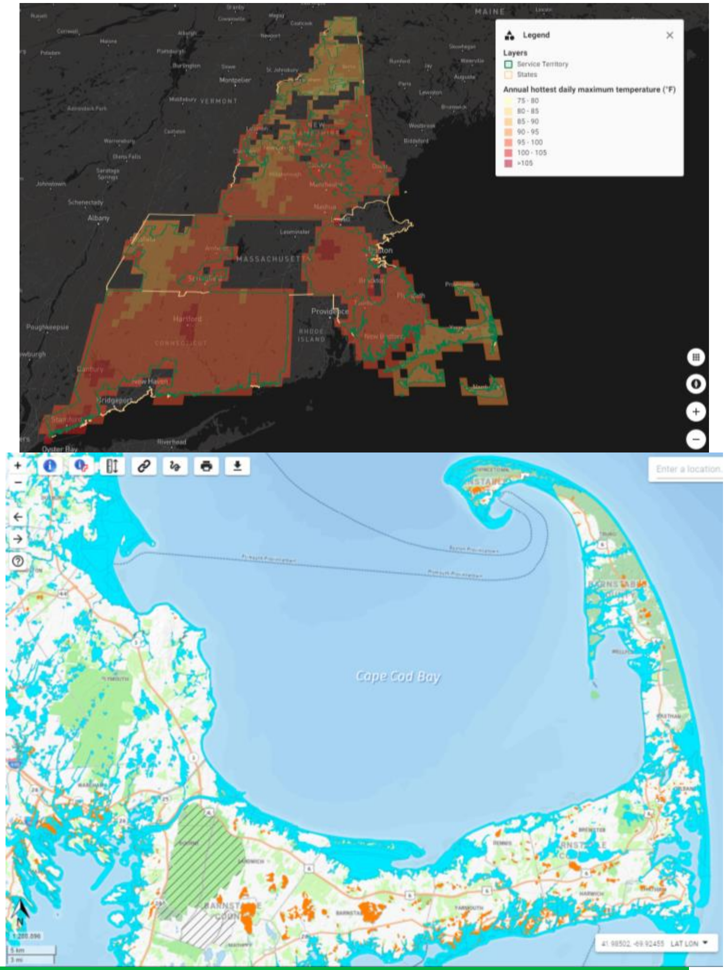
What does this mean for you?

This information is meant to help you understand how frequently outages occur and how long they last, on average, in your community. It also shows you how your community compares to the state's averages. Those that do lose power may be restored faster or be without power longer than the average.

Proactive Focus on EJ Communities



Climate Change Vulnerability Assessment



https://maps.massgis.digital.mass.gov/

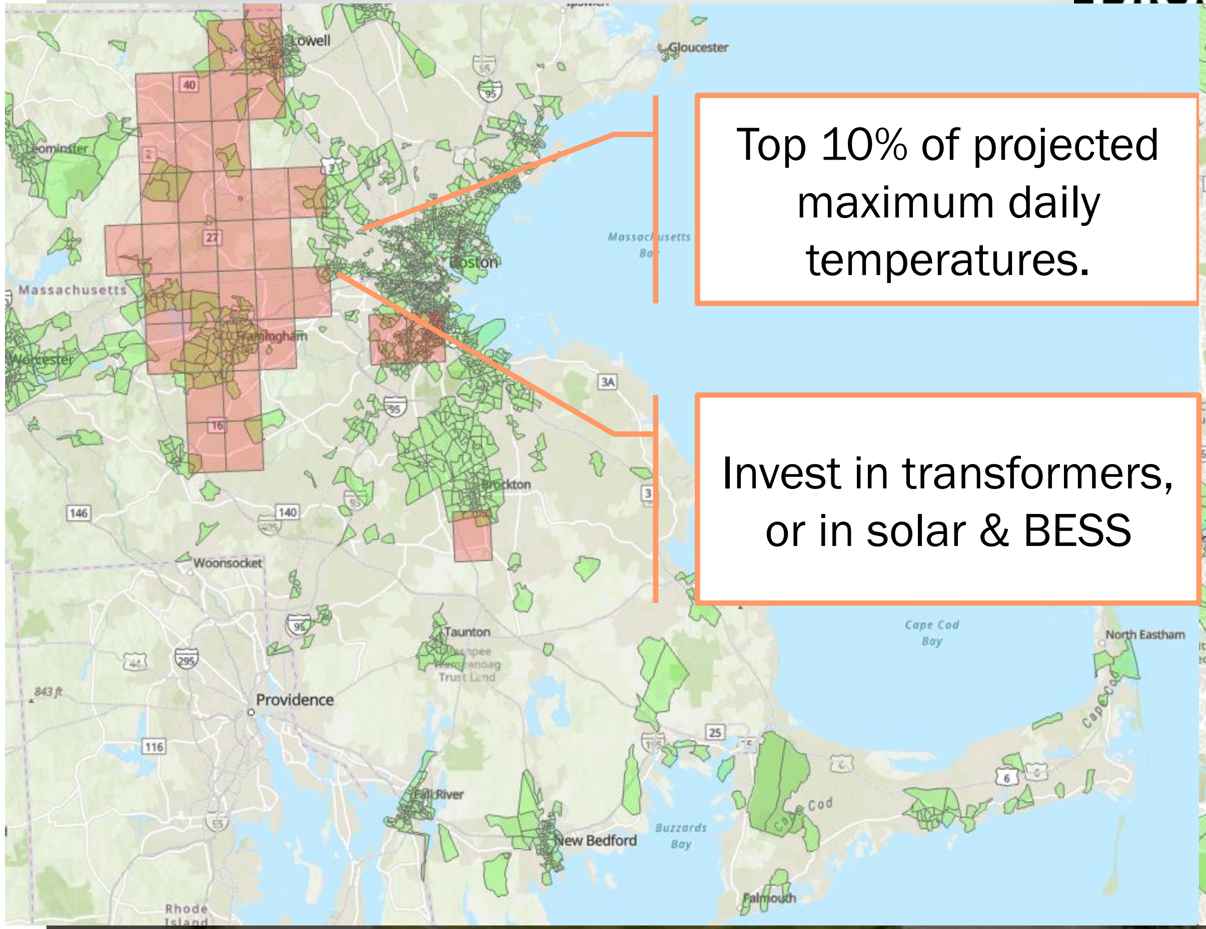
How to balance cost efficiency, system improvements & energy equity for all?

How Are EJ Communities Impacted By Climate Change?

*https://education.nationalgeographic.org/resource/biloxi-chitimacha-cho

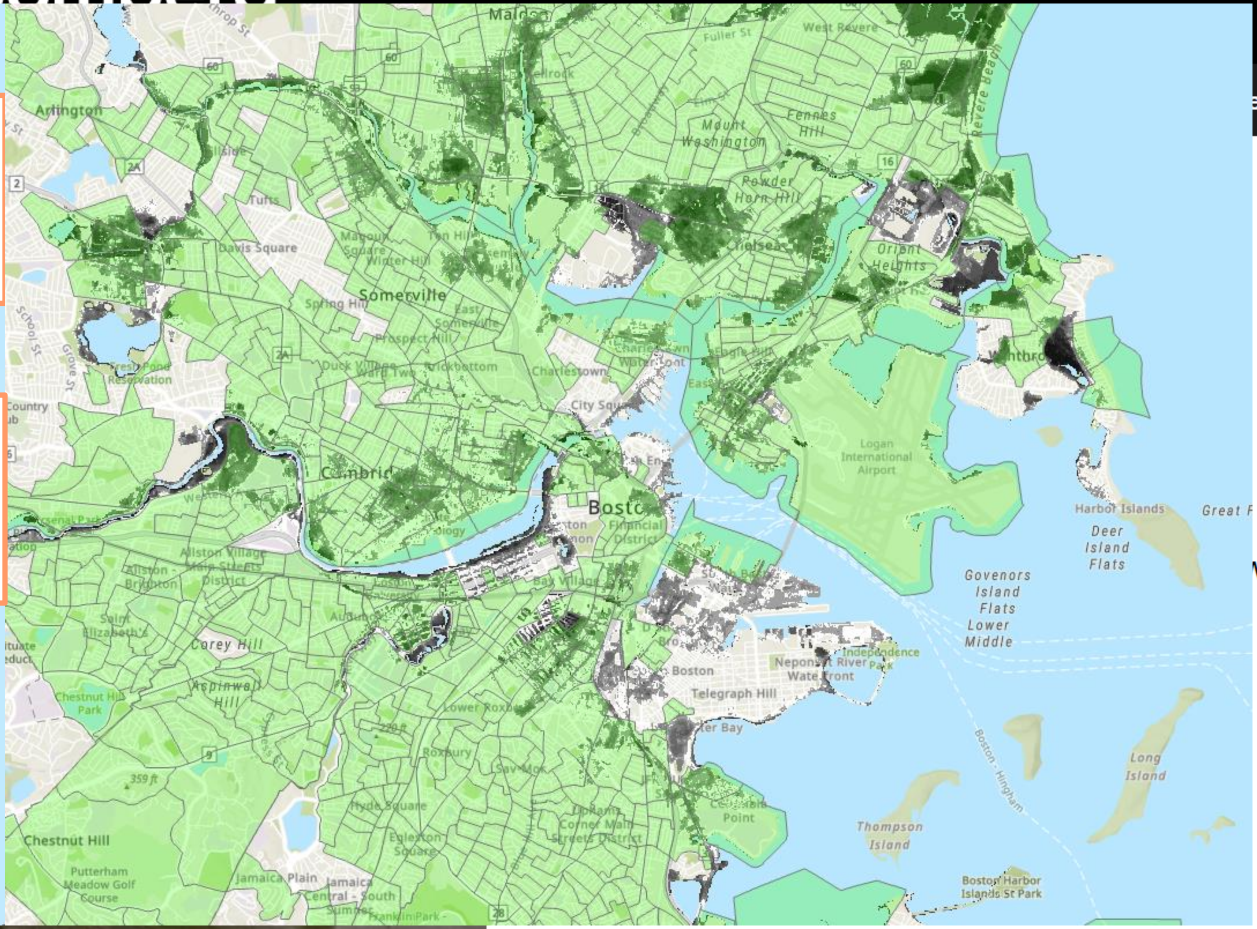
Bloomberg the Company & Its Products | Bloomberg Terminal Demo Request | Bloomberg Anywhere Remote Login | Bloomberg

Bloomberg



Top 10% of projected maximum daily temperatures.

Invest in transformers, or in solar & BESS



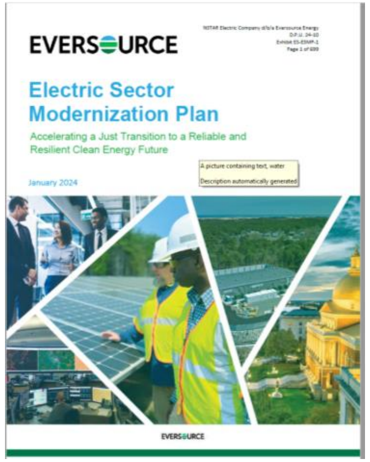
Other Impacts of Climate Change- OSHA Heat Standard & Utility Implications

EVERSOURCE ENERGY

Existing	Proposed*
• Recommendations on training only • No quantification of when "heat stress" occurs	• Specific directions on mitigations • Sets "initial heat trigger" at 80F and "high heat trigger" at 90F.

* Proposed in August 2024, comments open till year end.

Utility Practices for Resilience- Cost Justification



Historical vulnerabilities

Climate hazard projections

Metric needed to baseline, quantify improvements and set targets

Grid resilience

Community resilience

Benefit-cost analysis for proposed investments

Utility Practices for Resilience- Undergrounding

EVERSOURCE ENERGY

The New York Times

Hurricane Helene didn't just knock down power lines across the Southeast — it also flooded many electrical substations, which can take weeks or months to repair if they are severely damaged.

The time it takes to repair a substation can depend on what equipment is affected. The most important component is the transformer, which steps up and down the voltage of electricity. There is currently a global shortage of transformers because of soaring demand from renewable energy developers, according to Wood Mackenzie, a consulting firm. Wait times for some new equipment can be two to three years, on average.

Undergrounding costs average $2M - $6M.

NRECA America's Electric Cooperatives

One of the state's co-ops, Blue Ridge Electric Cooperative in Pickens, saw its underground power lines wash down the mountainside, along with trees and power poles, Couick said.

MOUNTAIN Electric Cooperative

We have been instructed by Avery County inspectors office that each house in the Meadows at Land Harbor will have to be inspected before we can restore power. We have numerous primary and secondary boxes turned on their tops and every meter base in this area was flooded as well.

We still have a lot of damage to underground infrastructures, and it is very time consuming to repair.

POWER

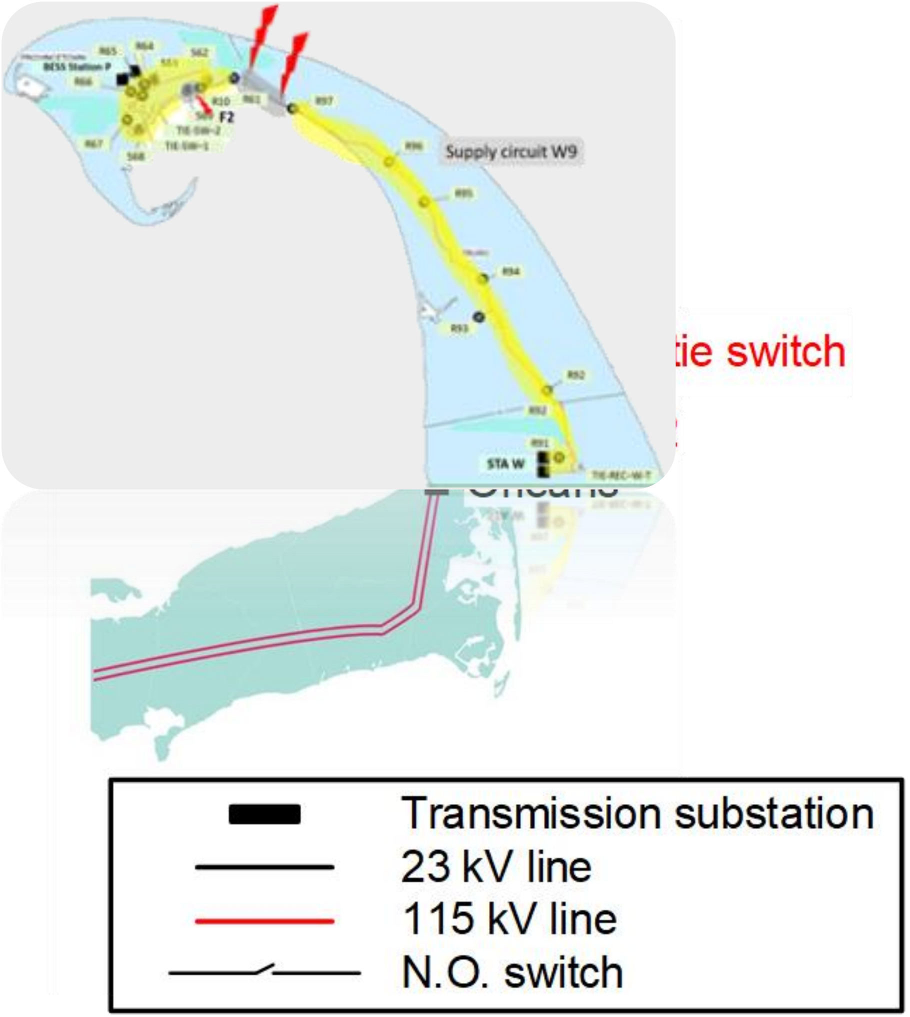
Cowlick noted that even undergrounding efforts did not prove effective in the power of the storm. A landslide in Blue Ridge Electric Cooperative's territory "took out every bit of their underground, so nothing was immune to the power of Helene," he said.

https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/electric-reliability/undergrounding-program-description#:~:text=According%20to%20PG%26E%2C%20SCE%20and,%2D%246.1M%20per%20mile)

Utility Practices for Resilience- BESS Microgrids

EVERSOURCE ENERGY

- Environmental benefits:
  - 25MW/38MWh BESS deferred a new 13-mile line through the Cape Cod National Seashore
- EJ benefits
- Resilience & reliability benefits:
  - 80% less customers interrupted during a major storm.
- ~$20M DOE award to coordinate customer-owned solar, thermostats & batteries to extend the coverage the BESS provides.



DOE Innovations: Resilience and Energy Systems

- **Dan Ton**, Microgrid R&D Program Manager, Office of Electricity
- **David Parsons**, Senior Advisor, Grid Deployment Office
- **Elaine Ulrich**, Senior Advisor, Office of Cybersecurity, Energy Security and Emergency Response (CESER)

DOE Microgrids R&D Program

Dan Ton
Manager, Microgrids Research and Development
Office of Electricity
November 2024

Office of Electricity

- Lead U.S. Department of Energy's research, development, and pilot demonstration programs to strengthen and modernize **electricity delivery system** to ensure reliable, resilient, secure, and affordable electric power grid
- Drive **technological and operational** advancements that ensure reliable access to affordable energy
- Focus on **software, hardware, and modeling** and addresses systems integration, security, policy and other cross-cutting issues.

Reliability	**Resilience**	**Security**	**Affordability**

Microgrids R&D Program Scope and Major Activities

Grid-connected Microgrids

Develop integration approaches, tools, and technologies into distribution systems to meet the DOE performance targets and community resiliency objectives

- Standard, modular **microgrid building blocks**
- Integration platform (generation mixes, T&D)
- **Microgrid protection and control**

Resilience Modeling

Develop **advanced models and approaches** for pre-event preparation, during-event detection and mitigation, and post-event response, recovery, and remediation

- Simulation and analysis of microgrids for critical facilities (ports, urban centers)
- **Software standardization** for microgrid planning and design

Networked Microgrids

Develop advanced capabilities of sharing loads and resources - including self-assembly or dynamic boundaries of microgrids - that support critical loads under extreme events, while attaining optimized performance under normal operating conditions

- Tool for resilient operations of networked microgrids
- **Dynamic microgrids** as a building block for the future grid

Standards and Institutional Framework

Support developing and implementing microgrid standards, test methods, best practices, and enabling regulatory and business models

- IEEE microgrid-related standards
- NARUC-NASEO Microgrid State Working Group
- Technical assistance (resilient communities)

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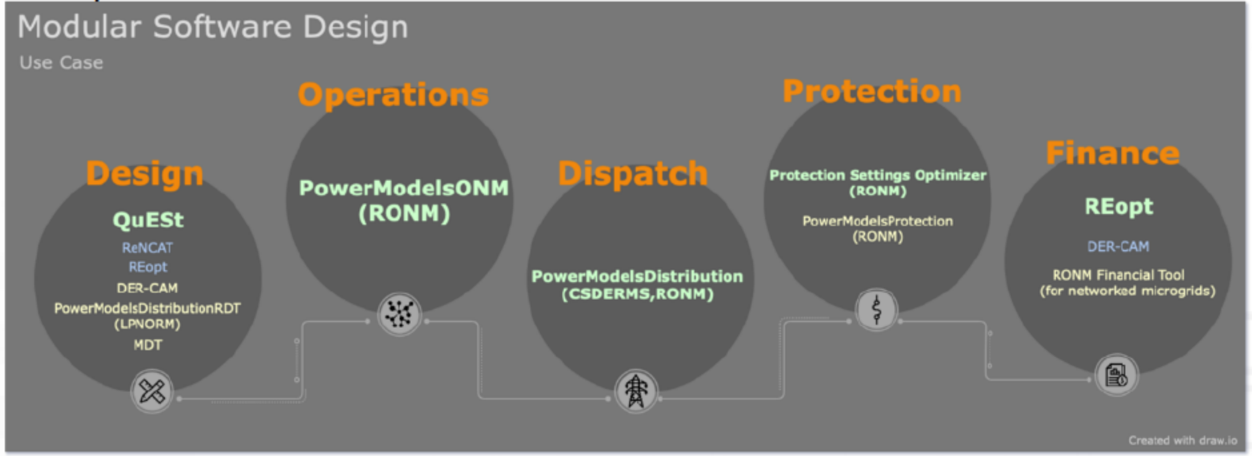
Integrated Workflows and Tools for Microgrid Design and Analysis (RAVENS)

Develop a data exchange standard for tools developed under DOE programs to support effective integration internally and externally

- Support plug-and-play architectures and ease of adoption by industry
- Ready integration with utility planning/analysis Validated workflows for designing microgrids for cost-benefit analysis, implementation feasibility, and protection coordination



Technical Scope

1. **API development:** *Standard for ingesting and exchanging information between tools*
2. **Use case development:** *demonstration of practical value of API with an integrated tool use case*
3. **Adoption by legacy tools:** *Demonstration of how legacy tools can be compatible to the API*
4. **Interactive microgrid tool catalog:** *Living documentation of capabilities that are compatible with the API*
5. **Prototyping integration with ADMS**

Team Partners

- ✓ LANL (Lead)
- ✓ NREL, SNL, LBNL
- ✓ NRECA
- ✓ Industry Advisory Board

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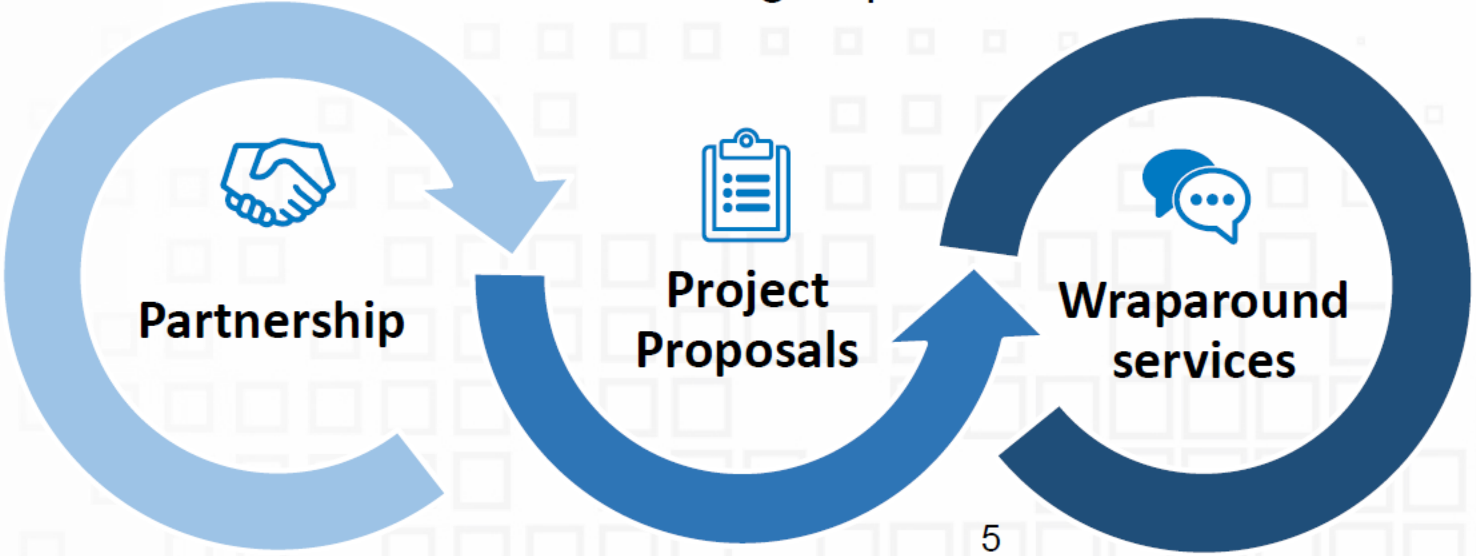
Community Microgrid Assistance Partnership (C-MAP) Objectives

- Form a microgrid development partnership focused on knowledge sharing on UICM.
- Release a simplified competitive solicitation focused on improving or developing microgrid systems in electrically isolated communities in Alaska, Hawai'i, and Tribal lands.
  - ➢ Solicitation released on 10/3/2024, with applications due on 12/20/2024
  - ➢ Anticipated awards ranging from $200K to $650K with technical assistance (Details available on the OE website)
- Provide wraparound support services to ensure long-term success and facilitate knowledge sharing across remote microgrid-powered communities.



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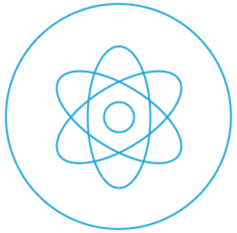
Grid Resilience Investments and Technical Assistance

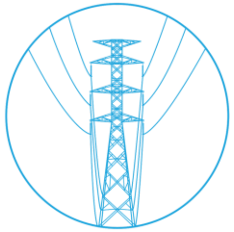
Dave Parsons, Senior Advisor
Grid Deployment Office
U.S. Department of Energy

OVERVIEW

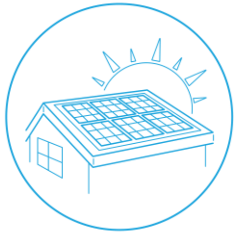
GRID DEPLOYMENT OFFICE: MISSION AND GOALS

Ensure **resource adequacy** by supporting **critical generation sources** and expanding and enhancing **electricity markets**.




Catalyze the development of new and upgraded **high-capacity electric transmission lines** and an improved **distribution system** nationwide.

Prevent **outages** and enhance the **resilience** of the electric grid.

OVERVIEW

GDO PROGRAMS AT A GLANCE

Resource Adequacy	Transmission Permitting	Transmission Planning, Financing, & Commercial Facilitation	Grid Modernization
Civil Nuclear Credit Program **Hydro Incentives:** More than $750 million **Wholesale Electricity Market Studies and Engagement**	**Coordinated Interagency Transmission Authorizations and Permits (CITAP)** **Presidential Permits** **Export Authorizations** **Environmental Reviews**	**Transmission Facilitation Program:** $2.5 billion **Transmission Facility Financing:** $2 billion **Transmission Siting and Economic Development Grants:** $760 million **National Transmission Needs Study** **National Transmission Planning Study** **Offshore Wind Convenings** **National Interest Transmission Electric Corridors (NIETCs)**	**Grid Resilience State/Tribal Formula Grants:** $2.3 billion **GRIP Program:** $10.5 billion **Puerto Rico Energy Resilience Fund:** $1 billion **Territory Recovery Assistance**

STATE AND TRIBAL FORMULA GRANTS

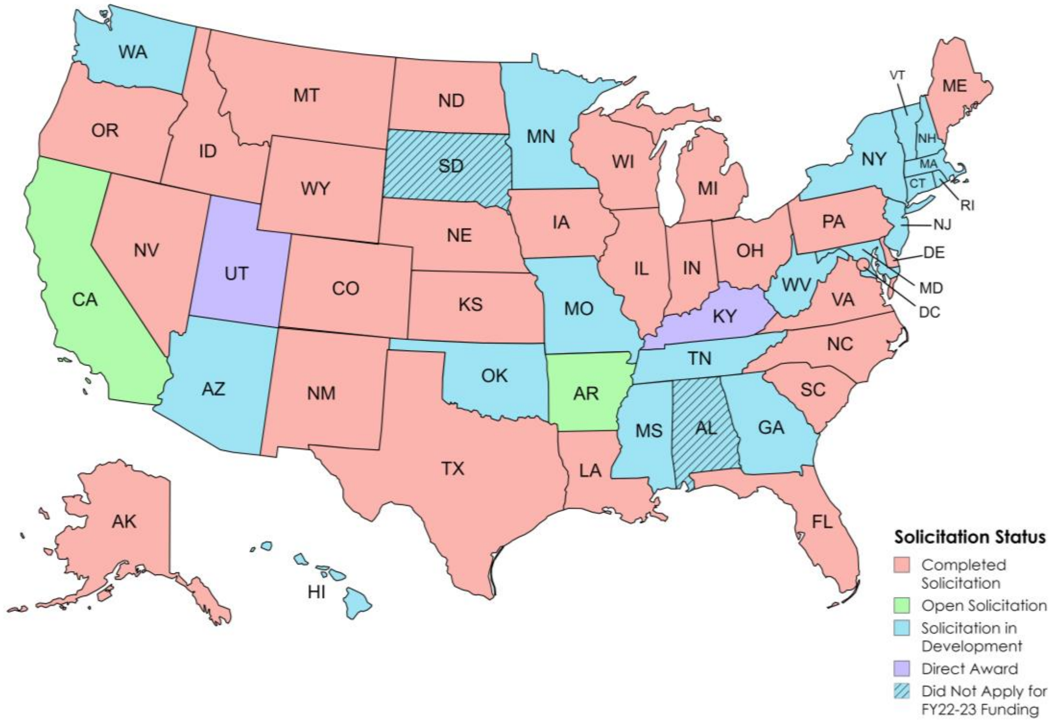
What is it?

- **$2.3 billion** in *non-competitive* formula grants to:
  - Prevent outages and enhance the resilience of the electric grid
  - Demonstrate measurable improvements in energy resilience to natural hazards
  - Mitigate the impact of extreme weather
  - Invest in modernized grid infrastructure

Who is eligible?

- States, territories, and Indian tribes

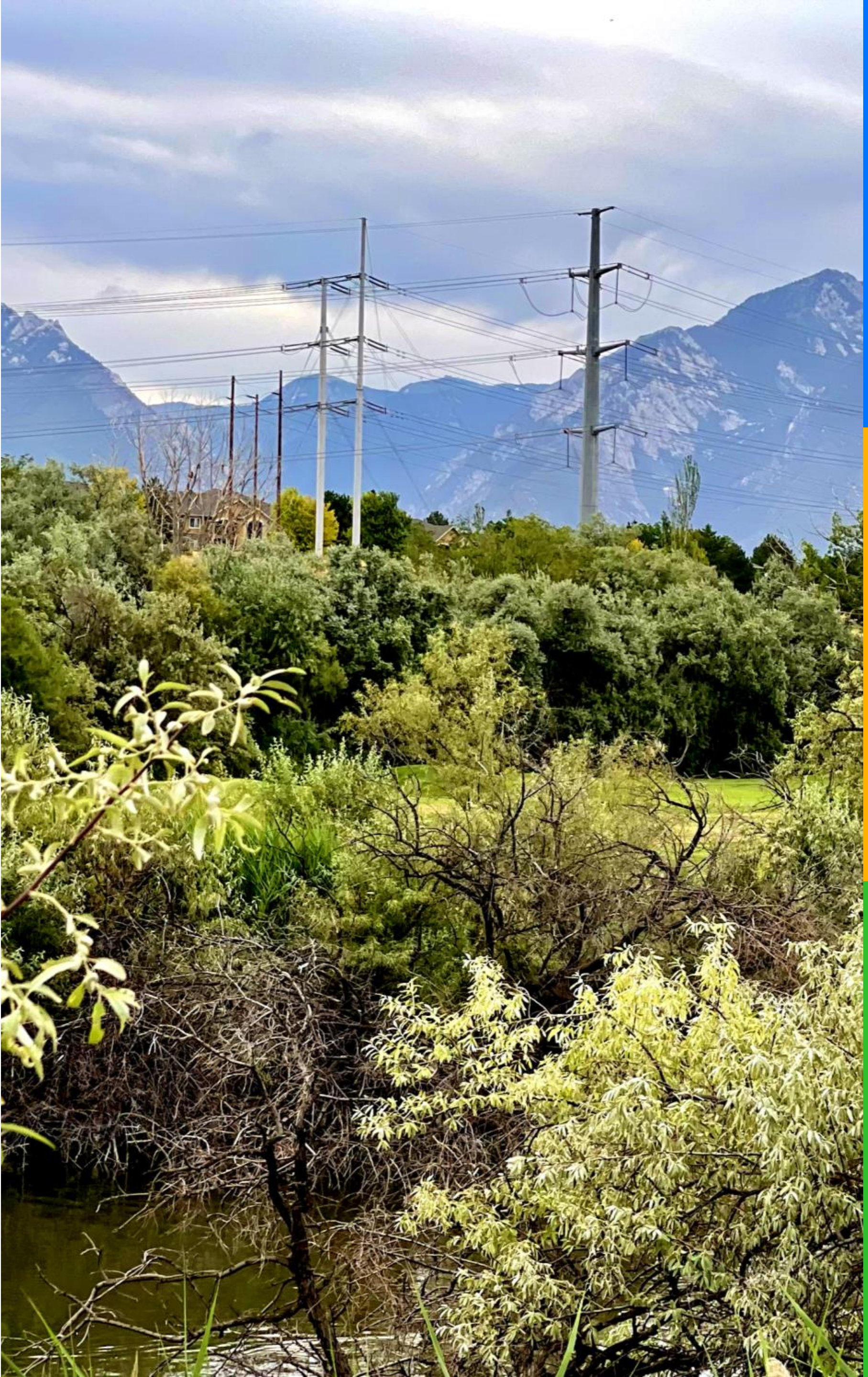
As of October 2024, GDO has awarded more than $1.2 B to states, tribes, and territories



RESILIENCE GRANT PROGRAMS

PUERTO RICO ENERGY RESILIENCE FUND

- $1 billion from the FY2023 Consolidated Appropriations Act to improve the resilience of the Puerto Rican electric grid
- Targeting renewable energy and storage for vulnerable households
- Will remain available until expended



RESILIENCE GRANT PROGRAMS

WHAT IS GRIP?

Grid Resilience and Innovation Partnerships (GRIP)

$10.5 billion in ***competitive grants*** to enhance grid flexibility and improve the resilience of the power system

Grid Resilience Utility & Industry Grants

- **$2.5 billion** for resilience projects that reduce the likelihood and consequence of impacts to the electric grid due to extreme weather, wildfire, and natural disaster
- **Eligible entities**: Grid operators, storage operators, electricity generators, transmission owners/operators, distribution providers, fuel suppliers

Smart Grid Grants

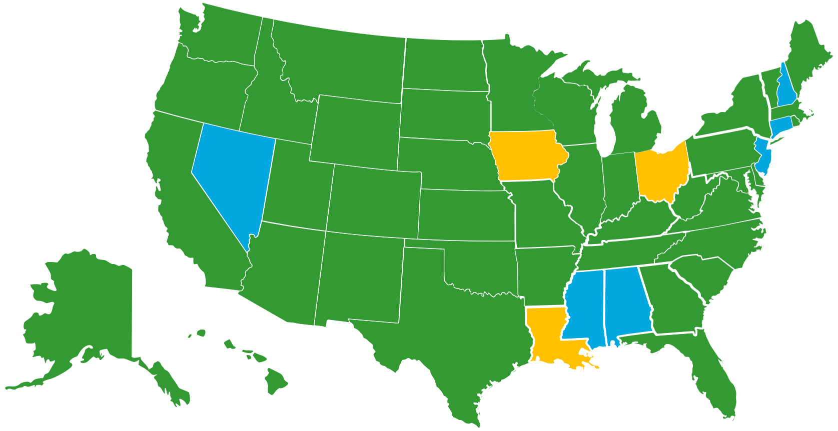
- **$3 billion** for innovative and ambitious uses of cutting-edge, market-ready technologies
- **Eligible entities**: Institutions of higher education, for-profit entities and non-profit entities, state and local governmental entities, tribal nations

Grid Innovation Program

- **$5 billion** for high-impact, innovative projects that improve grid reliability and resilience on the local, regional, and interregional scales
- **Eligible entities**: States or a combination of states, tribal nations, units of local government, public utility commissions

RESILIENCE GRANT PROGRAMS

GRIP IMPACTS



Lead or significantly impacted by one or more projects

GRIP 1
GRIP 2
GRIP 1 and 2

104 projects

50 states + DC

90 million homes and businesses benefitting

$7.6 billion federal investment

$22.6 billion public & private investment

55 GW expanded grid capacity and new resources

2,600+ miles of new or upgraded **transmission** lines

Nearly **15,000 jobs** created or supported

$500+ million dedicated to **community benefits**

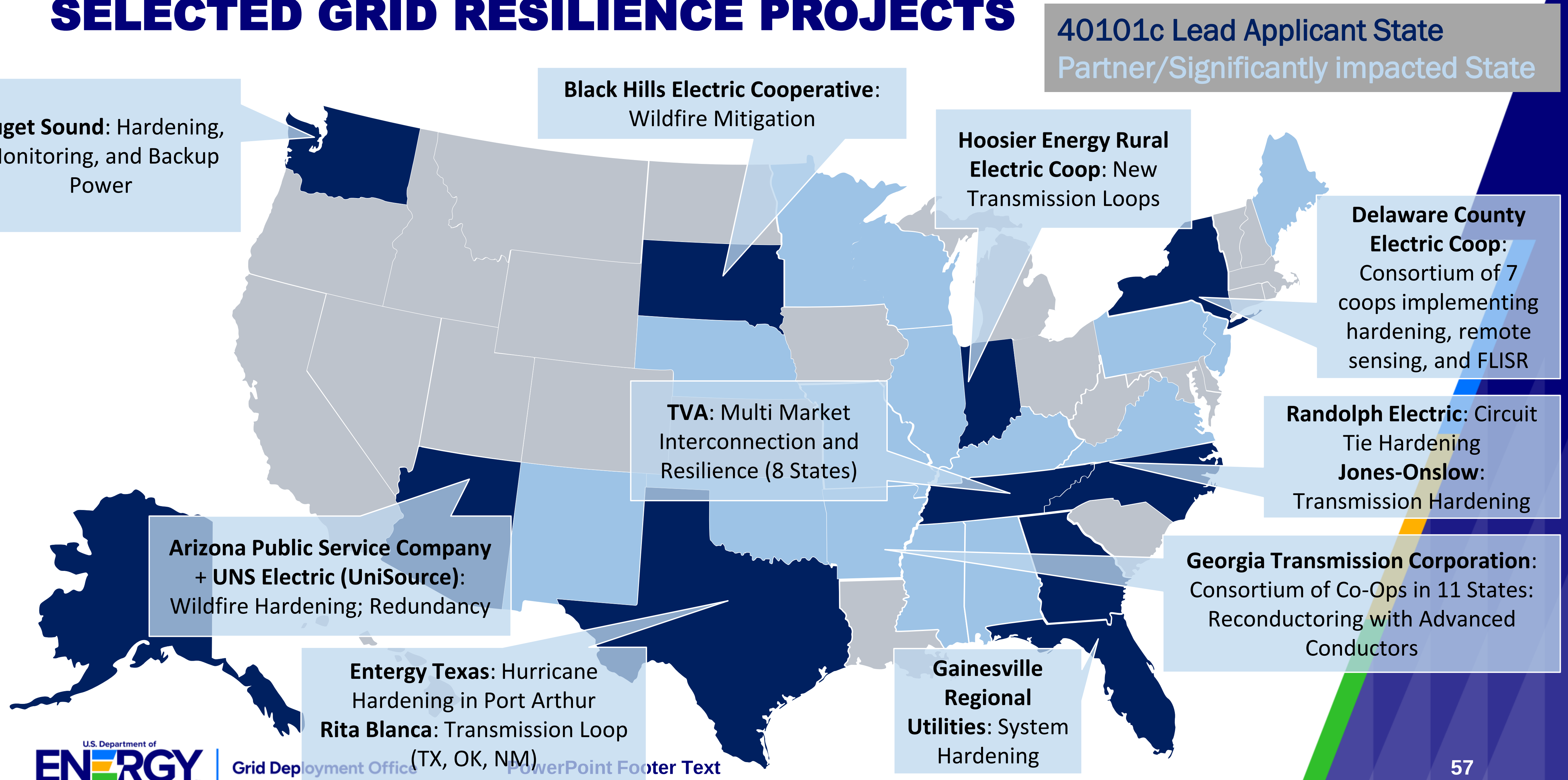
U.S. Department of ENERGY | Grid Deployment Office

SELECTED GRIP INVESTMENT THEMES

Resilience and Reliability	• Resilience investments focus on wildfire as well as hurricane hazards (flooding, high winds) • Examples: fault location, isolation & service restoration (FLISR), reclosers, undergrounding, monitoring & control
Microgrids	GRIP projects will support investment in over 400 microgrids, which are a group of interconnected loads and distributed energy resources that can provide electricity to a smaller community or region, which enhances the resilience of the grid against extreme weather.
DER Integration	• 9 microgrid, storage-as-NWA, and/or VPP projects • 3 projects focused on V2G orchestration • Interconnection hardware and software improvements • 20 GW total capacity enabled
Transmission Innovation	• 12 projects with new or reconductored transmission • At least 15 projects deploying advanced conductors • 950+ miles total of transmission innovation • Transmission loops for reliability

RESILIENCE GRANT PROGRAMS

SELECTED GRID RESILIENCE PROJECTS



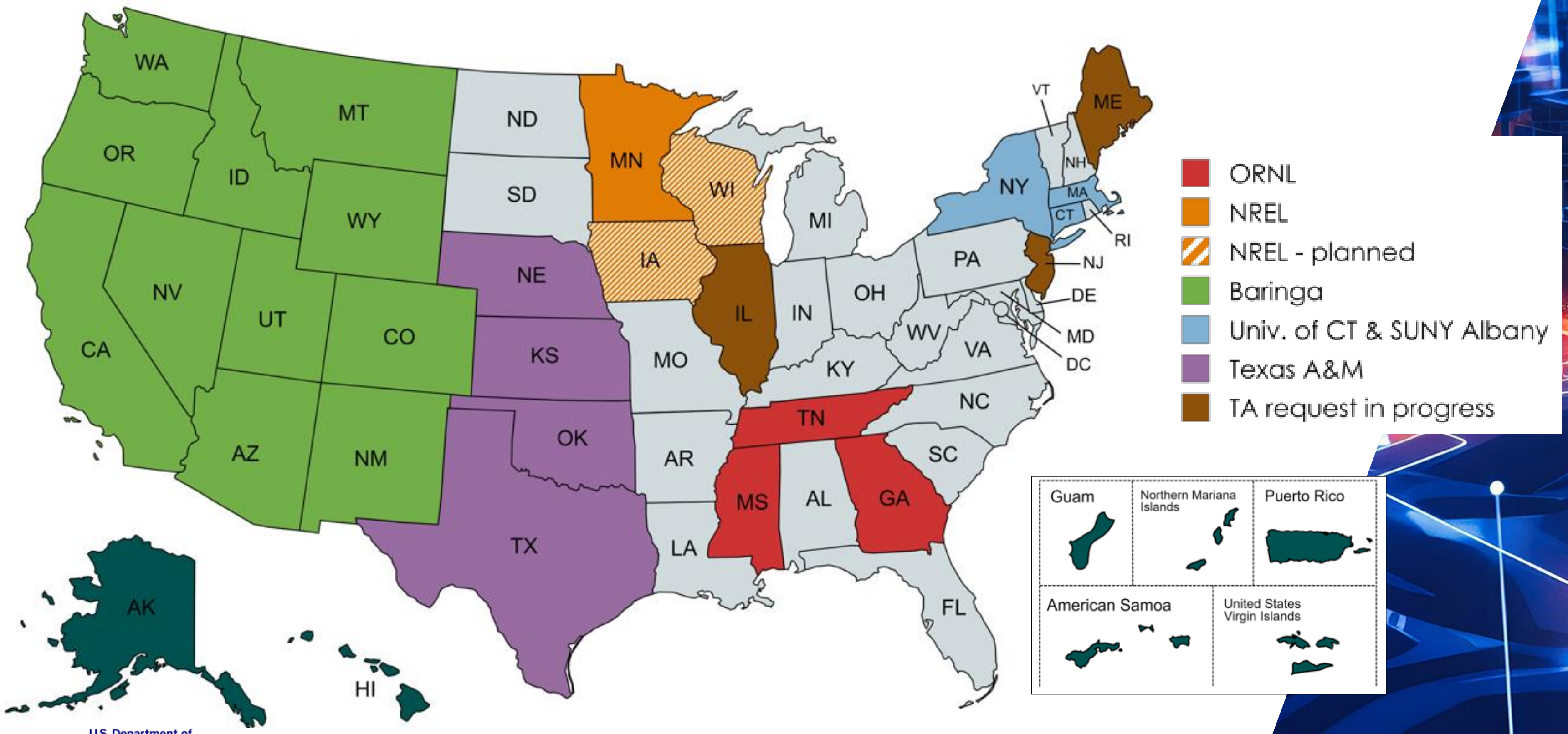
GRID RESILIENCE TECHNICAL ASSISTANCE

GDO provides training, analyses, and technical support to improve long-term grid resilience planning and investment decision-making

- **Risk assessment:** What are the outage threats being faced now and could face in the future? How likely are they? How severe could they be? How does this coincide with other critical services?
- **Grid vulnerability assessment**: What elements of the system are performing well or poorly against outage threats? What are expectations about future performance based on asset condition, climate projections and demand changes? Which entities within the jurisdiction are finding success, which ones may need more support?
- **Resilience strategy tradeoffs**: What options are available to enhance grid performance and resiliency? Do the benefits outweigh the cost? What projects align with resilience goals and which projects are feasible within DOE funding parameters?
- **Prioritization and valuation**: Once the risk, needs and options are understood, how should projects be prioritized? What are all qualitative and quantitative aspects that should be considered in the decision making? What criteria need to be considered to meet DOE requirements?

GRID RESILIENCE TECHNICAL ASSISTANCE

GDO is providing funding to universities, industry, and National Laboratories to work directly with states, territories, tribes, and utilities on grid resilience assessments and planning



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STAY CONNECTED

Visit: https://www.energy.gov/GDO

Email: david.parsons@hq.doe.gov

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Resilience Metrics for Power Systems and Community Planning

- **Mohamed Ben-Idris**, Associate Professor, Michigan State University
- **Igor Linkov**, Senior Scientific Technical Manager, U.S. Army Corps of Engineers
- **Andrew Jin**, Research Environmental Engineer, U.S. Army Engineer Research and Development Center
- **Ryan Dorland**, Economic Development and Energy Analyst, Virginia Department of Energy

Building Resilience for Power Grids and Communities

Mohammed Ben-Idris

Associate Professor, Michigan State University

2024 Workshop: Solar and DERs for Community Energy Resilience
U.S. Department of Energy Solar Energy Technologies Office (SETO)

MICHIGAN STATE UNIVERSITY

E-RESILIENCY
Energy Reliability, Security, Stability, Resilience & Efficiency

Why now?

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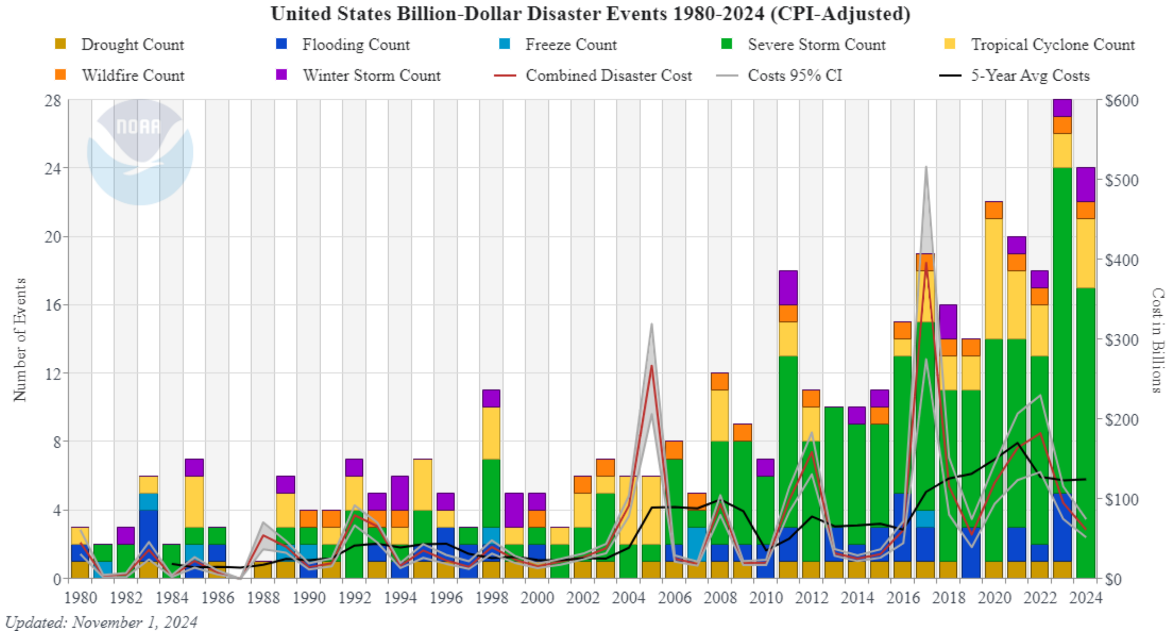
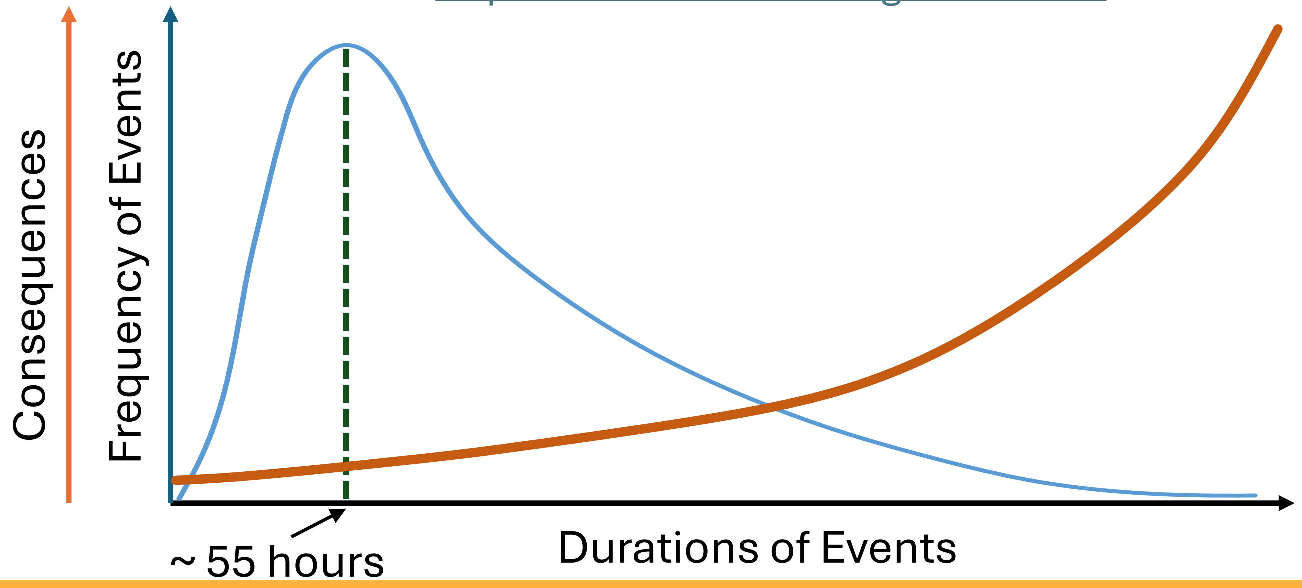
- The average number of annual extreme events over the last three years is more than **2.47** times the average number of annual extreme events over the past 40 year.
- Enhancing power supply resilience is no longer a priority; it is a necessity.
- The frequency and long duration power outages —whether from natural disasters, climate change, or infrastructure failures—are signals for utilities and communities to prepare, absorb, recover, and bounce back stronger than before.



https://www.ncdc.noaa.gov/billions/



Resilience Definitions

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- Several definitions have been proposed by different institutions (IEEE, CIGRE, EPRI, etc.), but they have not been approved/adopted by regulatory agencies such as North American Electric Reliability Corporation (NERC).
  - As of November 2024, NERC has not formally adopted a specific definition of "resilience" for power grids.
- However, most definitions converge to specific attributes:

✓ **Withstand:** ability to withstand contingencies without suffering operational compromise

✓ **Absorb:** ability to endure a disruption without significant deviation from normal operative performance,

✓ **Recover:** ability to recover quickly from potentially disruptive events; and

✓ **Adapt:** ability to adapt to a shock to normal operating conditions.

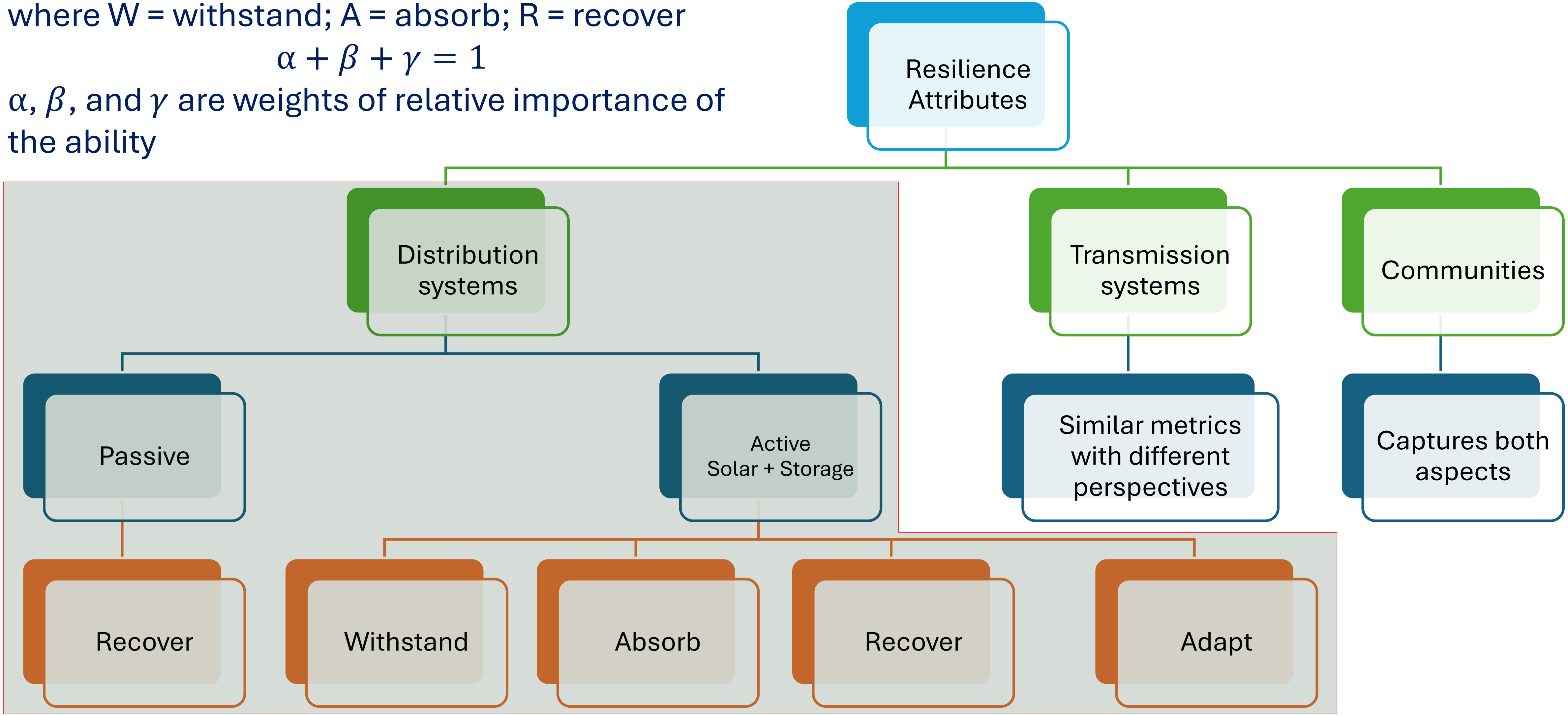
Resilience Attributes

Collective resilience (R) $= W^{\alpha} \times A^{\beta} \times R^{\gamma}$ ⟵ Based on Cobb-Douglas Production Function

where W = withstand; A = absorb; R = recover

$$\alpha + \beta + \gamma = 1$$

α, β, and γ are weights of relative importance of the ability



Energy Storage

– the Buffer We Have Been Looking For, Mohammed Ben-Idris & Zhenyu Huang

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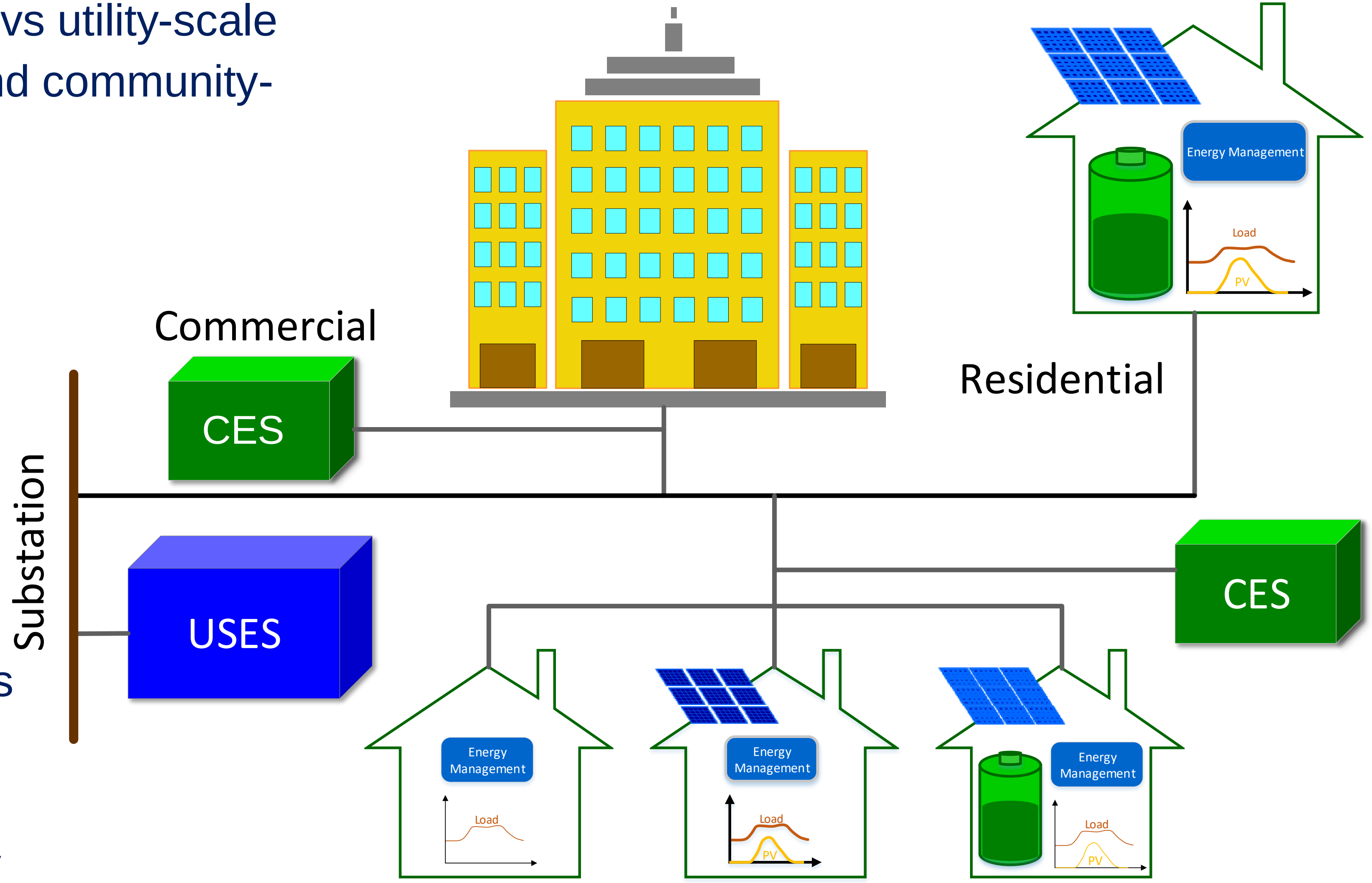
- For more than a century, the power system has been an amazing balance act – how much electricity is generated must be exactly how much is consumed. *This is a quite unique situation.*
- Most other complex systems – natural or man-made – has buffers built in: Rivers can have reservoirs; supply chain systems have warehouses; and gas systems have tanks.
- These buffers decouple the flows and make system operation more flexible and resilient, and fluctuations can be contained in local areas.
- If the power supply has buffers, the power flow will continue even if the main grid is out.
- The questions is: who pays for this buffer?

PV + Shared Energy Storage: *Local buffers*

- Behind-the-meter energy storage vs utility-scale shared energy storage (USES) and community-shared energy storage (CES)
- Remote virtual storage is attractive for customers with high-energy bills, and it is more attractive for low-income and multi-family customers.

Local Government Dilemma

- Upfront cost of resilience solutions
- Unpredictable events that could affect critical facilities
- How does (or can) resiliency "Pay For Itself"?



Community Safety Center: *A hub for critical infrastructures*

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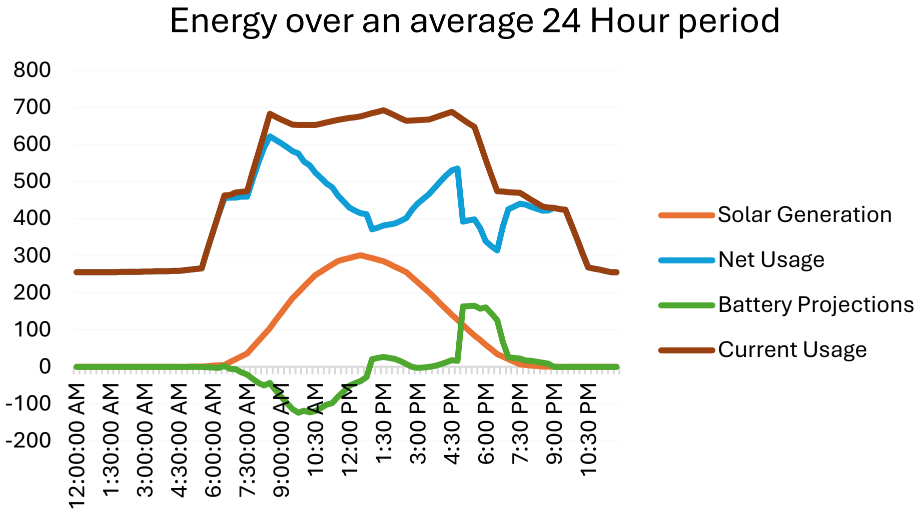
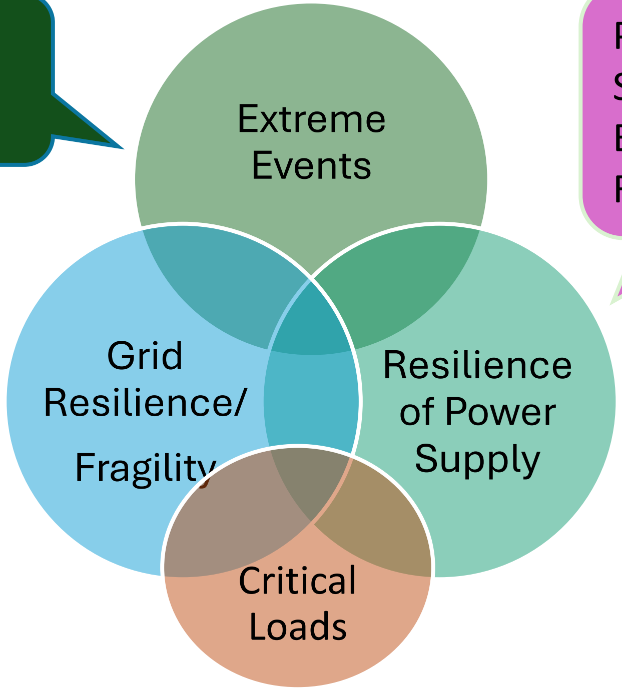


Region, type, duration, intensity, and frequency



PV and Energy Storage Can Enhance Grid Resilience

Avoided interruption costs due to solar plus storage installation?

Critical Loads supplied by Solar + Storage

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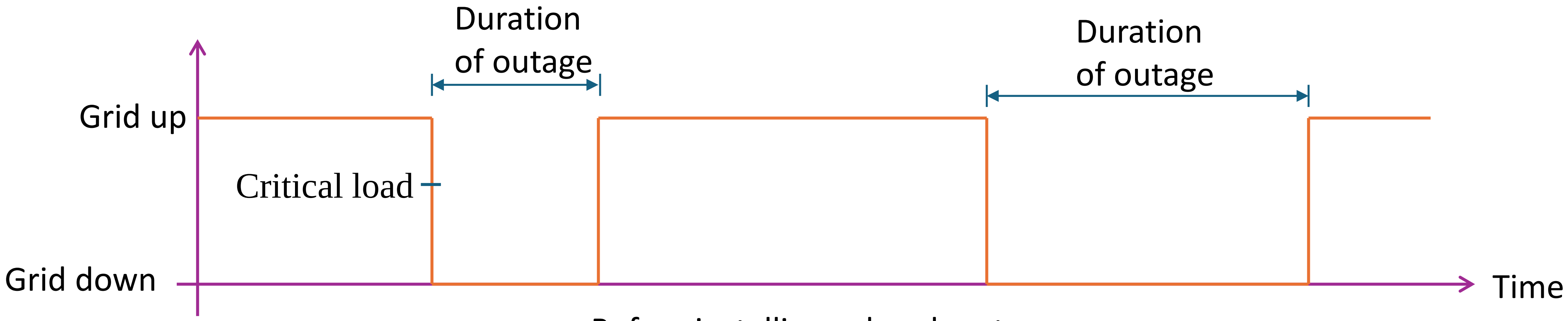
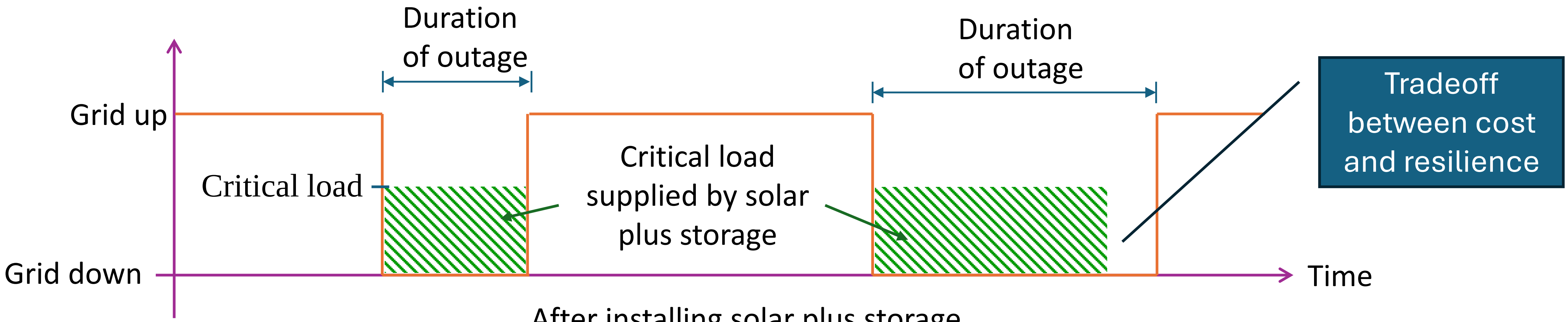
An example of outage event with and without adding solar plus storage



Before installing solar plus storage



After installing solar plus storage

Utility and Community Collaboration

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Prepare
- Utilities: Prepare resources, crews, reserves, etc.
- Communities: Prepare and cooperate with utilities

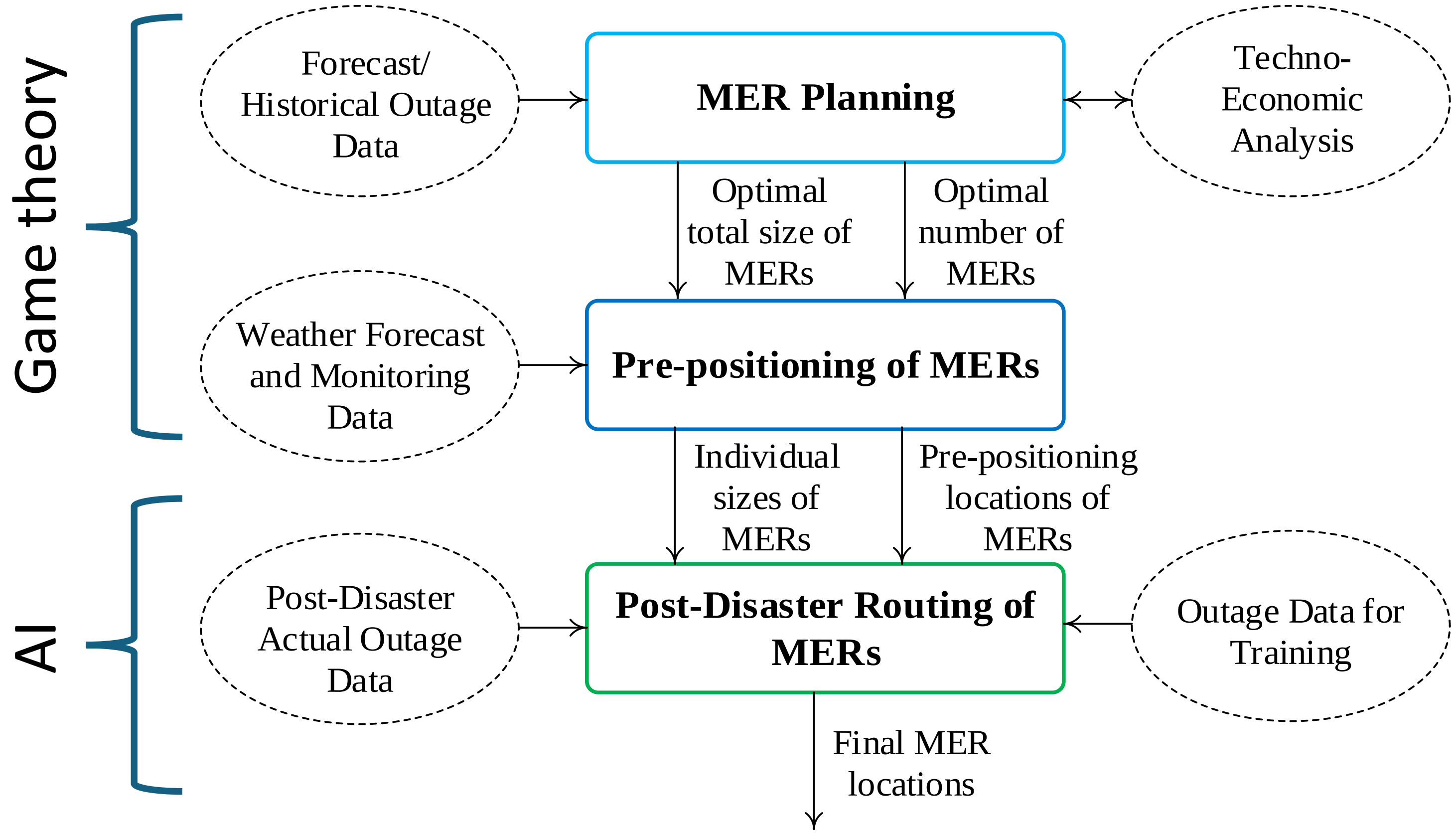
Absorb
- Utilities: Dispatch resources, crews, and prepare for repairs
- Communities: Limit energy usage to critical loads

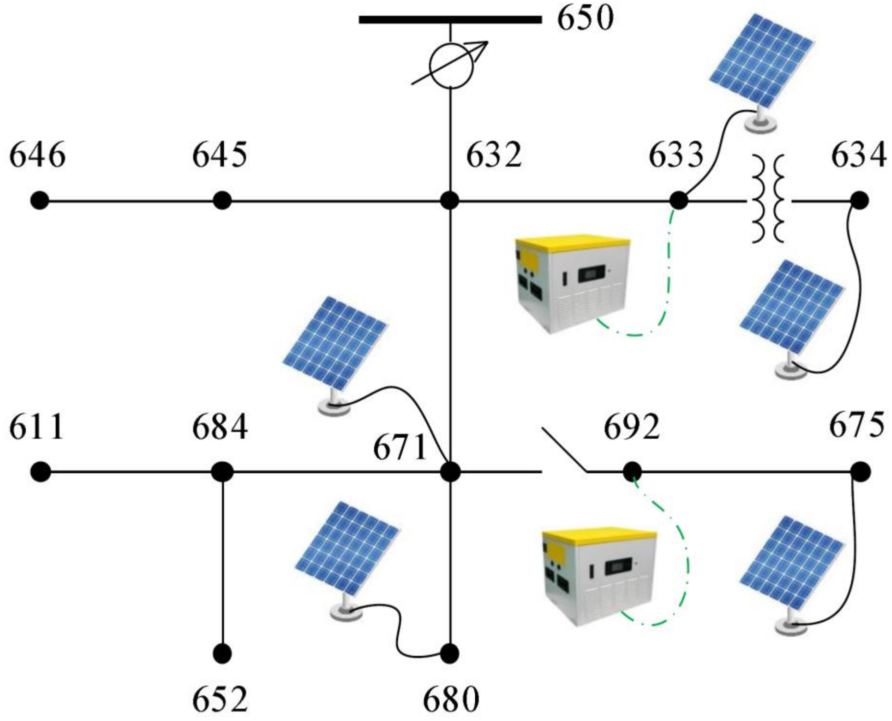
Recover
- Utilities: Service restoration, repair damaged equipment
- Communities: Demand response and return to normal operation

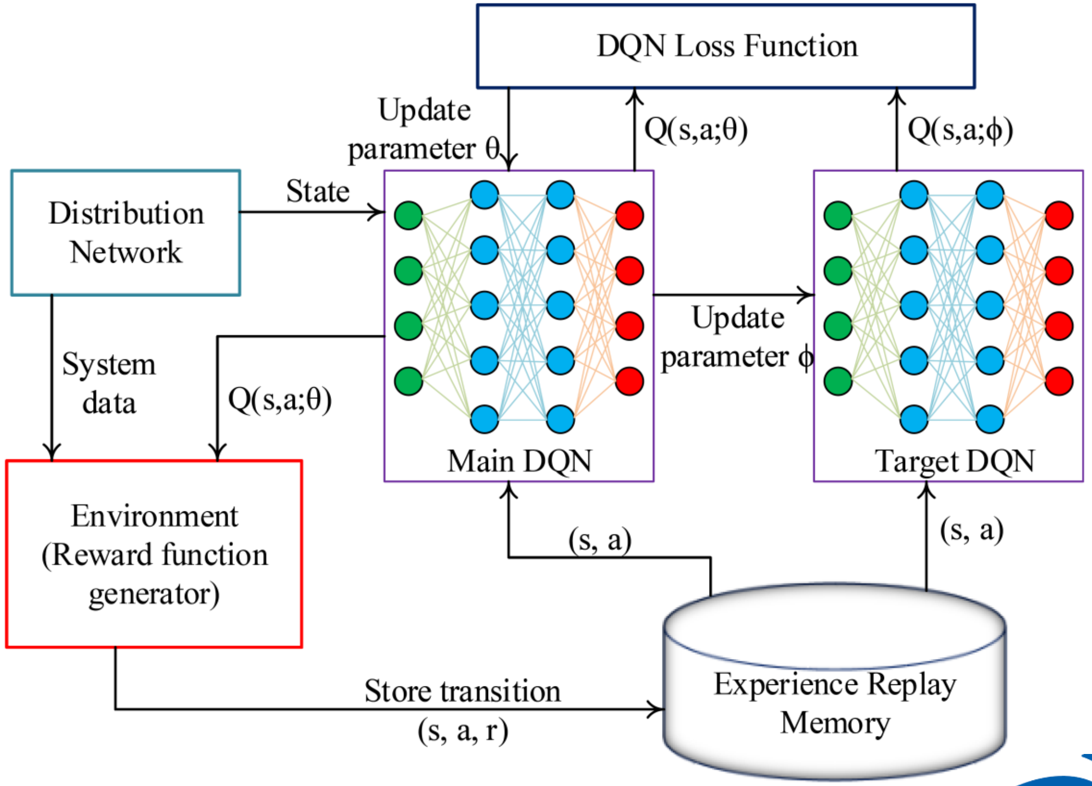
Adapt
- Utilities: Analyze system response and strengthen its resilience
- Communities: Collaborate on ways to strengthen their resilience

Movable Energy Resources (MERs)

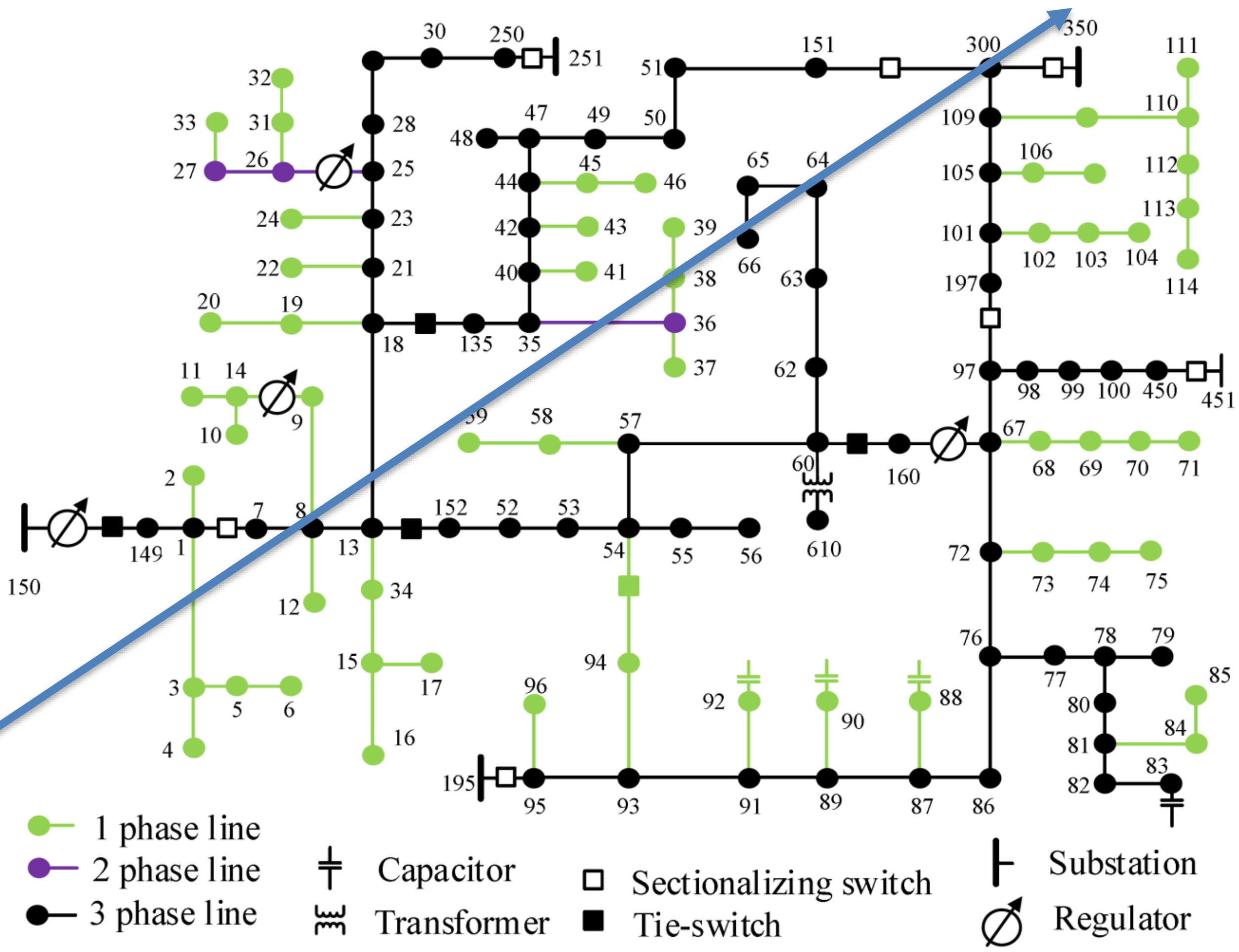
Planning and preparation







Deep Q Network



Movable Energy Resources (MERs)

Recovery Stage

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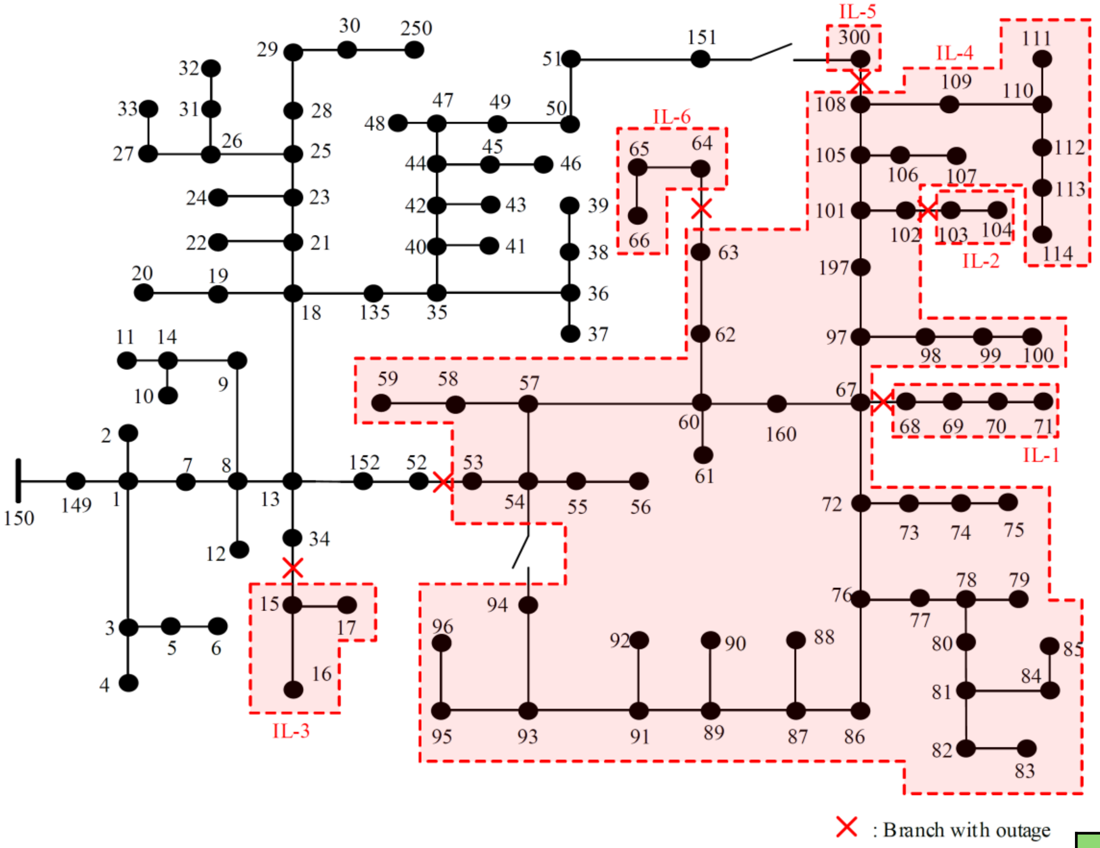
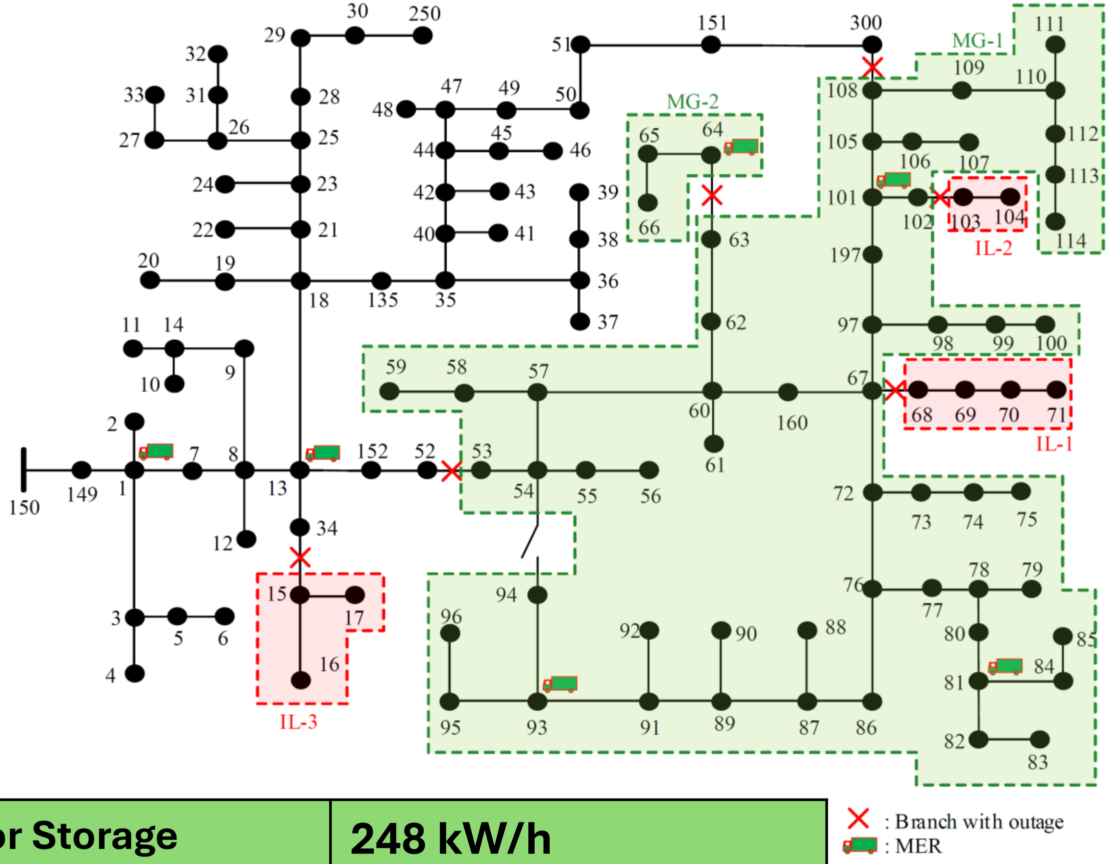
Reconfiguration & Movable Energy Resources



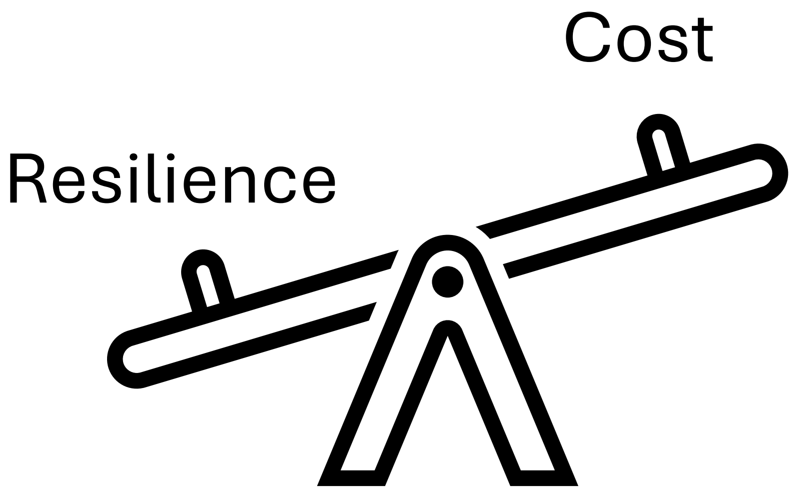


$$\text{Expected Rate of Recovery (EROR)} = \frac{\text{Recovered Load}}{\text{Recovery Time}}$$

Without PV or Storage	**248 kW/h**
With PV and Storage	**683 kW/h**

Takeaway

- Lack of a universal understanding of what resilience is and how it can be adopted in the electricity sector.
- Enhancing grid and community energy resilience has become a necessity not a priority.
- Pending questions for resilience enhancement: value of resilience, what standards to use, and who pays for it.
- Cost of building resilience should be used to compare alternatives not to decide whether to improve the resilience of the power supply
  - ❑ Failure to act will be extremely costly



Tools and Databases

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- **Climate Mapping for Resilience and Adaptation:**
  https://resilience.climate.gov/
- **REopt® techno-economic decision support platform:**
  https://reopt.nrel.gov/
- **National Vulnerability Database:**
  https://nvd.nist.gov/
- **The Interruption Cost Estimate (ICE) Calculator:**
  ICE Calculator
- **PV Watts & SAM**
  https://pvwatts.nrel.gov/https://sam.nrel.gov/
- **MicrogridDesign Tool**
  https://energy.sandia.gov/download-sandias-microgrid-design-toolkit-mdt
- **ReNCATfor resilient community microgrids**
  https://energy.sandia.gov/energy/ssrei/gridmod/resilient-electric-infrastructures/

Thank You

Acknowledgement:

- DOE: Solar Energy Innovation Network (SEIN) Round 2: Quantifying the Resilience Value of Solar Plus Storage
- DOE/SETO: Optimization of Excess Solar and Storage Capacity for Grid Services
- NSF CAREER: Reliability and Resilience Assurance of Cyber-physical Energy Systems

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RESILIENCE METRICS FOR ENERGY SYSTEMS

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U.S. ARMY

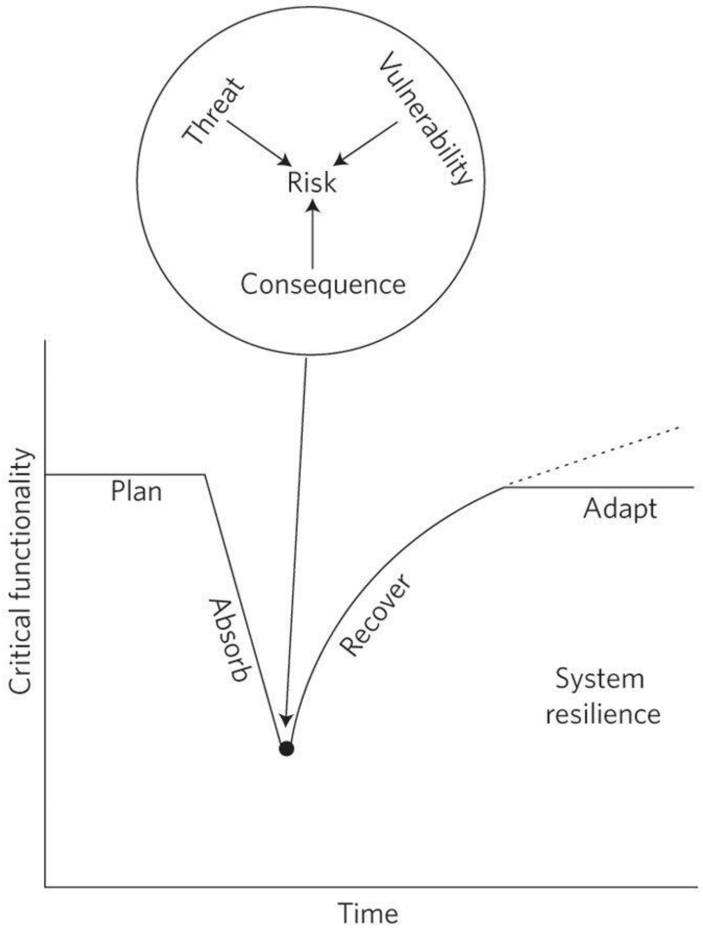
US Army Corps of Engineers®

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

RESILIENCE IS OFTEN CONFLATED WITH CONCEPTS SUCH AS ROBUSTNESS OR RELIABILITY

- Resilience management goes beyond traditional risk assessment by focusing on recovery

- SAIFI/SAIDI and similar reliability metrics hide key problems in resilience
  - Resilience should be threat agnostic – SAIFI/SAIDI only apply to known disruptions
  - SAIFI & SAIDI can hide disparities from energy systems (i.e. long disruptions for small numbers of customers can be washed out)



Comment | Published: 20 October 2021

Building resilience will require compromise on efficiency

Andrew S. Jin, Benjamin D. Trump, Maureen Golan, William Hynes, Martin Young & Igor Linkov

Nature Energy 6, 997–999 (2021) | Cite this article

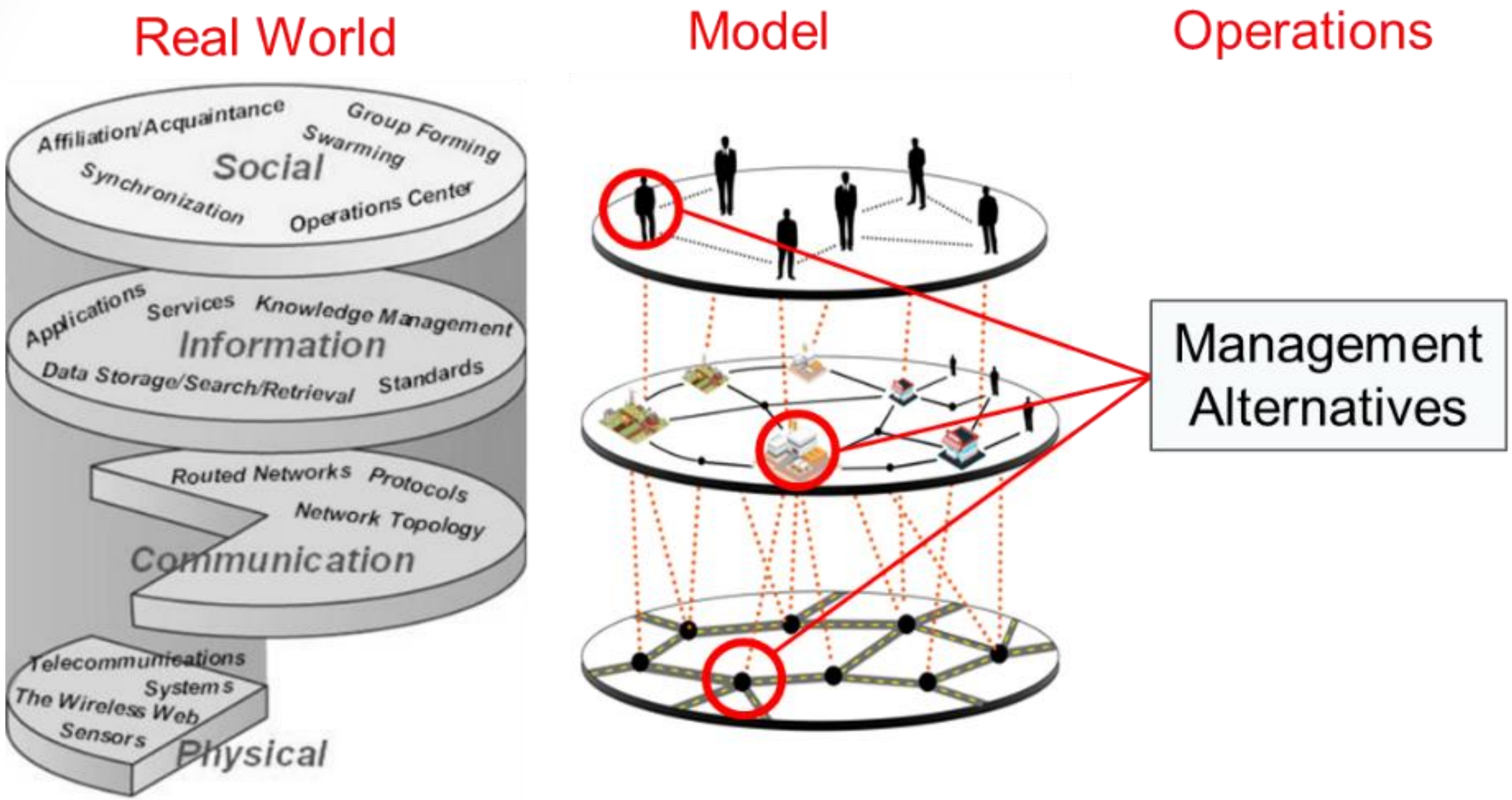
Commentary | Published: 28 May 2014

Changing the resilience paradigm

Igor Linkov, Todd Bridges, Felix Creutzig, Jennifer Decker, Cate Fox-Lent, Wolfgang Kröger, James H. Lambert, Anders Levermann, Benoit Montreuil, Jatin Nathwani, Raymond Nyer, Ortwin Renn, Benjamin Scharte, Alexander Scheffler, Miranda Schreurs & Thomas Thiel-Clemen

Nature Climate Change 4, 407–409 (2014) | Cite this article

A VISION FOR ENERGY SYSTEMS RESILIENCE



The case for value chain resilience

Igor Linkov, Savina Carluccio, Oliver Pritchard, Áine Ní Bhreasail, Stephanie Galaitsi, Joseph Sarkis and Jeffrey M. Keisler

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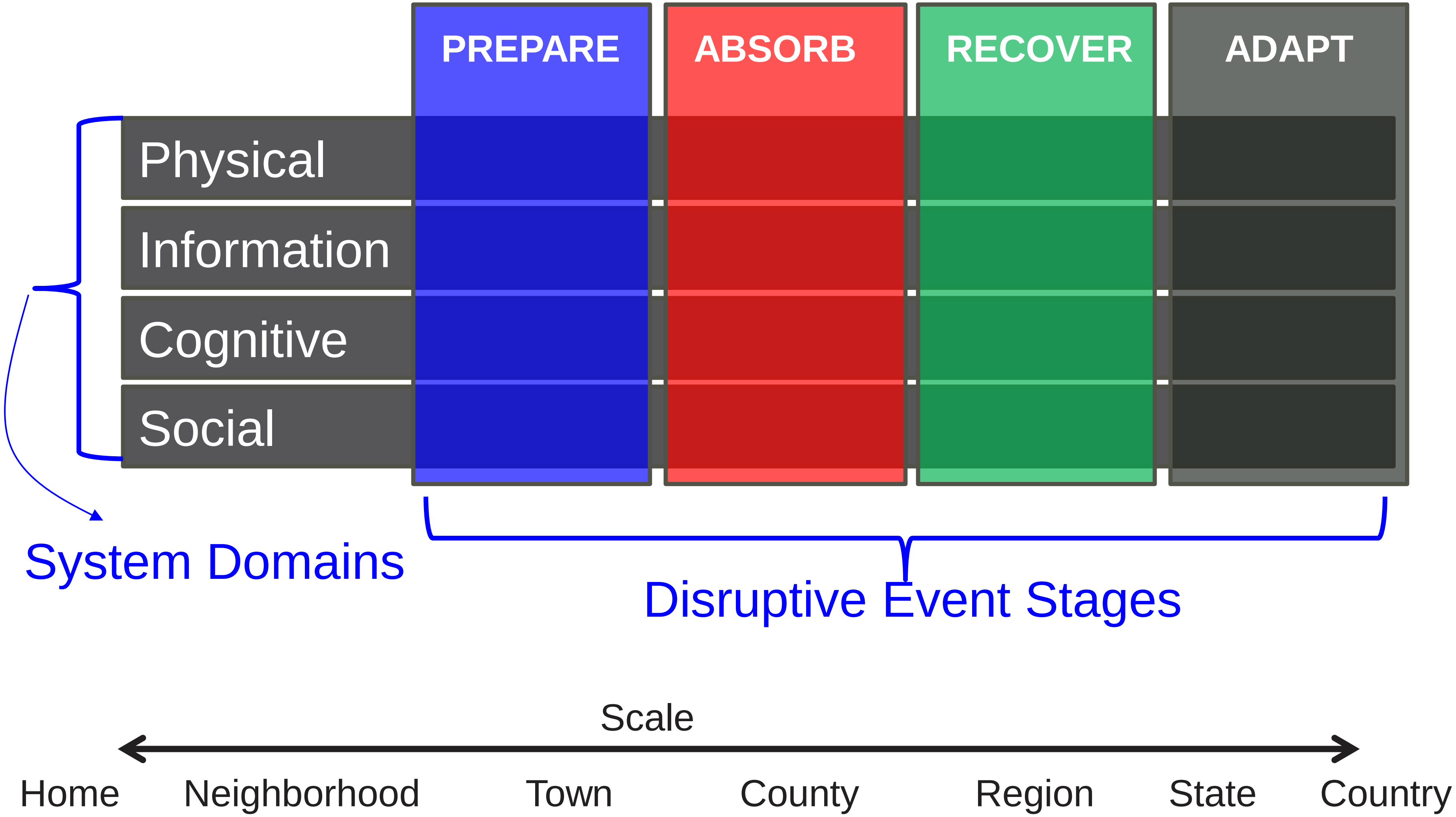
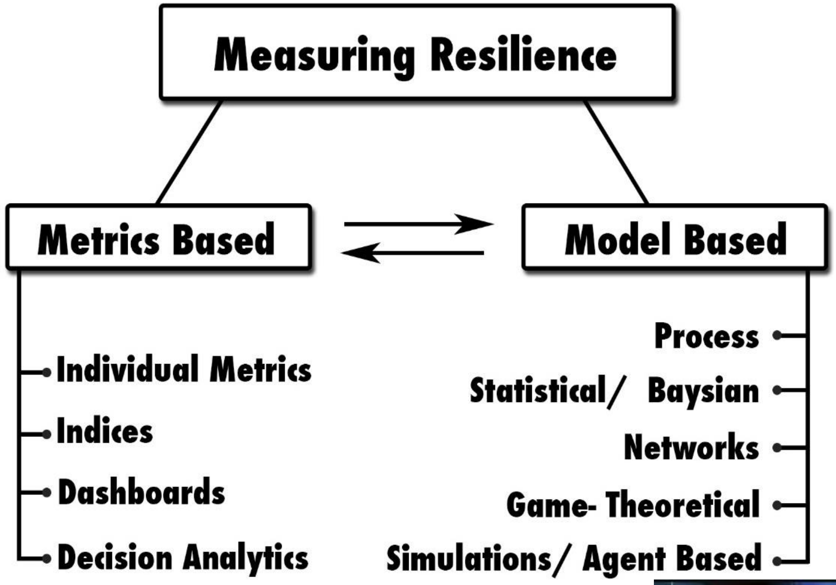
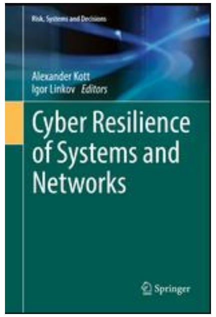
RESILIENCE MATRIX APPROACH FOR METRIC DEVELOPMENT



SPECIFIC MEASURABLE INDICATORS CAN BE INTEGRATED TO RESILIENCE ACROSS VARIOUS TEMPORAL AND OPERATIONAL DOMAINS

	Plan and Prepare for	Refs	Absorb	Refs	Recover from	Refs	Adapt to	Refs
Physical	Reduced reliance on energy/increased efficiency	A,B, E,F, H	Design margin to accommodate range of conditions	B,C, I,J,K	System flexibility for reconfiguration and/or temporary system installation	C,D, F,H, K	Flexible network architecture to facilitate modernization and new energy sources	C,D, F,K
	Energy source diversity/ local sources	A,E, F,H, K	Limited performance degradation under changing conditions	B,C, F,I,K	Capability to monitor and control portions of system	B,I, K	Sensors, data collection and visualization capabilities to support system performance trending	D,E, I,K
	Energy storage capabilities/ presaged equipment	B,H, K	Operational system protection (e.g., pressure relief, circuit breakers)	I,K	Fuel flexibility	C,D, E,F	Ability to use new/alternative energy sources	C,F, H
	Redundancy of critical capabilities	D,E, I,K	Installed/ready redundant components (e.g., generators, pumps)	D,I, K	Capability to re-route energy from available sources	C,D, F,I,K	Update system configuration/ functionality based upon lessons learned	C,D, L,F,I, K
	Preventative maintenance on energy systems	I,K	Ability to isolate damaged/ degraded systems/ components (automatic/ manual)	E,I,K	Investigate and repair malfunctioning controls or sensors	I	Phase out obsolete or damaged assets and introduce new assets	A,C, D,I, K
	Sensors, controls and communication links to support awareness and response	H,I, K	Capability for independent local/sub-network operation	D,K	Energy network flexibility to re-establish service by priority.	F,I,K	Integrate new interface standards and operating system upgrades	D,I, K
	Protective measures from external attack (physical/ cyber)	A,D, I,K	Alternative methods/ equipment (e.g., paper copy, flashlights, radios)	B,H, K	Backup communication, lighting, power systems for repair/recovery operations	I,K	Update response equipment/ supplies based upon lessons learned	D,I
Information	Capabilities and services prioritized based on criticality or performance requirements	B	Environmental condition forecast and event warnings broadcast	E,H, I	Information available to authorities and crews regarding customer/community needs/ status	D,I	Initiating event, incident point of entry, associated vulnerabilities and impacts identified	A,D, H,I, K
	Internal and external system dependencies identified	B,G, H	System status, trends, margins available to operators, managers and customers	D,E, H,I, K	Recovery progress tracked, synthesized and available to decision-makers and stakeholders	D,I	Event data and operating environment forecasts utilized to anticipate future conditions/ events	D,H, I,K
	Design, control, operational and maintenance data archived and protected	B,I	Critical system data monitored, anomalies alarmed	D,E, I,K	Design, repair parts, substitution information available to recovery teams	K	Updated information about energy resources, alternatives and emergent technologies available to managers and stakeholders	D,F, H,I
	Vendor information available	B	Operational/troubleshooting/ response procedures available	I,K	Location, availability and ownership of energy, hardware and services available to restoration teams	K	Design, operating and maintenance information updated consistent with system modifications	F,I,K





Energy Policy
Volume 72, September 2014, Pages 249-256

Short Communication

Metrics for energy resilience

Paul E. Roege [a], Zachary A. Collier [b], James Mancillas [c], John A. McDonagh [c], Igor Linkov [b]

THERE ARE NUMEROUS COMMUNITY RESILIENCE METRICS WITH NO ONE SIZE FITS ALL SOLUTION

NIST Technical Note 2172

A Review of Community Resilience Frameworks and Assessment Tools: An Annotated Bibliography

>7,000 Individual Indicators → 56 Community Resilience Frameworks →

Mapping the indicators to the resilience matrix can show some gaps in existing resilience methodologies

		Absorb			Recover			Adapt		
		Physical	Information	Social	Physical	Information	Social	Physical	Information	Social
Agency	**Program**									
DHS	Building Resilient Infrastructure and Communities (BRIC)	F, T	G, T	G			G	G		
	Flood Mitigation Assistance (FMA) (97.029)	F, T	T							
	Hazard Mitigation Planning		G							
	National Flood Insurance Program (NFIP)				F					
	Public Assistance Grant Program				F			F		
	Rehabilitation of High Hazard Potential Dams Grant Program	T	T							
	National Dam Safety Program (97.041)	T, F, G	T, F, G	T, F, G						
DOC	Lake Level Viewer		G							
	National Coastal Resilience Fund (11.419)									
	Sea Level Rise Viewer		G							
	National Coastal Zone Management Program (11.419)	F	F					F		
DOI	Flood Inundation Mapping Program		G							
HUD	Community Development Block Grant - Disaster Recovery (CDBG-DR)							F,T	F,T	F,T
	Community Development Block Grant Mitigation (CDBG-Mit)	F	F	F						
USACE	Emergency Preparedness, Response and Recovery (PL 84-99)	T	T, G	T	T, G	T, G				
	National Flood Risk Management Program / Silver Jackets Program		T	T, G		G	G		T, G	
	Continuing Authorities Program (CAP)	T								
	Floodplain Management Services Program		T, G							
	Planning Assistance to States (PAS)		T			T			T	
	Specifically Authorized Projects (General Investigations Program)							G, T		
USDA	Emergency Watershed Protection (EWP) & Floodplain Easement Program (EWP-FPE) (10.923)				F, T			F, T		
	Watershed Rehabilitation (REHAB) Program (10.916)	F, T						F, T		

Ellinport et. Al (In preparation)

USACE RESILIENCE MATRIX METHODOLOGY: APPLICATION TO COMMUNITIES

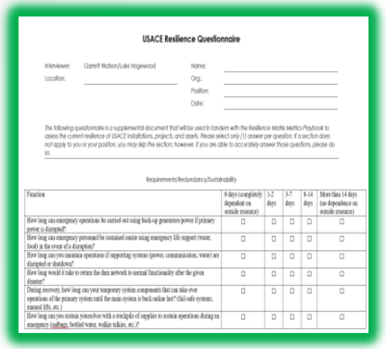
Resilience Matrix

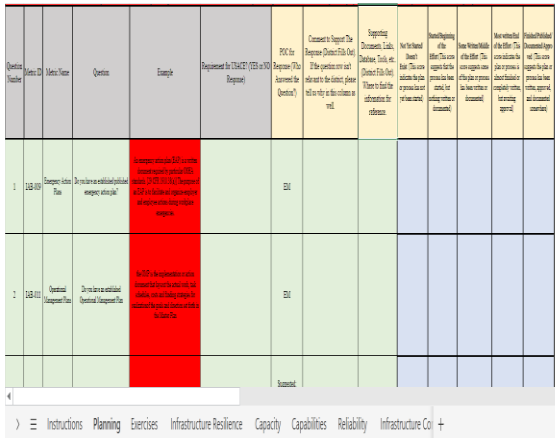
	Absorb	Recover	Adapt
Physical	System Performance/Functionality System Reliability Robustness Consequences of failure System Vulnerability Hazard Mitigation Measures Redundancy Back-up Systems Emergency Resources	Recovery Time Temporary Facilities Recovery Resources	Adaptive Capacity Infrastructure Condition Modularity
Information	Failure Detection Systems Hazard Forecasting Risk Assessment/Data Emergency Planning Mitigation Planning Disaster Propagation Models	Recovery Tracking Data Models for Recovery Scenarios Recovery Planning	Post-disaster data collection Adaptation Planning Plan Improvements
Social	Emergency Staffing Emergency Support Agreements Community Communication Staff Emergency Training	Community Recovery Assistance Contractor Agreements Recovery Agreements	Training Exercises Community Education Improved Legislation

Master Metrics

Metric Identification and Categorization						Me	
Metric Name	Unit of Analysis	System Doma	Resilience Phas	Metric Category	Critical Function	Measure Full Name	Level of Detail
Risk Assessment Score	Capability	Physical	Absorb	System Vulnerability	FRM	Score from most recent Risk Assesment	Tier 2
Last Inspection Date	Capability	Information	Absorb	Risk Assessment	FRM	Years since the most recent comprehensive inspection of the dam	Tier 2
Last EAP Revision	Capability	Information	Adapt	Planning Improvements	FRM	Years since the most recent revision to the emergency action plan (EAP)	Tier 2
Last EAP Exercise	Capability	Social	Adapt	Training Exercises	FRM	Years since the most recent EAP exercise	Tier 2
Worst Case Consequences Estimate	Capability	Physical	Absorb	Consequences of Failure	FRM	Estimated economic cost for the worst-case dam failure scenario (Maximum High Pool - Breach)	Tier 2
Operations Plans	Capability	Information	Absorb	Mitigation Planning	FRM	Degree (1-5) of completeness of operations plan	Tier 1
Planning Review	Capability	Information	Adapt	Planning Improvements	FRM	Years since the most recent review and update of the operations plans	Tier 2
Emergency Exercises	Capability	Social	Adapt	Training Exercises	FRM	Years since the most recent emergency operation test exercise (or most recent emergency response)	Tier 2
After-Action Reports	Capability	Information	Adapt	Post-disaster Data Collection	FRM	% of exercises/events in the past 5-10 years where an after-action report was generated and reviewed by the district	Tier 2

Solicitation Template





Scorecard

	Absorb	Recover	Adapt
Physical	3.8	5.0	3.5
Information	4.4	3.8	4.4
Social	3.7	5.0	5.0

SRB-FRM Case Study

Measuring USACE Resilience in the Savannah Basin – manuscript for peer review

The Savannah Watershed serves as a critical component, crucial to the well-being of numerous communities and ecological systems. Leading in the maintenance of this significant resource is the United States Army Corps of Engineers (USACE). With an established history in water resource management, the USACE is responsible for executing a range of essential missions within the watershed. These include flood risk management, hydropower generation, aquatic ecosystem restoration, water supply, navigation infrastructure maintenance, and recreational land-use. This paper aims to examine the various roles of the USACE to guarantee mission assurance in this critical region. It places particular emphasis on the collaborative efforts between the USACE, local governance, and various stakeholders.

USACE Report

A Resilience Matrix Approach

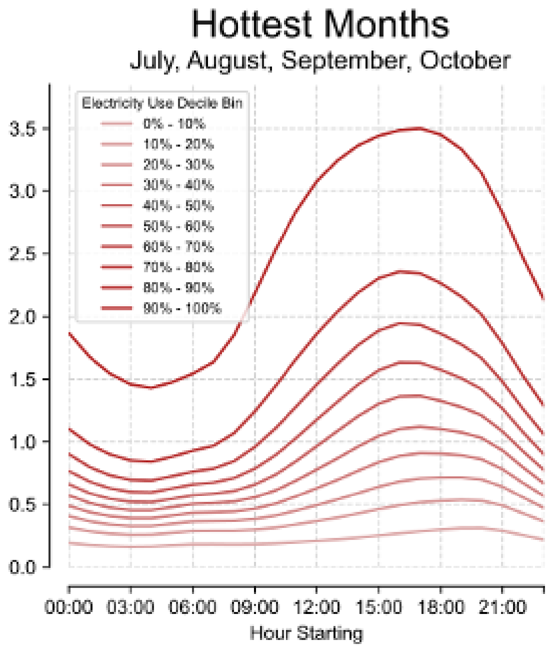
to USACE MISSION in the Savannah Watershed

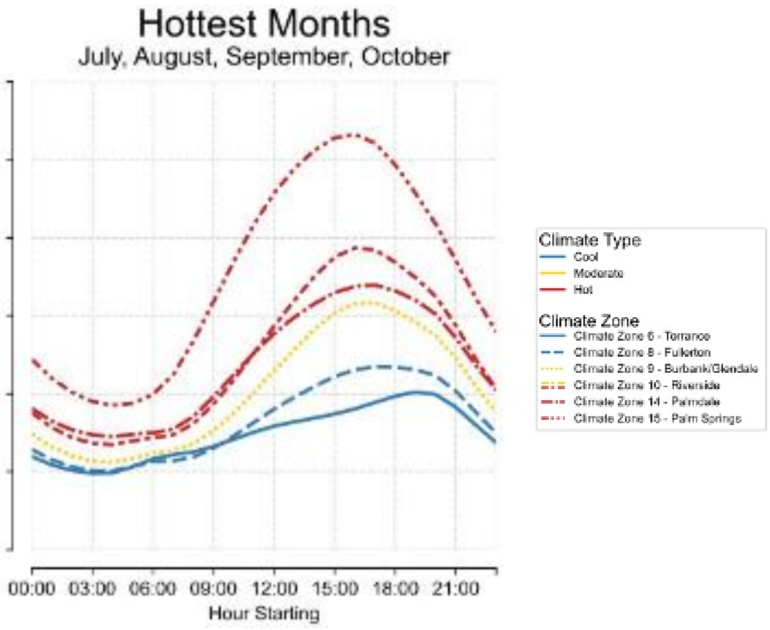
Academic Literature Review → Restructuring of Resilience Matrix → Development of Decision Support Tool → USACE Document Review → Development of Master Metrics → Development of Solicitation Survey → Development of Resilience Scorecard → Conducting/ Writing FRM Case Study → Compiling/ Writing Report on USACE Resilience →

Development of a documented/published methodology for a transferrable/replicable process that provides a cost effective and accurate procedure that can be used to assess USACE and Community Resilience from infrastructure, to critical function, to mission.

NEW DATA TOOLS LIKE SMART METERS CAN IMPROVE RESILIENCE THROUGH DEMAND-SIDE MANAGEMENT

- New technologies such as smart meters can provide better insight into resilience by capturing how people use energy diurnally
- Real-time data methods to detect anomalies (Resilient-by-Intervention), or to correctly sizing resilient systems.
- Can give insight into behavioral patterns on different classes of users to improve planning for resilience needs





CONNECT WITH US

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LinkedIn

YouTube

BEYOND the GATES

How ERDC makes the difference

Scan this QR code with your phone for instant access

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US Army Corps of Engineers®

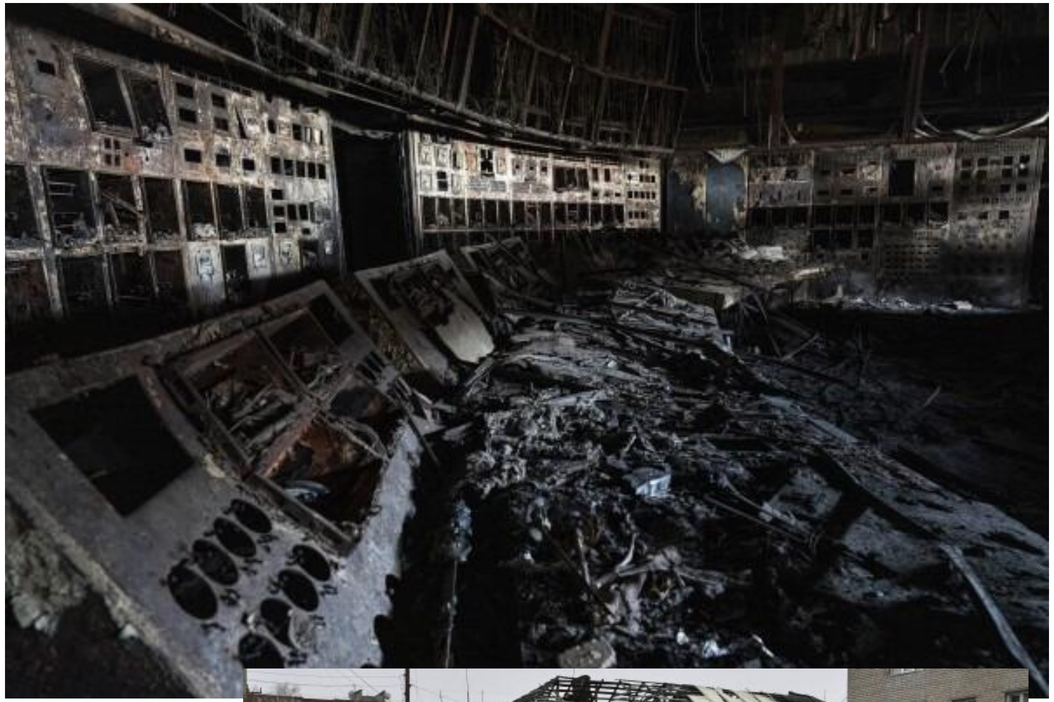
ERDC

ENGINEER RESEARCH & DEVELOPMENT CENTER

UKRAINE ENERGY RESILIENCE

ERDC

- Russia has systematically attacked the transmission network of the Ukrainian energy grid
- Resources such as distributed solar and batteries have been critical to maintaining both civil and military operations during current rolling blackout operations



Funded by U.S. Department of Energy – Solar Energy Technology Office (SETO)

RACER – Virginia Economically Disadvantaged Communities Energy Resilience Study (VER)

Ryan Dorland, Ph.D. – Economic Development & Energy Analyst
ryan.dorland@energy.virginia.gov

Project E-mail: resilience@energy.virginia.gov

Virginia Energy

VIRGINIA STUDY

<u>Project Lead:</u>
Virginia Department of Energy

<u>Project Subrecipients</u>:

- The Center for the Advancement of Sustainable Energy at JMU
- Resilient Virginia
- Clean Energy States Alliance
- Solar Workgroup of Southwest Virginia
- Virginia Clean Cities

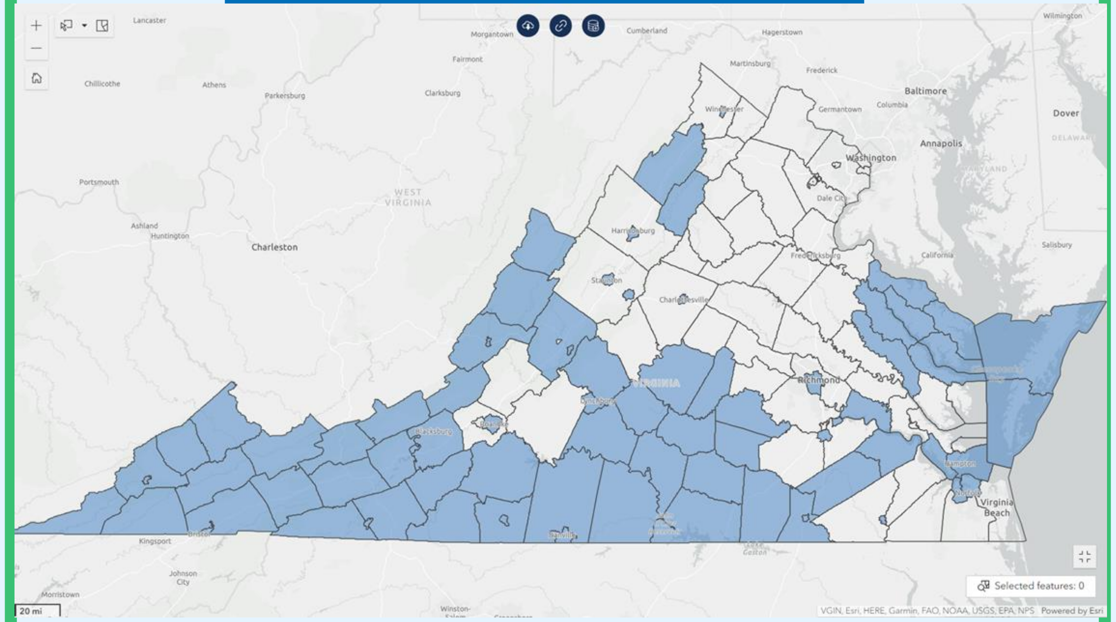
Project period: 2023-2025

VIRGINIA STUDY

WHAT ARE WE DOING?

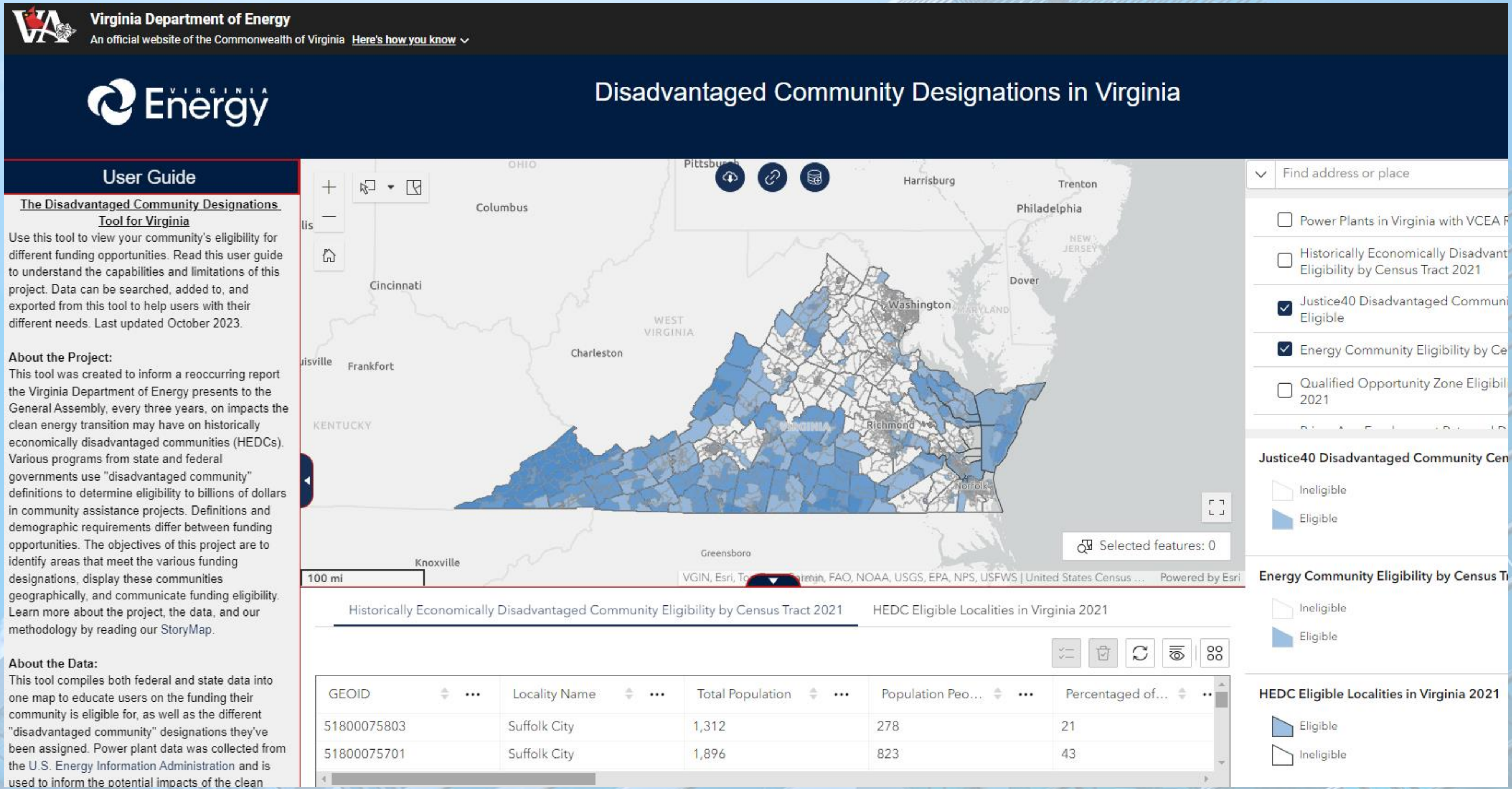
- Developing community-based **energy resilience metrics** with the help of 15 communities (2024)
- Conducting 35 additional energy resilience assessments in Historically Economically Disadvantaged Communities (HEDCs) in Virginia (2025).
- Deliver energy resilience plans supported by **10 case studies (resilience hub designs)** that will incorporate **solar plus storage**.

WHO WILL IT HELP?



HEDC counties & cities in Virginia.
Census tracts and towns may be eligible in gray-shaded counties.
GIS tool developed to guide project.

NOTE: PICTURE SHOULD BE CHANGED TO GO WITH YOUR SPECIFIC PRESENTATION



Please visit our site for more details!

VIRGINIA Energy

VIRGINIA ENERGY RESILIENCE

METRIC DEVELOPMENT

FRAMEWORK

Our project is not about evaluating the resilience of a physical energy system.
It is about how resilient communities are when they lose electric power.

- **Basic Community Profile**
- **Hazard Exposure and Risk Assessment**
- **Capability and Resilience Analysis**
- **Impact Assessment**
- **Potential Solutions**

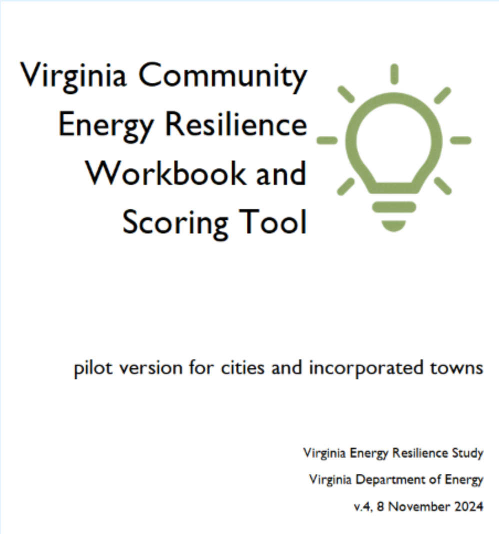
EXISTING METRICS

Additional metrics and tools used to assess community energy resilience:

- Census Demographic Data
- FEMA Resilience Analysis Planning Tool
- FEMA Disaster Declarations for States and Counties
- FEMA National Risk Index
- CDC Social Vulnerability Index
- LBL Power Reliability Event Simulation Tools (PRESTO)
- CAIDI, SAIFI, SAIDI
- US DOE Low-Income Energy Affordability Tool (LEAD)
- NOAA Climate Mapper
- HHS emPOWER map
- Rural Capacity Index
- Census, Community Resilience Index for Heat
- Census, American Community Survey data

METRIC DEVELOPMENT

INCORPORATING COMMUNITIES


Virginia Community Energy Resilience Workbook and Scoring Tool

pilot version for cities and incorporated towns

Virginia Energy Resilience Study
Virginia Department of Energy
v.4, 8 November 2024

COMMUNITY INVOLVEMENT

.

Phase I – 2024 Outreach Goals

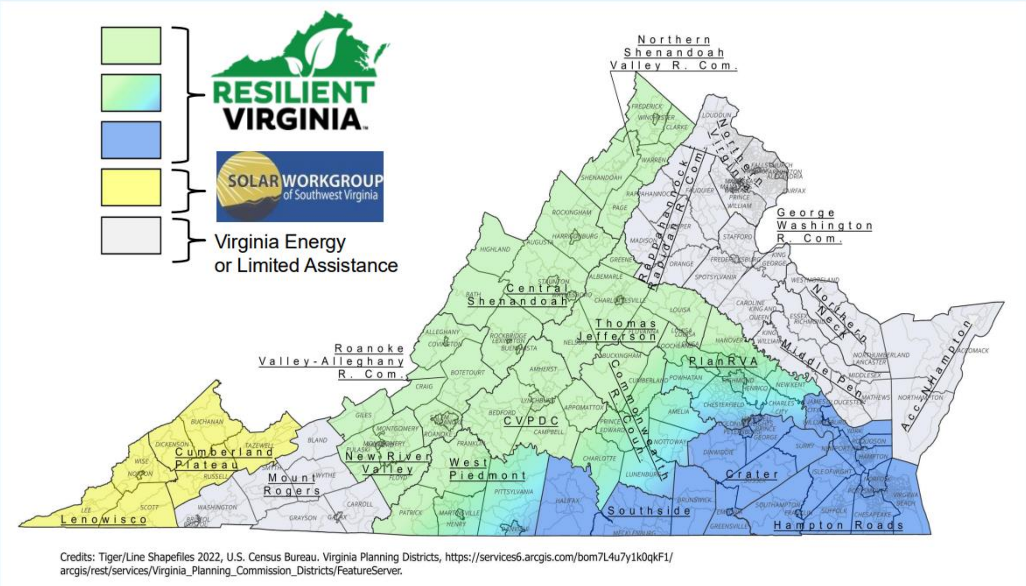
Goal One: Determine if/where energy or other resilience planning efforts are taking place and strategically work with them for outreach, engagement, and stakeholder recruitment.

Goal Two: Develop a list of key cross-sector stakeholders across HEDCs who can serve as advocates and project participants.

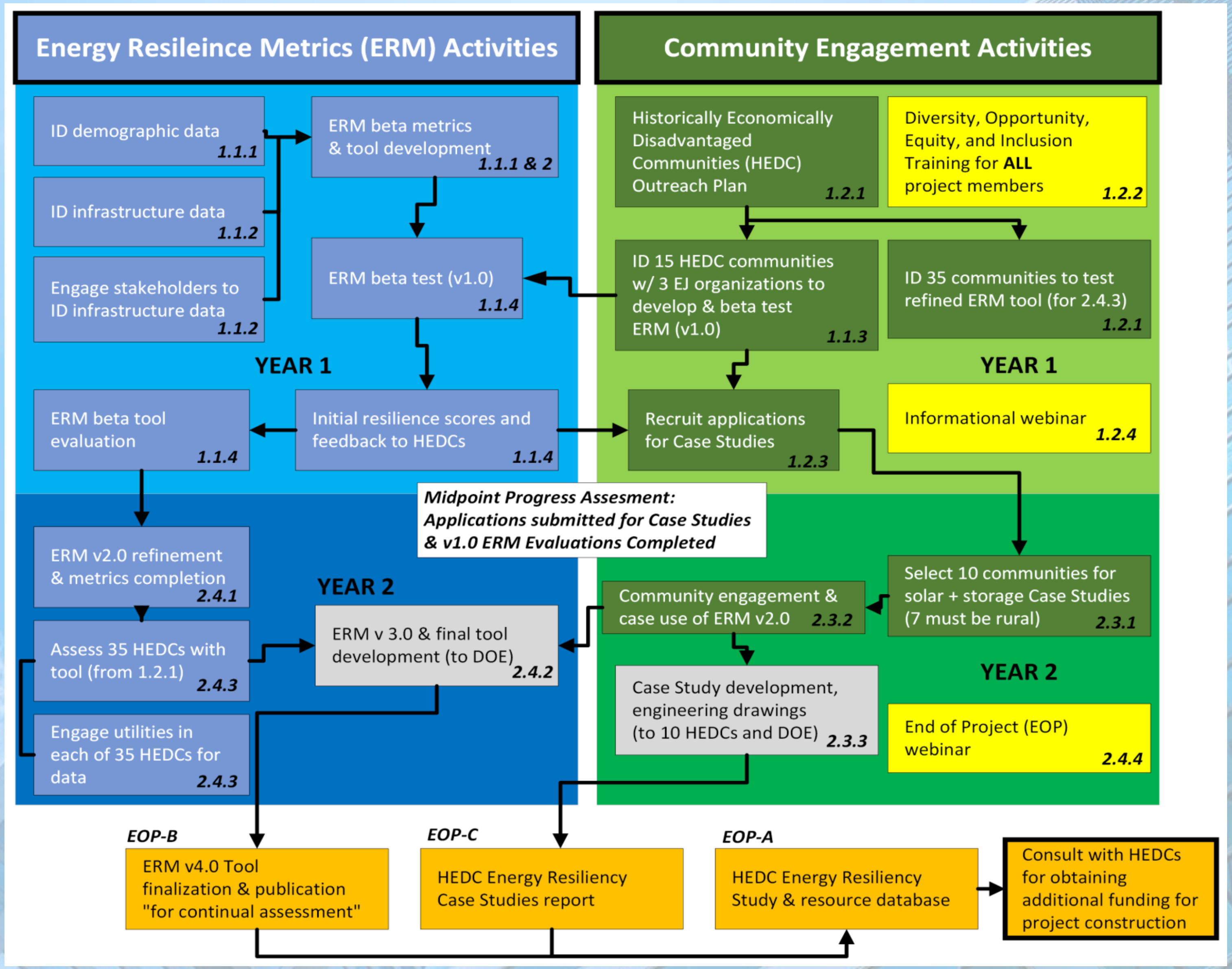
Goal Three: Share information about and create opportunities for participation in the Virginia Energy Resiliency Study project (VER).

Goal Four: Incorporate the views and perspectives of stakeholders into project deliverables.

OUTREACH BY CBOS



CBO Partners Engaged in Outreach



Task 1: Development of Energy Resiliency Metrics

Task 2: HEDCs Identification and Outreach

Task 3: Case Study (Resilience Hub) Development

Task 4: Refinement of ERM and Evaluation of 35 HEDCs

VIRGINIA Energy

THANK YOU!

For questions or more information on participation or materials, please contact Virginia Energy at resilience@energy.virginia.gov

Follow us!

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Solar and DERs Enhancing Community Energy Resilience

- **Marriele Mango**, Project Director, Clean Energy Group
- **David Wright**, VP of Energy Programs, Groundswell
- **Andrea Mammoli**, Principal Member of Technical Staff, Sandia National Lab

Community-Centered Energy Resilience
Advancing Battery Storage in Underserved Communities

Marriele Mango, Project Director

November 2024

CleanEnergyGroup

CleanEnergyGroup

Affordable, reliable, clean energy for all.

Climate Resilience and Community Health

Distributed Energy Access and Equity

Energy Storage and Flexible Demand

Fossil Fuel Replacement

www.cleanegroup.org

Equitable Solar Communities of Practice

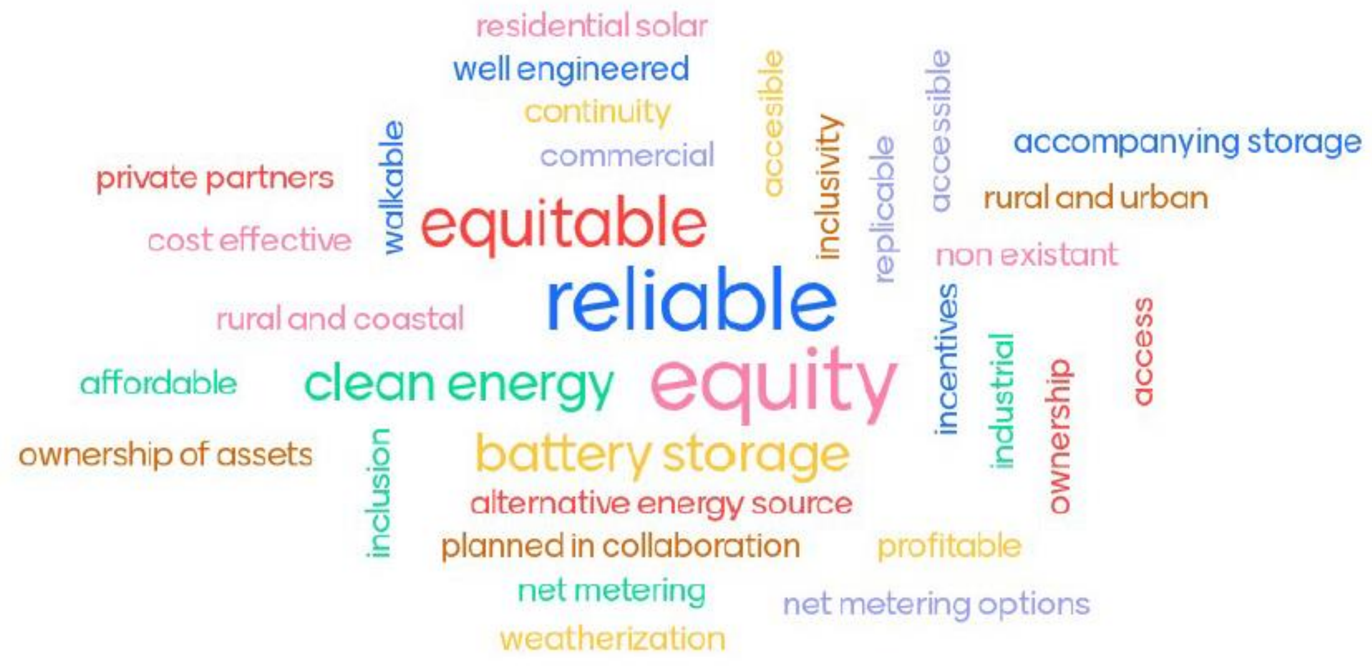
Clean Energy Group was the lead organization for the Department of Energy, Solar Energy Technologies Office **"Resilience, Storage and Grid Benefits"** Equitable Solar Communities of Practice, with **six Core Team members** from the following mission-aligned organizations:

Key Term: Community-Centered Energy Resilience

Community-centered energy resilience is a **comprehensive model** of renewable and resilient power development that includes **energy justice** principles in the development of solar paired with battery storage systems.

The community is involved in the **development, ownership, and benefits** (economic and otherwise) of the project.

Community-Centered Energy Resilience in the communities I work with/serve includes...

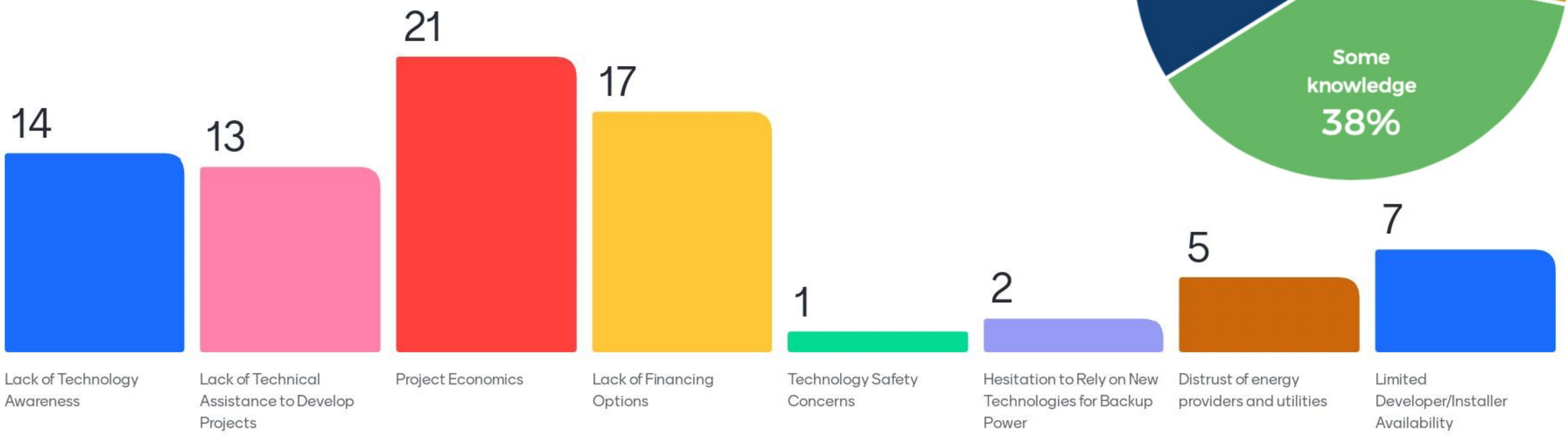


The above graphic resulted from participant input during Clean Energy Group's virtual Community Convening.
Source: Clean Energy Group/Mentimeter

Barriers

- Pre-Development Support
- Economic Feasibility

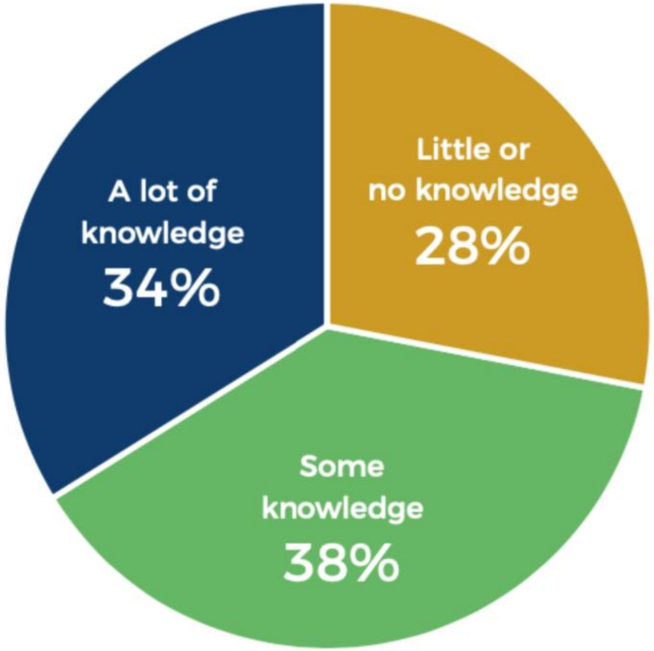
Top Barriers to Developing Solar & Storage at Community Facilities



Source: Community Convening, Webinar, Clean Energy Group and Department of Energy

Level of Existing Knowledge of Solar and Storage Technologies

Source: Technical Assistance Fund Exit Survey, Clean Energy Group, 2021 - 2023



Key Takeaway: Optimize Value of Resilience Framework for Community-Led Energy Resilience

Prioritize Public Health

Design programs that meet the needs of the most vulnerable in the event of a power outage. Customers reliant on electricity-dependent medical equipment will benefit the most from reliable backup power.

Savings for All Ratepayers

Utilities can utilize grid services and virtual power plant models through aggregation of participating batteries and reduce costs for ratepayers.

Bolster Grid Resilience

By strategically deploying storage during times of high demand, utilities can successfully avoid brownouts and blackouts. Incentivize participation in vulnerable areas of the grid.

Reduce Carbon Emissions

Battery storage programs designed to charge from the grid during times of high renewable curtailment and deploy during high demand times reduce the need for fossil fuel burning peaking resources.

Reduce Energy Burdens

Historically marginalized communities have the highest energy burdens. Solar and battery storage can reduce utility costs, and ratepayer expenses.

Key Takeaway: Prioritize Technical Assistance

Program Highlight: Technical Assistance Fund

Location: Nationwide

Organization: Clean Energy Group

Overview: One-on-one tailored technical assistance and small grant awards to support solar paired with battery storage feasibility assessments for community-serving facilities.

Technical assistance funding spurs larger investment. Every Technical Assistance Fund dollar invested in early-stage support has activated, on average, $127 in external capital to install solar and battery storage.

Obstacles to Scale: Requires significant internal capacity, both to manage day-to-day operations and ensure outreach is sufficient in reaching the organizations that would most benefit from the program. Demand exceeds funding available.

Source: Clean Energy Group

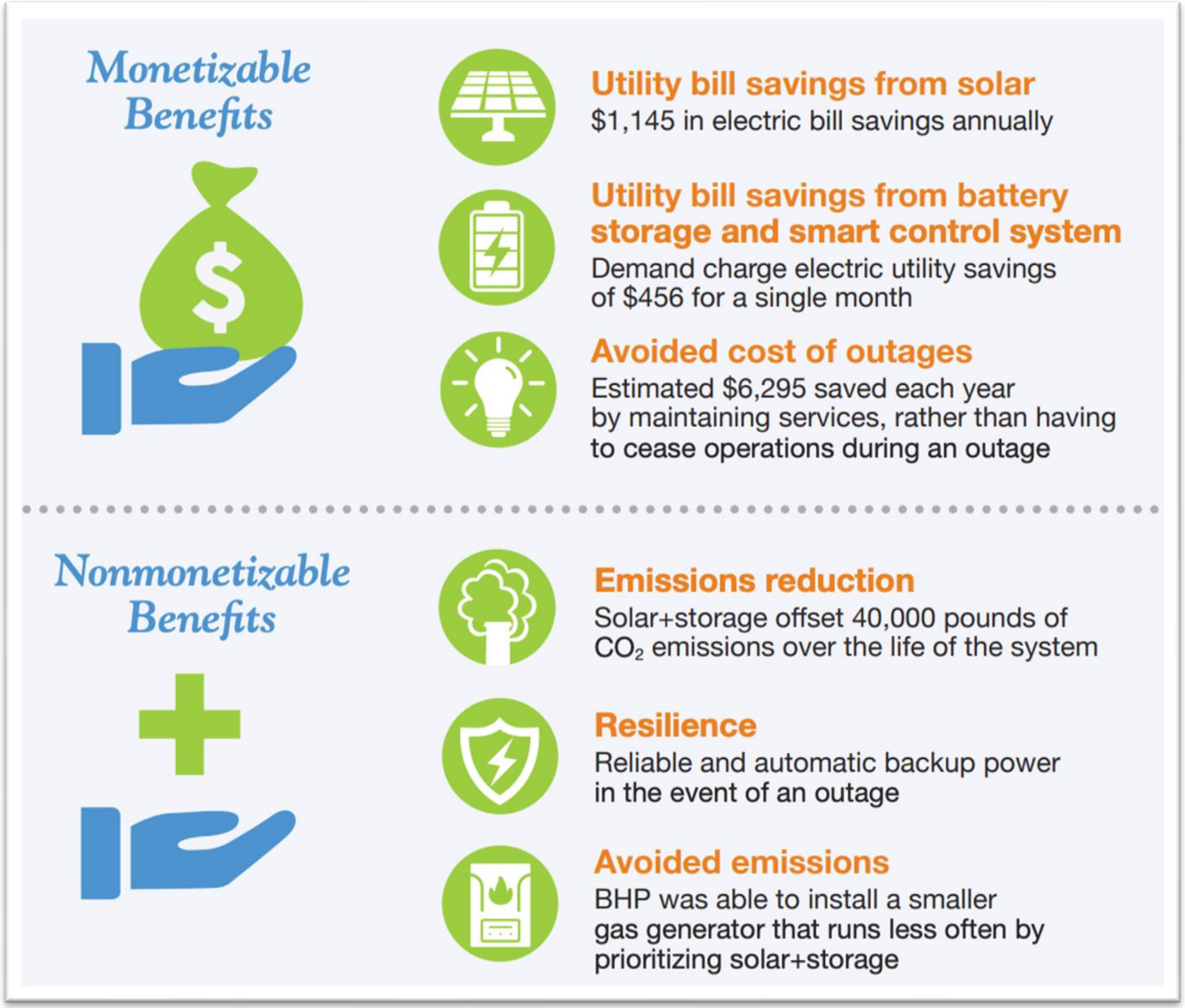
Case Study: Boulder Housing Partners

Boulder Housing Partners is the leading affordable housing provider for the City of Boulder and provides command-post services to over 3,000 low-income residents during emergencies.

System: 20.67-kW solar system and 45-kWh lead acid batteries

Additional Backup: 6-kW natural gas/propane generator

Resilience: 12+ hours backup power to headquarters and EV chargers (longer with gas generator)



Case Study: California Indian Museum and Cultural Center

The California Indian Museum & Cultural Center (CIMCC) is a vital hub for 24 Tribes and over 25,000 Native American people across Sonoma, Lake, and Mendocino Counties.

System: 76.5-kW solar system and a 220-kWh lithium-ion battery storage system

Resilience: 72-hours of backup power to cooling center,air filtration system, kitchen (with refrigeration), community space, lighting, and outlets for charging

Obstacles: Finding a contractor to install the battery, accessing incentives, and interconnection.

"Our technical assistance grant from Clean Energy Group supported our efforts to verify the feasibility of our Resilient Native Generations project. In serving our local tribal community, it is critical that we implement strategies that provide environmental and cultural resource protection and emergency response during wildfires and power outages."

- Nicole Lim, Executive Director, CIMCC

Marriele Mango
Project Director
Clean Energy Group
Marriele@cleanegroup.org

Clean Energy Group (CEG) is a national nonprofit that works to accelerate an equitable and inclusive transition to a resilient, sustainable, clean energy future. CEG fills a critical resource gap by advancing new energy initiatives and serving as a trusted source of technical expertise and independent analysis in support of communities, nonprofit advocates, and government leaders working on the frontlines of climate change and the clean energy transition. CEG collaborates with partners across the private, public, and nonprofit sectors to accelerate the equitable deployment of clean energy technologies and the development of inclusive clean energy programs, policies, and finance tools.

CEG created and manages the Resilient Power Project to accelerate access to the benefits solar PV and battery storage technologies in historically marginalized and underserved communities.

Learn more at *www.cleanegroup.org* and *www.resilient-power.org*.

Resilient Communities, Maryland (RCM)

DE-EE0010415

David Wright
VP of Energy Programs, Groundswell

2024 Solar and Distributed Energy Resources (DERs)

Community Energy Resilience Workshop

U.S. Department of Energy (DOE)

Solar Energy Technologies Office (SETO)

James V. Forrestal Building - Washington, DC

Thursday, November 14, 2024

RCM Research Team

Groundswell

Groundswell, Inc.

David Wright
Vice President of Energy Programs

Tiffani Lawson
Energy Programs Lead Mid Atlantic

Andre De Souza Coelho
Resiliency Fellow

Elvis Moleka, Ph.D
Vice President of Labs and Data Science

Ayika Solutions, Inc.

Erica L. Holloman-Hill, Ph.D
Chief Envisioning Officer
Chief Scientific Officer

Azania Heyward-James, MSEd, BCDHP
Community Climate Adaptation Strategist
Chief Ethnographic Data Analyst

National Renewable Energy Laboratory (NREL)

Jordan Burns
Risk & Resilience Researcher/Resilient Systems Design & Engineering

Sara Peterson
Cyber Resilience Researcher

Project Overview

Groundswell

Goal:
Research, develop, test, and validate an equitable, **community-driven energy resilience framework** that communities across Maryland can apply to understand and advance community and energy resilience in underserved areas towards replication and scale statewide.

Conducting research in 3 Maryland jurisdictions:

- ❑ Baltimore City (urban)
- ❑ Montgomery County (suburban)
- ❑ Eastern Shore (rural)

Energy Planning Participation

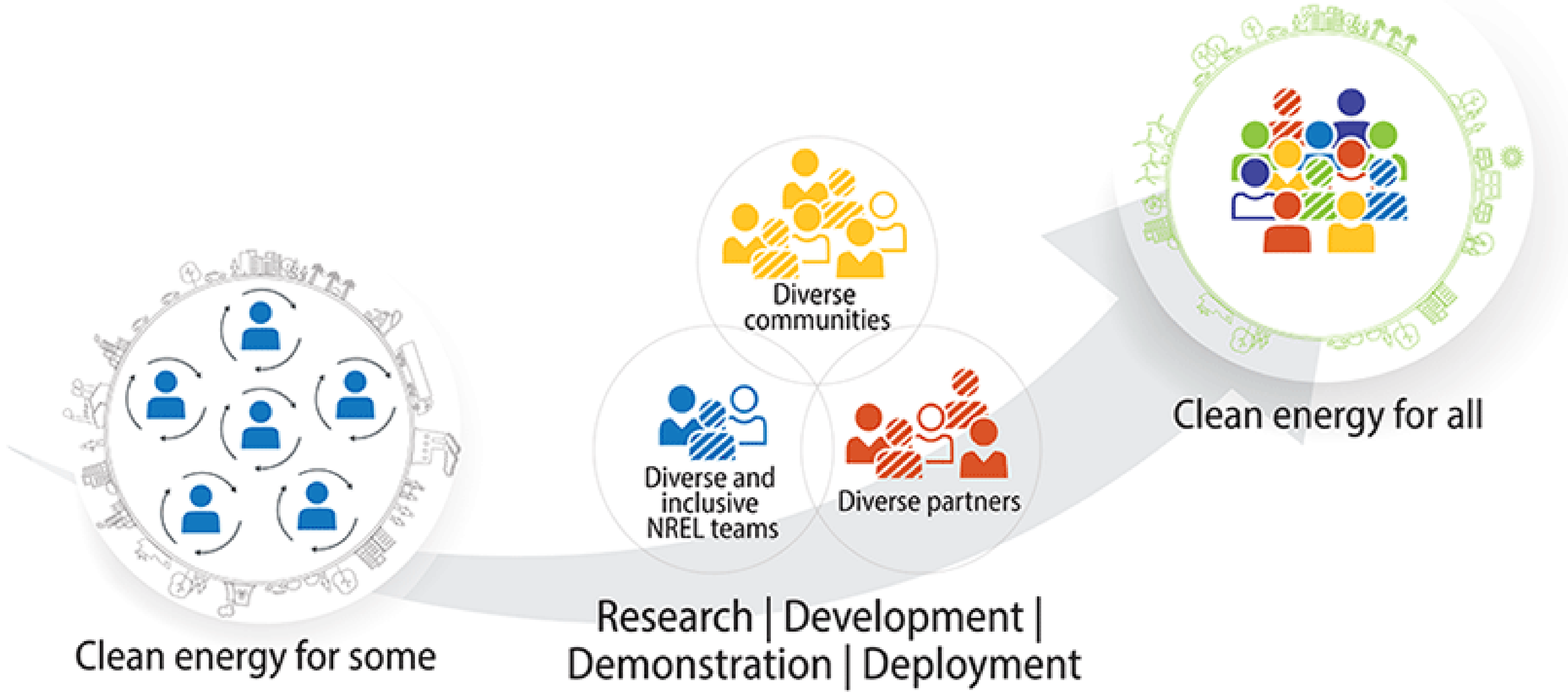
Groundswell

Meaningful participation is achieved when two key criteria are met:

- ❑ Planners involve stakeholders *outside* energy fields
- ❑ Planners use community input to shape real energy decisions

Achieving this standard requires that energy planning processes are *transparent* and *understood* by community members.

Alignment with Energy Justice



NREL Energy Justice - https://www.nrel.gov/about/energy-justice.html

RCM Resilience Metric

Groundswell

Accessibility measures how easily (or not) people can access essential services:

- *What types of services* do facilities provide?
- *How much* of these services do different facilities provide?
- *How accessible* are these services to area residents?

Research Approach

Community Outreach

↓

Initial Accessibility Calculation

↓

Community Engagement (Resiliency Council/Round Table)

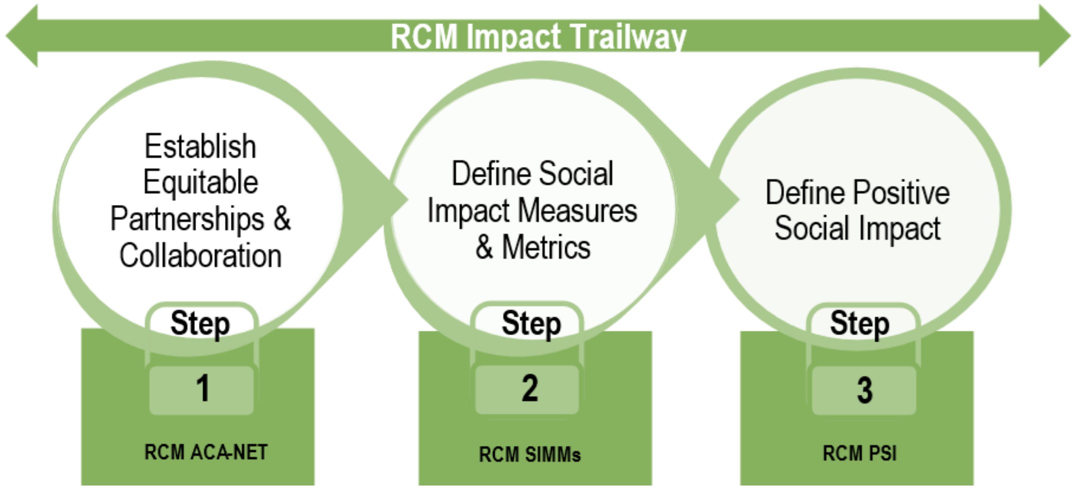
↓

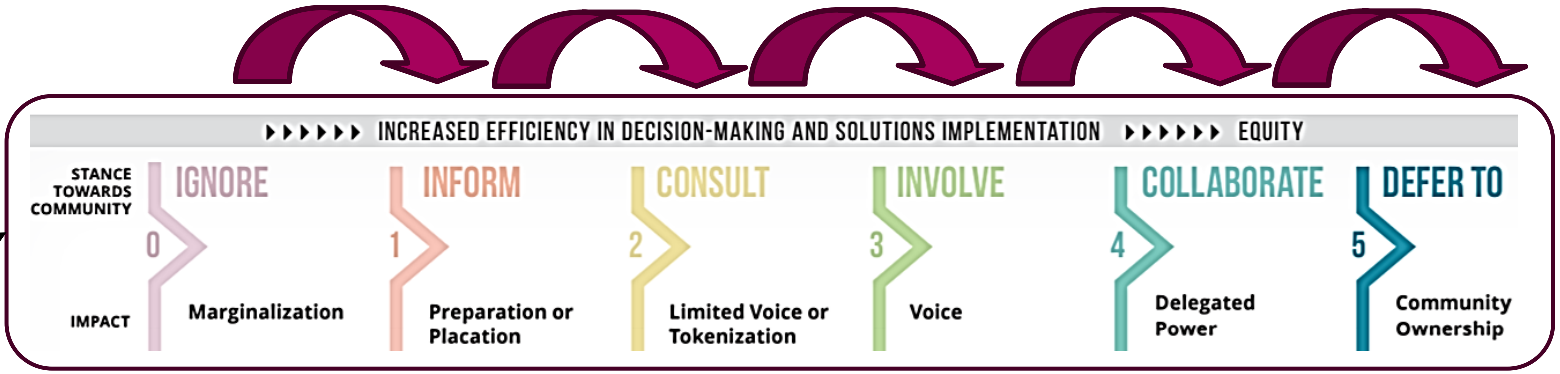
Revised Accessibility Assessment

↓

Community-Based Framework

A.C.E. Impact Trailway™- (Ayika Solutions Inc.)





Rosa Gonzalez, 2019 - The Spectrum of Community Engagement to Ownership

Key Takeaways: Baltimore

Groundswell

1) Revised categories of services to better reflect community members' perspectives

Before: FEMA Lifelines

- Food & Hydration
- Safety & Security
- Health & Medical
- Shelter
- Communications
- Transportation
- Fuel
- Water Systems

After: Council-Driven Categories

- **Provisions**
  - Food
  - Hydration
  - Fuel
- **Health & Medical**
  - Medications
  - Healthcare
- **Public & Emergency Services**
  - Public Services
  - Shelter & Mutual Aid
- **Education & Workforce**
- **Institutional Population**

1) Revised scoring of facilities:

- Decrease scores for nursing homes, churches, and gas stations
- Increase scores for grocery stores

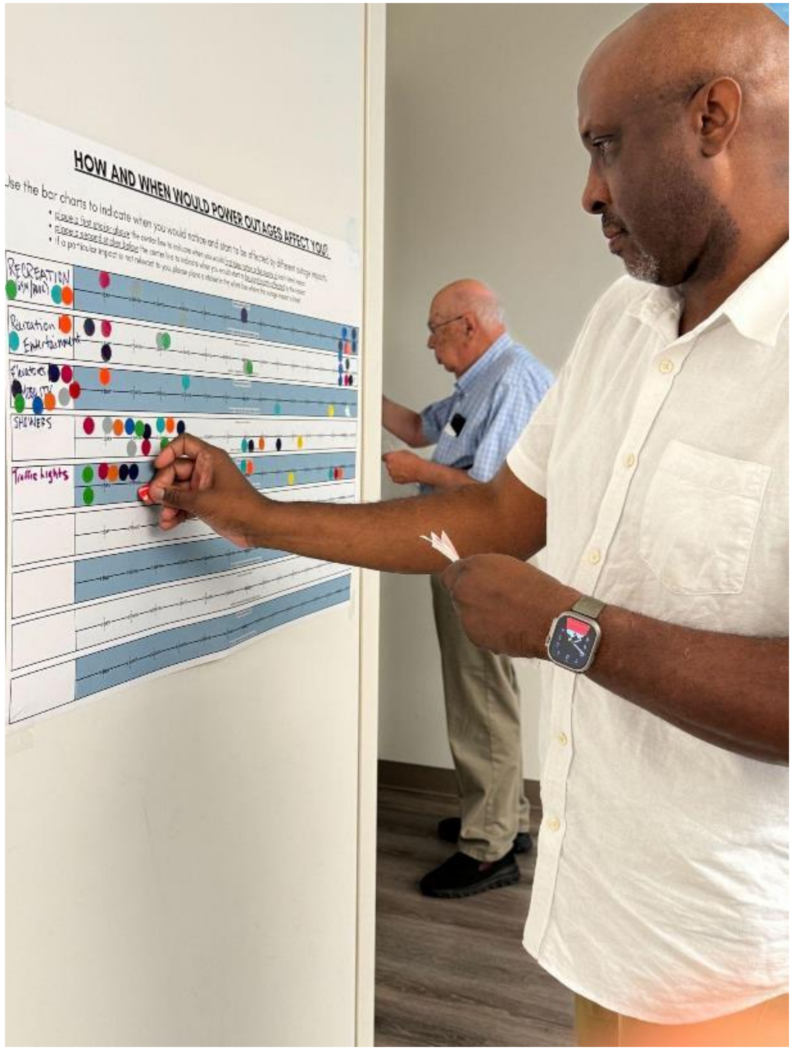
Key Takeaways: Montgomery County

1) Built on strong foundation in Baltimore

- Added services based on community feedback: EV charging, Section 202 senior housing, and hardware/outdoor stores
- Service scores refined by facility size for hospitals, grocery stores, and schools to improve accuracy

2) Explored new questions

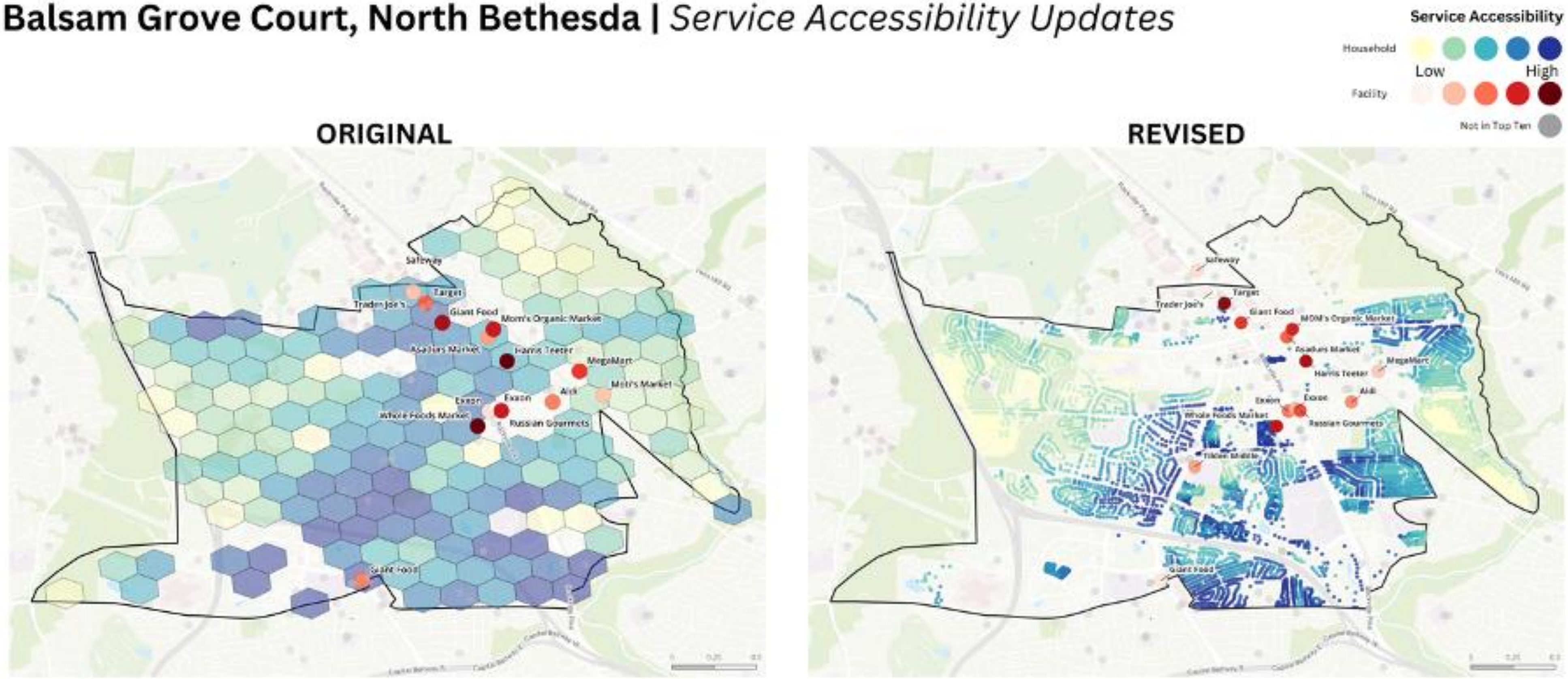
- Service importance varies by outage duration: daily essentials are prioritized, and non-essentials become critical after four days.



Key Takeaways: Montgomery County

Groundswell

Balsam Grove Court, North Bethesda | *Service Accessibility Updates*



The revised service accessibility map *(right)* incorporates your feedback about the original service accessibility map *(left)*.

Key changes include:

- **Adding new services** (e.g., EV charging) and service locations (e.g., Hardware Stores & Outdoor Stores and Section 202 Housing)
- **Modifying scores** of certain service locations (e.g., grocery stores, hospitals, and schools) to reflect the differing levels of service within location type
- **Incorporating population weighting** into facility scores and visualizing population based on actual housing locations

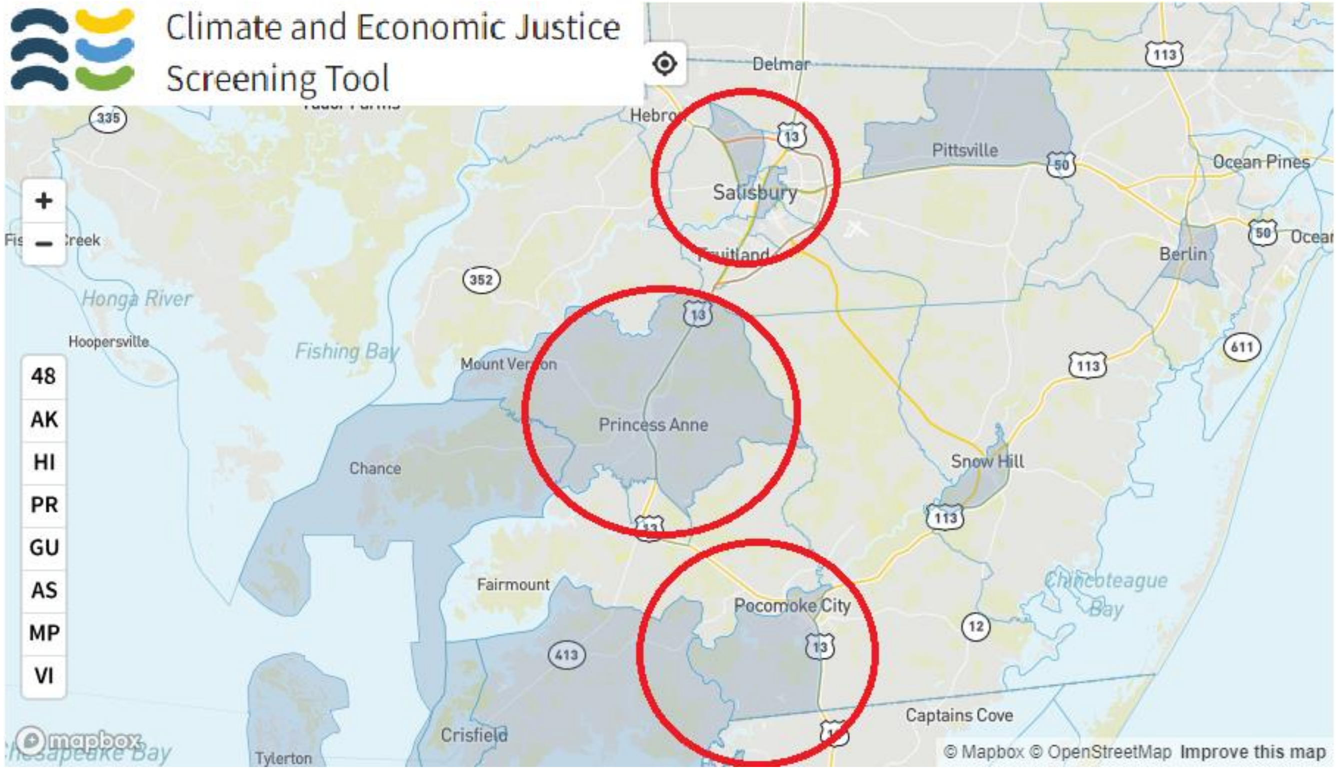
Expected Results

Groundswell

- ✓ Community outreach strategies
- ✓ Community engagement activities
- ✓ Community-tested metric
- ✓ Service landscape scoring matrix
- ✓ Service landscape over time
- ✓ Creation of framework: metric + process

Next Step

Groundswell



Community Engagement Areas in Maryland Eastern Shore:

- **Princess Anne**
- **Salisbury**
- **Pocomoke City**

Contact Us

David Wright
VP of Energy Programs
david.wright@groundswell.org
240-772-1331

Groundswell
COMMUNITY POWER

Sandia National Laboratories

Exceptional service in the national interest

EXPERIENCES IN COMMUNITY ENERGY RESILIENCE

What is resilience? How do communities engage?
How can the labs deliver value?

Andrea Mammoli, PMTS

8812 Renewable Energy and Distributed Systems Integration

November 14, 2024

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OLIKTOK, AK

HAU`ULA, HI


HCA
HAU`ULA COMMUNITY ASSOCIATION
Ko`olauloa Community Resilience Hub
Hui o Hau`uLa
+ Lab
G70
Hawaiian Electric
WINDWARD COMMUNITY COLLEGE
Kahuku Medical Center
verizon
uli A`wa: The design combines cultural wisdom with modern building intelligence, providing near absolute protection for 2000 people. Critical lifelines include:
Food, Water, Power, Medical/Health & Communications.
Hui A`wa will serve the community daily as an anchor regenerating ecology, cultural practice and promoting a circular economy.
For more information or to join in a Community Volunteer Day Call 808-255-6944. WWW. HAUULACOMMUNITYASSOCIATION.COM

GUAM

MARTHA'S VINEYARD, MA

Technology Innovation Session 1: Energy Restoration Enabled by Solar and DERs

- **Fei Ding**, Researcher in Electrical Engineering, National Renewable Energy Laboratory
- **Jairo Giraldo**, Research Assistant Professor, University of Utah
- **Sachiko Graber**, National Partnerships Lead, Cooperative Energy Futures

NREL Transforming ENERGY

Data Orchestration and Solar-Assisted Restoration for Resilience Enhancement

Fei Ding, Ph.D.
Manager, Grid Automation and Controls Group
Power Systems Engineering Center
National Renewable Energy Laboratory (NREL)

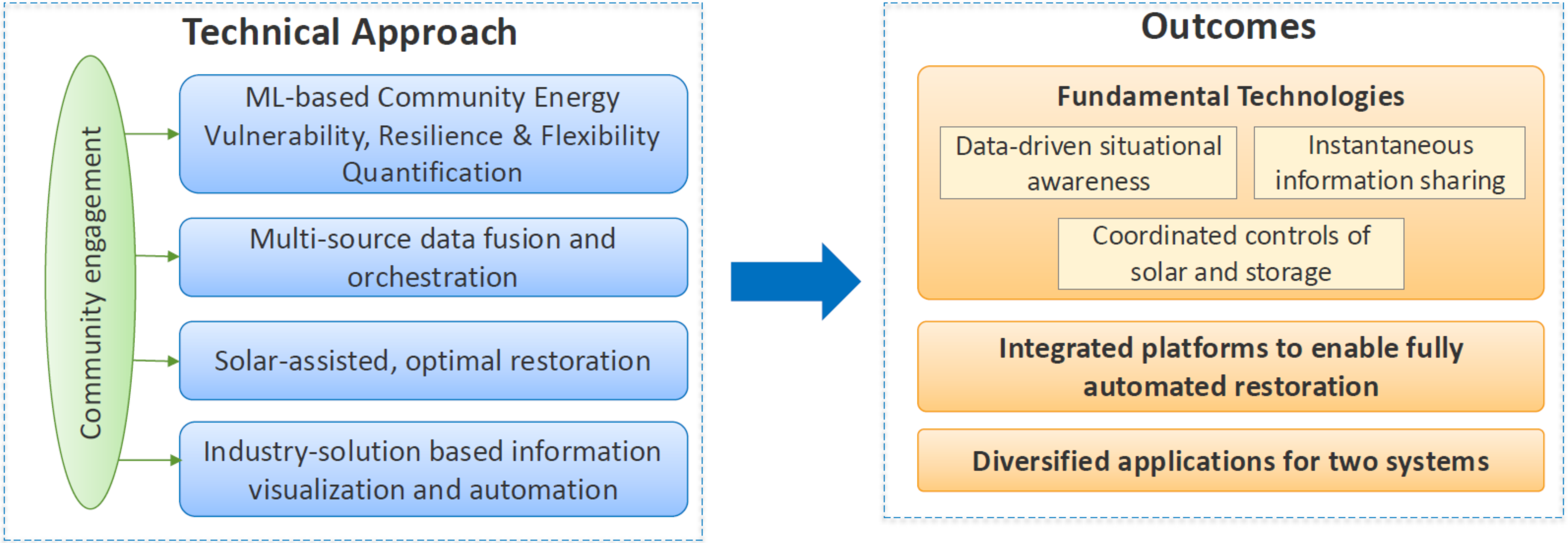
Photo from iStock-627281636

Automated Restoration is Essential for Enhancing Grid Resilience:

- Data analytics-based situational awareness
- Robust and instant information sharing
- Optimal method to manage both utility assets and DERs

Solar-Assisted, Stakeholder-Engaged Autonomous Restoration with Data Orchestration (Solar-HERO)

Funded by: SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy



Performance Period: April 1, 2023 – March 31, 2026

Project Team: NREL, Iowa State University, Colorado School of Mines, NEC Labs America, Great Plains Institute, Connexus Energy, United Power, Survalent, Camus Energy, EGM, Copper Labs, DataCapable

Community Engagement

MN
- City of Blaine
- Anoka County
- Sherburne County
- Vadnais Heights
- Coon Rapids

CO
- Boulder County
- Adams County
- Northglenn
- Westminster
- Broomfield

- Conducted three quarterly cohort meetings on 2024-01-29, 2024-05-17, 2024-09-17
- Conducted interviews with the 10 communities separately

- Commonalities:
  - All communities recognize the importance of community resilience
  - Both utilities see increasing penetration of distributed solar PVs, and are interested in quantifying the value of PVs on resilience
- Broomfield water resource manager is conducting a lot of work on water resource planning and vulnerability analysis
- Westminster local emergency manager is interested in improving GIS information to know which area has vulnerable people
- United Power is building a microgrid project around its local water treatment facility

Community Vulnerability and Flexibility Analysis


Solar-HERO
Solar-Assisted, Stakeholder-Engaged, Autonomous Restoration with Data Orchestration
NREL Transforming ENERGY

Community Survey for Solar-HERO Project

Has a power outage ever left you in the dark for hours on end, disrupting your daily activities and inconveniencing you and your family?
Researchers at the National Renewable Energy Laboratory and Colorado School of Mines are working to understand how long-duration power outages impact households and what can be done to reduce impact on your life.
More information about the research project can be found at this website:
https://www.nrel.gov/news/program/2023/nrel-and-partners-build-all-data-approach-for-automated-grid-recovery.html.

For this survey, a **long-duration outage** is a power outage that may last several hours to several days or weeks and most likely occurs due to an extreme weather event or natural disaster.

The goal of this survey is to

1. Explore your concerns, needs, and any issues that may lead to inconvenience, vulnerabilities, or health concerns during a long-duration power outage
2. Estimate the flexibility of your energy consumption when the electricity availability is limited.

The survey consists of 5 parts, requiring approximately **10-15mins to complete**. All questions, with the exception of the consent question, are optional. As a token of appreciation for survey participation, any participant, who answers at least 80% of all questions, will receive a $10 e-gift card. Please be sure to provide your email address at the end of the survey so that we can email you the gift card.

Note: The data collected from the survey will be anonymized and your personal information will not be shared with anyone outside those conducting survey analysis.

For more accessibility, this form is also available at the following URL: https://forms.office.com/g/x1pvPASgGK.

* Required

Consent Agreement

1. By proceeding with this survey, you are providing your voluntary consent, indicating the following:
   - Your willingness to participate, without any external pressure or influence.
   - Confirmation that you are at least 18 years of age.
   - Awareness that your survey responses will be utilized for research purposes and data analysis.

*

○ I have read the above statements and consent to participate in this survey.

Next

Microsoft 365

This content is created by the owner of the form. The data you submit will be sent to the form owner. Microsoft is not responsible for the privacy or security practices of its customers, including those of this form owner. Never give out your password.
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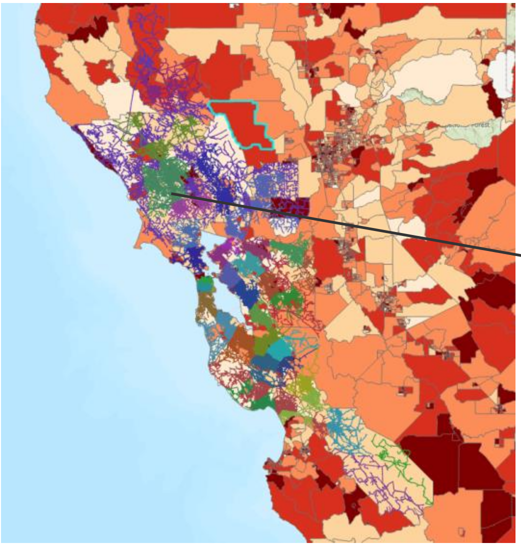
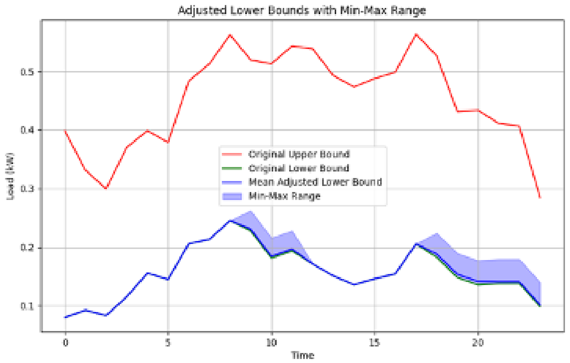
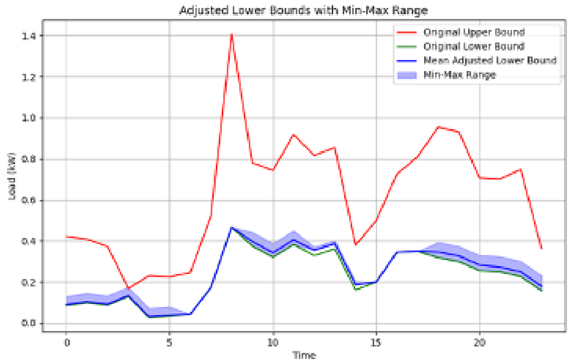
Social Vulnerability Analysis

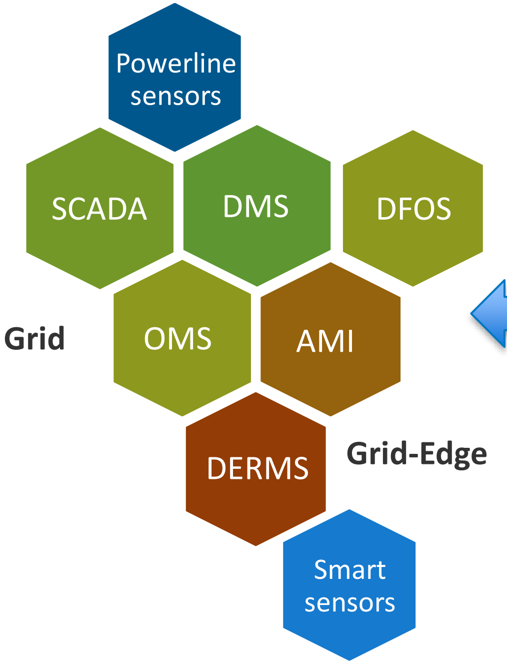


Energy Consumption Flexibility Analysis





Orchestrated Situational Awareness



Resilience States:

- Building Energy Usage and Flexibility
- Bus Voltages and Branch Currents Phasors
- Outage Existence and Customer Location
- Fault Location
- Network Topology
- Utility Asset Damage Conditions
- PV and Storage Statuses

Orchestrated Situational Awareness Techniques:

Topology Identification

Outage Identification

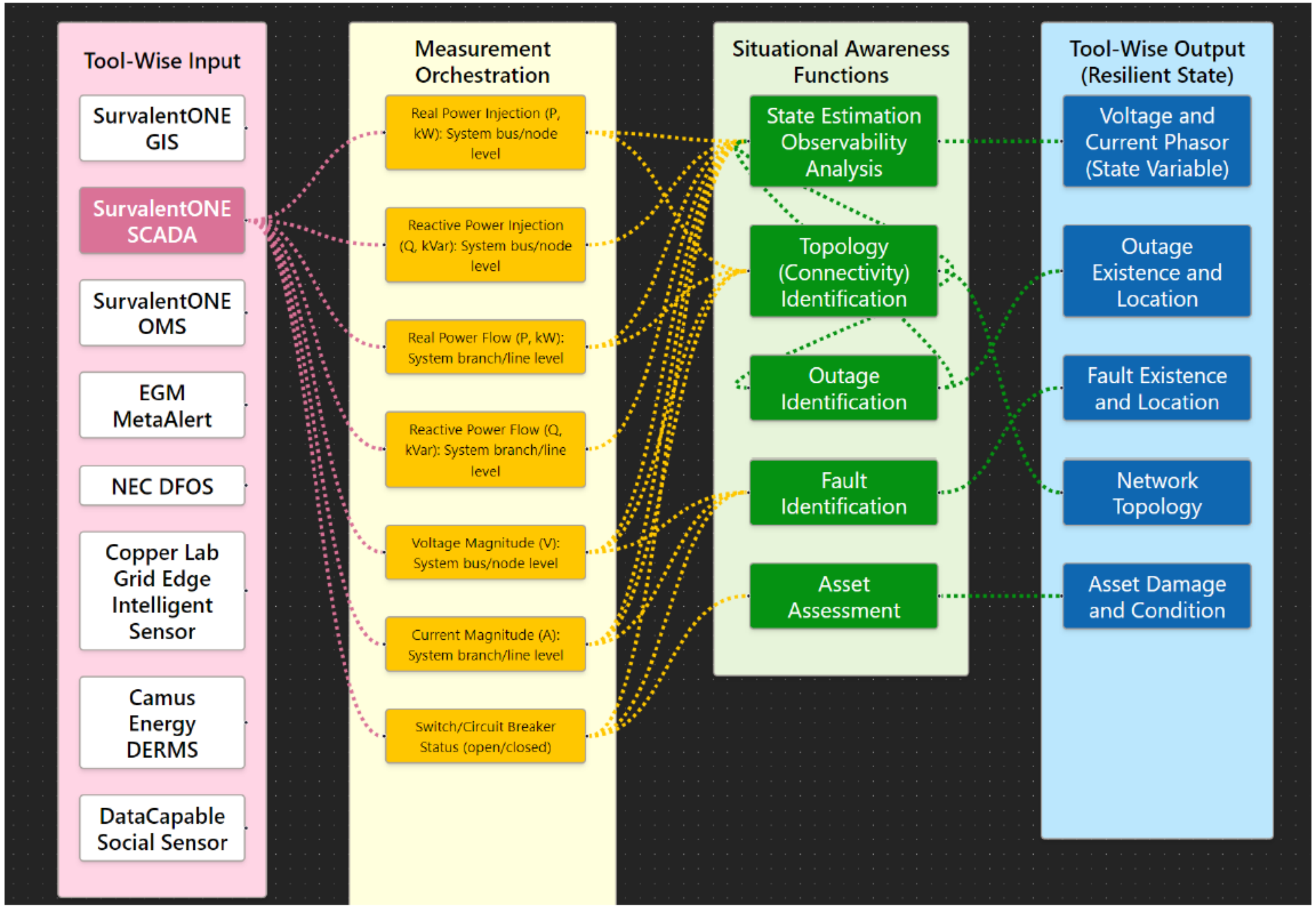
Observability Analysis

State Estimation

Utility Asset Assessment

Achieve **resilient situational awareness** via **multi-source data fusion** that orchestrates measurements with different type, fidelity, density, and reporting rate.

Orchestrated Situational Awareness



Optimized Restoration using Solar Plus Battery

- The objective is to maximize the restored loads considering priorities with the help of GFM and GFL DERs.

$$\max_{\boldsymbol{x}} \sum_{t \in \mathcal{T}} \left(K_i \sum_{i \in \mathcal{B}_L} P_{i,t} \right) \Delta t$$

- Subject to constraints:
  - Grid-forming inverter operation and synchronization.
  - Switching operations.
  - Dynamic radiality constraints.
  - Static and dynamic frequency constraints.
  - Three-phase unbalanced power flow constraints.
  - Cold load pick up

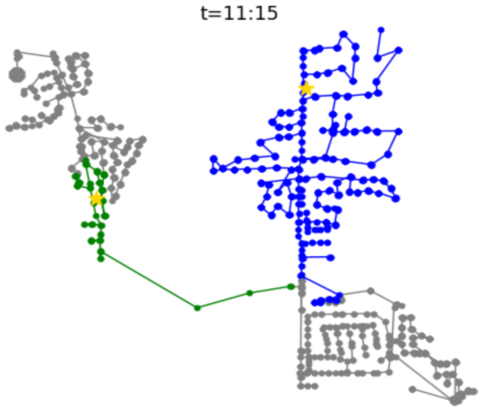
- Decision variables ($\boldsymbol{x}$):
  - Time of starting GFMIs.
  - Sequence of energizing cranking paths.
  - Sequence of activating grid-following resources.
  - Sequence of load pickup.
  - Sequence of synchronizing decisions.

Nomenclature:
$\mathcal{B}_L$: set of buses with load
K_i: Social-vulnerability indices
$\mathcal{T}$: time horizon of problem
Δt: time step
$P_{i,t}$: power demand at time t in i^{th} bus

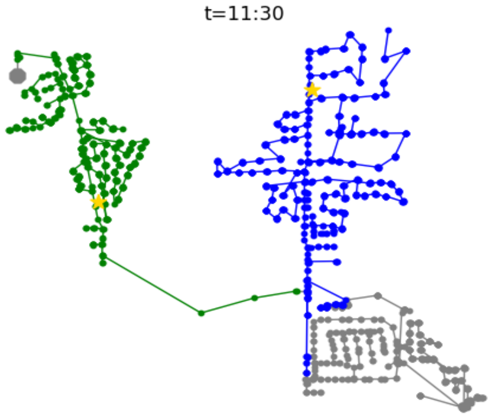
Full Restoration Process

Started black start at 11:00 and transmission grid comes online at 13:15.

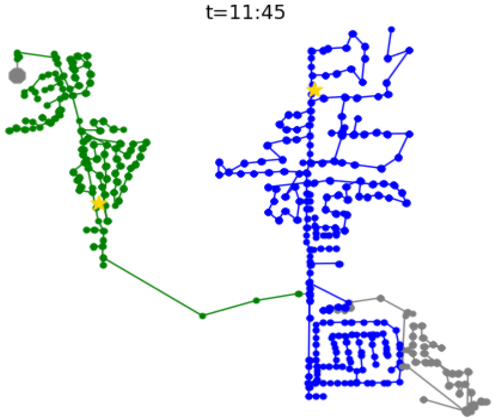
GFMIs started



Neighbouring bus block energized



Expansion of cranking paths in MGs.



Further expansion of Cranking paths in MG2.

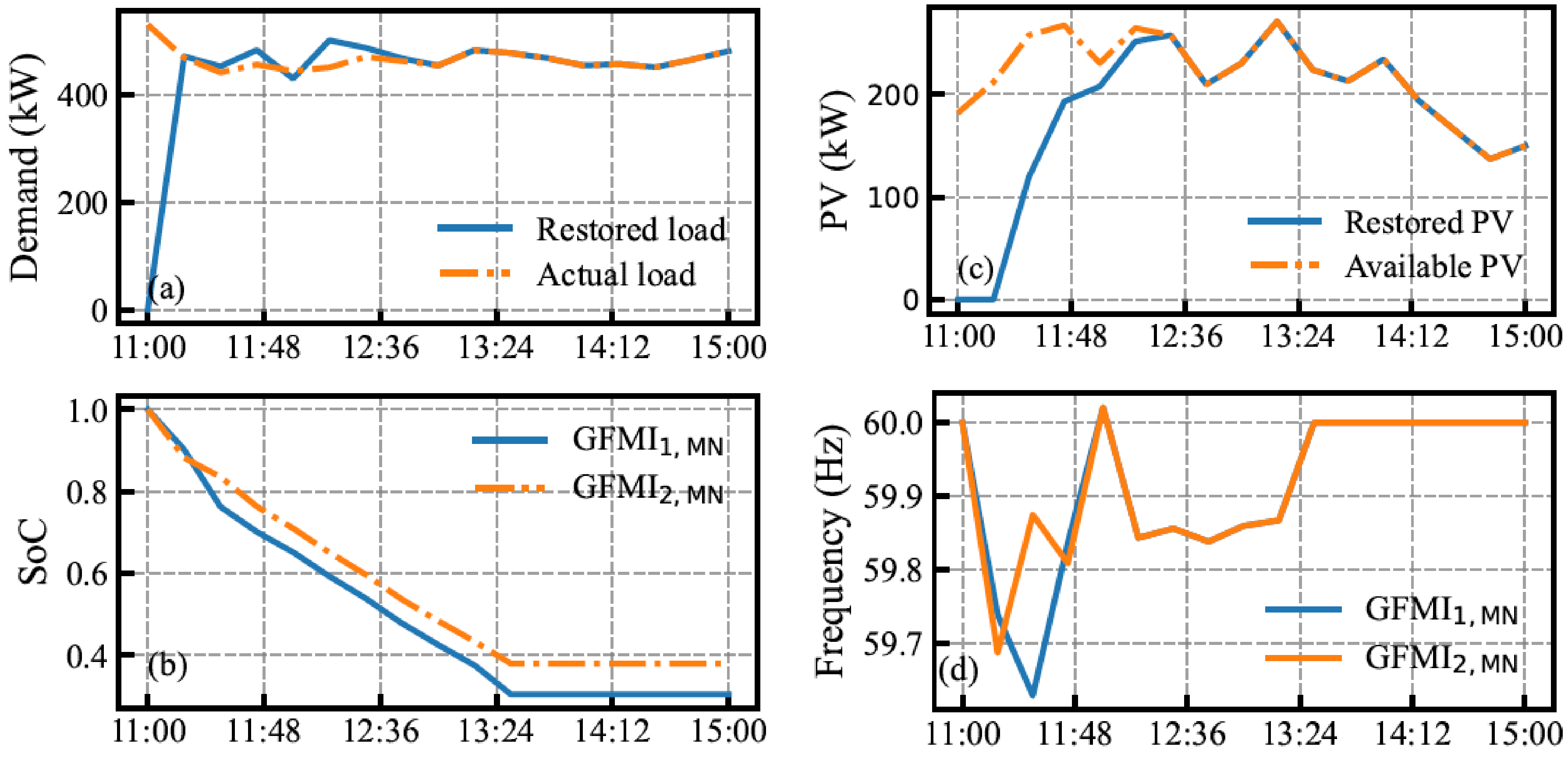
Synchronization of two MGs

Energization of the last bus block

Recovery of Trans. grid

Synchronization with Trans. grid.

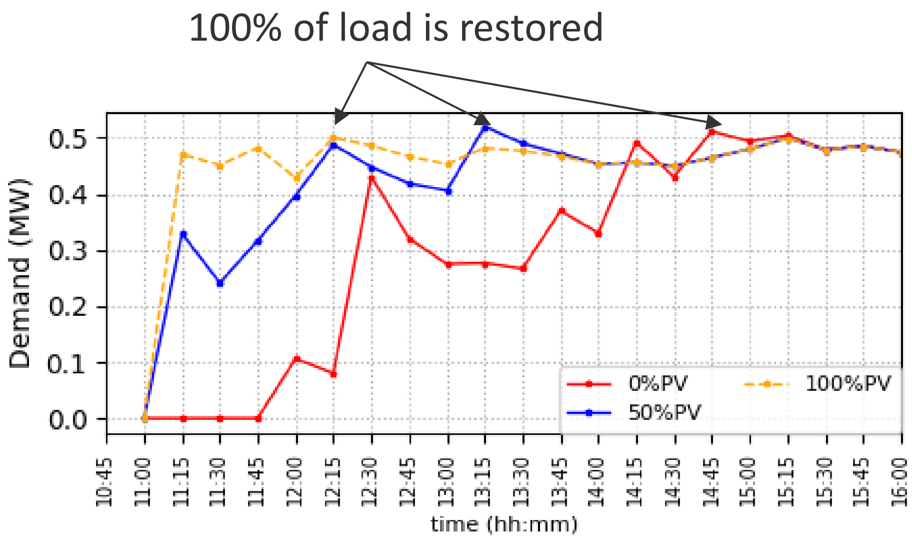
Overall Restoration Performance



Impact of PVs and Load Flexibility

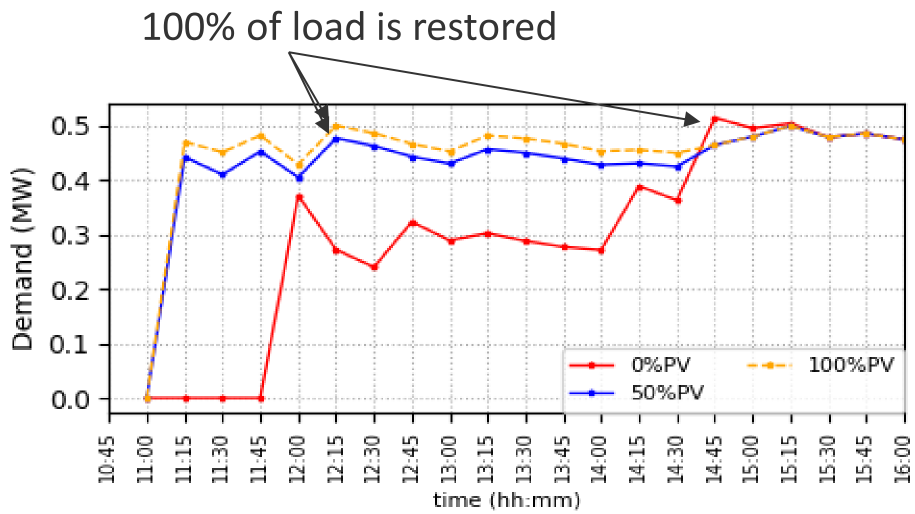
Assume transmission grid comes online at 14:15.

PV penetration levels	Time to restore 100% loads	Total customer hours restored
0%	3hrs 45 min	1.58 MWh
50%	2hr 15 min	2.19 MWh
100%	1hr 15 min	2.35 MWh



PV helps accelerate restoration process and increase total restored loads.

PV penetration levels	Time to restore 100% loads.		Total customer hours restored	
	w/o DR	With DR	w/o DR	With DR
0%	3hrs 45min	3hrs 45min	1.58 MWh	1.58 MWh
50%	2hr 15min	1hr 15min	2.19 MWh	2.26 MWh
100%	1hr 15min	1hr 15min	2.35 MWh	2.35 MWh



Load flexibility can further improve restoration.

Thank You!

Contact: fei.ding@nrel.gov

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding is provided by U.S. DOE Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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U.S. Department Of Energy

NREL Transforming ENERGY

Detection, Response, and Mitigation of Cyber Anomalies and Extreme Weather Events in Power Distribution Systems

Jairo Giraldo,
Research Assistant Professor
Utah Smart Energy Lab (U-Smart)
The University of Utah

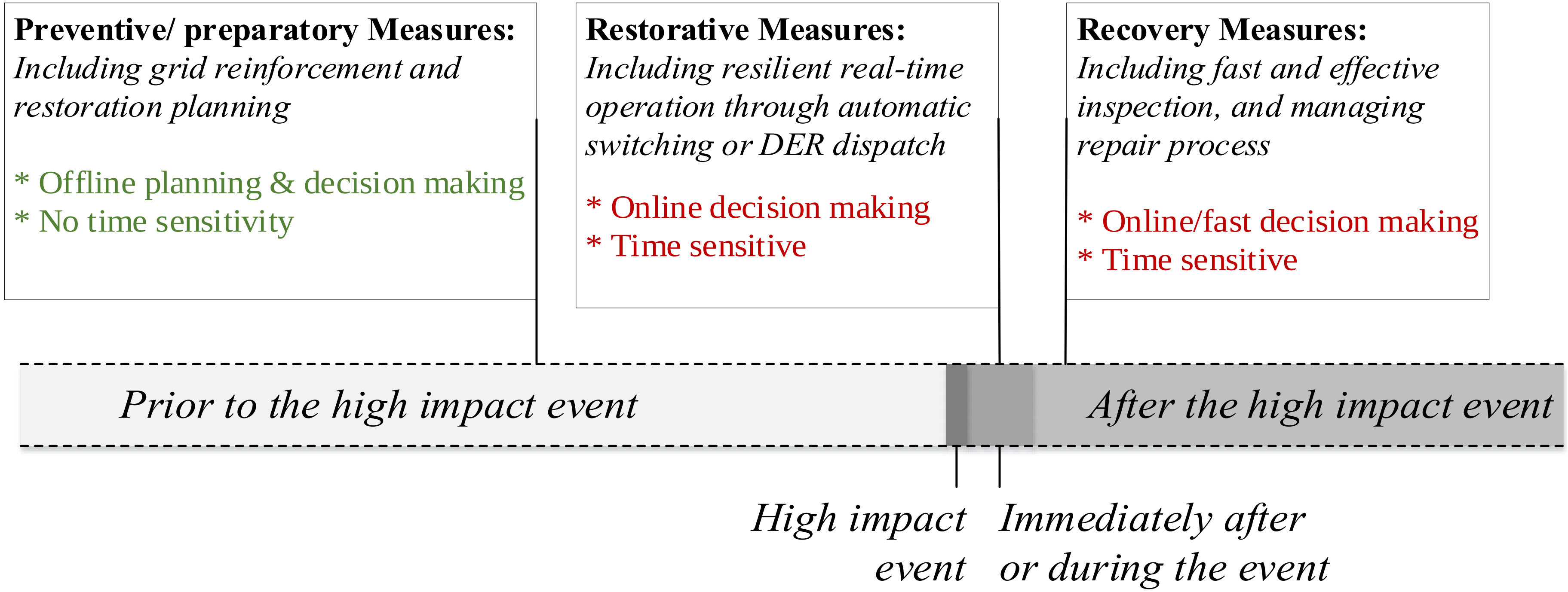
THE UNIVERSITY OF UTAH

SMART UTAH SMART ENERGY LAB

SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

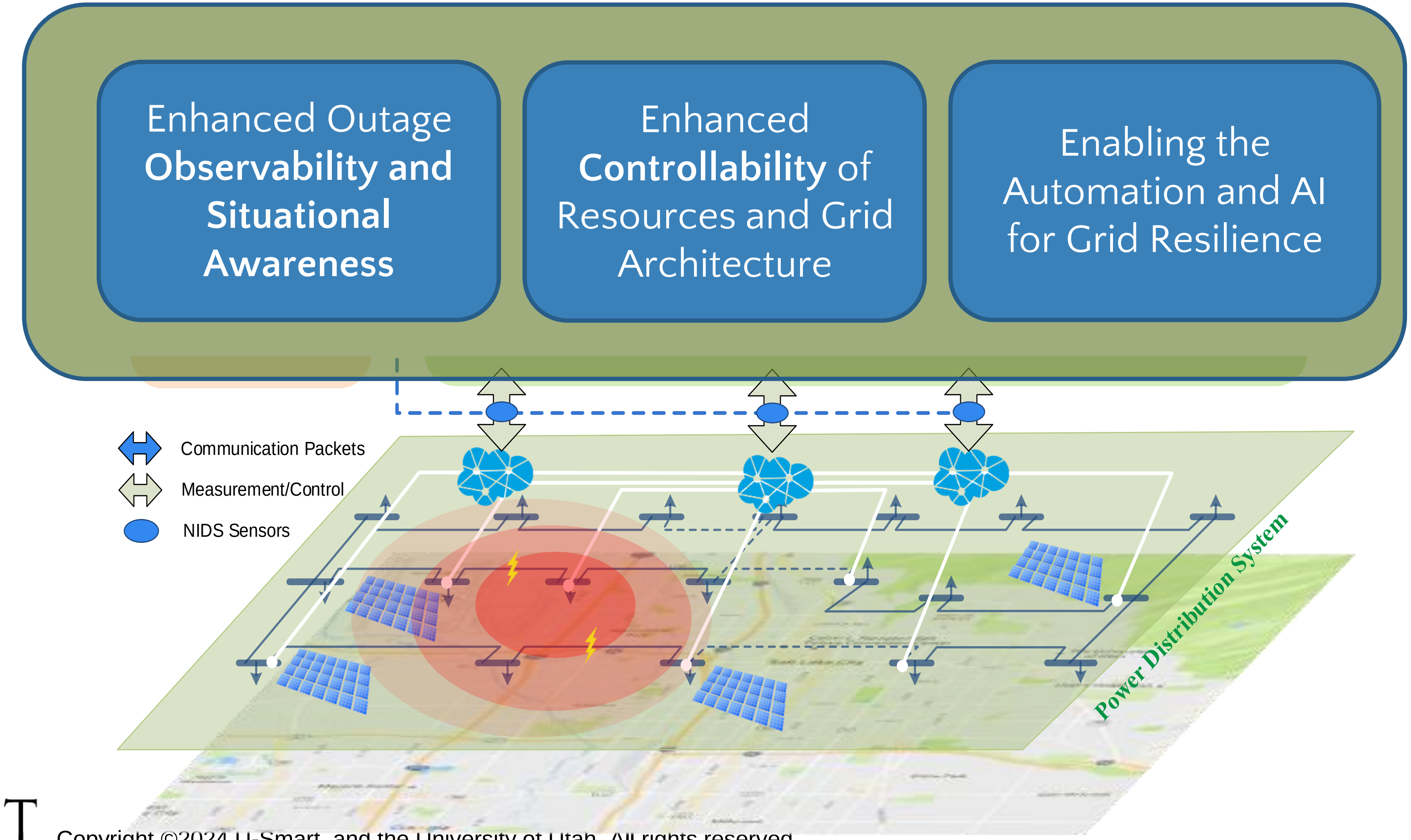
Stages of Resilience Enhancement

Resilience is the ability of power grid to **prepare** for and **adapt** to changing conditions and **withstand and recover rapidly** from adverse events (such as severe weather).



Restorative measures are more time sensitive and require real-time, efficient and reliable operational algorithms.

Grid Modernization to Enhance Recovery Operation



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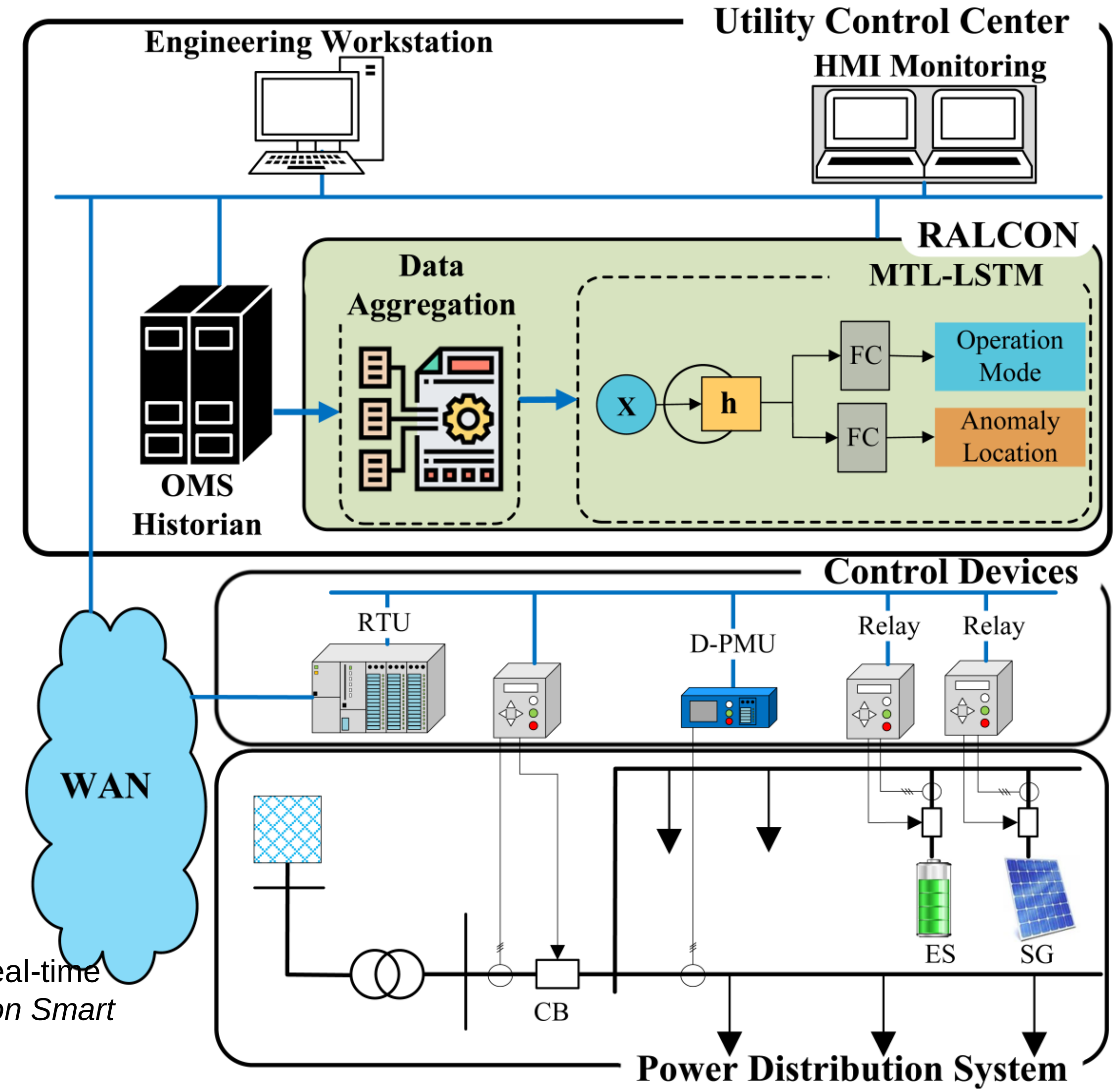
Fault and Attack Location and Classification (FALCON)

Main Challenge

- The need to detect, classify and locate anomalies in real-time in order to generate adequate responses
- Anomalies may cause similar impacts (e.g., fault and remote relay tripping attack) but with specific physical signatures

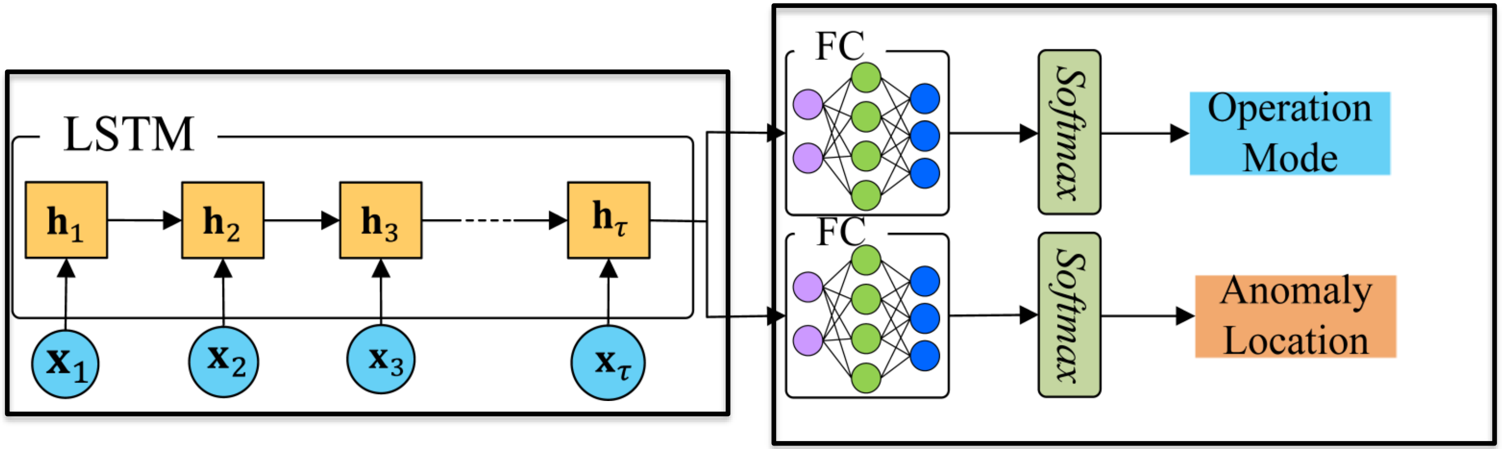
FALCON features

- Handling input measurements with different sampling rates
- Classifying different anomaly types (e.g., cyber attack, fault, DG switching)
- Determining the location of the anomaly.



M. Ganjkhani, et al., "Multi-Source Data Aggregation and Recurrent Neural Network for Real-time Anomaly Classification and Location in Power Distribution Systems," *IEEE Transactions on Smart Grid*, vol. 15, no. 2, pp. 2191-2202, 2024.

Fault and Attack Location and Classification (FALCON)



Recurrent Neural Network (RNN)

- Remembers information through time
- It is useful in time series prediction
- Enables the real-time prediction including the transient of the anomaly

Multi-Task Learning

- Multiple learning tasks are solved at the same time
- It improves learning efficiency and prediction accuracy for the task-specific models
- It reduces the number of classes

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Challenges to Develop Resilient Controllers

- Power systems are exposed to frequent uncertainties (e.g. load & generation) and rare uncertainties (e.g. hurricane & cyber attack)
- The common operation method is to generate stochastic scenarios and run stochastic optimization.

Challenges:

- High dimensionality (many potential scenarios)
- Scenario reduction is required
- Runtime is higher than real-time

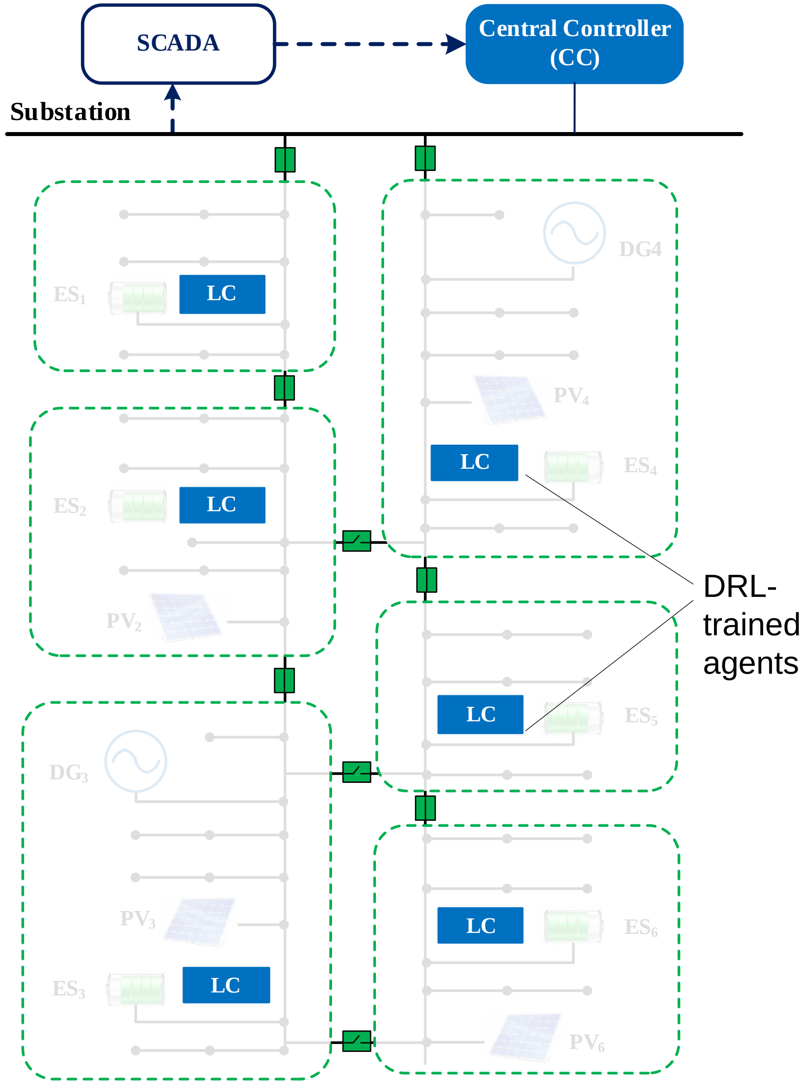
- ML-based approaches cannot guarantee optimal solution and may result in unfeasible actions

Hierarchical Resilience Controller

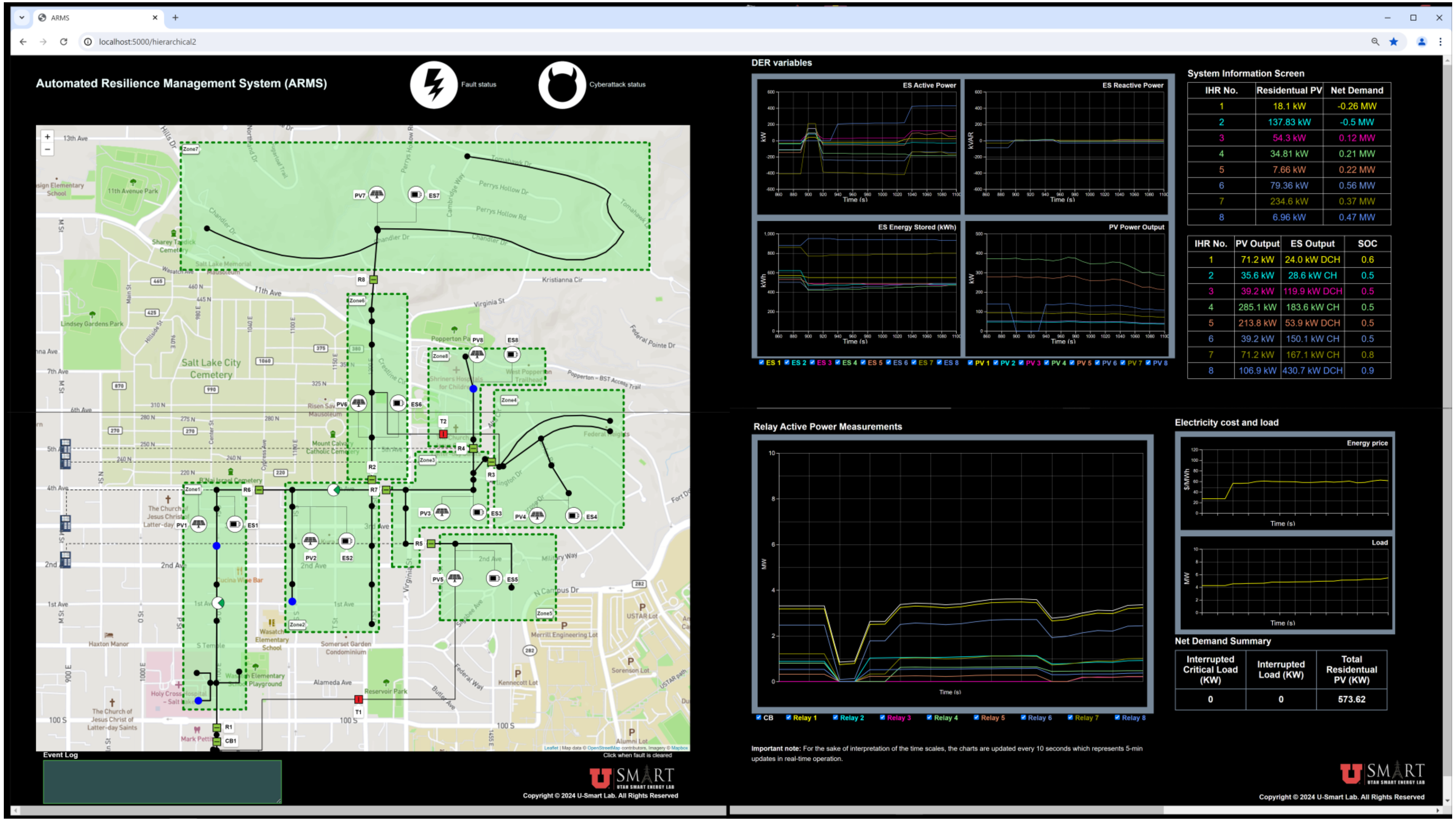
- DRL and optimization can be coupled in a hierarchical structure for PDS operation.
- PDS is divided into smaller zones with integrated hybrid resources (IHR)

$$|V_{it} - V_{jt}| < \delta, \quad \forall t, \forall i, j, \in \mathcal{I}_z, \forall z \in Z$$

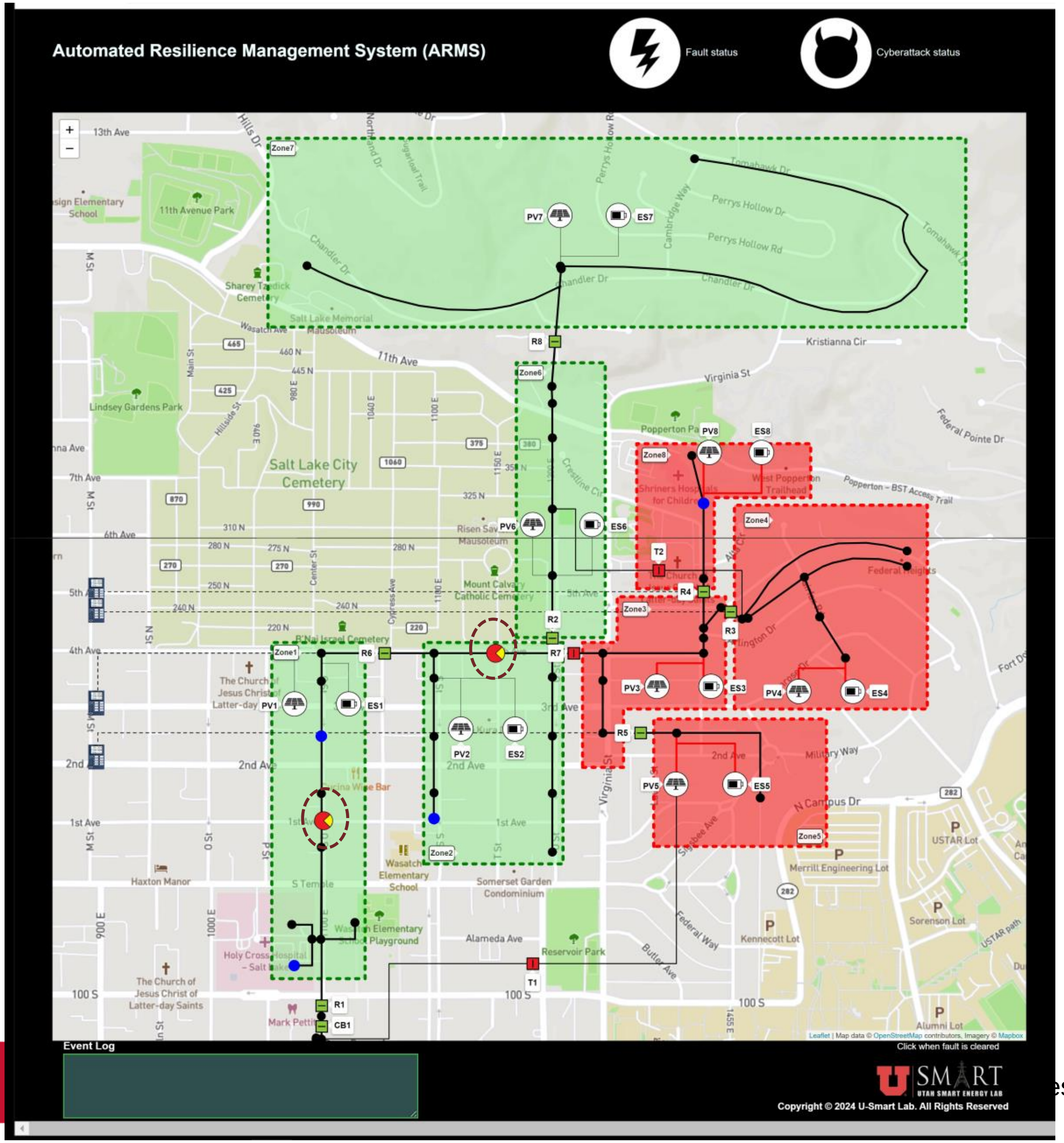
- Central controller runs a classic optimization over zones (instead of all nodes) to enforce grid constraints and determine switching status.
- Local control receive area set-points from the CC and then dispatch DERs using the DRL-trained agent.



Hardware-in-the-Loop Demonstration

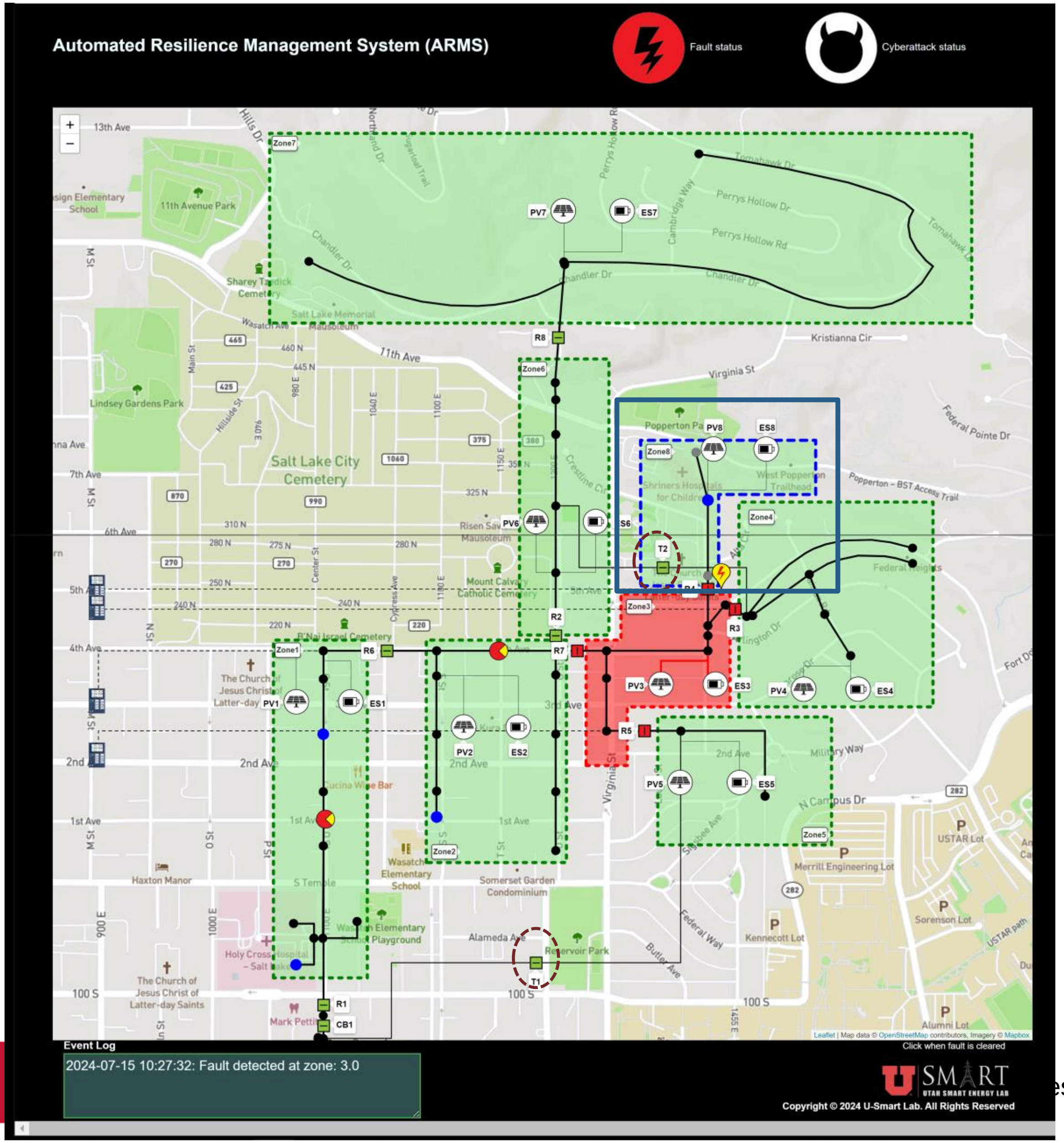


Fault in zone 3



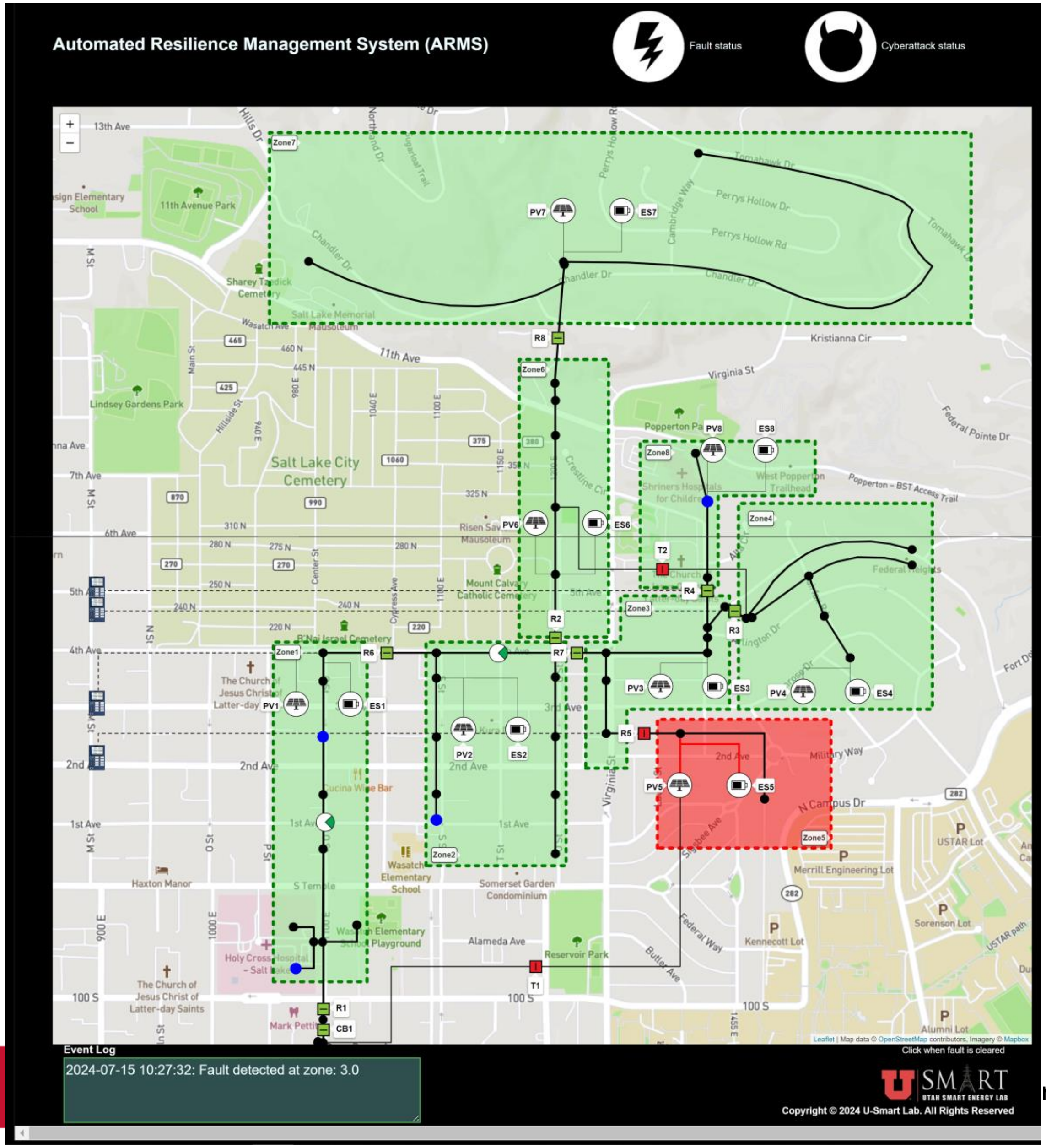
- A short-circuit fault occurred on zone 3
- Protection relays immediately isolated the fault
- Fault indicators detected the overcurrent caused by the fault
- Interrupted load: 2,138 kW

Recovery



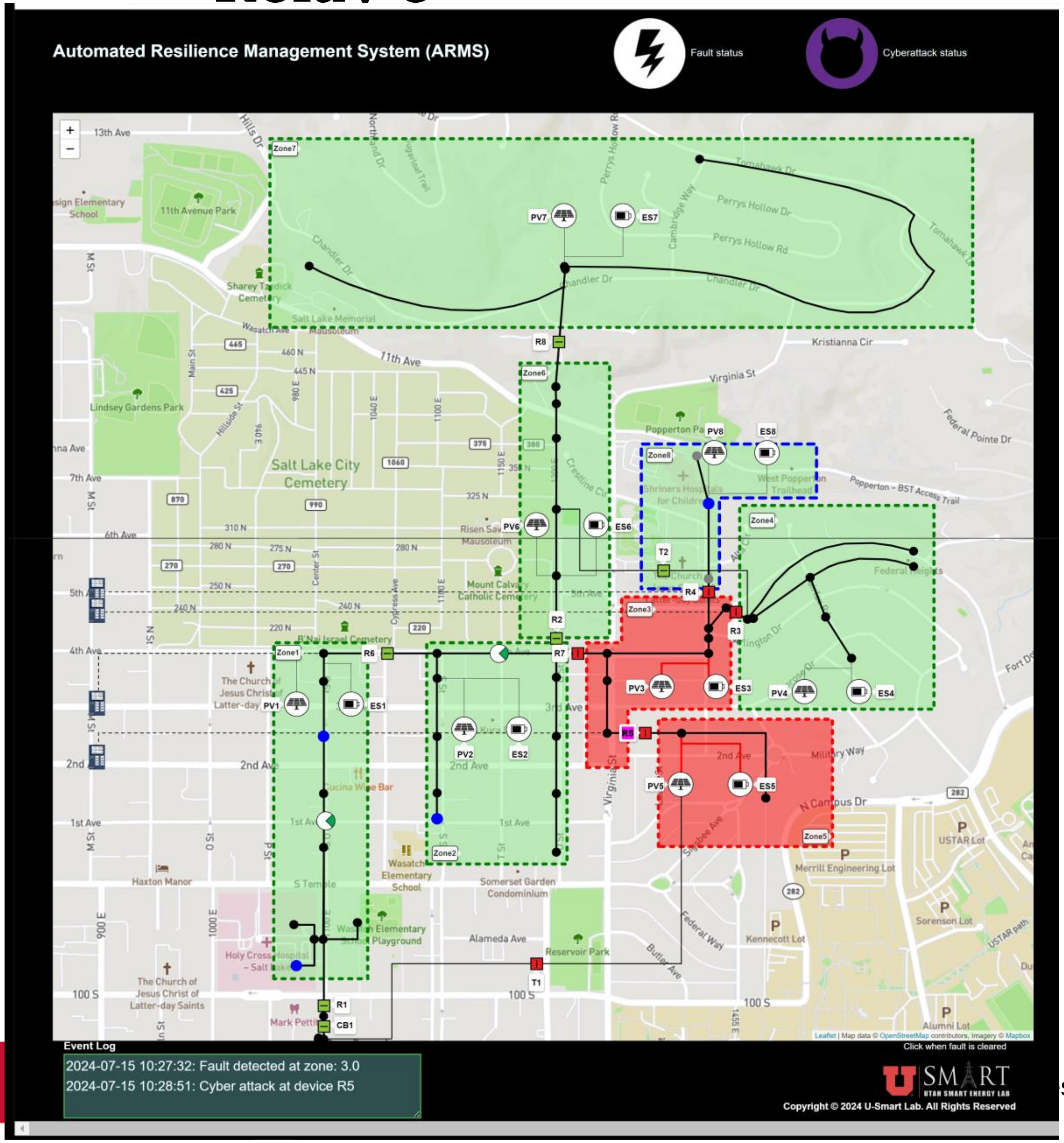
- A few seconds after the trip, FALCON classified the anomaly and determined the zone it occurred
- The central controller then computed a reconfiguration of the network topology
- ES with grid forming capabilities in zone 8 allowed the zone to operate isolated
- Interrupted load: 656 kW (about 70% was restored)

Remote tripping attack in Relay 5



- A cyber attack on relay 5 caused a remote tripping, isolating the zone.
- The attacker continues sending closing and opening commands aiming to cause significant damage to customers and their equipment.
- Vulnerable load: 588.78 kW

Remote tripping attack in Relay 5



- Relay 5 is isolated to avoid it affects any adjacent area.
- If the attack continues closing or opening the relay it won’t impact any zone.
- Vulnerable load: 0 kW

Publications

Real-Time Anomaly Classification and Localization

Testbed Implementation

Combination of Deep Reinforcement Learning and Quadratic Programming for Distribution System Restoration

Latest Updates from Hurricanes Helene and Milton

- **Isaac Panzarella**, Director, U.S. DOE Southeast Onsite Energy Technical Assistance Partnerships. Associate Director, Clean Energy Technology Center, North Carolina State University
- **Kris Davis**, Associate Professor, University of Central Florida
- **Mengjie Li**, Assistant Professor, University of Central Florida

Helene brought record rainfall, flooding and destruction to Western North Carolina

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

30+ inches of local rainfall

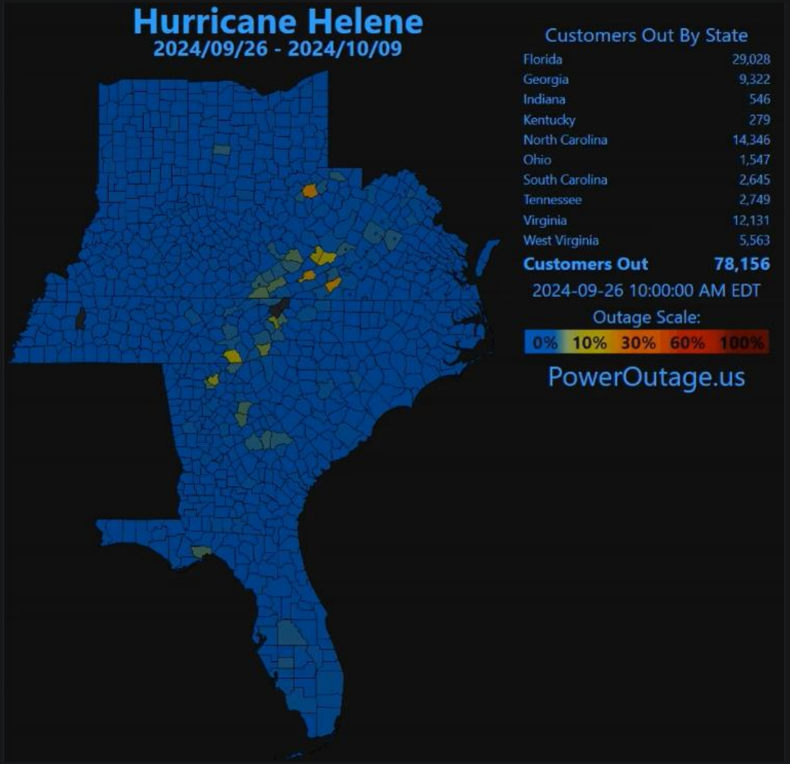
2K landslides

1,000-year river flooding

102 North Carolina deaths

1.2 M power outages homes and business

39 FEMA disaster-declared counties



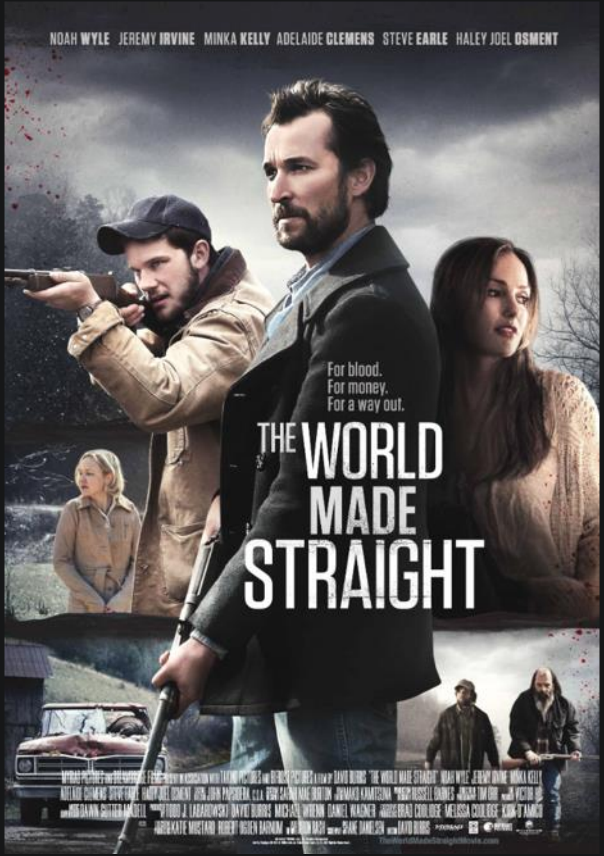
https://imgur.com/hGX1ifJ

Asheville, NC After Helene

Hot Springs, NC after Helene

Ben Childers https://www.youtube.com/watch?v=pRW4w7iOib8

Marshall Substation and Hot Springs, NC



Duke Energy Marshall Substation (top/bottom) http://Instagram.com/plainwithsprinkles http://www.imdb.com/title/tt2420166

Hot Springs, NC – Duke Energy microgrid

SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

- 2MW AC Solar PV / 4.4 MWh battery storage
- Resiliency solution for town served by a single radial line, commissioned 2023
- Outage began Friday 27 Sep at 1121 when breaker opened due to safety concerns
- Duke reached town on Monday 30 Sep at 1500
- Microgrid load ready Tuesday 01 Oct at 1900
- After distribution repairs microgrid started load pickup on Wednesday 02 Oct at 1030 and powered Hot Springs until 08 Oct at 1000 when mobile substation at Marshall was energized
- Supported downtown and critical services in Hot Springs; Fire Station, Sara Jo's Station, Dollar General, Smoky Mountain Diner

NC STATE UNIVERSITY

NC CLEAN ENERGY TECHNOLOGY CENTER

Footprint Project – Local Solar Mutual Aid

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

The Footprint Project operates to deploy solar microgrids, using fleet of mobile solar microgrids and enabling local solar installers to serve as emergency responders.

https://www.footprintproject.org/

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Footprint Project – Community Bldg, Poplar, NC

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Poplar residents wanted a solar microgrid so they could save money on gas and invest it in the recovery

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Footprint Project - Marshall, NC

Footprint Project – Pensacola – Camp Miller

Local emergency operations center, relief center and forward operating base for the NC National Guard

Footprint Project – Poder Emma, Asheville, NC

Powered well pump with 10 kW of PV and 20 kWh battery -> delivered water to 1,000s in surrounding community

https://www.poderemma.org

Footprint Project Response to Helene

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

97 requests / assessments

49 sites supported

100+ kW solar PV deployed

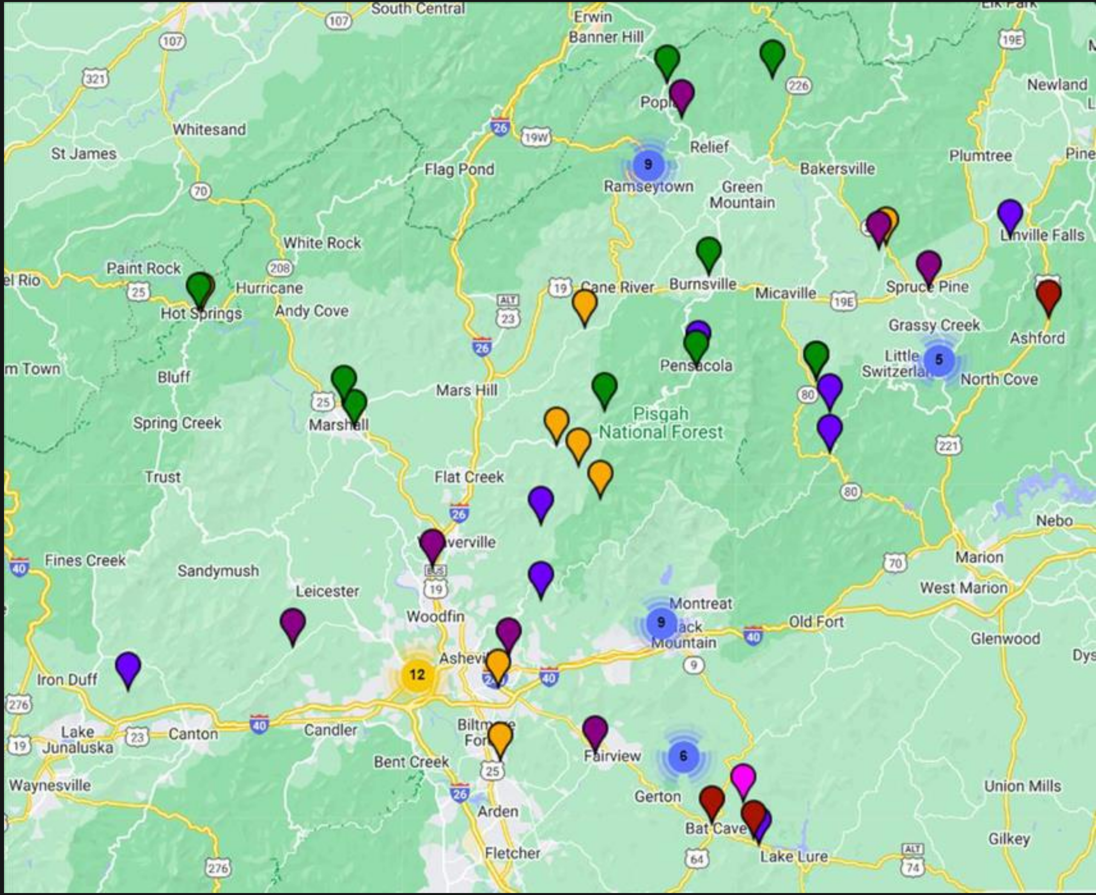
250+ kWh battery storage

2000+ people served daily

$500K+ value grounded

As of 10/23/2024

http://www.footprintproject.org



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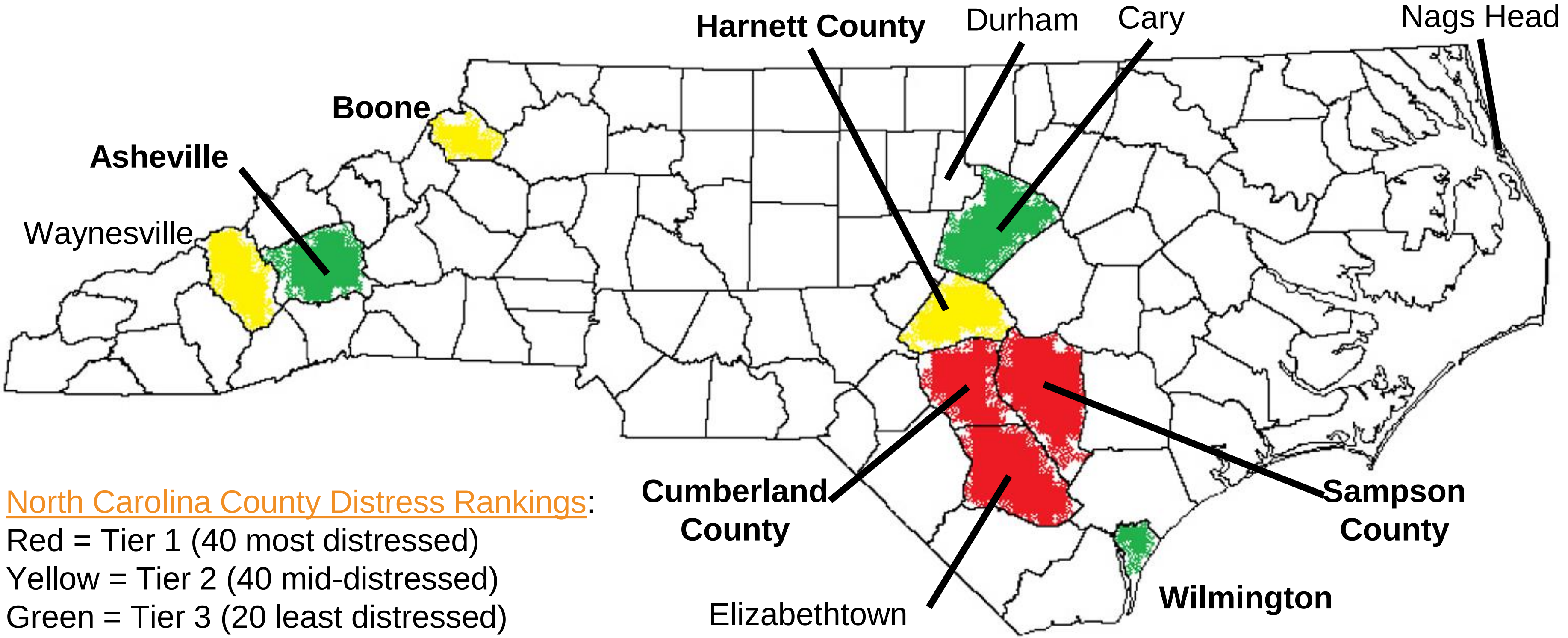
DOE RACER Project: Resilient REDDI Communities

(Renewable Energy to Diminish Disaster Impact on)

Funded by: SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy



North Carolina County Distress Rankings:
Red = Tier 1 (40 most distressed)
Yellow = Tier 2 (40 mid-distressed)
Green = Tier 3 (20 least distressed)

11 NC communities currently receiving technical assistance and participating in the Resilient REDDI Communities project.

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DOE Workshop - Resilience

Clean, Affordable, and Resilient Energy Systems (CARES) for Socially Vulnerable and At-Risk Communities

UCF

IDEAS For Us

The University of Central Florida Board of Trustees
Award: DE-EE0010418
Presentation Date: Nov/14/2024
PI: Prof. Kristopher O. Davis

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

Living Through Hurricanes

- Impact of hurricanes Helene and Milton
- Power outage – situational awareness
- Energy resilience solutions

Hurricane Size Comparison

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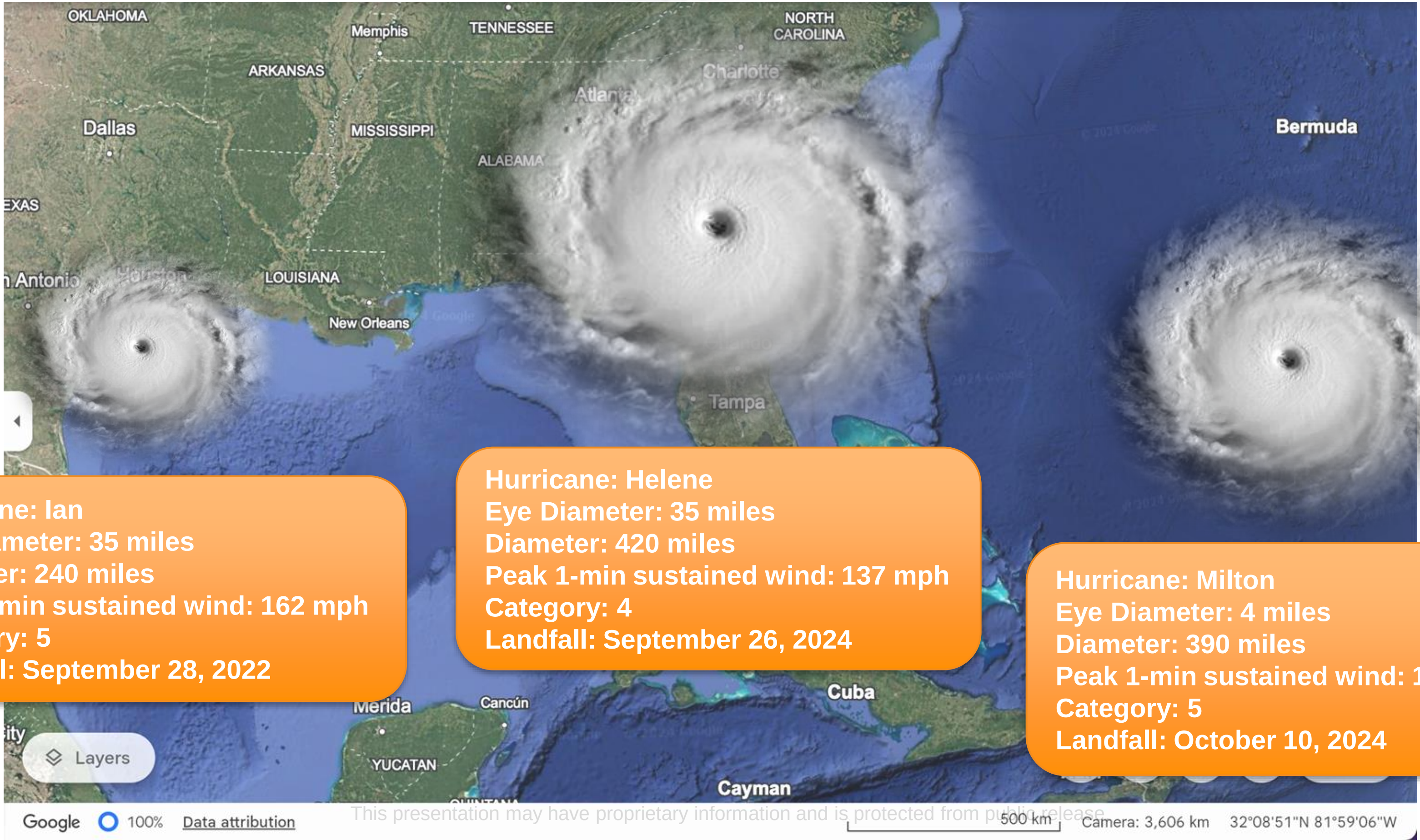

Hurricane: Ian
Eye Diameter: 35 miles
Diameter: 240 miles
Peak 1-min sustained wind: 162 mph
Category: 5
Landfall: September 28, 2022

Hurricane: Helene
Eye Diameter: 35 miles
Diameter: 420 miles
Peak 1-min sustained wind: 137 mph
Category: 4
Landfall: September 26, 2024

Hurricane: Milton
Eye Diameter: 4 miles
Diameter: 390 miles
Peak 1-min sustained wind: 180 mph
Category: 5
Landfall: October 10, 2024

Hurricane Helene Impact

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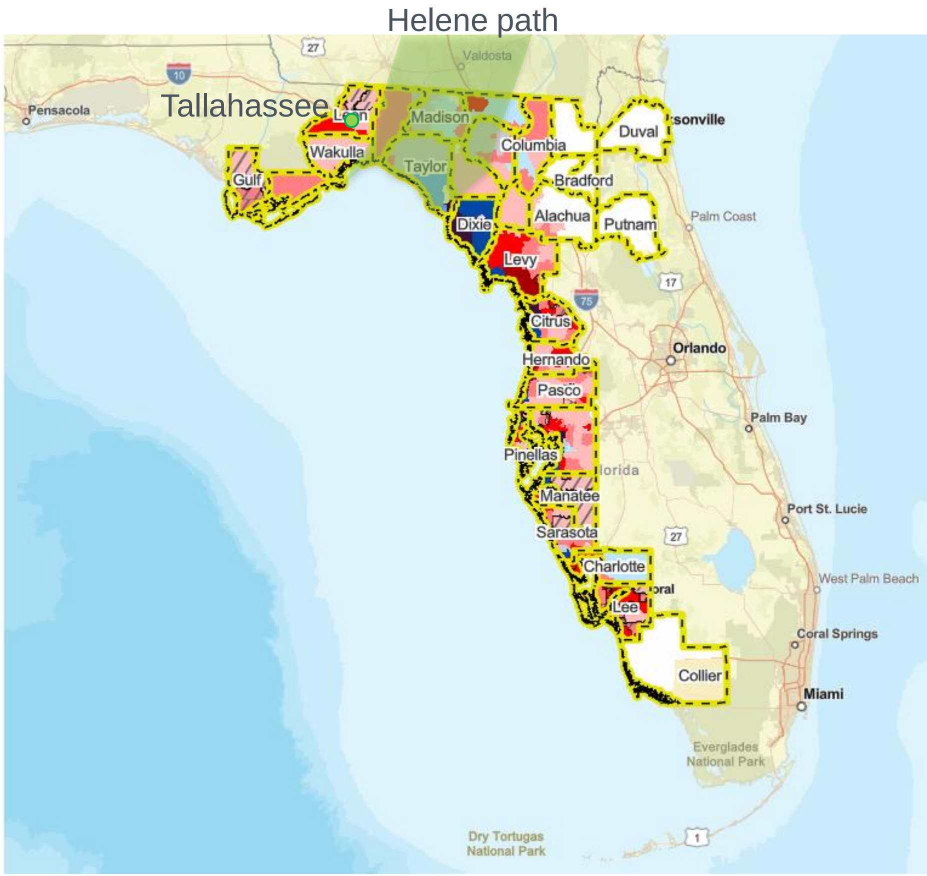

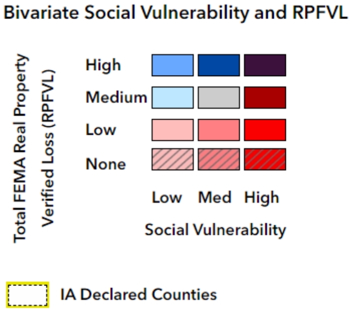

About the map:

This depiction of Total Real Property Verified Loss (RPFVL) and social vulnerability across the HURRICANE HELENE impact area is derived from FEMA Open IA data. Places where greater losses intersect higher social vulnerability areas may help pinpoint most-distressed areas where unmet needs may be higher. Understanding where potential areas of greater unmet needs occur across a disaster impacted area can be useful for emergency response, recovery, and mitigation planning and program development.

Spatial analytics derived by the vulnerability mapping and analysis platform at the University of Central Florida - www.vulnerabilitymap.org

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Hurricane Aftermath

Tampa after Hurricane Milton - power outage of 5 days

Orlando after Hurricane Ian - power outage of 5 days

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Resident Feedback

– Outage Information

- Held 1 stakeholder meeting (May 2023), and 5 focus group meetings in Orlando, Tampa, Tallahassee, and Panama City (56 people total)
- Feedback from residents on outage information:
  - **Dashboard add-ins:** probability of an outage (92%); links to social services for outage (69%); power restoration timeline (61%); community groups (54%).
  - **Issues with power outages:** access to better information (73%); mental and emotional impacts (58%); food and water; routine disruption.

"I know the power's gonna come back on, but it's always like you don't know where you fall in line, like how bad your area is compared to others. […] So just not knowing or having an idea I think is a big concern." – Joy, Tallahassee

"Getting the utility back on is the major thing for me to help things start going back to normal. As long as the power is out, you just like, you know, waiting pattern, waiting for to see what's gonna happen, when it's gonna happen, if you are gonna have to throw your food out, or how you're gonna stay cool, what you're going to eat and stuff like that." -Kay, Tallahassee

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Resident Feedback

– Technology Solutions

- **Perceptions of energy technology:** familiar with solar, but apprehensive about the cost; unfamiliar with energy storage; some safety concerns.
- **Relationships with utilities:** high distrust of utilities; most not willing to pay more for greater grid resilience – distrust and lack of financial resources.
- **Small interest and awareness of community resilience hubs or concepts related to resilience hubs**

"Well, I mean, if I wanted to spend the money for it in a whole house generator, I could choose to do that. […] I have a friend with a generator and I have another friend with a generator and I have another friend that has a generator. So there are places for me to go. I'm not in that place of putting that infrastructure in my home. And I'm not alone in that. There are a lot of people that don't have the ability to pay that extra money because of all the other things that we have to pay every ding dong day because they charge us for everything and everything and everything. And depends on your situation. Like, I'm single, I live alone. I have my salary is my salary full stop." -Violet, Tallahassee

"I was gonna mention that the stores are really, um, awesome. 'cause I saw a lot of people outside of Publix, um, charging their stuff. Yeah. They didn't really say anything. They just let it happen. So that I think really made a difference too, um, because you did have a huge homeless population that didn't have a place. – Koko, Tallahassee, reflecting on power outages during the tornado outbreak in May of 2024

Power Outage Detection

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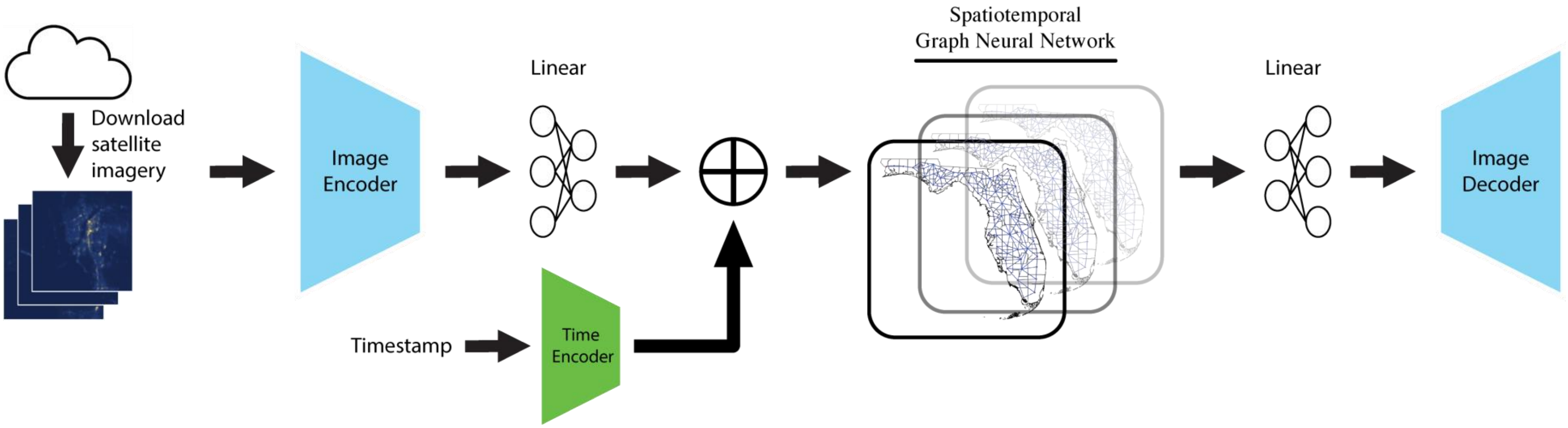
Spatiotemporal Graph Neural Network for short-term risk maps and recovery forecasting.

Input: set of images (*t*-n, *t*)
Output: set of images (*t*, *t*+*n*)

*until *n*=5 with low error



Power Outage Detection

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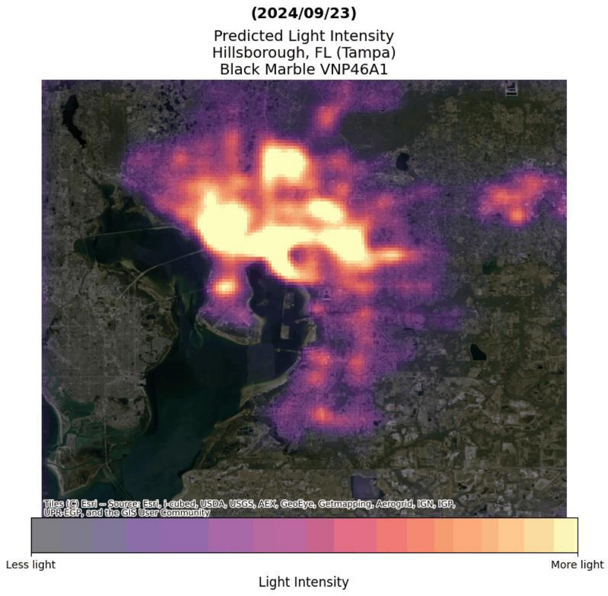
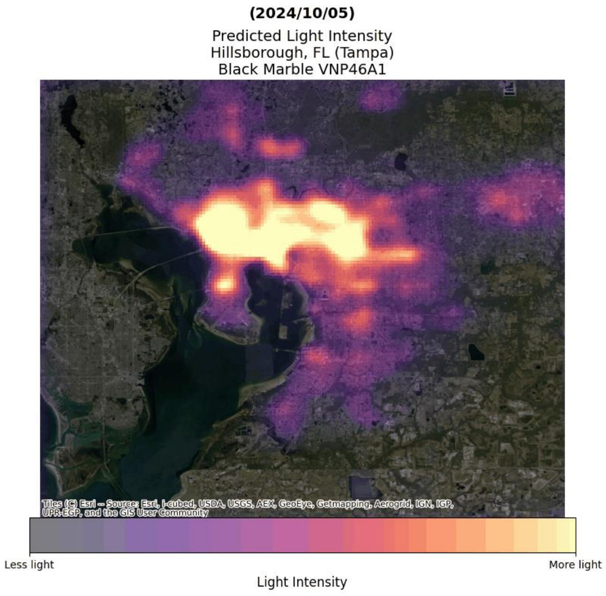
Hurricane Helene Hillsborough County, FL (Tampa)



Hurricane Milton Hillsborough County, FL (Tampa)

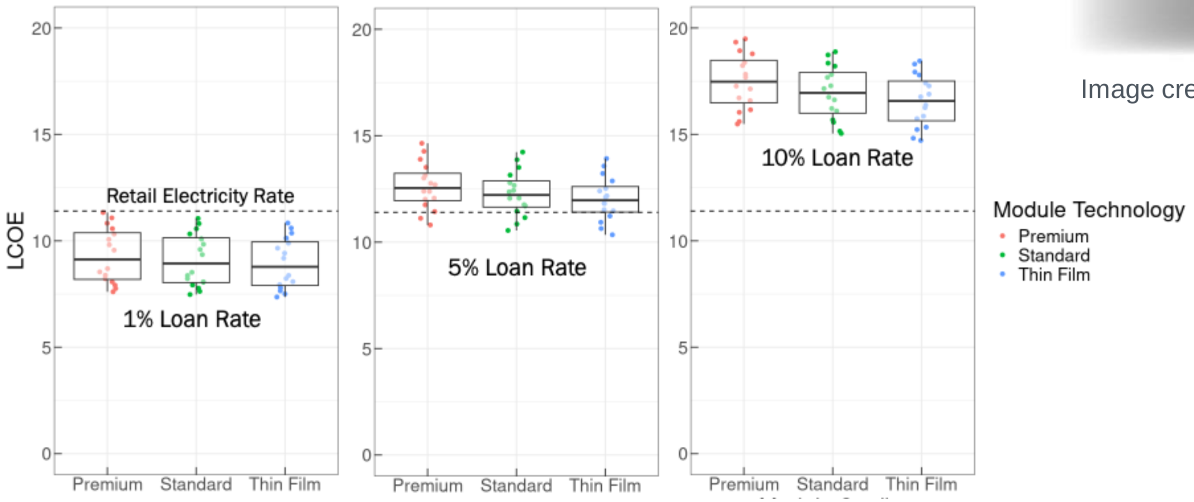


Energy Resilience Solutions

Funded by: U.S. Department of Energy — Office of Energy Efficiency & Renewable Energy — Solar Energy Technologies Office

- Residents interested in photovoltaics (PV), but unsure of the costs and unfamiliar with energy storage options
- Actual cost to customer driven more by financing than technology selection

Levelized Cost of Energy (LCOE) of PV with Battery System



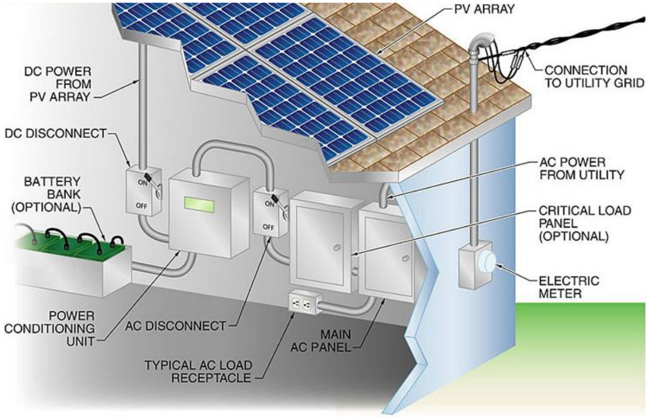


Image credit: J. Dunlop, *Photovoltaic Systems*, 2012.

Community PV + Storage

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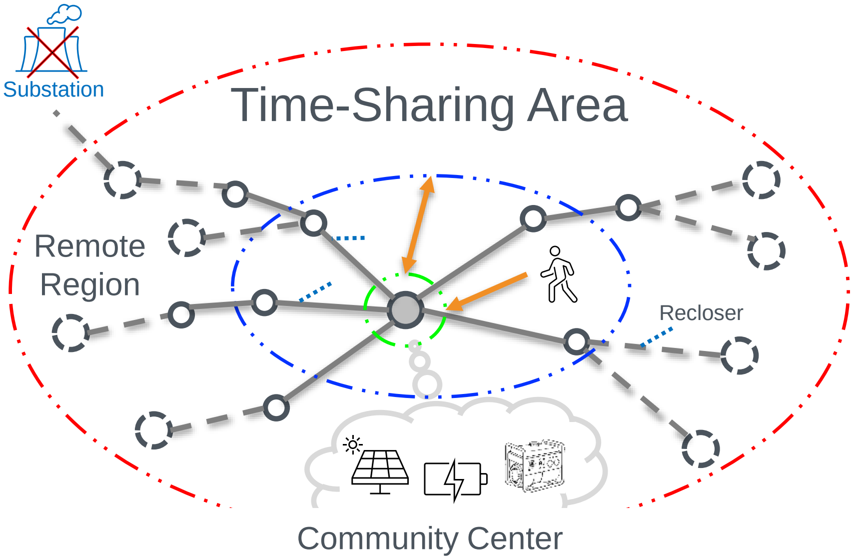


Fig 1. System configuration

- Extreme weather may cause physical damage that takes substations offline.
- Should the substation be offline, the community center (CC), if available, could provide power.
- PV + Battery installed at the community center should be designed to provide resilience during the outages.
- Reclosers can be installed to reconfigure the network to enable a time-sharing resilience strategy (TSRS).
- The load clusters can be adaptively reconfigured with respect to power capacity available, despite of variations in solar irradiance.
- Residences nearby are encouraged to visit CC to use appliances collectively for energy-saving purposes.

Breakout Session

Question 1
How do you define resilience?

Question 2
Which energy resilience metrics are important? How these should be implemented?

Question 3
What resilience benefits can be provided by solar and other DERs such as batteries and EVs?

Question 4
What can be improved to provide equitable access to solar?

Question 5
How do you think solar and DERs should be included in energy restoration processes after extreme events?

Question 5
How do you think solar and DERs should be included in energy restoration processes after extreme events?

Question 6
What are the workforce challenges for community microgrids? (e. g. expertise needed for design and operations)

Wrap up

Technology Innovation Session 2

Solar and DER Management: Interdependencies with User Behavior

- **David Pinney**, Principal, Analytical Tools and Software Products, National Rural Electric Cooperative Association
- **Max Ferrari**, R&D Associate, Oak Ridge National Laboratory
- **Austin Counts**, Solar & Electrification Projects Manager, Appalachian Voices

CIDER, Community Integrated Distributed Energy Resilience

A Cooperative Model for DER Restoration

SETO Peer Review 2024

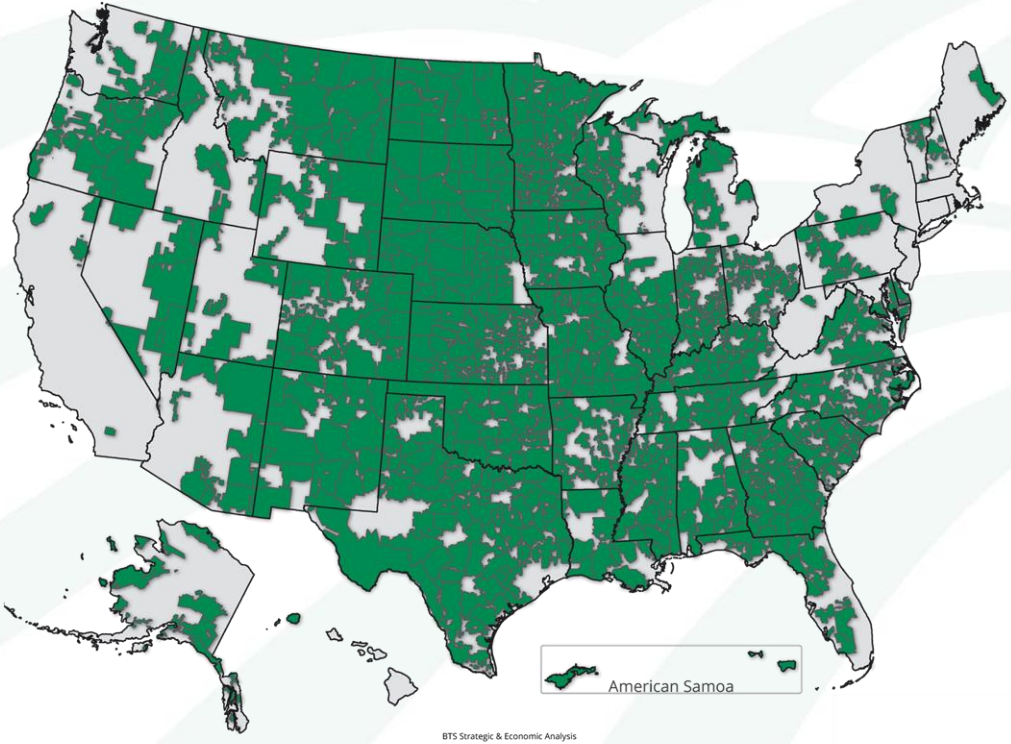
David.Pinney@NRECA.coop (PI)

March 27, 2024

NRECA
America's Electric Cooperatives

America's Electric Cooperatives

- Serve 42 million people in 47 states through 65 generation & transmission (G&T) co-ops and 840 distribution co-ops
- Consumer-owned not-for-profits
- Average 7.4 consumers per mile of distribution line versus 40+ at IOUs and Munis
- Serve 92% of all US Persistent Poverty Counties



BTS Strategic & Economic Analysis

NRECA
America's Electric Cooperatives

Our RACER Project, CIDER

Problem Statement:

- Reliability of the US bulk power system is getting much worse [1]
- Outage events from extreme weather are increasing in frequency [2]
- 70% of new generation additions are DERs, growth rate is exponential [3]
- Only a minority utilities are even planning to coordinate with behind-the-meter DERs [4]

Our Solution:

- A next level DERMS (Low-cost device integration, battery-equivalent controls, restoration planning integrated into a real-time data platform can unlock the potential of DERs as resilience assets).

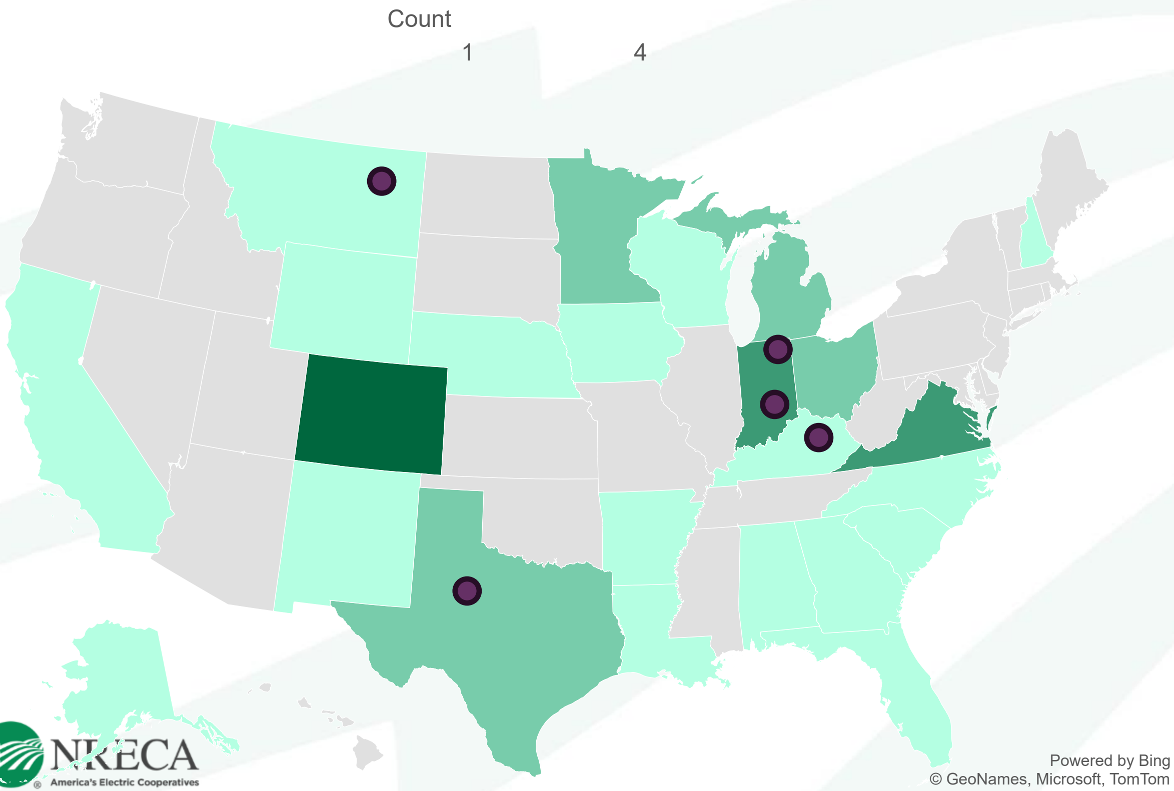
Timeline:

- Solution developed and deployed at 5 rural electric cooperatives.
- Measuring benefits through 2026

NRECA America's Electric Cooperatives CAMUS EMULATE **← Project Team Members**

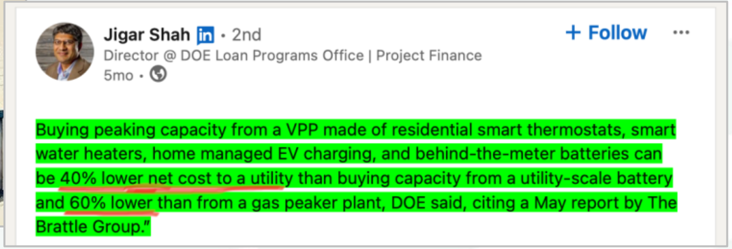
Huge Level of Utility Interest

Purple



Co-op Name	State	Co-op Type
Poudre Valley REA	Colorado	Distribution
Lumbee River EMC	North Carolina	Distribution
Wolverine + Cherryland	Michigan	G&T
Hendricks Power	**Indiana**	**Distribution**
Tipmont REMC	**Indiana**	**Distribution**
Trinity Valley EC (Rayburn EC)	**Texas**	**G&T**
Hoosier Energy	Indiana	G&T
Buckeye Power	Ohio	G&T
Great River Energy	Minnesota	G&T
Minnesota Valley Electric Co-op	Minnesota	Distribution
DEMCO	Louisiana	Distribution
Midsouth Electric Cooperative	Texas	Distribution
South Central Power Co	Ohio	Distribution
Flathead EC	**Montana**	**Distribution**
SECO Energy	Florida	Distribution
Kenergy + G&T Big Rivers	**Kentucky**	**G&T**
Kotzebue Electric Association	Alaska	Distribution
Anza Electric	California	Distribution
Midwest Electric	Nebraska	Distribution
Tombigbee EC	Alabama	Distribution
Pierce Pepin	Wisconsin	Distribution
Powder River	Wyoming	Distribution
HomeWorks Tri-County EC	Michigan	Distribution
Kit Carson EC	New Mexico	Distribution
Cobb EMC	Georgia	Distribution
CEPCI (S. Carolina)	South Carolina	G&T
United Power	Colorado	Distribution
Grand Valley Power	Colorado	Distribution
Rappahannock EC	Virginia	Distribution
Northern Neck EC	Virginia	Distribution
CIPCO (Iowa)	Iowa	G&T
New Hampshire EC	New Hampshire	Distribution
Ozarks Electric Coop	Arkansas	Distribution
Vermont EC	Virginia	Distribution
Holy Cross	Colorado	Distribution

How We'll Use DERs to Improve Resilience


Jigar Shah · 2nd
Director @ DOE Loan Programs Office | Project Finance
5mo ·
+ Follow

Buying peaking capacity from a VPP made of residential smart thermostats, smart water heaters, home managed EV charging, and behind-the-meter batteries can be 40% lower net cost to a utility than buying capacity from a utility-scale battery and 60% lower than from a gas peaker plant, DOE said, citing a May report by The Brattle Group."

Backup Power for Critical Loads

- Can backup power be offered more affordably? (e.g. normal operations control for savings)

Outage Response for Critical Loads

- Can we prioritize load shedding around DER-backed loads?
- Can we provide backup power on-demand to critical loads? (e.g. can EVs used for mobile restoration.)

DER in Restoration

- With good control and visibility can we energize parts of the system for some hours during multi-day bulk system outages? (e.g. during daytime with solar + storage.)

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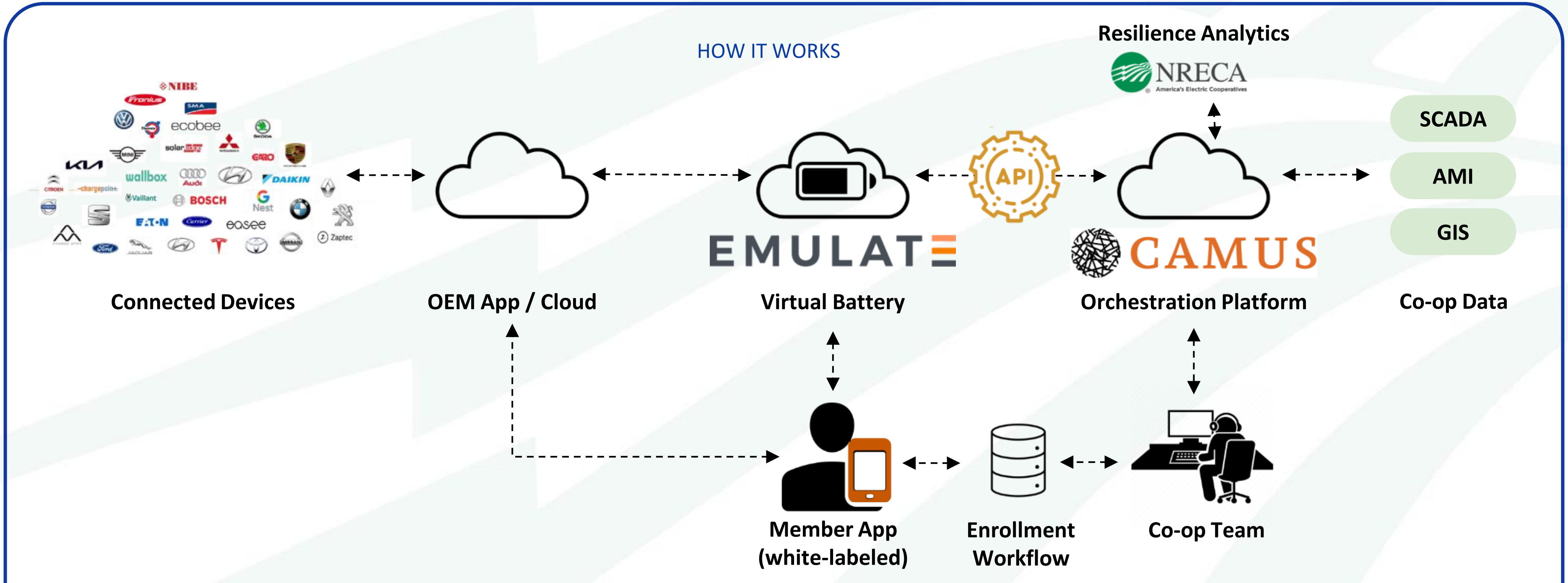
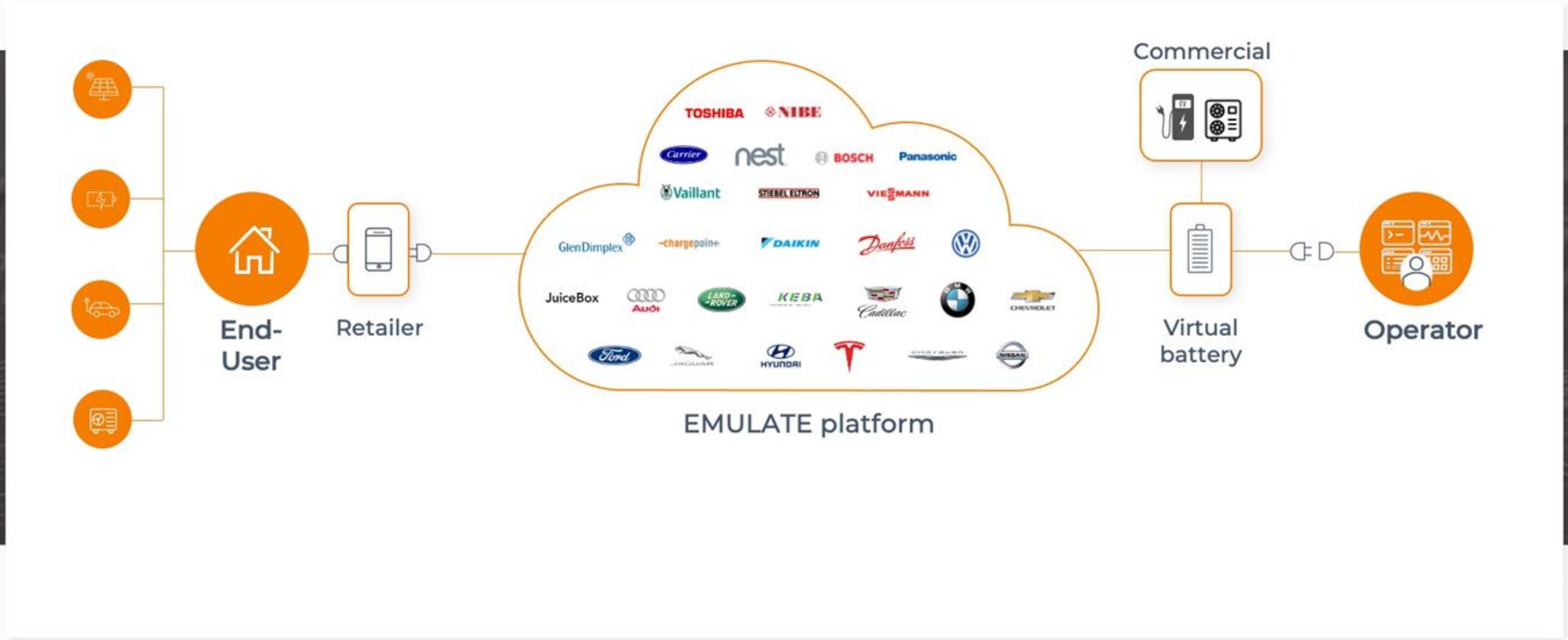
DERMS Ain't Easy (Technical Architecture)

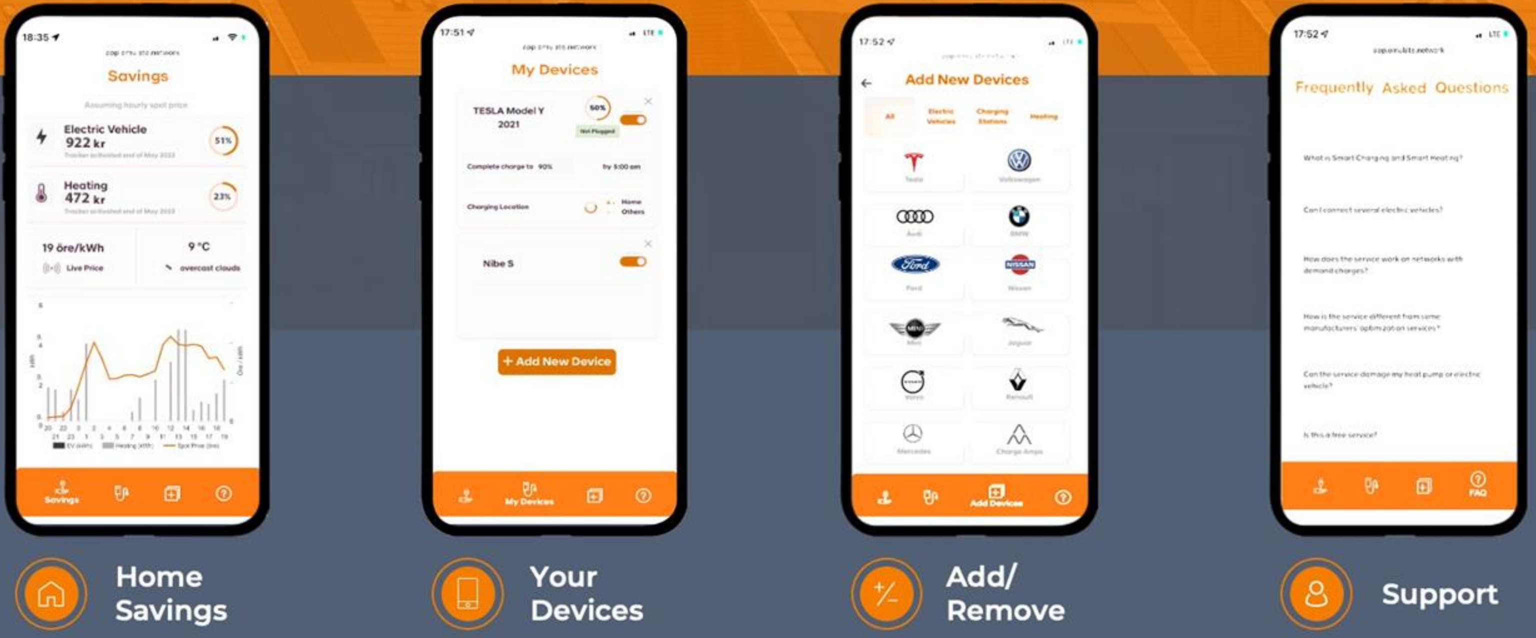


Program Design: Power System Engineering, Inc. (powersystem.org)

Emulate: Affordable and Durable DER Connectivity Through Smart Home Technology

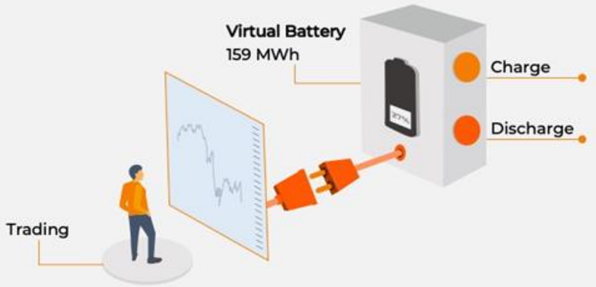


Emulate: Expanding Utility Smartphone Apps to Provide a Great DER Management Experience



Emulate "Virtual Battery" makes controlling multiple types of DERs at the same time easier

Control could not be easier - the battery spec defines the limitations of what can be done without **user comfort** being affected negatively.



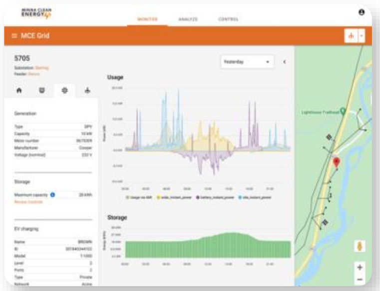
"Virtual batteries" could lead to cheaper, cleaner power

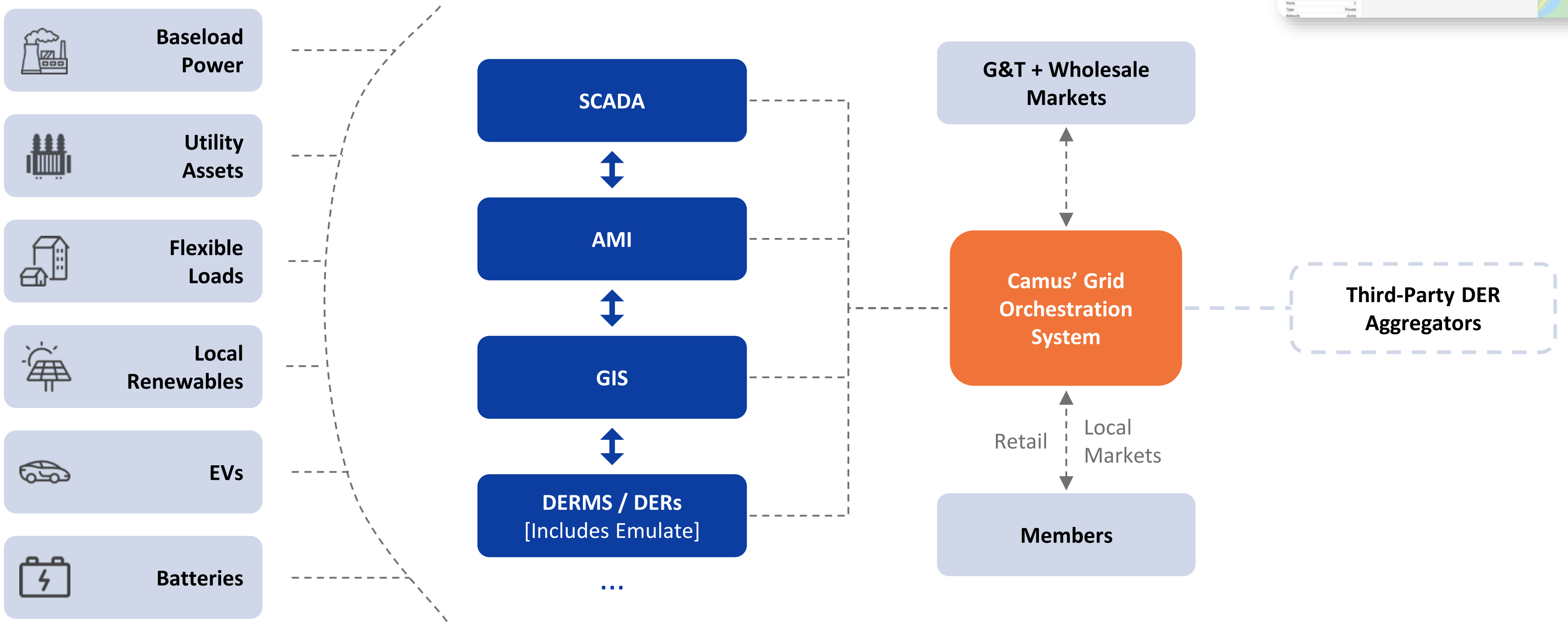
Coordinating smart appliances and electric cars may help balance supply and demand in the power grid.

Larry Hardesty | MIT News Office
March 24, 2017

Coordinating smart appliances and electric cars may help balance supply and demand in the power grid, according to a new study.

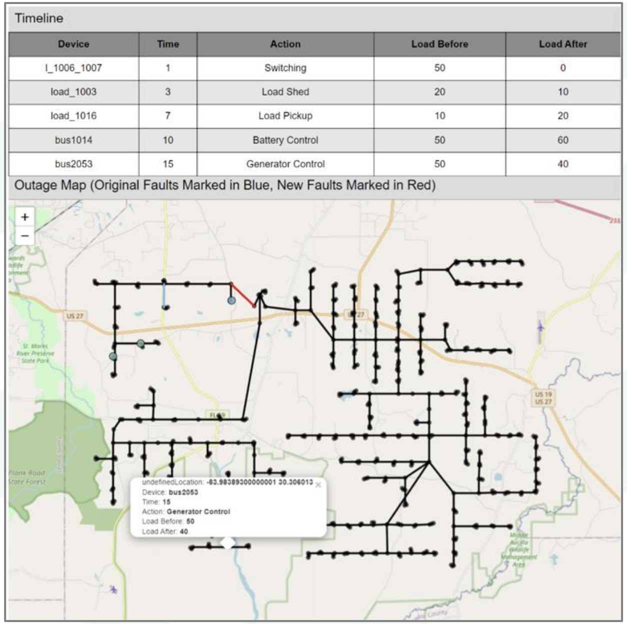
Camus: Solving our Data Integration Challenge





Restoration With DERs Demands New Tools

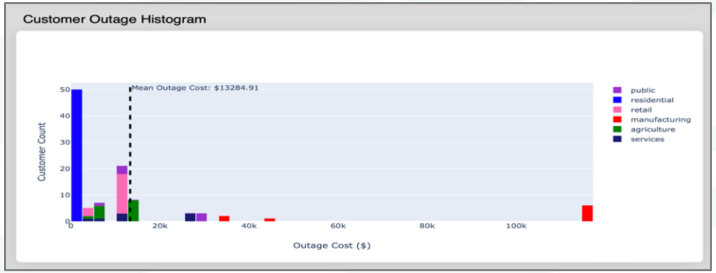
- Restoration with DERs is a huge challenge (e.g. 3 steps become 20+)
- Leverage optimization-based approach to dispatching DERs, switching, and re-regulating.
- Per-meter impact calculation: are we meeting member needs?

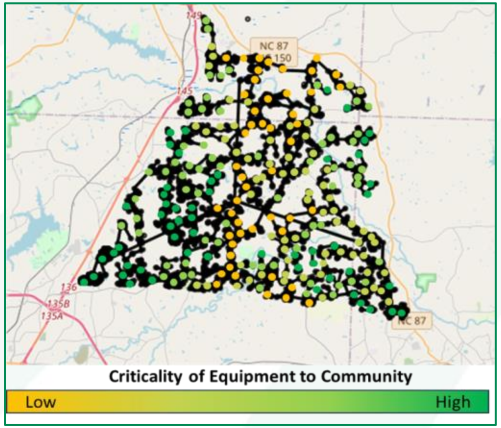


Device	Time	Action	Load Before	Load After
l_1006_1007	1	Switching	50	0
load_1003	3	Load Shed	20	10
load_1016	7	Load Pickup	10	20
bus1014	10	Battery Control	50	60
bus2053	15	Generator Control	50	40

Spatio-temporal plan for control actions for restoration

Per-meter outage duration and economic impact calculation





Impact adjustment based on community impact

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Our Progress and Plans

Today

2024

Solution Developed and Deployed With the 5 Utilities

2025

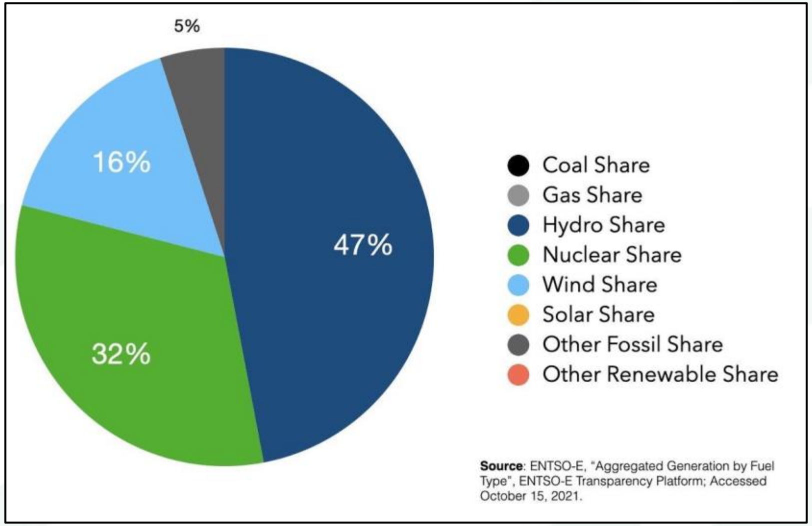
DER Programs go Live and We Begin Measuring Impacts

2026

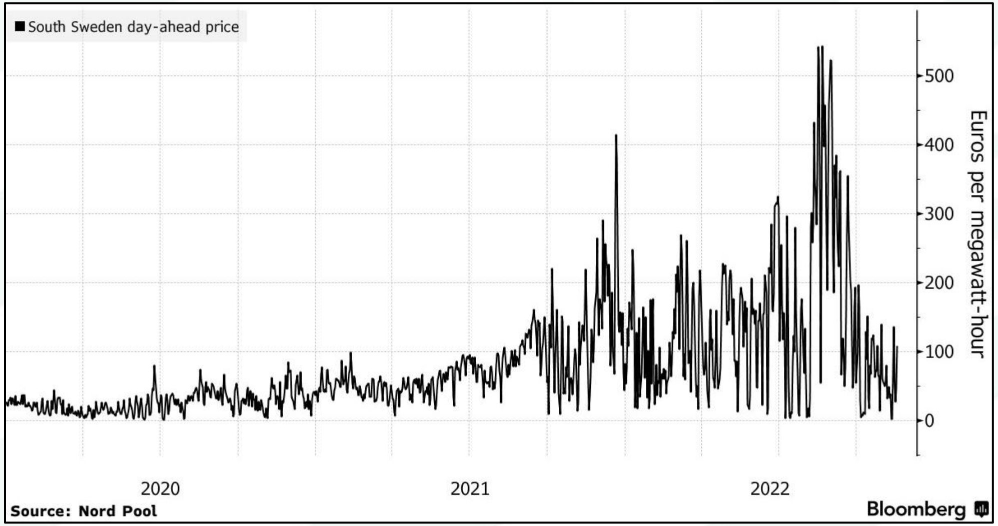
Benefits Quantified, Expanding to More Utilities

Bonus: Emulate's Experience from Sweden

Generation Mix is Fabulous...



... And Yet Prices Swung 10x



<u>This DER control technology will not be beneficial, it will be essential.</u>

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Community-owned, solar-based microgrids on rural, hurricane Prone areas: Adjuntas, Puerto Rico

SETO Award: 37771

Maximiliano Ferrari, PhD
Grid-Systems Integration Group
Oak Ridge National Laboratory

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Adjuntas Microgrid Projects

- Adjuntas experienced a prolonged power outage (~6 months) after Hurricane Maria in 2017. **Casa Pueblo** and the **Honnold Foundation** lead the construction of two solar-based community microgrids in the town square.

- Microgrids serve as a resiliency hub during natural disasters, reduces reliance on diesel, and lowering electricity costs for 15 businesses. **3 months islanded operation**

- ORNL and Casa Pueblo are launching a new "Resiliency Center" microgrid to train the local workforce, power homes, and enhance infrastructure to support the community during natural disasters

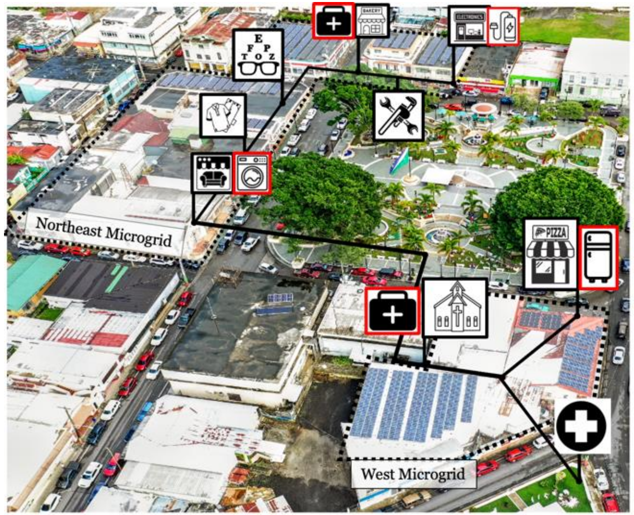


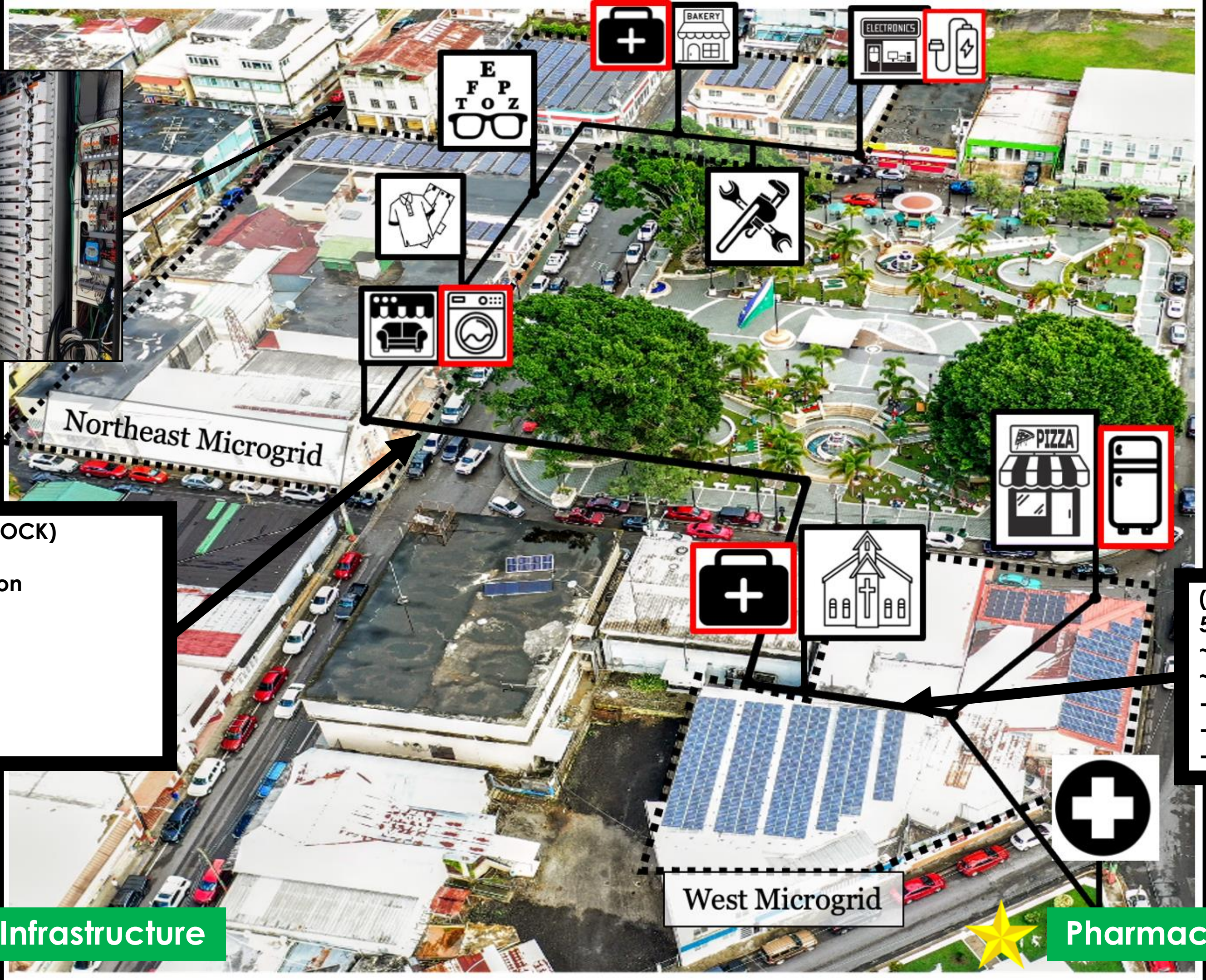
Figure 1: Microgrid Model Adjuntas Town Square. 250 kW PV based microgrid with 8-135 kWh power packs manufactured by Rivian.

ORNL Lead Research

- Propose controls and hardware for **network microgrid operation**, validate them at ORNL's Grid-C Network Microgrid Testbed DC and AC interlinks for networked microgrids

- Field demonstration, includes a new microgrid installation that will serve as workforce development and demonstration site for ORNL technology

Figure 2: New microgrid sponsored by project, will serve 7 residences, allow networked operation, and be a space for workforce development. Planned completion, December 2024.



Microgrid (NORTH BLOCK)
10 BUSINESSES
~90kW PV generation
-Furniture shop
-Souvenir shop
-Furniture
-Bakery
-Cyber cafe
-Hardware Store

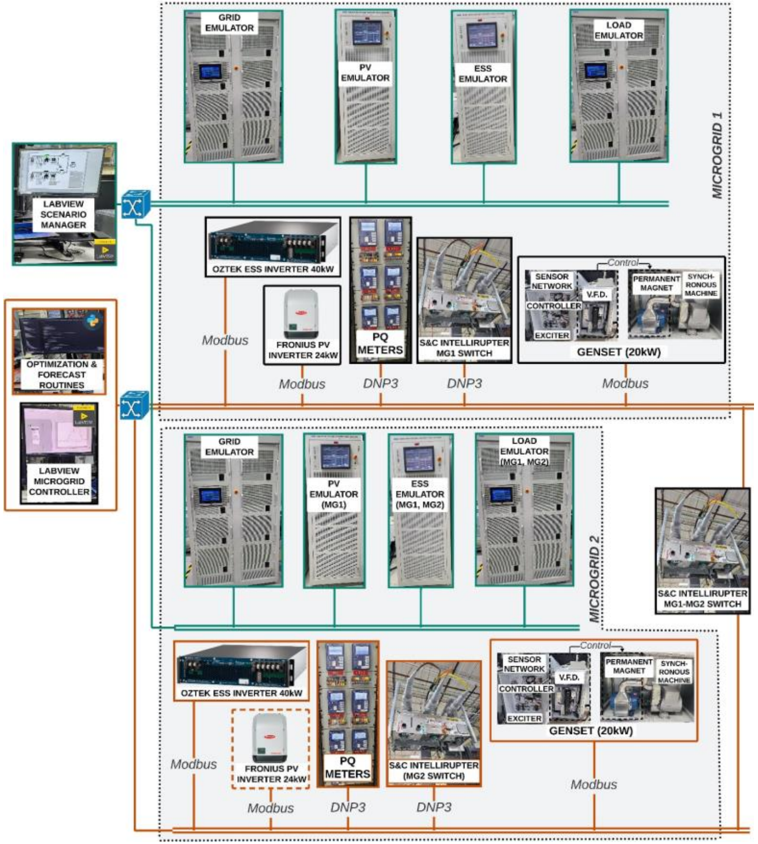
(EAST BLOCK)
5 BUSINESSES
~76kW PV generation
~660kWh ESS
-Pharmacy
-Church
-Pizzeria

Critical Infrastructure

Pharmacy

Fig 1: Left: Businesses in Northeast Microgrid. Right, businesses currently operating in island: Hardware store (a), optica, gift-shop, furniture stores (b,c), technology store (d). West microgrid (not shown), include a pharmacy, which must run 24/7 as it is a critical facility.

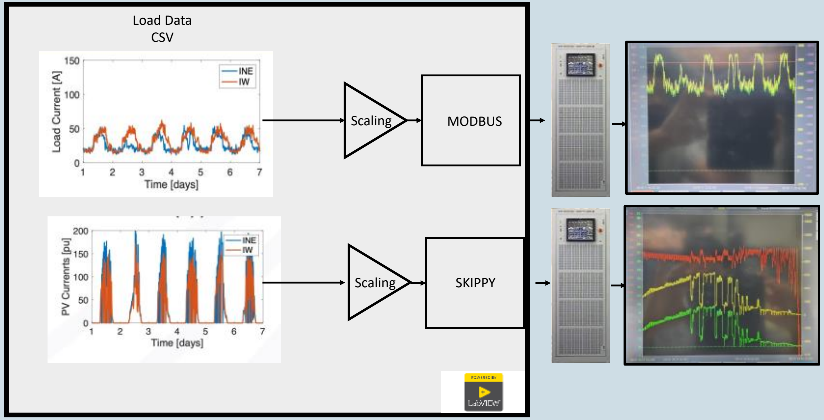
ORNL Network Microgrid Hardware Validation



ORNL's COMMANDER Network Microgrid Testbed

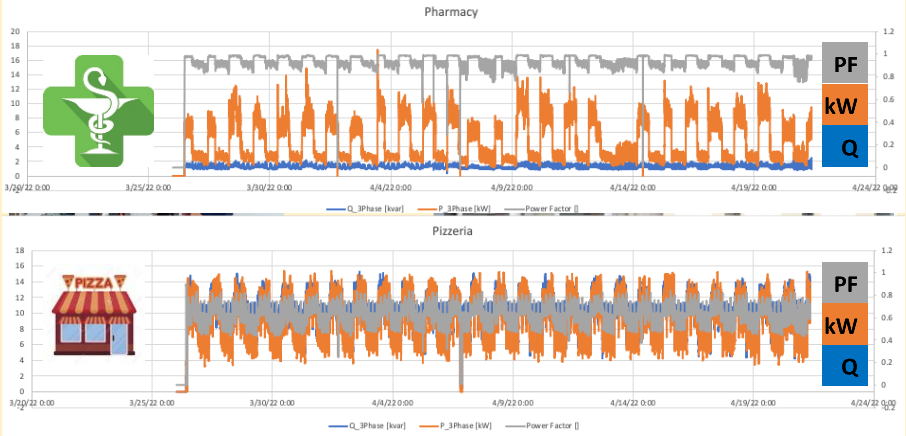
Active Load and PV Generation emulation

ORNL, Grid-C



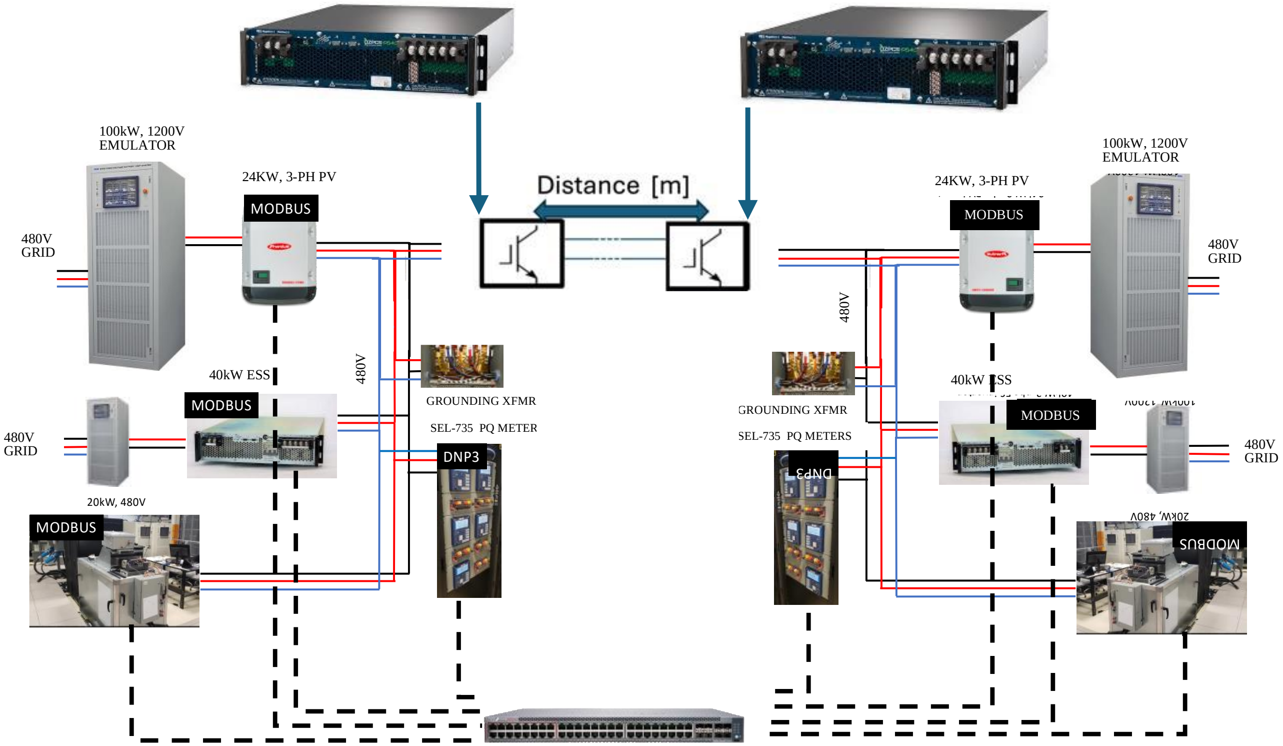
Data collected (offline)
Used in emulators

Adiuntas. PR



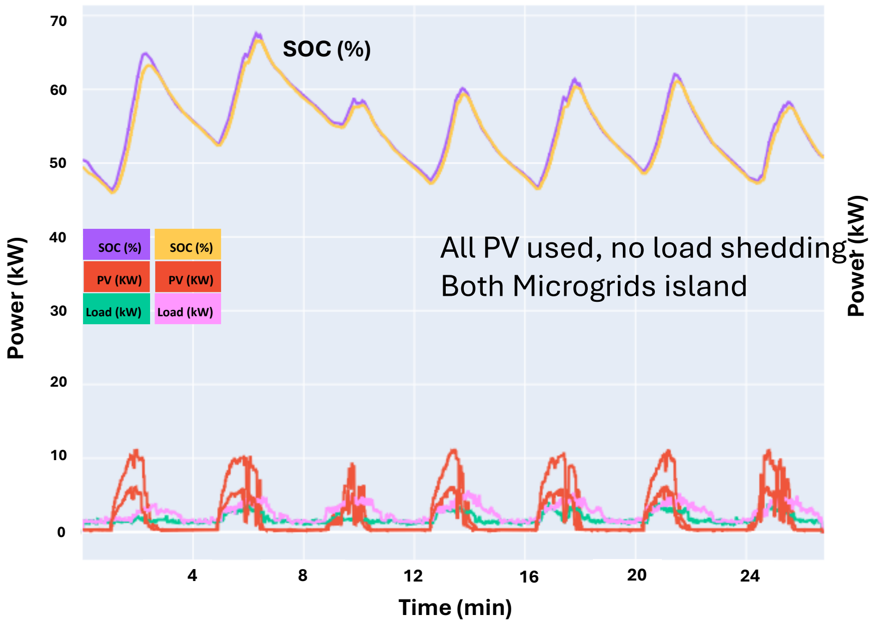
Oak Ridge National Laboratory

Laboratory Demonstration Networked Microgrid DC-interconnects

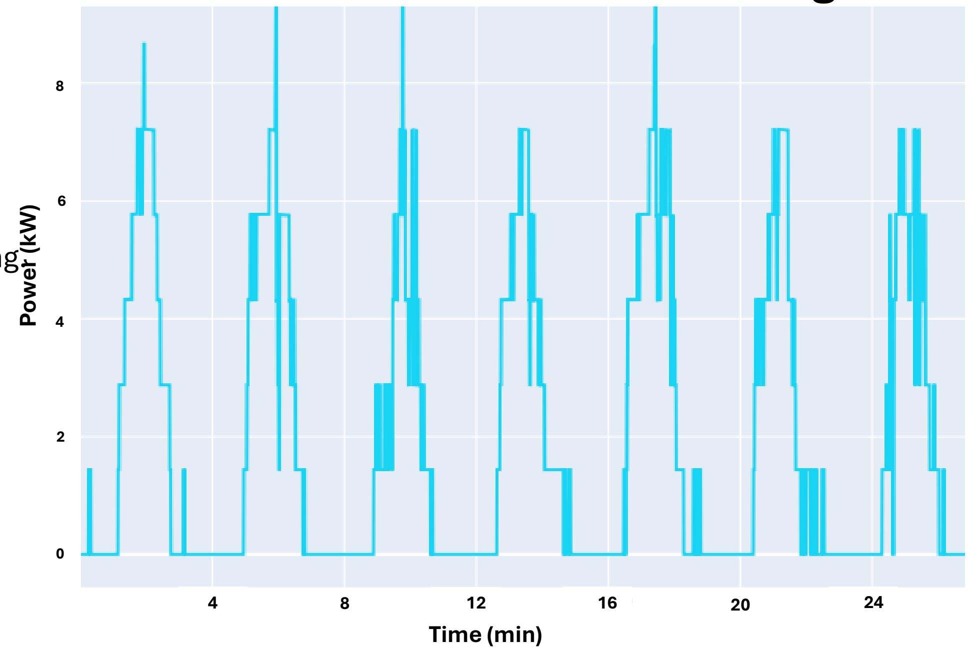


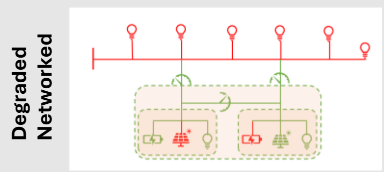
Networked Degraded Operation
Hardware validation accelerated test

North-East 100% PV. West 50% PV



Power Flow between microgrids





<u>Networked microgrids share resource for resiliency purpose, such as:</u>

<u>Scenario #1</u>: share battery as V/f resources to avoid one microgrid completely shutting down, so that critical load is survived.

<u>Scenario #2</u>: share PV to reduce load shedding/extending sustained period.

Resiliency Center and Workforce Development

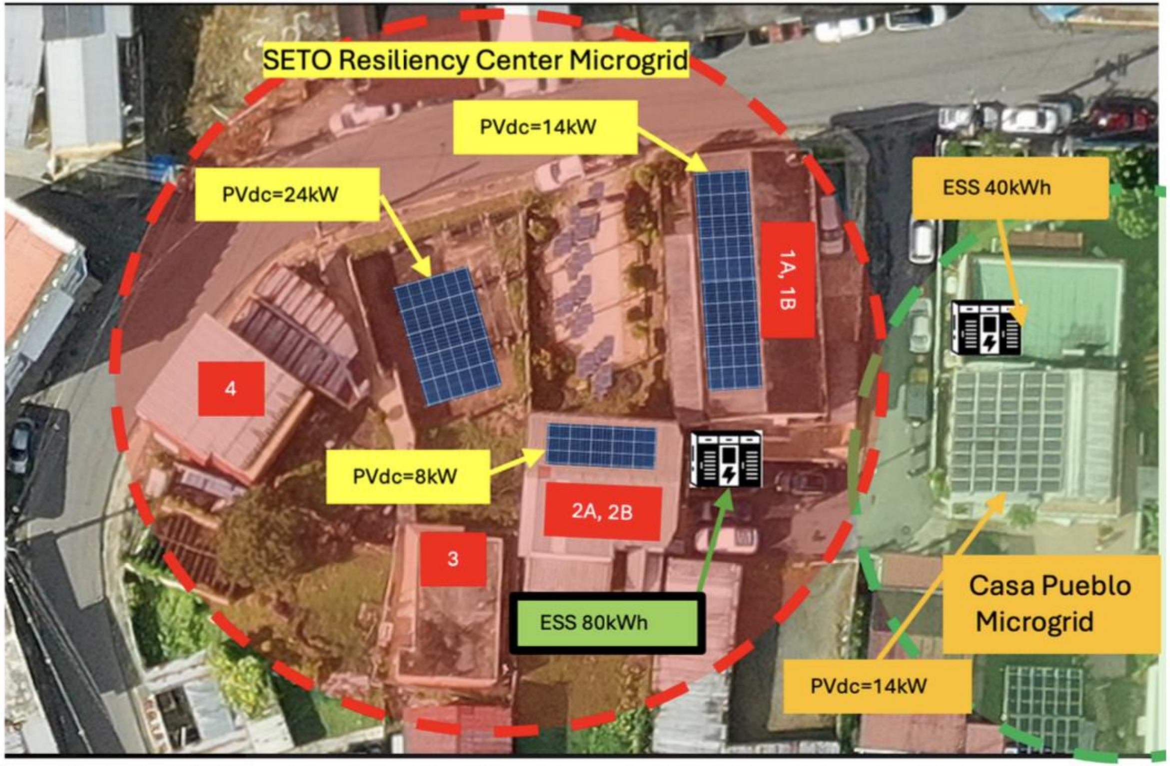
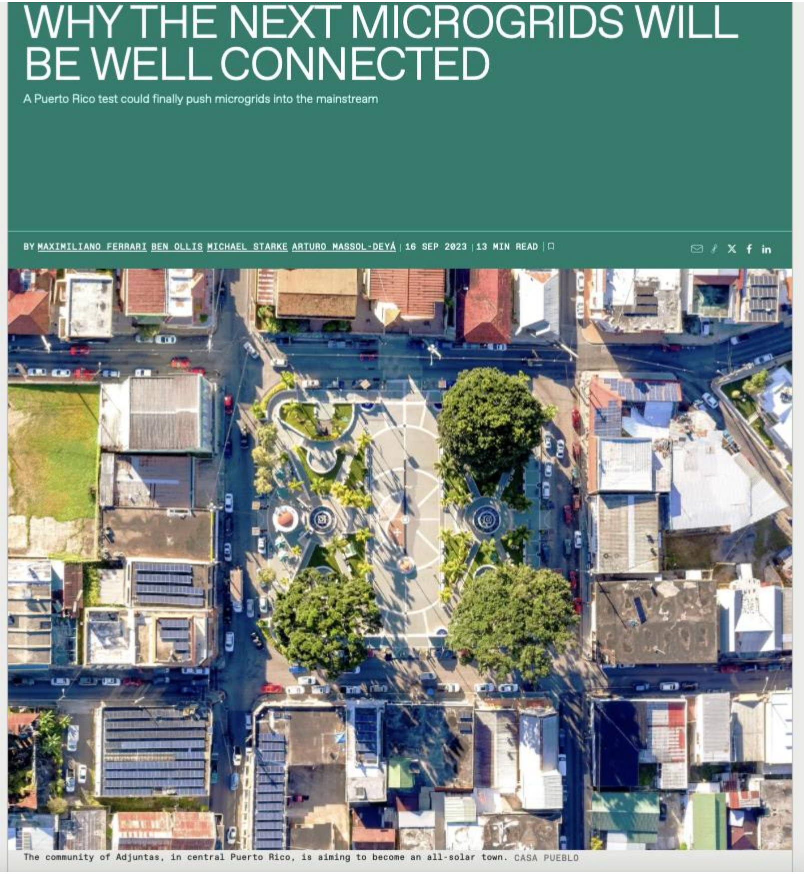


Fig 1: Aerial view of proposed Resiliency Center microgrid and Casa Pueblo's microgrid. Resiliency center microgrid will serve multiple homes in the event during prolonged outages such as the ones caused in the aftermath of natural disasters.

- Solar-based Casa Pueblo (CP) MG served community during natural disasters. The expansion of its microgrid will enhance its capacity to extend its reach and broaden the range of services offered
- Vulnerable population nearby the resiliency center will participate in the MG, which can power critical loads in their homes
- Workforce development and microgrid tool library for hands-on experience with technology
- Demonstration ORNL orchestrator for enabling networked operation of microgrids

Resiliency Center Microgrid

More information


WHY THE NEXT MICROGRIDS WILL BE WELL CONNECTED

A Puerto Rico test could finally push microgrids into the mainstream

BY MAXIMILIANO FERRARI BEN OLLIS MICHAEL STARKE ARTURO MASSOL-DEYÁ | 16 SEP 2023 | 13 MIN READ

The community of Adjuntas, in central Puerto Rico, is aiming to become an all-solar town. CASA PUEBLO

https://spectrum.ieee.org/microgrid

Lessons Learned

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Lessons Learned

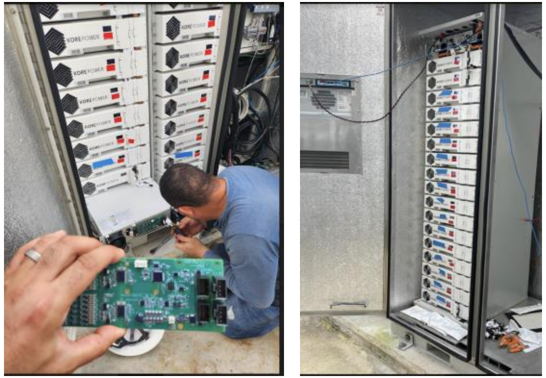
Installation

Integration and reliance on communications

String +8 inverters across businesses and rooftops : 1 master inverter

Vendors

Get extended warranty
Clear communication/boundaries



Equipment

Need good understanding of Grid-Forming Inverter is Key to success

Lessons Learned

Maintenance and Operation

Local Operation

Multiple levels of Support

Utilize local companies, their products, and workforce as much as possible

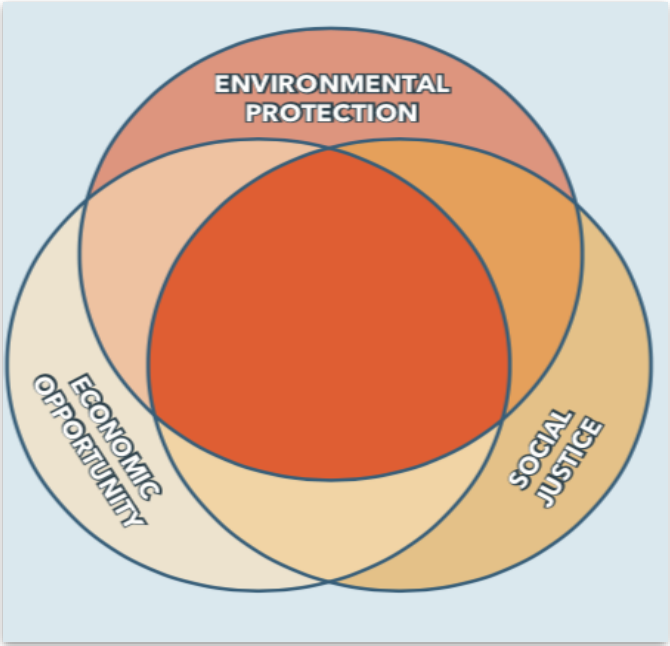
Appalachian Voices

Austin Counts - austin@appvoices.org
Solar & Electrification Projects Manager

Our Vision

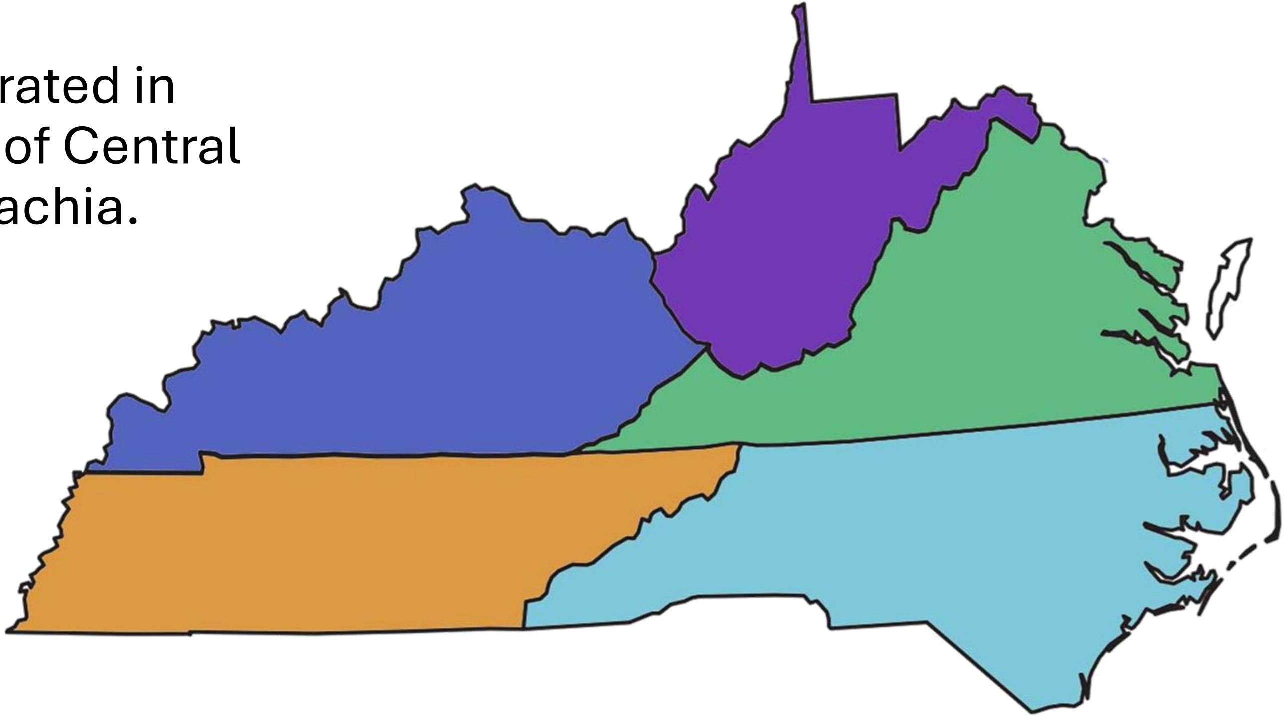
An Appalachia with healthy, intact ecosystems and generative local economies that allow communities to thrive in balance with our region's incomparable natural heritage

Theory of Change



Where we work

Our work is concentrated in the five-state region of Central and Southern Appalachia.

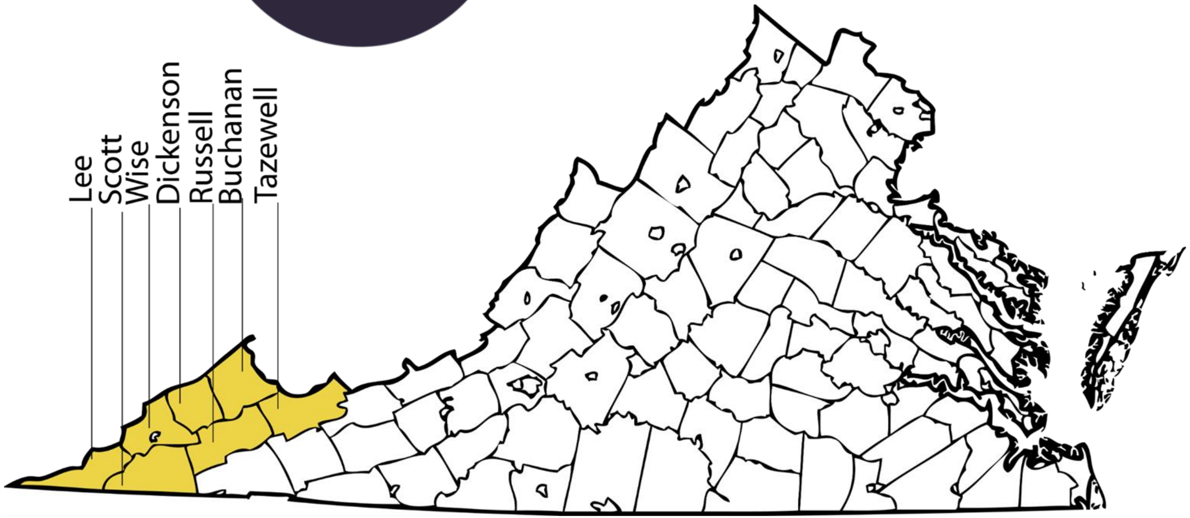


Where I work

Our New Economy Program focuses on the seven coalfield counties of Southwest Virginia in coalition with the Solar Workgroup of Southwest Virginia.

swvasolar.org

SOLAR WORKGROUP
of Southwest Virginia



Solar Workgroup of Southwest Virginia

The Workgroup is bringing solar energy development as a social and economic catalyst to coal communities.

Just this year, the Workgroup expanded into energy resilience, focusing for now on resilience hubs.

Community Led Resilience

Social dynamic challenges

- Government push or community need?
- Resilience or clean energy?

Infrastructure challenges

- Need for building resilience overall
- Basic efficiency needs first
- Local infrastructure to reduce travel burdens

Addressing concerns

- Reliability of solar
- Lack of technical understanding

Energy Resilience Projects

Virginia Energy Resilience Study - In partnership with VA Department of Energy, the Workgroup participates in the SETO funded RACER program to advance resilience planning and assessment in Southwest Virginia.

Resilience Hub Planning - By integrating resilience into multiple aspects of our work, we have identified four potential resilience hubs this year, including energy efficiency and building envelop upgrades.

Resilient Systems:
Critical Infrastructure Interdependencies

- **Xiaohui Zhou**, Director of Research and Innovation, Slipstream Group
- **Birk Jones**, Principal Member of Technical Staff, Sandia National Lab
- **Dan Alen Ricci**, Power Systems Engineer/Researcher, Idaho National Lab

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SOLAR ENERGY TECHNOLOGIES OFFICE

Resilient Systems:
Critical Infrastructure Interdependencies

An Open-source Platform to Enhance Grid and Community Energy Resilience

Xiaohui 'Joe' Zhou, PhD, PE, CEM
Slipstream Group, Inc.

November 14, 2024. Washington D.C.

Funded by:
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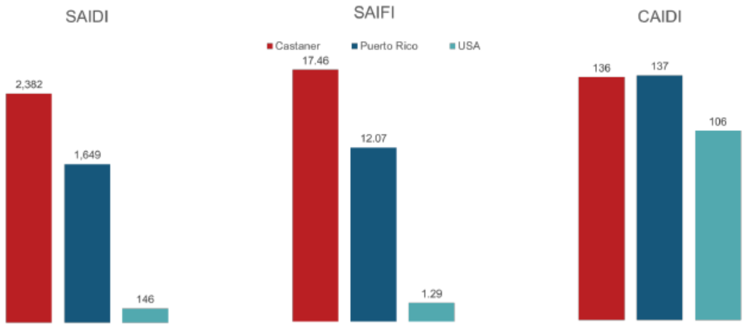
Castaner, Puerto Rico



- Total Population: 4,239
- Rural
- Underserved
- Poor
- Difficult to access

SAIDI: System Average Interruption Duration Index
SAIFI: System Average Interruption Frequency Index
CAIDI: Customer Average Interruption Duration Index

Castañer is experiencing many more outages and for longer durations

DOE RACER team: slipstream, IREC, LUMA, Cooperativa Hidroeléctrica de la Montaña, ACE IoT SOLUTIONS, TEXAS A&M UNIVERSITY

Keys to Community Energy Resilience

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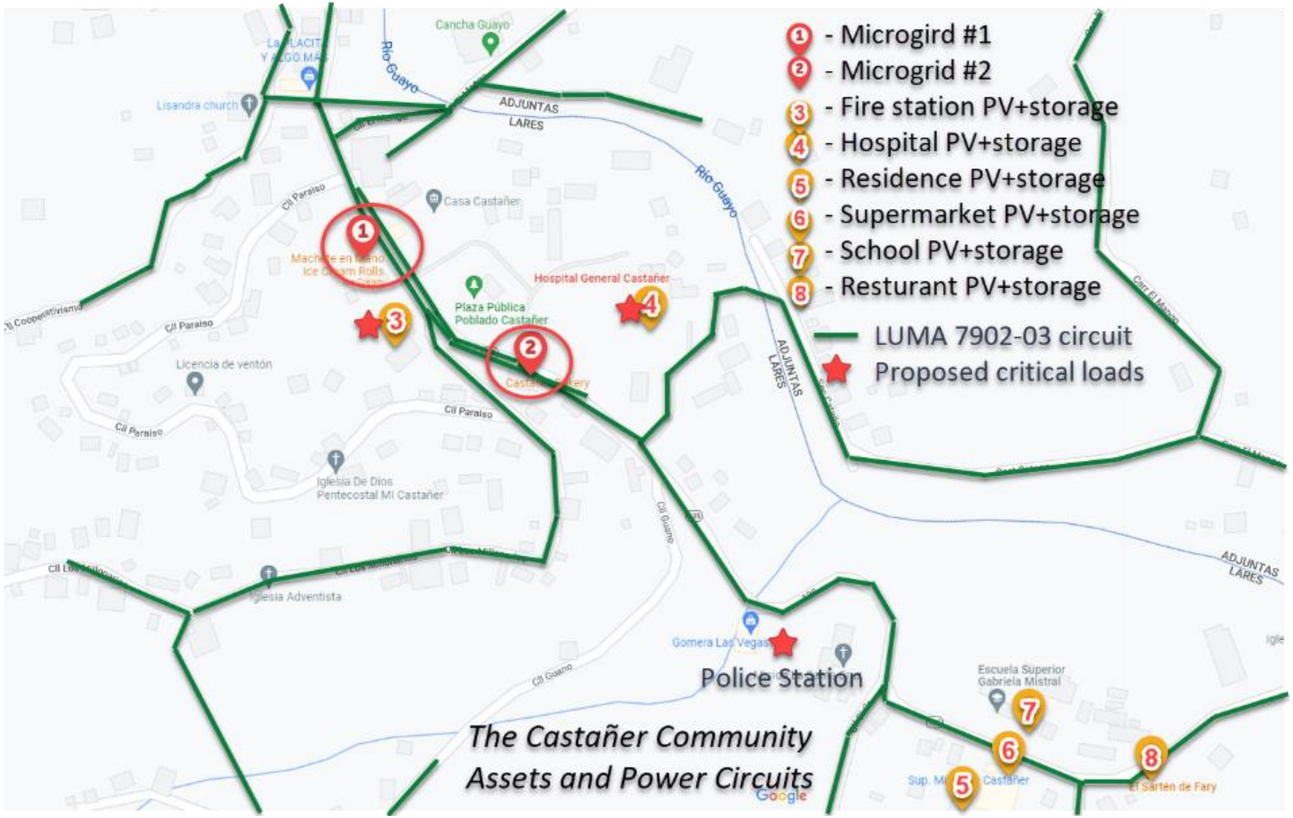

Community Energy Resilience

- Improve primary power quality
- Utilize local DERs (microgrids, solar PV, battery energy storage systems)
- End-use demand management
- Essential services: water and food access
- Access to shelters during emergencies
- Access to integrative health services
- Communication service reliability
- Road access and gas station services
- Community safety
- Community planning, governance and organizational capacity

Castaner Critical Services and Loads

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Castaner, PR

Castañer Critical Services and Loads

- Microgrid 1
- Microgrid 2
- Bedridden
- Church
- Castañer Hospital
- Firefighters
- Idenpendent Installation
- Puerto Rico Police
- Schools (shelters)
- Subsidized housing for agricultural workers
- Water and Aqueducts
- Subsidized housing for senior citizens
- Supermarket
- Gas Station
- Prepared Foods (bakeries, etc.)
- Other

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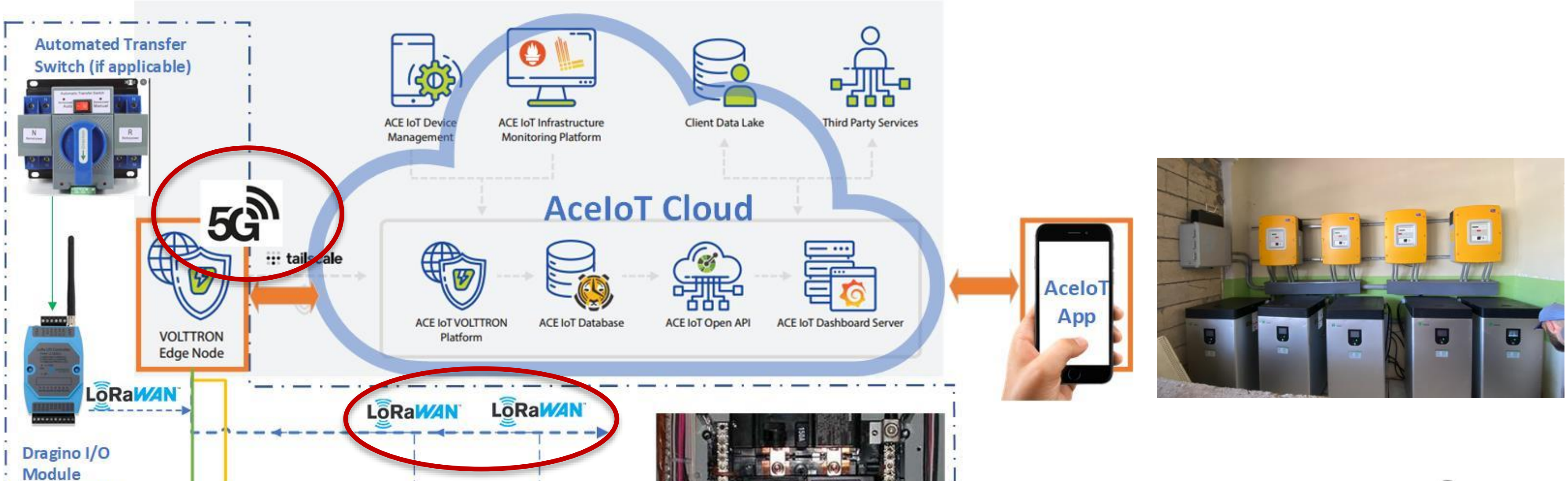
An Open-source Sensing and Control Platform



An Open-source Sensing and Control Platform

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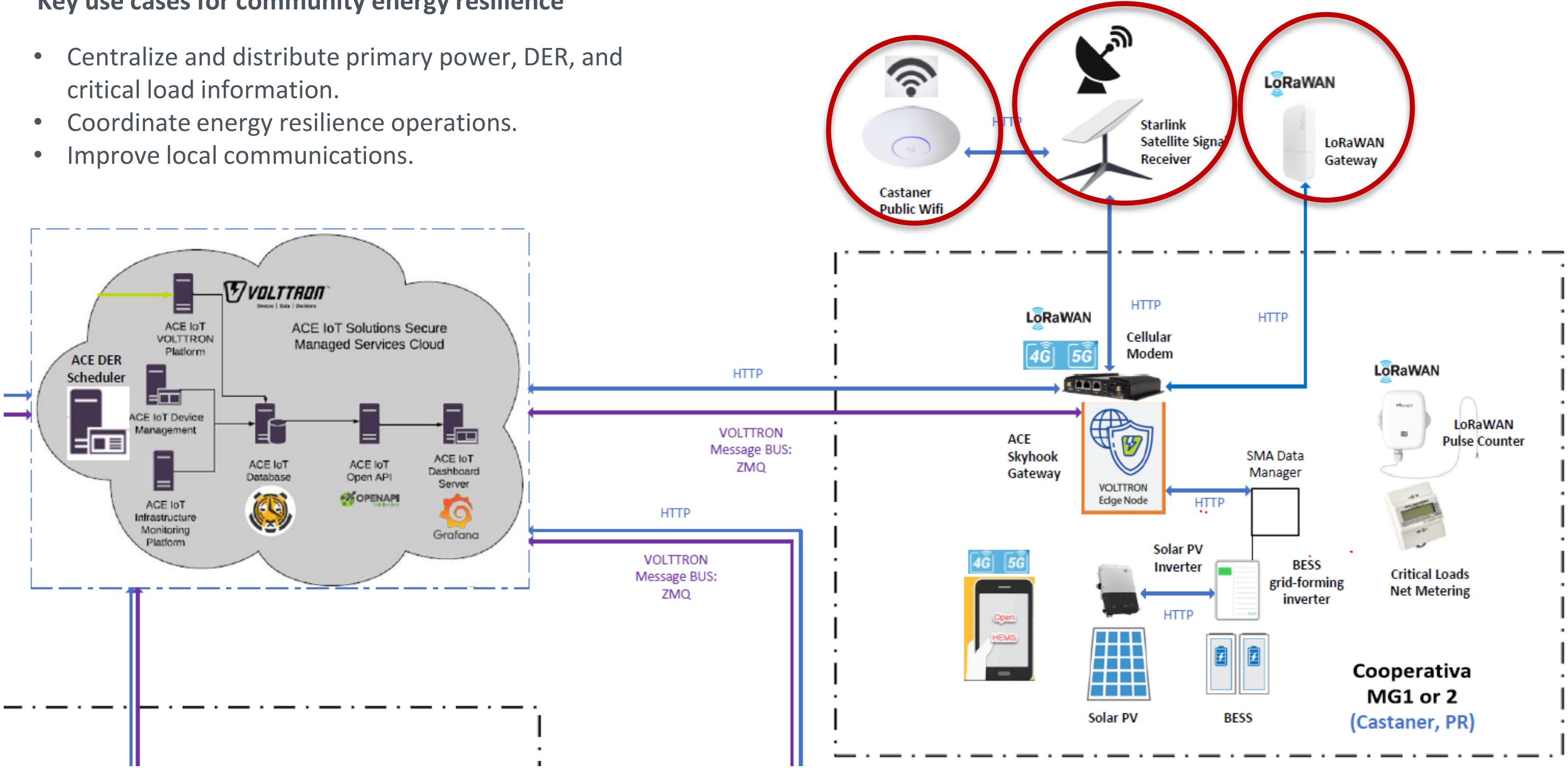
Key use cases for community energy resilience

- Centralize and distribute primary power, DER, and critical load information.
- Coordinate energy resilience operations.
- Improve local communications.



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Summary

Vulnerability in physical networks subject to extreme events

- No primary power (energy)
- No cellular network (communication)
- No wifi and internet access (information)
- Road is blocked (transportation)

Resilience improvement needed

- Backup power - especially at or near critical loads
- Backup/alternative communication methods
- Internet through satellite (information)
- Backup power to gas stations (transportation)
- Access to essential services (water/food/shelter/health service, etc.) need both power and communications

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SOLAR ENERGY TECHNOLOGIES OFFICE

Summary

Stakeholders' roles during extreme events/emergency

- Utility: restore primary power as quick as possible
- DER owners & critical facility operators: provide backup power to critical loads, and use demand management to extend the operating hours (given limited DER capacity)
- Community leaders: organize volunteers to connect with residents and direct them to critical facilities (shelter, hospital, grocery stores, etc.) Potentially utilize advanced communications (smart phone, satellite, LoRa wireless handheld, etc.) Provide education and training to community members.
- Residents: keep communications with community leaders. Participate education and training events.

Community Energy Resilience Plan

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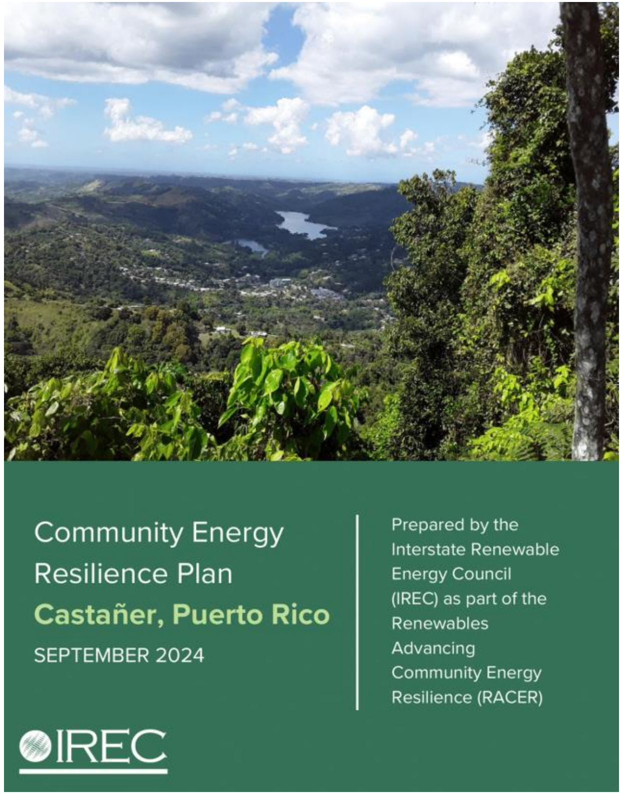
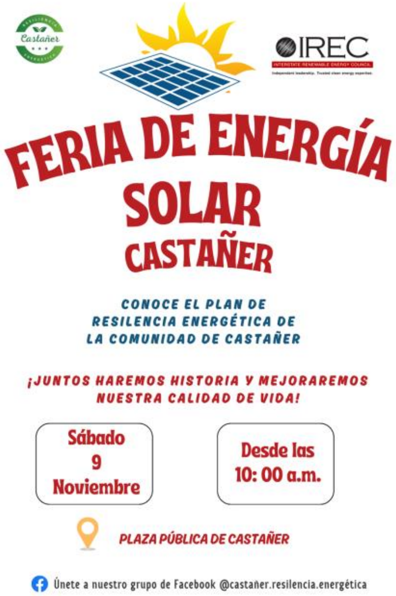
SOLAR ENERGY TECHNOLOGIES OFFICE





Security Vulnerability Considerations for Community Grid Resilience

C. Birk Jones, Ph.D.

DOE SETO Workshop: Solar and DERs for Community Energy Resilience

November 14, 2024

email: cbjones@sandia.gov

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SAND2024-XXXXX

Overview

November 14, 2024

C. Birk Jones, Ph.D.
Research focused on the integration, control, and security of Distributed Energy Resources.

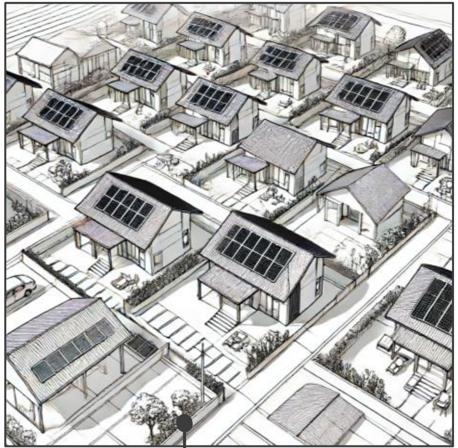
- Define Community Needs
- Coordinate Community Stakeholders
- Integrate DERs
- Implement Microgrids and/or other Resilience Measures
- Assess Vulnerabilities
- Estimate Risk
- Implement Mitigation Strategies

Scope of Discussion: Assess Vulnerabilities; Estimate Risk

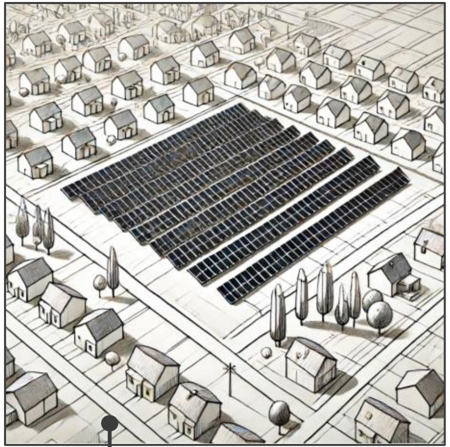
Path to Community Resilience

Environments of Interest

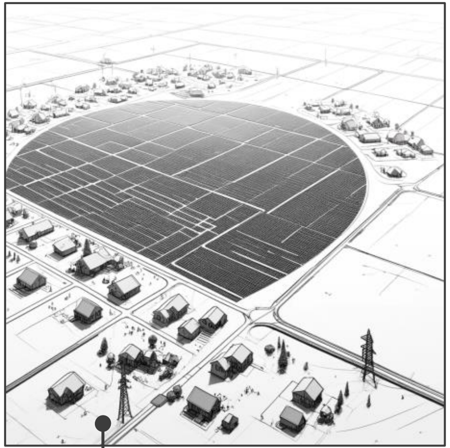
Residential



Community-Scale



Utility-Scale



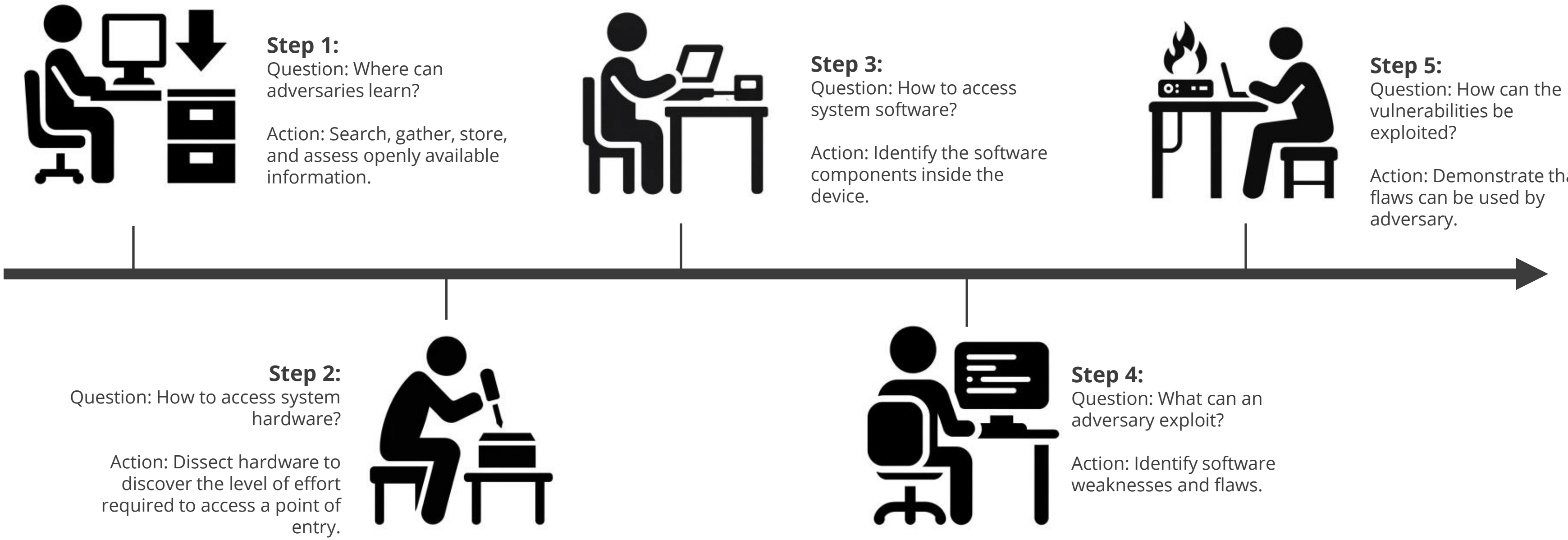
Cyber

- Residential: Local Area (Home) Internet Connection
- Community-Scale: Local Area (Site) Internet Connection
- Utility-Scale: Dedicated SCADA Network Connection

Physical

- Residential: Access dependent on house location & amenities.
- Community-Scale: Limited barriers and potentially exposed to human traffic on a regular basis (e.g., over parking lots.)
- Utility-Scale: Fencing barriers and security oversight to monitoring and prevent access to site.

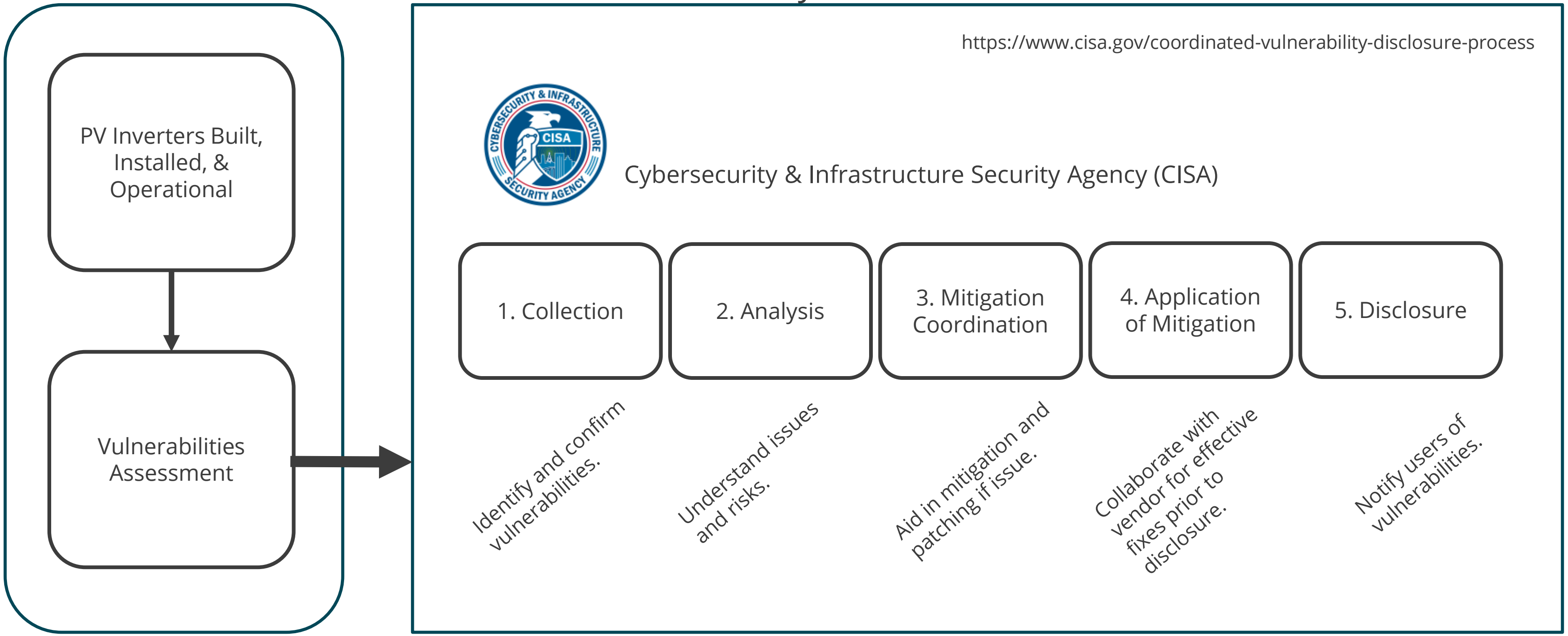
Vulnerability Identification



SAND Report: J. Hurtado, CB Jones, J. Johnson and B. Wright, "DEReliction: A Cybersecurity Vulnerability Methodology for Distributed Energy Resources"

Vulnerability Disclosure

Coordinated Vulnerability Disclosure



White Paper Report: CB Jones and J. Hurtado, "Overview and Commentary on Applying the Coordinated Vulnerability Disclosure Process to Photovoltaic System Devices"

Disclosed Vulnerabilities

Common Vulnerabilities and Exposures (CVE)

- Improper Neutralization of Special Elements
- Improper limitation of Pathname to a Restricted Directory
- Hard coded credentials embedded in code.
- Admin password set to last 6 digits of serial number
- Directory traversal
- Certification verification allows for MitM to read and later traffic

What could happen - Data or command injections, cross-site scripting, access sensitive information, upload malware, persistent access

In the news:

API for about 195 GW of solar had authorization vulnerabilities.

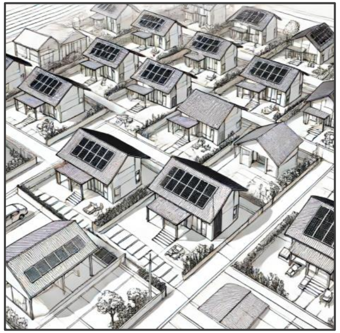
What could happen:

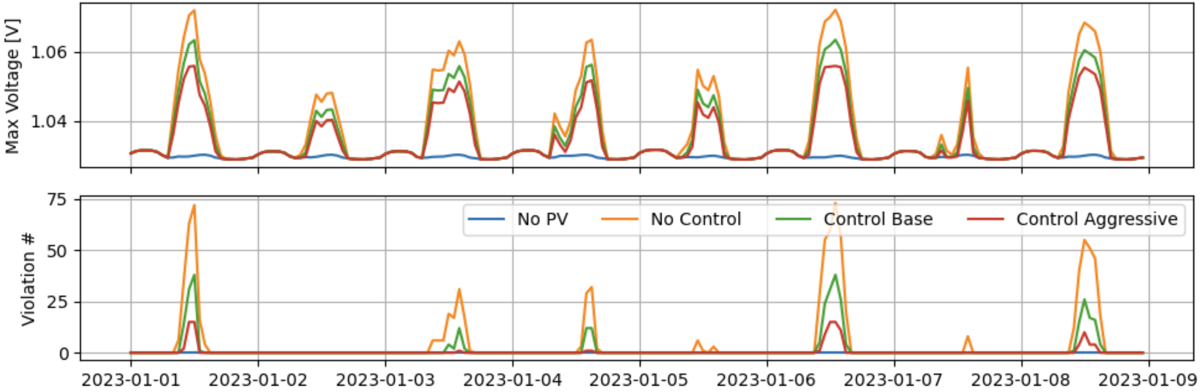
- Unauthorized Control
- Data Breaches
- Operational Disruptions

System Influence

Reactive Power Support

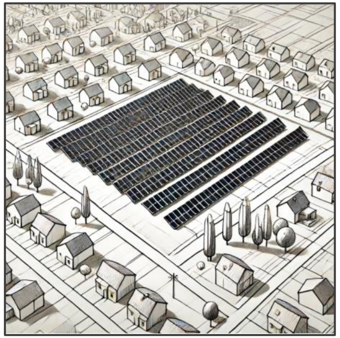
Residential Systems

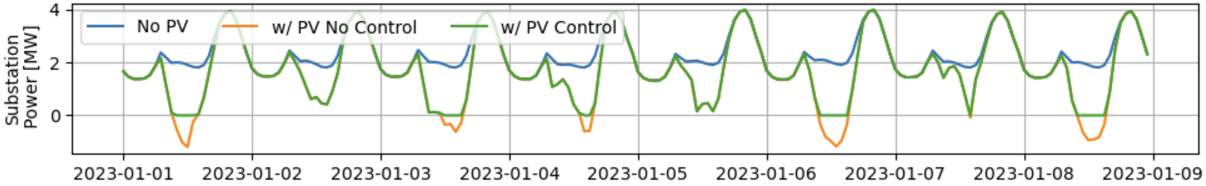




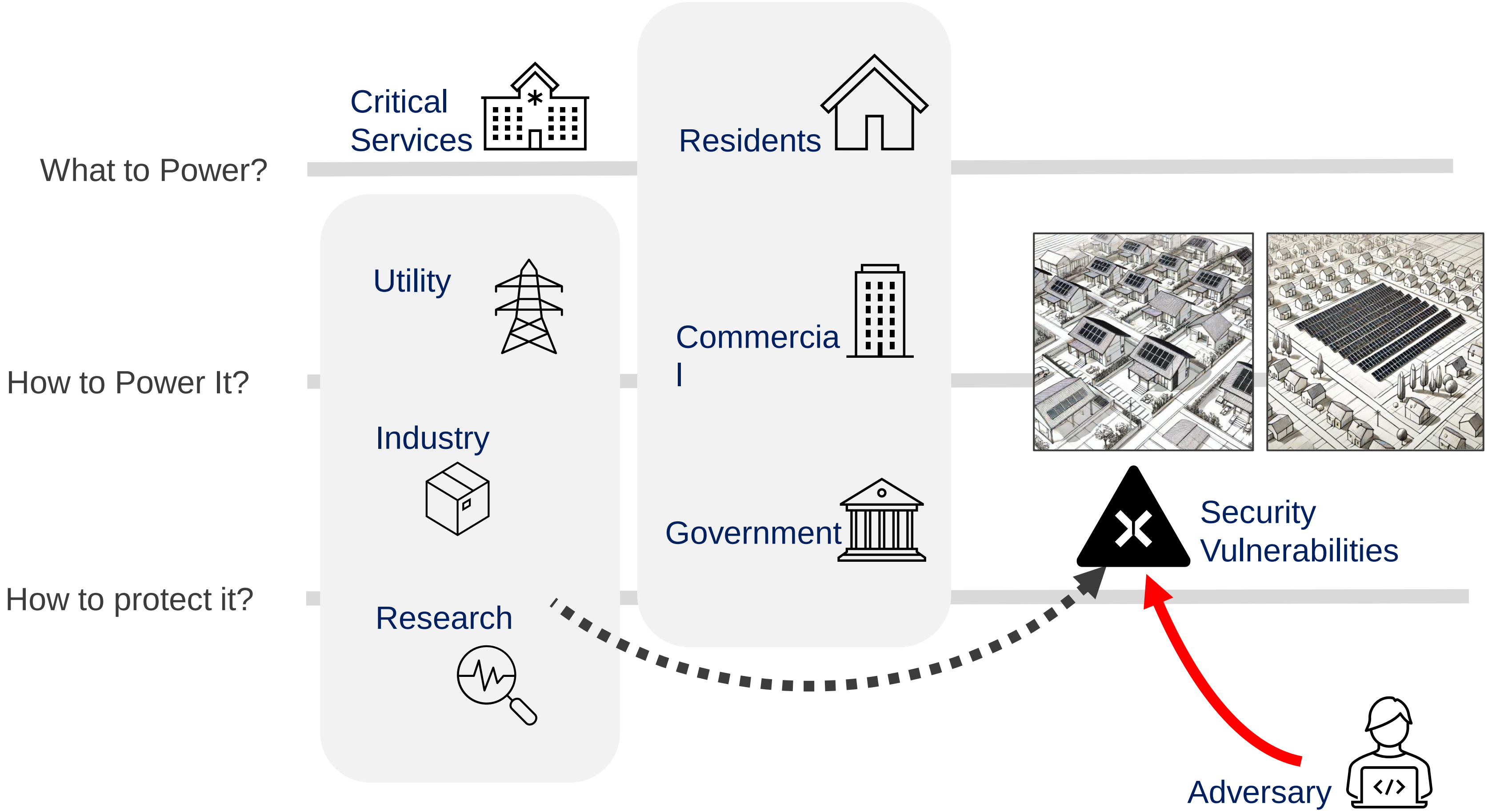
Substation back feed prevention

Large-Scale System





Community Collaborations for Secure & Resilient Power



Thank you

Contact Information:
C. Birk Jones, Ph.D.
cbjones@sandia.gov

November 14, 2024

Jake Gentle
Portfolio Manager

Dan Ricci
Power Systems Security Engineer/Researcher

CyberSHIELD: Securing Renewable Energy

Resilient Systems: Critical Infrastructure Interdependencies Panel

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy

Idaho National Laboratory

INL/CON-24-77490

Cyber SHIELD Overview

Cyber Security through Hardware Integration, Education, and Layered Defense:

Industry Impact

Cyber SHIELD is a program (people/tools) intended to help the renewable power generation industry "raise the floor" with respect to cyber security readiness and robustness. The initial focus has been deployment across renewable sectors (wind/hydro/solar), and participating renewable asset owners will generally work through the following phases of the program:

- Cyber Program Assessment
- Asset Interaction Analysis
- Architecture Basics

Each step in the program leverages DOE-INL tools. INL team members will work with asset owners/operators to integrate these tools into their existing operations processes.

Program Evolution

Like most INL tools and resource programs, Cyber SHIELD is an iterative process that builds upon successes and setbacks. However, overall success depends on industry engagements.

Measuring Success

The success of this effort will be measured by its impact to the renewable sector, particularly with respect to the prioritization of and investment in cybersecurity.

*Cybersecurity Evaluation and Risk Tool – (CERT)

INL Cyber SHIELD-INL CERT

INL Cybersecurity Evaluation and Risk Tool

Key Challenges Targeted

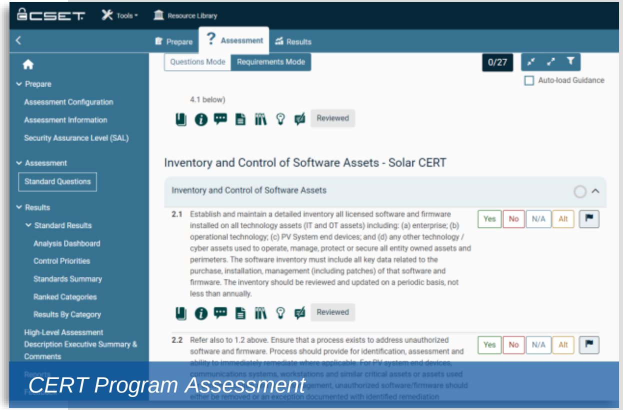
Provide insight and guidance for better-informed risk-based investment decisions for renewable asset owners'/operators' IT and OT cybersecurity programs through Cybersecurity Evaluation and Risk Tool (CERT) – Renewable CSET (Open-Source DHS CISA/DOE funded tool for public use)

Key features:

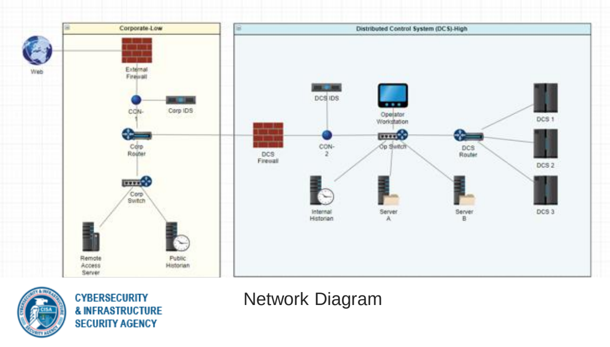
- ✓ Renewable Sector Focused Capability
- ✓ Tuned for renewable industry
- ✓ Identifies gaps in Cybersecurity process and procedures

Top 3 Benefits:

1. Guided cybersecurity assessment and risk-based report
2. Map network architecture within the purview of the assessment to control areas to help identify or validate asset owner/operator cyber posture
3. Support cyber program and resource planning to accelerate asset owner/operator Cybersecurity maturity objectives and readiness by providing document templates and process flows to integrate with existing organization configuration management, maintenance, incident response and recovery procedures



CERT Program Assessment



CERT Architecture Basics

SHIELD – Malcolm

Asset Interaction Analysis

Key Objectives Targeted

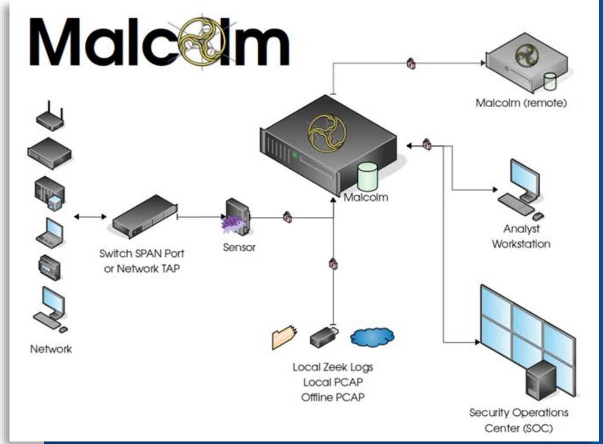
Provide asset owners/operations with initial baseline of assets linked to operational technology (OT) and business processes. Detect and visualize threats and vulnerability identification/analysis for renewable OT environments. Malcolm is an Open-Source DHS CISA/DOE funded tool for public use.

Key features:

- ✓ OT Asset to business processes mapping
- ✓ Log collection & analysis tool suite
- ✓ Increases cyber maturity by adding visibility of assets and threats

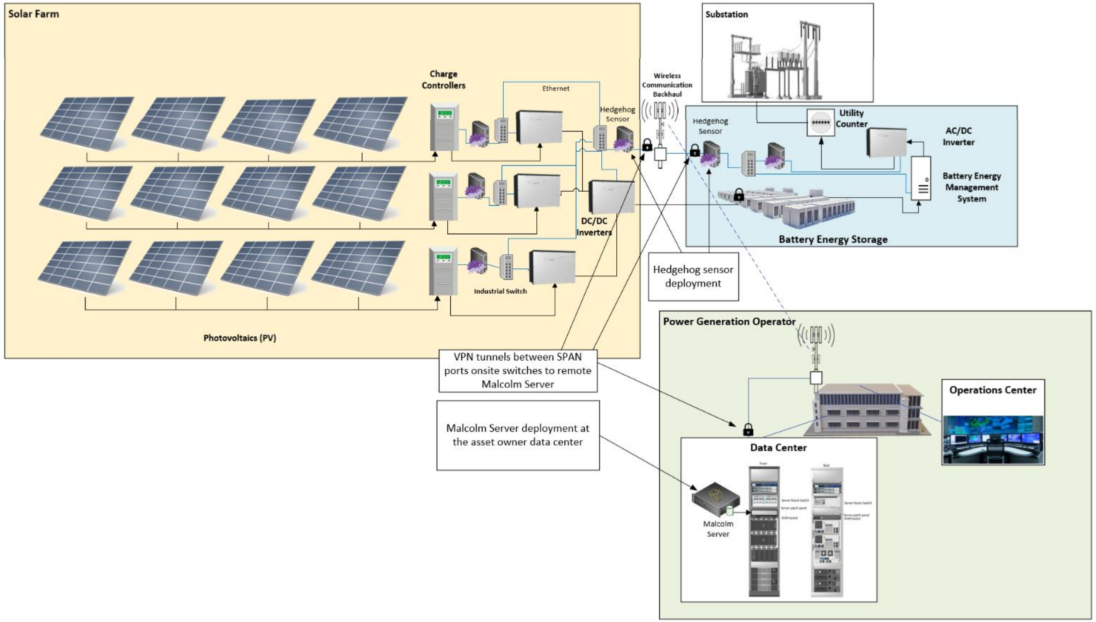
Top 3 Benefits:

1. Better knowledge of assets, clear view of asset risk levels based on devices, protocols, and configurations.
2. Identify potential cyber-attacks, exposed software vulnerabilities, and active exploits impacting assets/devices data through passive monitoring
3. Increases network visibility through dashboard visualization to enable informed decisions and improve operational reliability.



Malcolm Deployment for Solar Guide

- This guide provides detailed instructions for deploying Malcolm in Solar Power Generation systems.
- Deployment process within ICS/OT network architecture
- Configuring network switches and Switched Port Analyzer (SPAN) ports or mirror ports or TAPs
- Best practices for deploying Hedgehog sensors, another critical component in these systems.



SHIELD Tools Links

- CSET Renewable as its own branch: cset-renewables-download.inl.gov
- Malcolm site for industry to interact with dashboards and view functionality: https://training.malcolm.fyi/dashboards
- Malcolm GitHub Site for industry to download and install on local hardware or virtual machine: https://github.com/cisagov/Malcolm
- CyberSHIELD Industry Engagement Website: https://resilience.inl.gov/inlcybershield/
- Email for specific program contacts: CYBERSHIELD@INL.GOV

INL

Idaho National Laboratory

Climate Change: Risks, Adaptability, and the Role of Solar and DER Technologies

- **Jordan Burns**, Researcher, National Renewable Energy Laboratory
- **Jonathon Monken**, Principal, Converge Strategies
- **Broderick Bagert**, Lead Organizer, Together Louisiana

SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

Solar at the Convergence of Resilience & Equity

(SCORE)

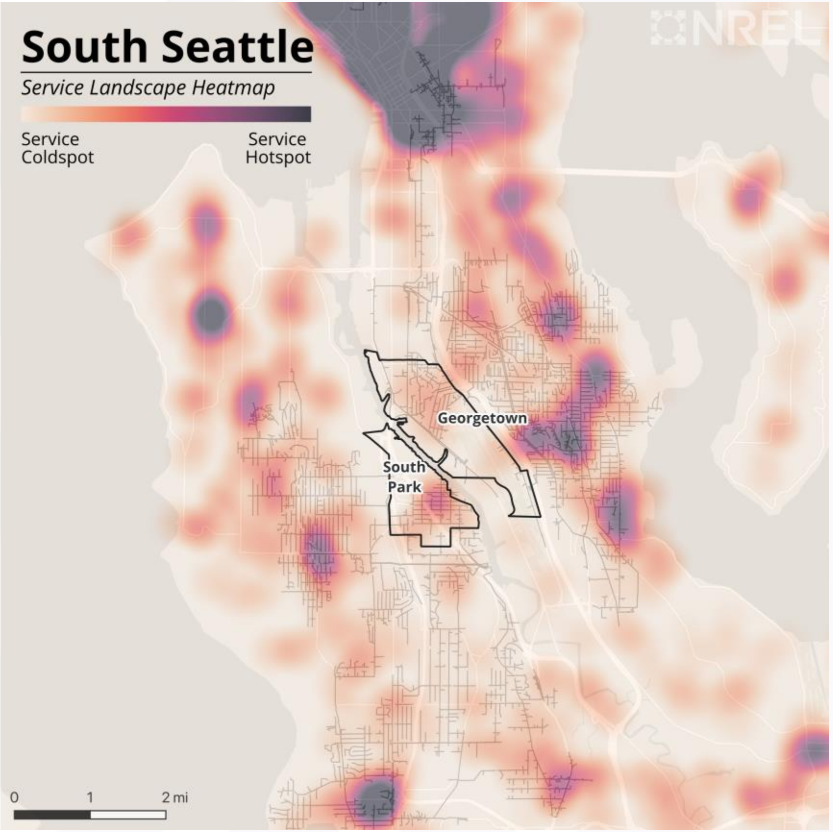
A Performance Metric for Resilience

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Baseline Service Landscape

Service Score ÷ Travel Time

- Where are service deserts?
- Which locations contribute most?
- Which feeder segments contribute most?



A Performance Metric for Resilience

Baseline Service Landscape

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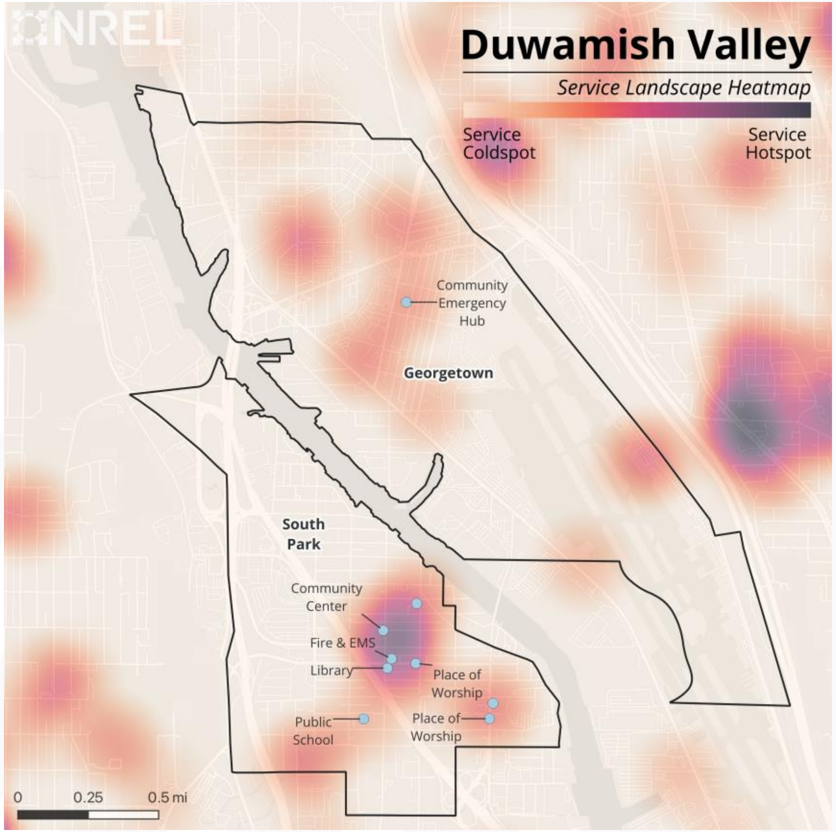

A Performance Metric for Resilience

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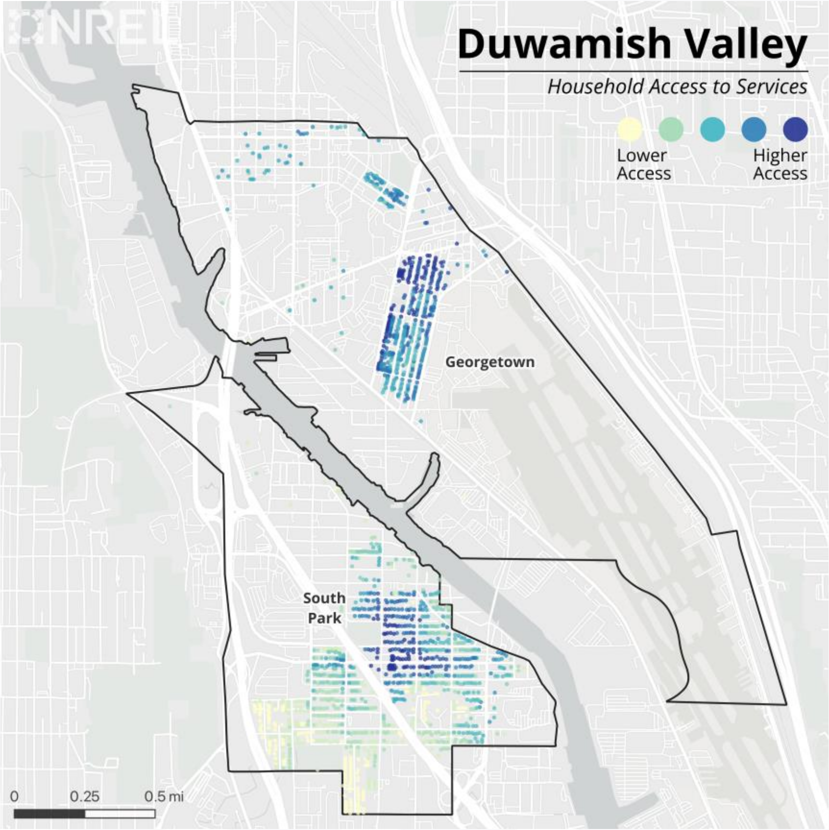
Outage Service Landscape

- How much does access decrease?
- Where does access decrease the most?
- In which service categories does access decrease the most?



A Performance Metric for Resilience

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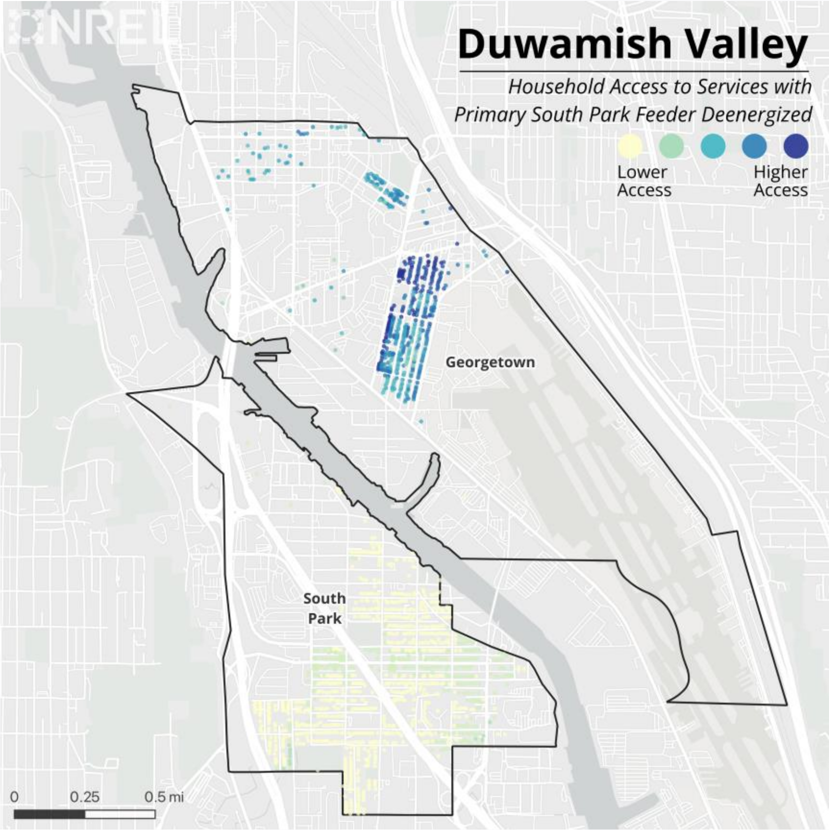
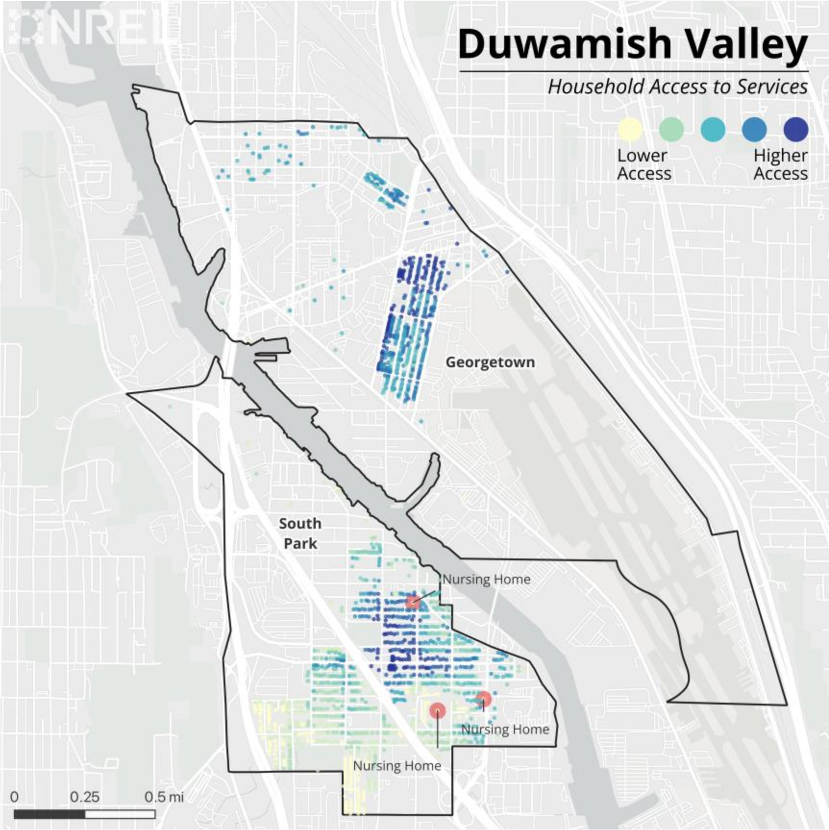


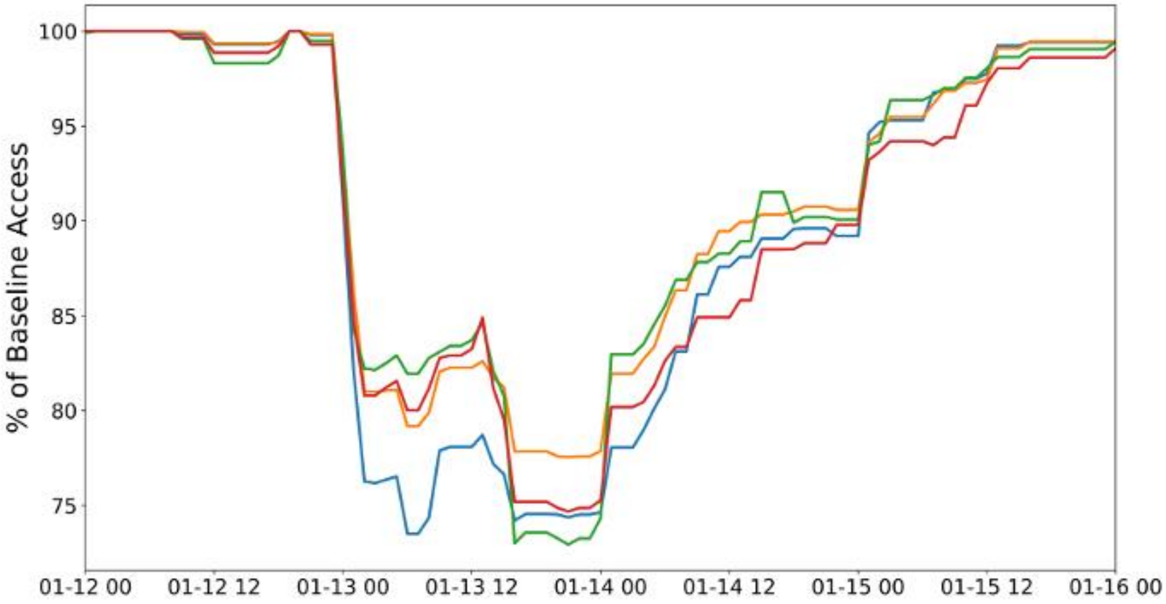
Addressing Vulnerability

The Service Landscape is a step in the right direction.

- Census limitations
- Point-level vulnerability data
- Moving away from binary boundaries



Optimizing Investments



Winter Storm
Seattle, January 2021

Where do outages create the highest burden for households?

Service Categories
- Provisions
- Health & Medical
- Public & Emergency Services
- Education & Workforce

AN INTRODUCTION TO

community lighthouse

NEIGHBORHOOD RESILIENCY CENTERS

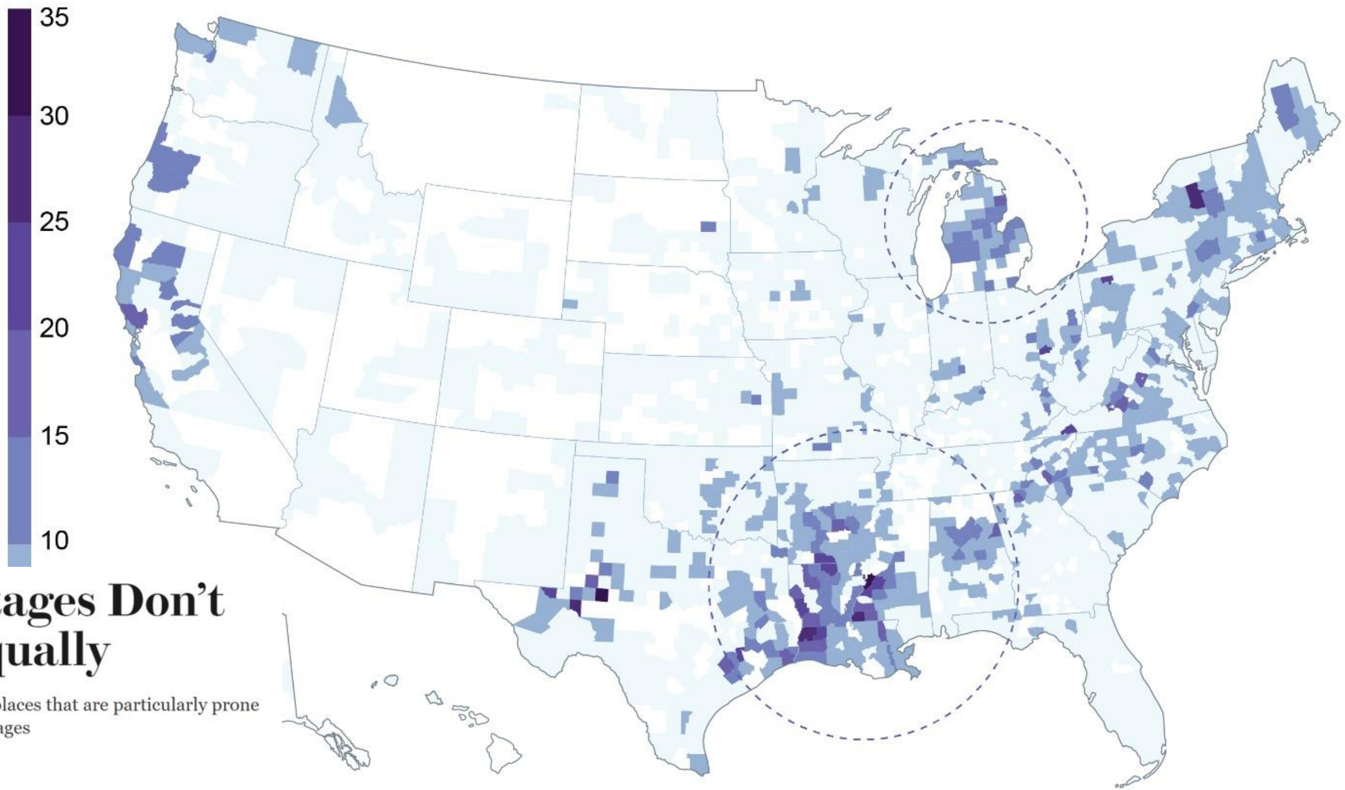
WITH SOLAR + STORAGE

TOGETHER LOUISIANA

Power outages have become the leading cause of disaster-related death in Louisiana & the Gulf Coast.

LA, TX, MS: ground zero for outage risk

Number of Power Outages Lasting More Than Eight Hours, by County (2018–2021)



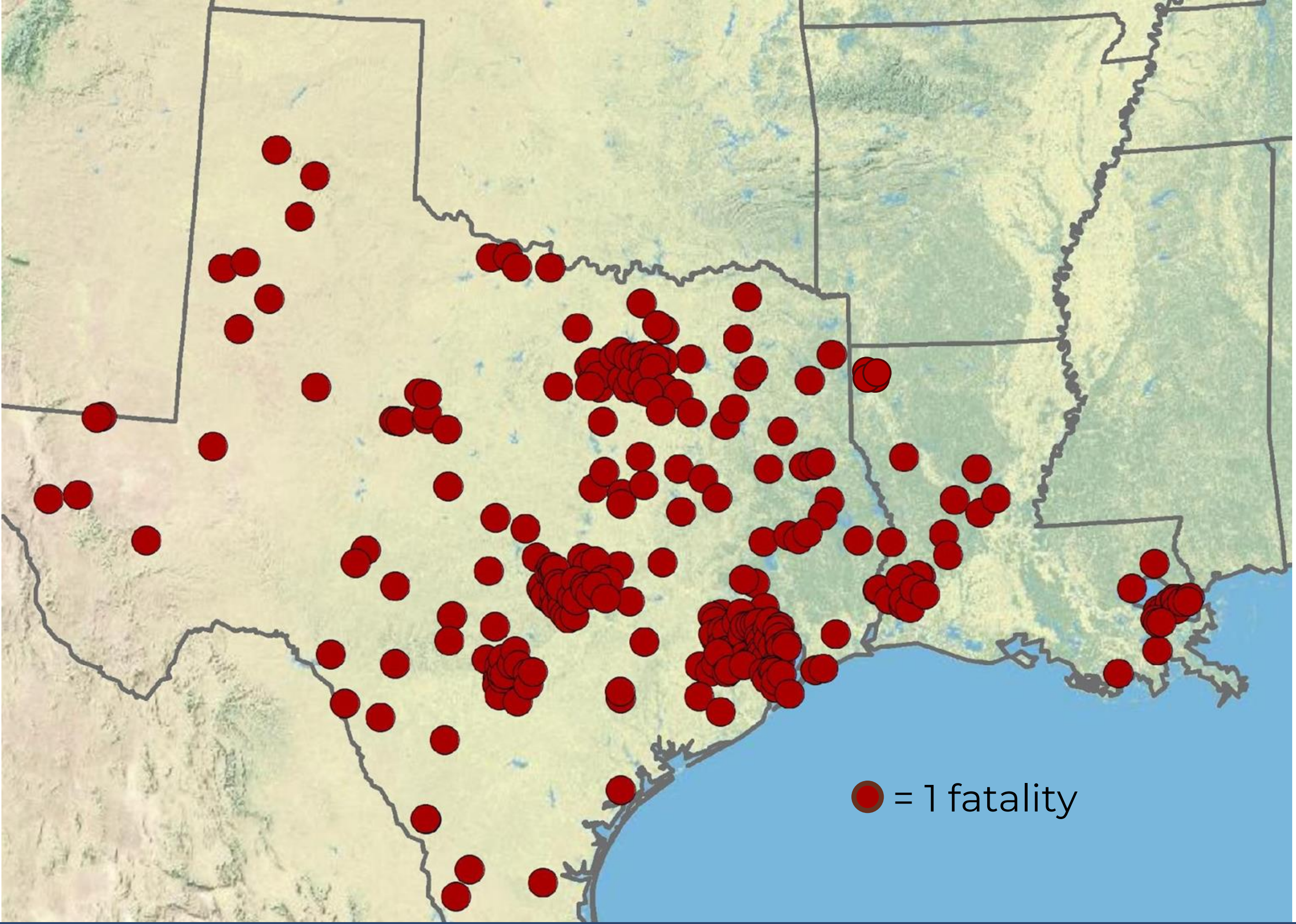
Source:

SCIENTIFIC AMERICAN®

Increasing Power Outages Don't Hit Everyone Equally

Some of the most vulnerable communities in the U.S. live in places that are particularly prone to frequent, prolonged power outages

By June Kim on July 26, 2023



Power outages caused ...

19 of the 31 deaths
in Hurricane Laura
(August 2020)

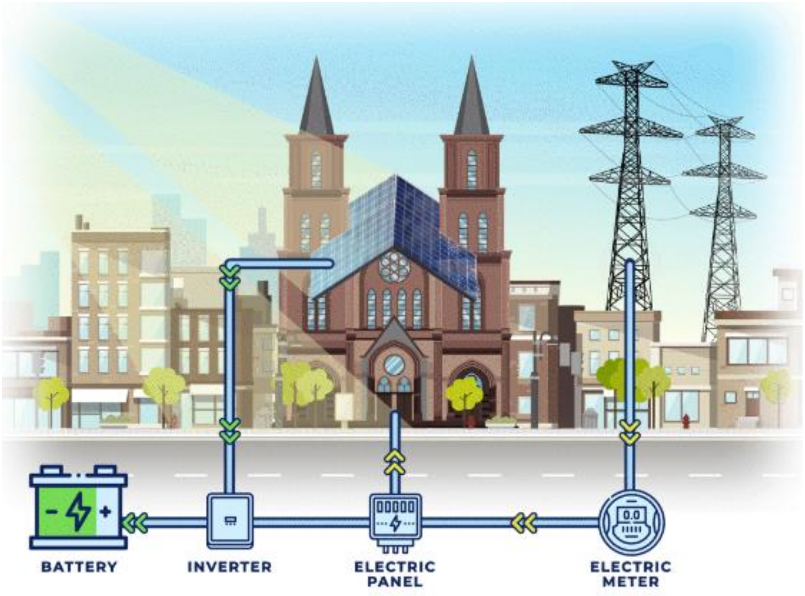
About 700 deaths
in Texas in Winter
Storm Uri
(February 2021)

30 of the 36 deaths
in Hurricane Ida
(August 2021)

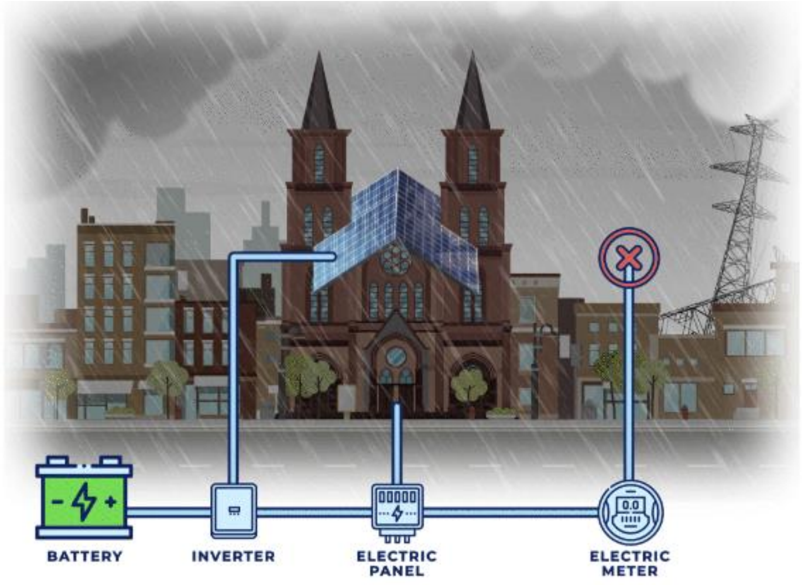
At least 2 deaths
in North LA outage
(June 2023)

TOGETHER
LOUISIANA

HOW IT WORKS



In normal times, the **solar array** helps defray electricity costs.



If the grid goes down, **battery storage** helps restore power quickly at community lighthouses.

ROLE OF LIGHTHOUSE

Food & water

Cooling & heating centers

Charging stations / internet

Portable battery exchange

THE VISION

community lighthouse

No one in Louisiana lives further than 15 minutes from a Community Lighthouse.

Ribbon cutting at first Community Lighthouse with TNO leaders & New Orleans City leadership *(March 2023)*

Ribbon cutting at seventh Community Lighthouse with Together LA leaders & US Energy Secretary Jennifer Granholm *(November 2023)*

community lighthouse

Bethlehem Lutheran Church

New Orleans

TOGETHER
NEW ORLEANS

community
lighthouse

Broadmoor Community Church
New Orleans

TOGETHER
NEW ORLEANS

community lighthouse

CrescentCare Health Center
New Orleans

TOGETHER
NEW ORLEANS

community lighthouse

Community Church Unitarian Universalist

New Orleans (West End)

TOGETHER NEW ORLEANS

community lighthouse

Trinity Community Center
New Orleans (Hollygrove)

TOGETHER NEW ORLEANS

community lighthouse

Household of Faith Church

New Orleans (West Lake Forest)

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community lighthouse

First Grace UMC
New Orleans

TOGETHER NEW ORLEANS

community lighthouse

Cornerstone UMC
New Orleans

TOGETHER LOUISIANA

community lighthouse

Corpus Christi-Epiphany Catholic Church
New Orleans

TOGETHER NEW ORLEANS

community
lighthouse

City of Love Church
New Orleans

TOGETHER
NEW ORLEANS

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Christian Unity Baptist Church
New Orleans

TOGETHER
NEW ORLEANS

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Sisters of the Holy Family
New Orleans

TOGETHER NEW ORLEANS

community lighthouse

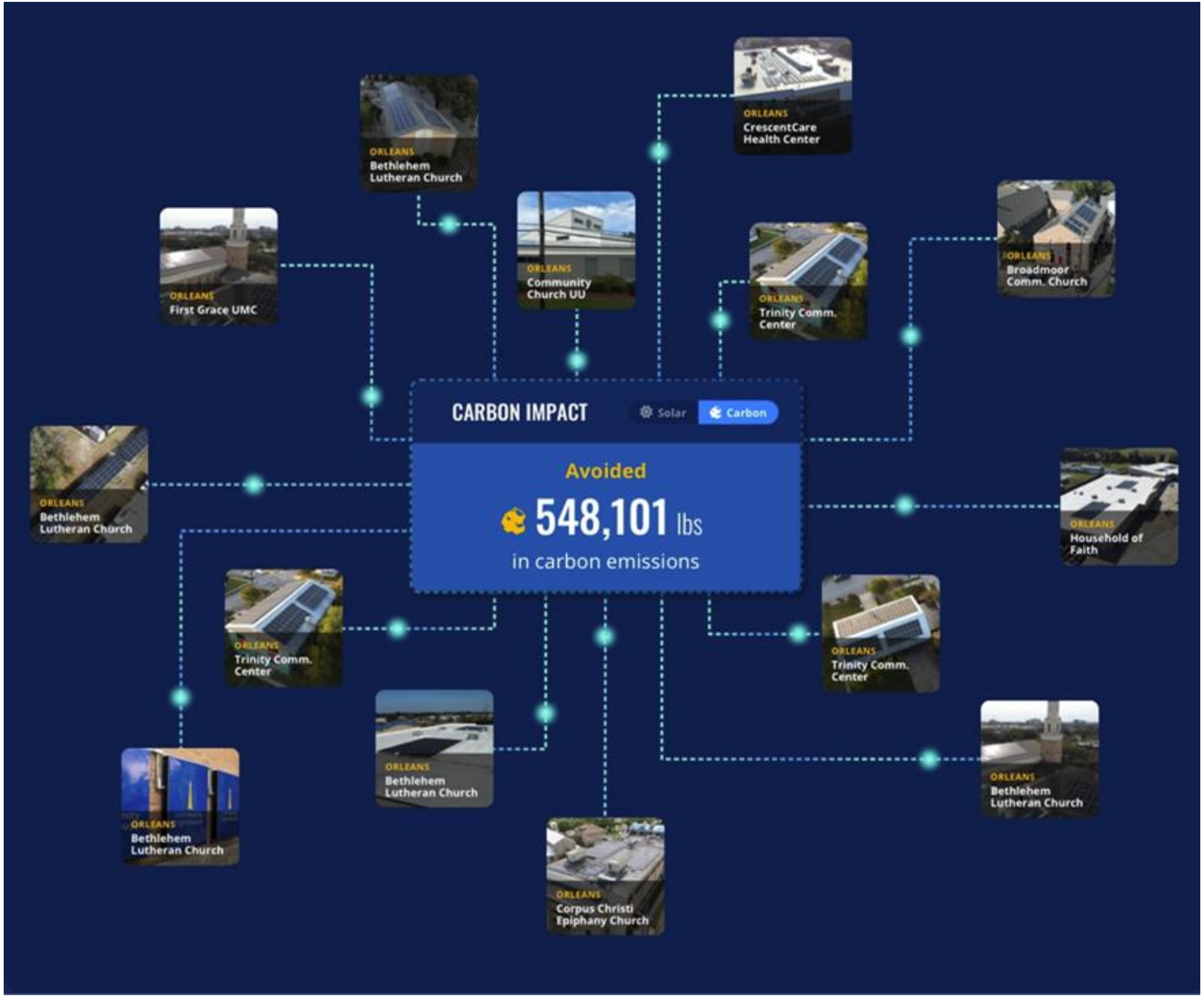
New Wine Christian Fellowship

LaPlace

TOGETHER LOUISIANA

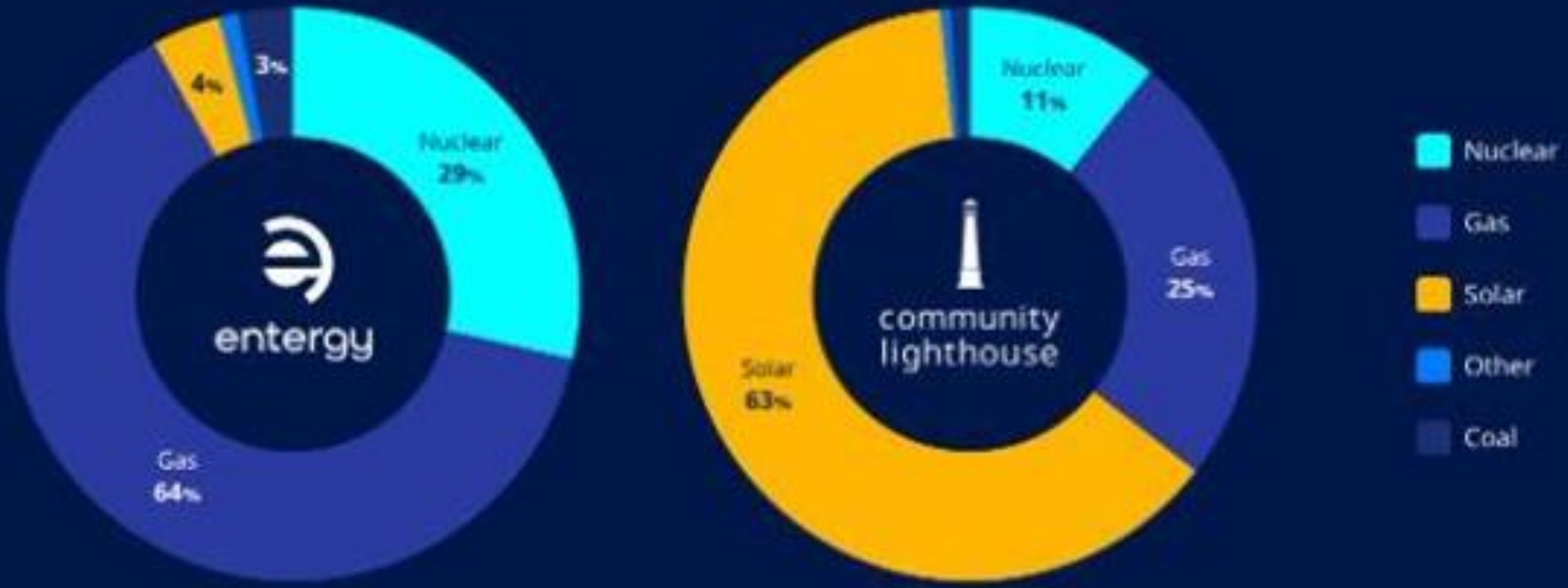
CURRENT NEW ORLEANS SITES


System Specs
15
Community Lighthouses
2,094
PV solar panels
1,002
kilowatts DC solar
1,656
kilowatt-hours battery storage


CARBON IMPACT
Solar
Carbon
Avoided
548,101 lbs
in carbon emissions
ORLEANS
Bethlehem Lutheran Church
ORLEANS
CrescentCare Health Center
ORLEANS
First Grace UMC
ORLEANS
Community Church UU
ORLEANS
Trinity Comm. Center
ORLEANS
Broadmoor Comm. Church
ORLEANS
Bethlehem Lutheran Church
ORLEANS
Household of Faith
ORLEANS
Trinity Comm. Center
ORLEANS
Trinity Comm. Center
ORLEANS
Bethlehem Lutheran Church
ORLEANS
Bethlehem Lutheran Church
ORLEANS
Bethlehem Lutheran Church
ORLEANS
Corpus Christi Epiphany Church

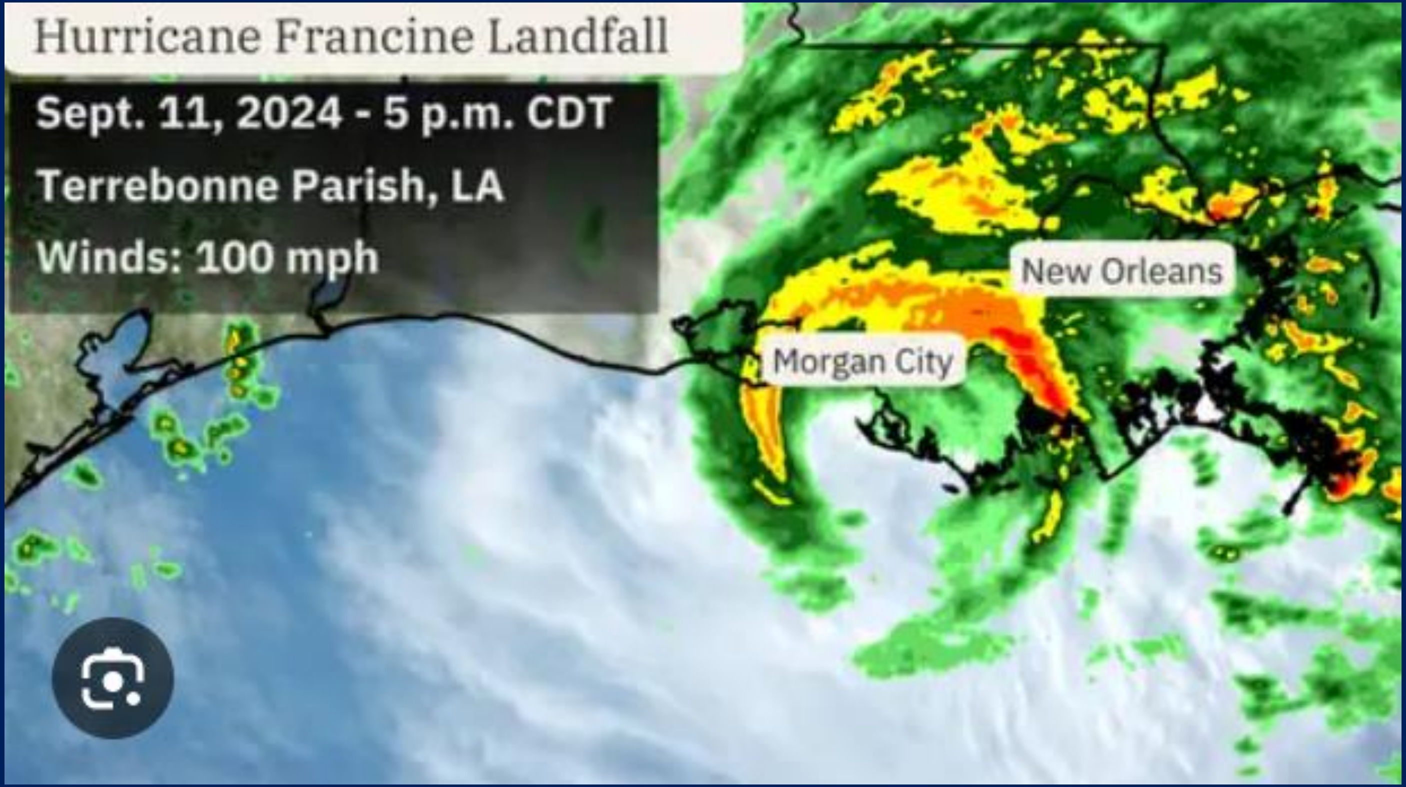
Powered by the Sun

Community Lighthouses slash reliance on gas and coal. **16 times more** of their energy comes from solar.



Source: Entergy New Orleans IRP 2022 vs Community Lighthouse average

FRANCINE RESPONSE



Welcome table

New Orleans Advocate

Pope Francis gives thumbs-up to movement

Together Louisiana leaders tout Community Lighthouse program

POPE

Continued from page 1B

Won changes to Community Solar rules, creating first viable community solar program in the Deep South

SINCE 1837

The Times-Picayune

THE NEW ORLEANS ADVOCATE

NOLA.COM | MONDAY, AUGUST 5, 2024 | $2.00

Solar program aims to lower bills

9 N.O. developers are awaiting Entergy approval

BY JOSIE ABUGOV
Staff writer

A community solar program for New Orleans intended to lower electricity bills for low- and moderate-income residents has been stalled for years, but it is now showing signs of progress after changes that have spurred interest among a full slate of developers.

The program, the first of its kind in the Deep South, garnered zero interest from developers from 2018 to 2023. But rate changes passed by the City Council last fall have shifted the outlook.

Such programs allow homeowners, renters, businesses and nonprofits to tap into the advantages of solar, even if they can't afford to install panels on their property. Developers build an off-site solar array that feeds into the city grid.

Anyone can then subscribe to own a share of the project in exchange for credit on their energy bill. Community solar exists in 43 states, but not Louisiana.

More than half of those states have passed legislation that supports or requires it, and 17 have passed legislation specifically for low-income community solar, according to the Department of Energy.

New Orleans may be next. A queue of nine developers has submitted applications to the city and are now awaiting Entergy approval.

All of the developers fall under the category requiring them to set aside at least 30% of subscriptions for low- and moderate-income customers. The program is meant to alleviate the high bills that have burdened New Orleanians in recent years, amid unprecedented heat waves and grid restoration after hurricanes.

Broderick Bagert, an organizer with the coalition Together New Orleans that backed the rule changes by the City Council, said that the program his advocacy group is developing will reduce bills for low-income households by at least 20%. A city staffer put the broader figure for the initiative at between 10 and 25%.

"We're feeling excited about it," Bagert said. "We're focused on having community solar succeed."

➤ See SOLAR, page 2B

EARTHBEAT
A PROJECT OF NATIONAL CATHOLIC REPORTER

Holy Family Sisters plan 22-acre community solar project in Louisiana

Broderick Bagert, a Together New Orleans organizer, listens to Sr. Alicia Costa, superior of the Sisters of the Holy Family, with the sisters' land designated for the solar field in the background. In the far background is St. Mary's Academy. (Kevin Fitzpatrick)

BY KEVIN FITZPATRICK
View Author Profile

New Orleans — June 12, 2024

East of the French Quarter or the Central Business District of New Orleans, drivers on the I-10 encounter a steep bridge crossing the Industrial Canal that connects Lake Pontchartrain to the Mississippi River. I-10 veers left at the bottom of the bridge, then a slight right leads to Chef Menteur ("Big Liar") Highway, a road best known for pill mills, staged accidents with semitrailers, human trafficking and sex work.

Started development on 22-acre / 5KW Community Solar farm with Sisters of the Holy Family

Won docket allocating $32M to expand microgrids & form VPP

SINCE 1837

The Times-Picayune

THE NEW ORLEANS ADVOCATE

NOLA.COM | FRIDAY, OCTOBER 25, 2024 | $2.00

New Orleans approves 'virtual power plant' plan

Resilience program to support electricity supply via batteries

BY JOSIE ABUGOV
Staff writer

The New Orleans City Council greenlit a plan on Thursday to create a "virtual power plant" to support the city's electricity supply — and the resilience program is generating buzz from architects, community activists and Tesla executives alike.

The council-approved plan, led by advocacy groups Together New Orleans and the Alliance for Affordable Energy, earmarks $32 million in Entergy settlement funds for batteries that would be installed in locations across town, then networked into a system to feed power to the grid.

The plan is part of a growing movement to transform how people get their energy, aiming to make communities less reliant on traditional fossil fuel-powered plants in favor of environmentally cleaner and more reliable options in the face of worsening storms and intensifying heat.

"The energy system we've relied on for the past century — it's not resilient," said Logan Burke, the executive director of the Alliance for Affordable Energy. "We know this because even very small storms are taking out our access to power and they lead to health impacts and economic loss."

The council also voted on Thursday in favor of a proposal to spend $100 million hardening the city's poles, transmission and distribution lines. This will include more than 3,000 structures and upgrading 63 electric line miles, according to Entergy.

Burke said the "answer should be both" when it comes to hardening the city's traditional energy system and pushing innovative approaches like distributed energy.

The micro-grid and virtual power plant proposal would build on Together New Orleans'

➤ See PLAN, page 2B

LESSONS

1) Trust is a big factor in speed of DER deployment
2) We've needed the power to change bad rules.

Networking Activity: The Brighton

- Group will walk from Forrestal to The Brighton (12 minute walk)
- Address: 949 Wharf St SW, Washington, DC 20024