U.S. DEPARTMENT of ENERGY | Federal Energy Management Program

Microgrid Case Studies: Successful Implementation Resulting in Resilient and Secure Infrastructure and Facilities

T2-S6 August 6th, 2025

FEMP Summer CAMP (Courses Aligned with Mission Priorities)

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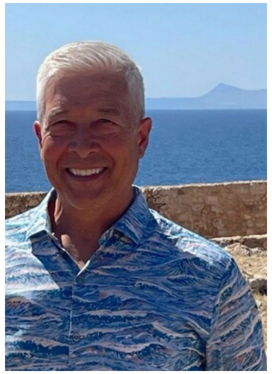
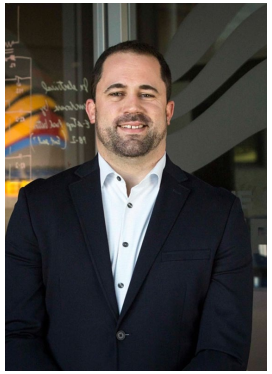
Agenda

- Session Learning Objectives
- Strategic Vision – Dr. William Anderson
- Tactical Implementation – Mr. Jarrod Ross
- Scaling Across the Marine Corps – Mr. Mick Wasco
- Cross-Cutting Lessons – Ms. Sandrine Schultz
- Panel Discussion with Audience Q&A
- Closing Reflections





Session Learning Objectives

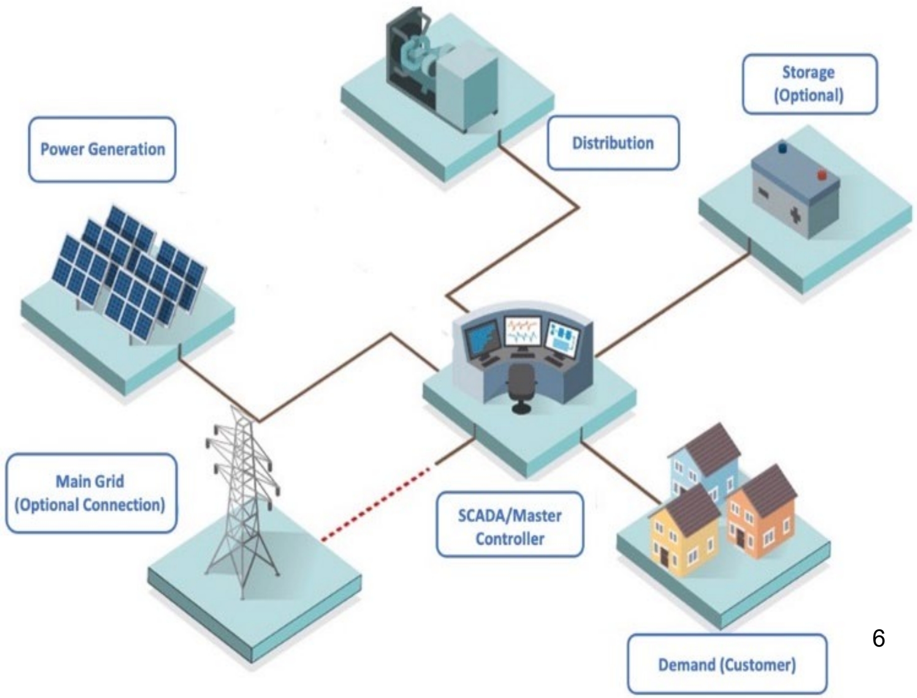
- Evaluate real-world examples of microgrids that enhance on-site resilience;
- Identify common challenges in designing and operating microgrids;
- Recognize key lessons learned from microgrid development and implementation;
- Compare how different organizations are applying microgrid solutions for resilience.

- Microgrids & resilience
- Resilience and costs assessment models
- Methodology to create resilience and costs tradespace
- Case studies

MICROGRIDS AND RESILIENCE

Microgrid:

- "…an integrated energy system consisting of interconnected loads and energy resources which, as an integrated system, can island from the local utility grid and function as a stand-alone system." [1]
- "A microgrid is a collection of generation and load centers with fixed limits …can operate in both grid-connected and isolated (island) modes.[2]
- With one or more of the following objectives:
  - Isolate damaged distribution line segments and possibly back-feed loads downstream from the damage.
  - Optimize the balance of distributed generation, renewable energy, and grid supplies for economic or other reasons.
  - Prioritize loads served by constrained or curtailed sources of power[3]



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Energy resilience:

- "the ability to avoid, prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions in order to ensure energy availability and reliability sufficient to provide for mission assurance and readiness, including mission essential operations related to readiness, and to execute or rapidly reestablish mission essential requirements." [4]
- "The microgrid's invulnerability and rapid and full recoverability from an improbable and severe disturbance" [5]

Resilience: High Impact Low Probability (HILP) disturbances

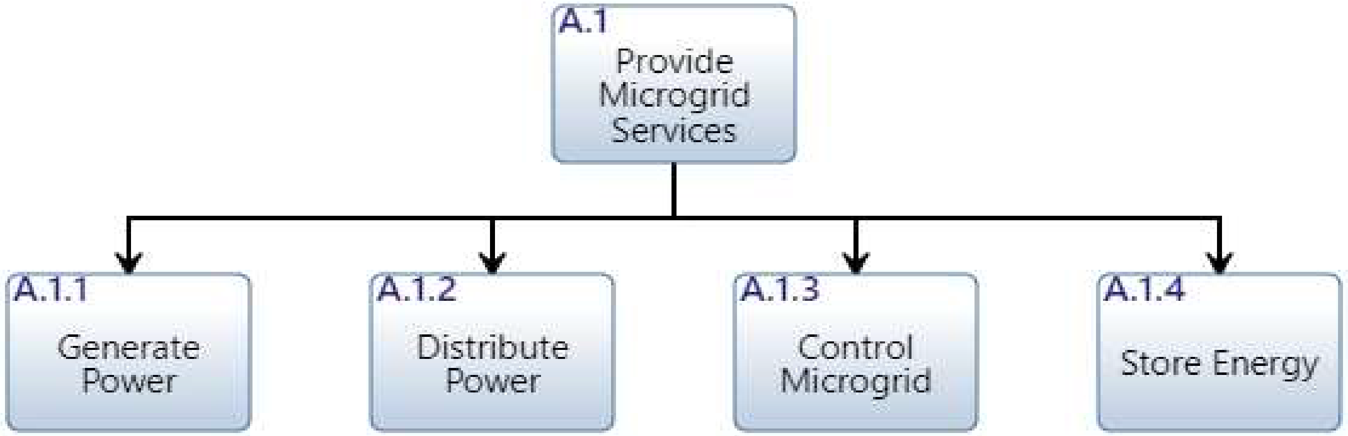
Reliability: Low Impact High Probability (LIHP) disturbances

Microgrid architectures are different when designed for resilience than reliability

[1]Military Installation Energy Resilience and Microgrid Overview Paper, https://www.acq.osd.mil/eie/Downloads/IE/ER%20and%20Microgrid%20One-Pager.pdf
[2]NAVFAC P-601 Microgrid Design Guide December 2018
[3] NAVFAC P-602 Three Pillars of Energy Security January 2021
[4]10 U.S.C. § 101(e)
[5]Anderson, "Resilience Assessment of Islanded Renewable Energy Microgrids, December 2020, https://apps.dtic.mil/sti/pdfs/AD1126753.pdf
[6]UFC 3-550-04, Unified Facilities Criteria (UFC), Resilient Installation Microgrid Design,March 2023, "1-1 Microgrid"

MICROGRID BENEFITS

- Keep your facility's power on during grid outages
- Store electricity and sell it back to the grid during peak demand
- Integrate on-site renewables such as wind and PV to increase energy independence

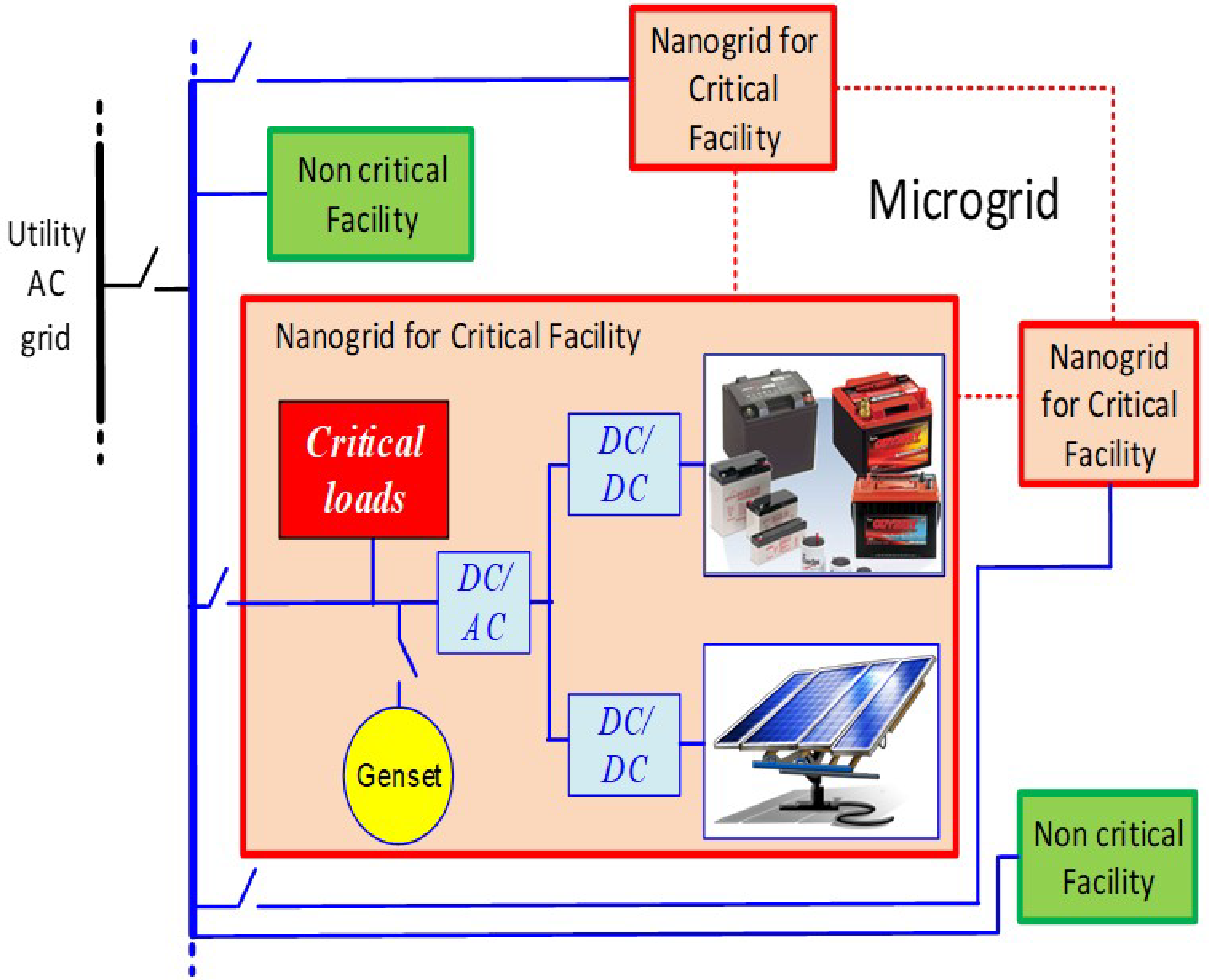


SCALING MICROGRIDS

Adopting the zonal shipboard power distribution approach to shore installations to achieve energy security.

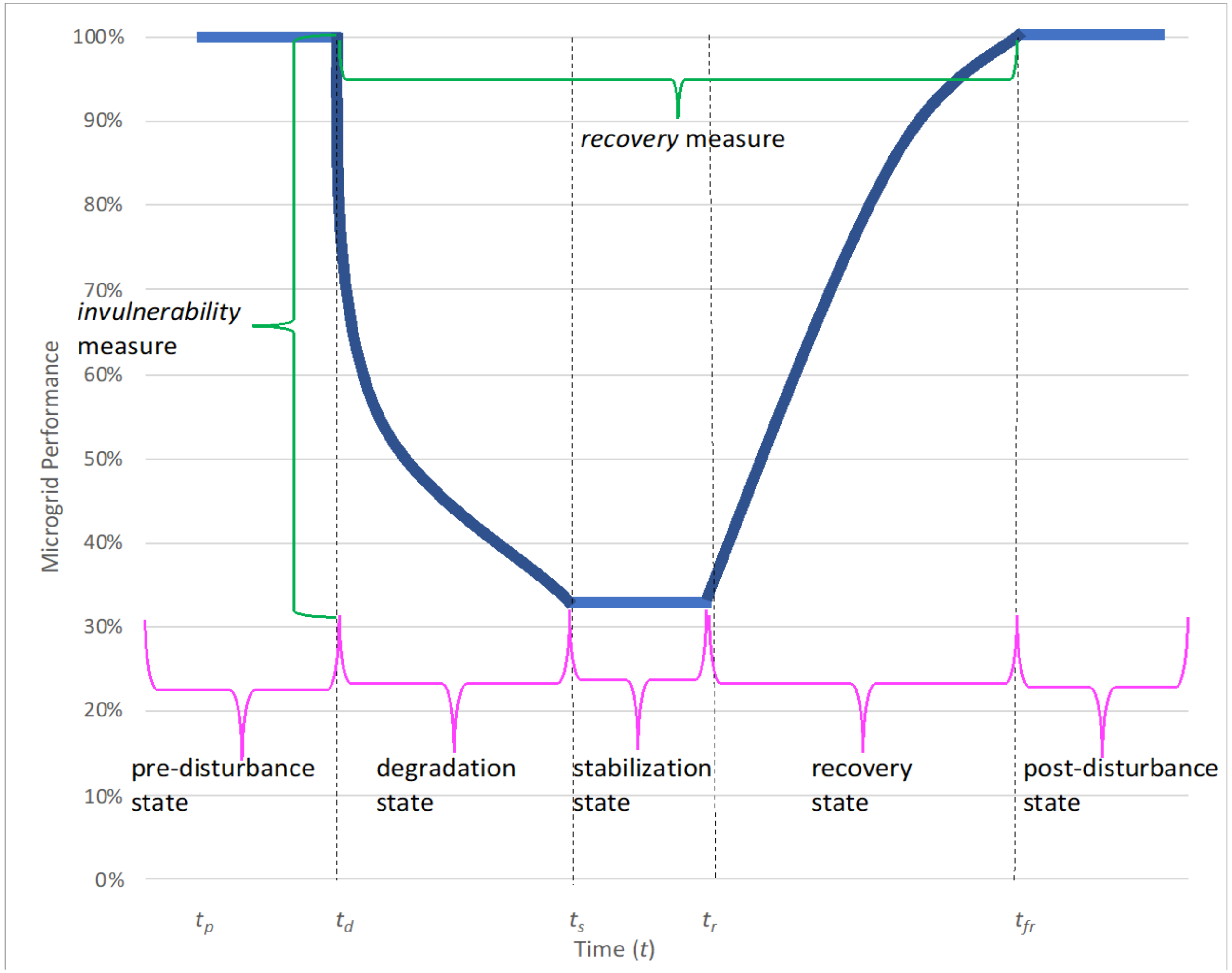
Comparing nanogrid building block architectures, such as conventional ac nanogrids and Uninterruptable Power Supply (UPS)-style nanogrids to assess size, weight, cost, and resilience.

Hardware-in-the-Loop models will focus on control and protection requirements necessary to combine multiple nanogrids into a larger microgrid



- **Increases resilience in small increments**
- **Electricity is continuously available to DCI regardless of HILP disruptions**

RESILIENCE MODEL



$$\xi = 0.5(invulnerability + recovery)$$

$$invulnerability = \frac{P_{t_s}}{P_{t_d}}$$

$$recovery = 1 - \frac{\sum_{t=t_d}^{t_{fr}} D_t - G_t}{\sum_{t=t_d}^{t_{fr}} D_t}$$

The microgrid's invulnerability and rapid and full recoverability from an improbable and severe disturbance

COST MODEL

$$LCOE = \frac{\text{NPV}\ (Costs + Benefits)}{\text{NPV}\ Energy}$$

$$LCOE = \frac{\sum_{y=1}^{p}\sum_{i=1}^{m}\frac{I_y + M_y + F_y - H_i}{(1+r)^y}}{\sum_{y=1}^{p}\frac{E_y}{(1+r)^y}}$$

“lifetime costs of the energy produced by a given source”

The Net Present Value (NPV) of costs and benefits divided by the NPV of the microgrid’s energy production

Assumptions:

- **Greater value on energy used today than in the future** (1 kWh today is worth more than 1 kWh tomorrow)
- Demand is always greater than microgrid’s power rating; no excess energy capacity

$$LCOED = \frac{\text{NPV}\ (Costs + Benefits)}{\text{NPV}\ (Energy\_produced\_to\_meet\_demand)}$$

- Modify *LCOE* by only considering the demand vice the generative power rating
- *LCOE* is NOT appropriate for military installations!

METHODOLOGY TO ASSESS RESILIENCE AND COSTS

OPTIMIZE A RENEWABLE ENERGY MICROGRID ARCHITECTURE

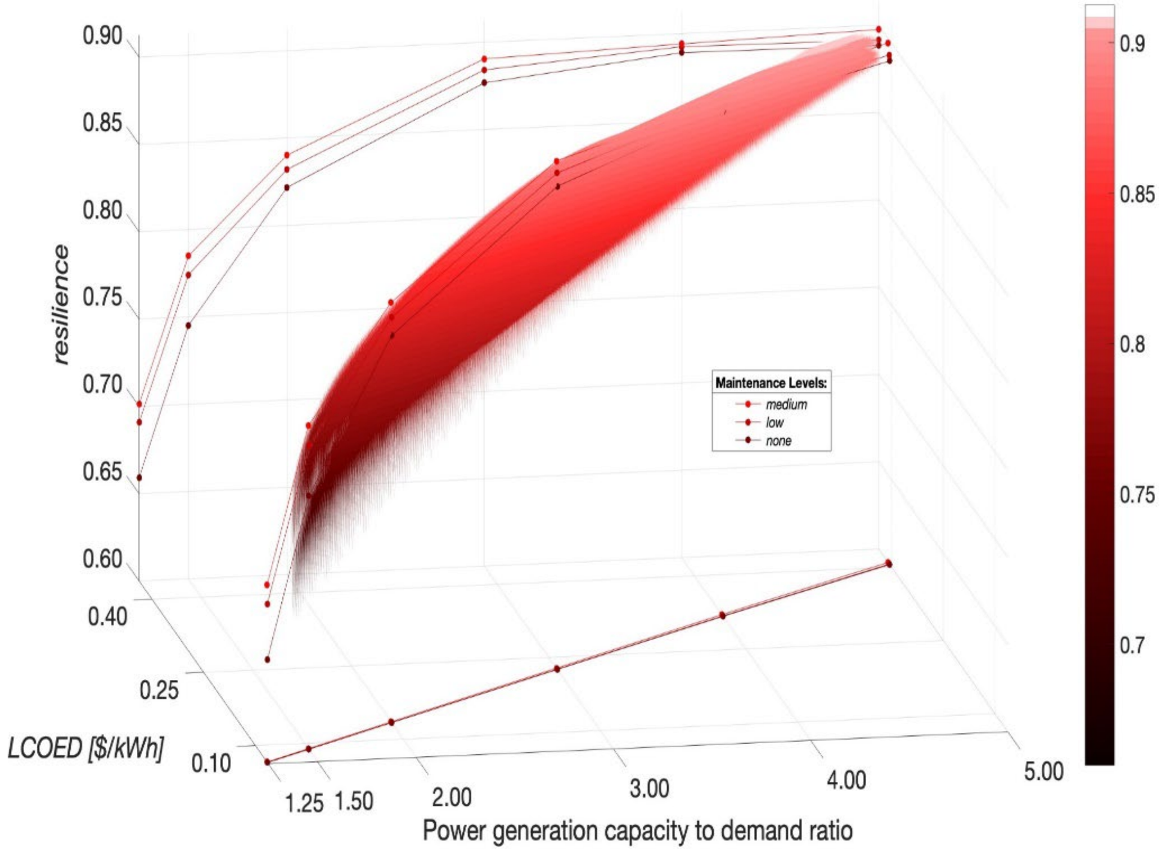
Create optimization construct and load site-specific data (parameters, input variables, decision variables, constraints) into XENDEE to perform optimization to minimize lifecycle costs [$/kWh]

ASSESS RESILIENCE AND COSTS

For optimized microgrid architecture and variants (+/-10%) , assess resilience and costs using Monte Carlo simulations (7,500) with exponential and normal probability distributions using the resilience and costs models (Excel and Python)

GENERATE RESILIENCE AND COSTS TRADESPACE

Generate trade-space (4D graphs in MATLAB) to convey costs and resilience of different renewable energy microgrid architectures

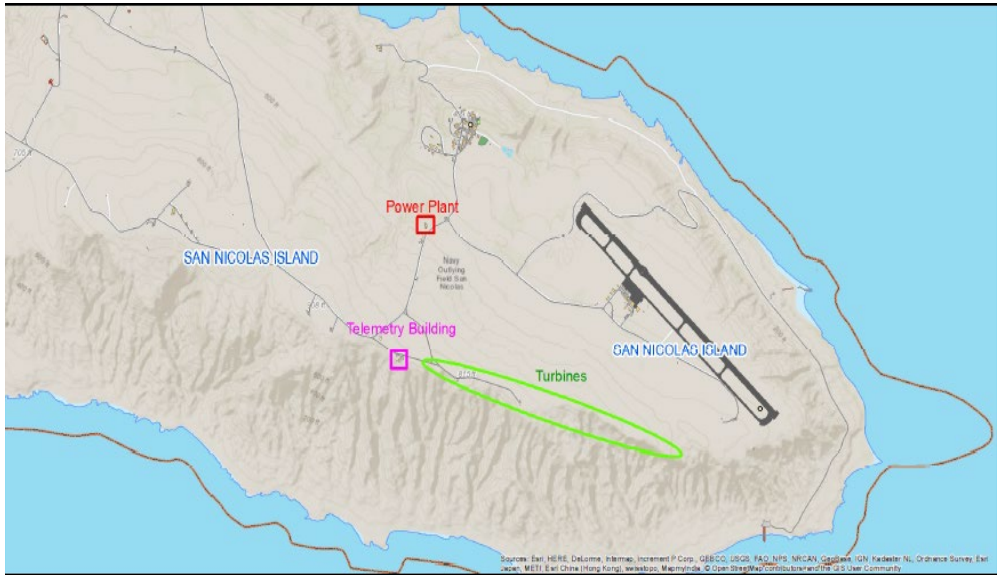


Findings: excessive power capacity, e.g. SNI's DGs, limits renewable energy integration and has diminishing returns on investment; redundancy is good

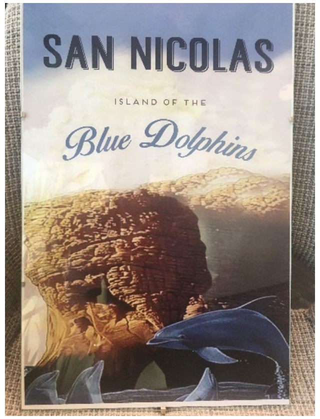
Tool generates cost of resilience using an appropriate cost metric (LCOED) for either combinations of distributed energy resources (DER) (SNI example), DER ratios, Power ratios (shown above), or redundancy (Rota case study). https://microgrid.nps.edu

SAN NICOLAS ISLAND (SNI)

- SNI's average demand is 500 kW and peak demand 900 kW
- 700 kW wind turbines power capacity
- 5.95 MW diesel gensets power capacity
- 1 MW/4 MWh energy storage to be completed 2025
- 1.3 MW solar PV planned
- SNI will be the world's first 100% RE powered military island!



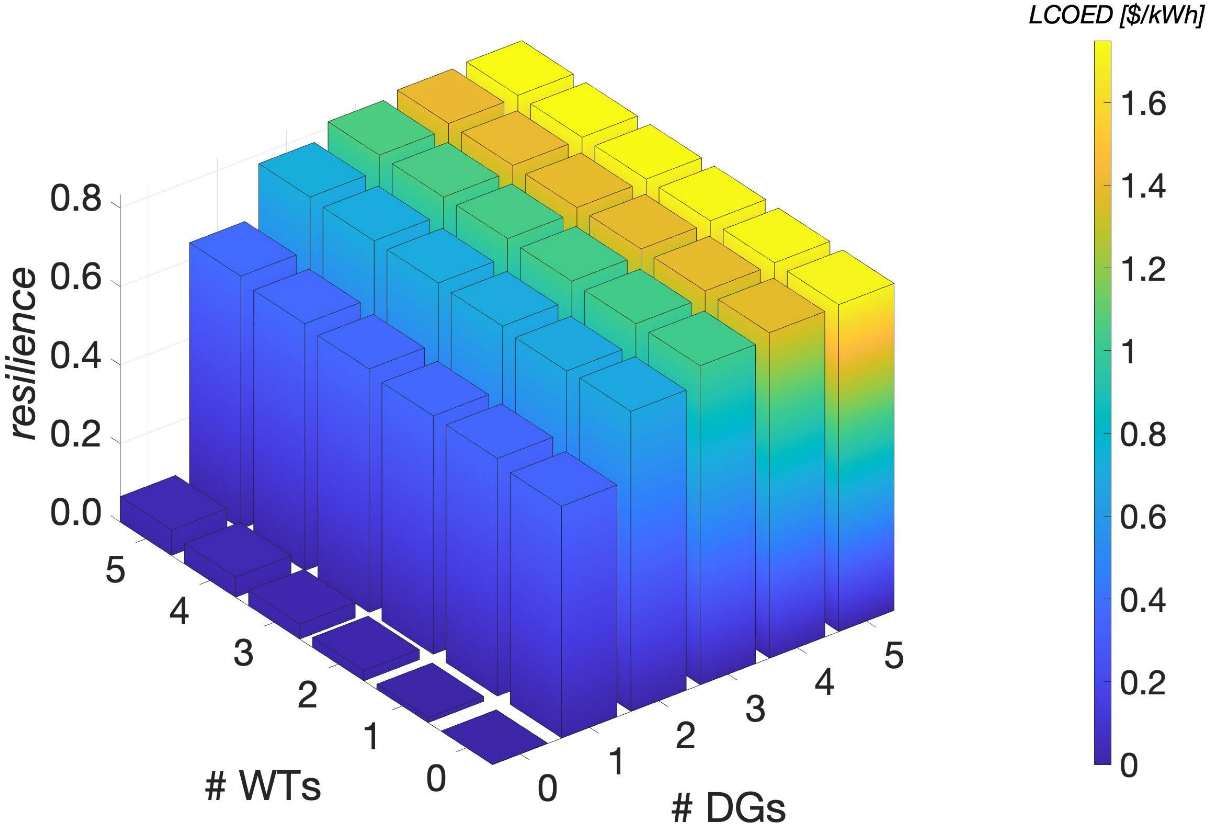
Turbine	Active state [%]	Power Output [kW]	Av. Power Limit [kW]	Effectiveness, %
#0079	38.1	37.2	85.4	32.5
#0262	50.6	37.8	86.8	43.9
#0263	33.1	27.8	82.6	27.3
#0264	33.5	33.8	82.1	27.5
#0265	51.6	28.1	87.2	45.0
#0266	27.8	24.4	79.2	22.0
#0267	45.5	37.2	87.7	39.9
mean	*40.0*	*32.3*	*84.4*	*34.0*



RESILIENCE AND COSTS TRADESPACE

Increase resilience by:

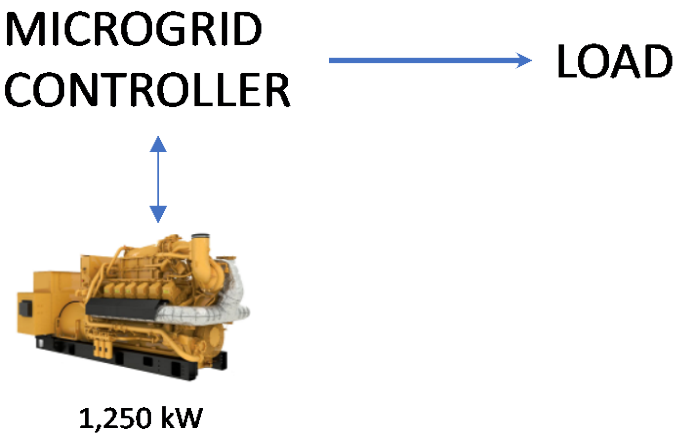
1. Redundancy of equipment
2. Diversity of equipment (both PV and wind, vice only PV)
3. Excess power beyond needs
4. Hardening of infrastructure
5. Maintenance policies, trained workforce, and spare parts



Relationship between resilience, number of wind turbines (WT), and number of diesel gensets (DG) at SNI. The color degrades from blue to yellow as *LCOED* increases.

NAVAL STATION ROTA SPAIN

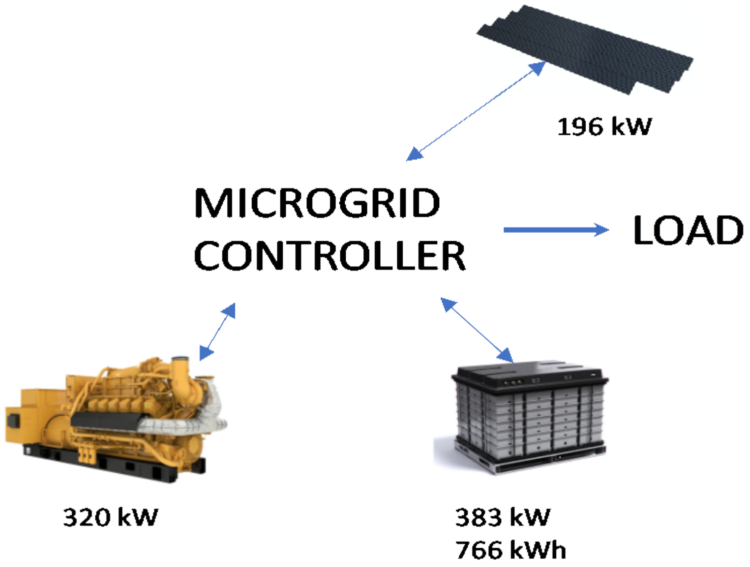
- Four experiments conducted:
  - Base case, morning tsunami
  - Base case, morning cyberattack



  - Xendee optimized, morning tsunami
  - Xendee optimized, midnight tsunami

Analyzed four scenarios at Rota Air Terminal involving cyber and tsunami threats. Solution maximized resilience at one-fourth of life cycle cost:

Architecture	*LCOED* [$/kWh]	*resilience*
Base case, only one DG, no redundancy	1.24	0.70
DG, quintuple	1.23	0.91
Optimized, quintuple	0.36	0.91



Falalop island, Ulithi Atoll, Yap State, Federated States of Micronesia

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Mr. Jarrod Ross

Resource Efficiency Manager

United States Army Garrison

Fort Hunter Liggett (FHL)

ARMY RESERVE

SUSTAIN SUPPORT DEFEND

UNITED STATES ARMY GARRISON FORT HUNTER LIGGETT, CALIFORNIA

FHL – At a Glance

- Total Force Training Center for U.S. military components and allied nations
- Over 165 thousand acres of diverse training land
- Suited for year-round training and large-scale joint exercises
- Over 300 sunny days per year, with little to no rain between March and December
- Mediterranean climate. Conducive for heat pumps and other energy efficient systems
- FHL Cantonment area = 1,078.60 acres
- 1,278,333 SQFT of Facilities

Why Build a Microgrid?

The Army's core purpose remains unchanged: *to deploy, fight, and win the nation's wars by providing ready, prompt, and sustained land dominance as part of the Joint Force*.

Continuity of Operations

FHL Challenges: FHL has longstanding challenges with electricity supplied by the utility

- FHL exists at the END of 3 distribution lines: 2 of them cannot support the cantonment load
- Wildfires continue to impact the state and are getting more prevalent: Dolan Fire in Fall of 2020 burnt areas of FHL and could be seen from the Hacienda within the cantonment
- Public Safety Power Shutoffs: utility companies in California can institute pre-emptive blackouts in response to wildfire conditions
- Remote Location: Distance to propane/diesel resupply of generators, no natural gas lines
- Extreme Conditions: Atmospheric river, mudslide, seismic activity, wildfir

Solution: To mitigate these challenges, FHL began developing a long-term strategic plan for an installation-wide Solar & Battery powered microgrid to achieve mission resilience.

Over a Decade of FHL Resilience

2011 - 2015

- Pilot site for:
  - Net zero energy and waste
  - Army Reserve Integrated Strategic and Sustainability Planning process
- Completed net zero energy assessment and adopted net zero energy plan to reduce reliance on fossil fuels
- Installed solar photovoltaic panels (multiple phases) and battery storage (legacy)

2016 - 2020

- Awarded projects:
  - Heating, ventilation, and air conditioning (HVAC) controls optimization, I2C2 Integration, & HVAC features (Unitary heatpumps)
  - Secondary wastewater treatment facility
  - Ground source heat pumps for housing buildings
  - Cantonment microgrid
- Installation Energy and Water Plan completed
- Waste-to-energy demonstration
- Solid waste characterization study completed

2021 - 2030

Efficiency:

- Complete ongoing building controls and metering projects; install advanced meters, and integrate all critical buildings into the main control center
- Implement energy and water efficiency measures for critical buildings
- Initiate solid waste characterization recommendations

Resilient Infrastructure:

- Complete construction of the cantonment microgrid (will be fully operational in FY25)
- Study and size additional battery storage for the cantonment microgrid
- Award Utility Energy Service Contract for potable well and ammo supply point microgrid (ongoing)
- Install emergency generator quick connects for Multipurpose Range Complex

Reduce Vulnerabilities:

- Complete design for water modernization project
- Repair water utility infrastructure
- Implement additional electrical overhead to underground projects
- Review third-party contracts for cybersecurity requirements “Hack-the-Grid”

FHL’s success would not be possible without the support of our partnerships across the industry.

- California Energy Commission
- Pacific Gas and Electric
- Ameresco
- U.S. Army Office of Energy Initiatives
- Lawrence Berkeley National Laboratory
- Pacific Northwest National Laboratory

Installation Energy and Water Plan

Army Goals (IEWP Assessment Guide)		
Critical Mission Sustainment	Critical Mission Risk Reduction	Installation Risk Reduction

USAG FHL IEWP Goals

1. Identify critical facilities and infrastructure to ensure that training support and base operations can be sustained
2. Identify energy and water efficiency measures to reduce overall demand
3. Leverage advance meters and building controls to better understand operating conditions
4. Adopt renewable energy and storage technologies to diversify supplies
5. Improve energy and water infrastructure to mitigate risk
6. Incorporate best practices into day-to-day operations
7. Align with Integrated Strategic and Sustainability Plan (ISSP) LOE 3: Infrastructure

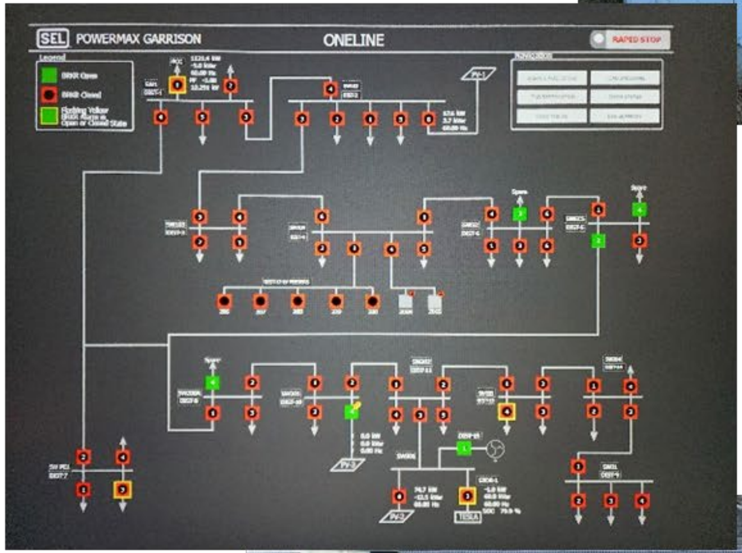
Critical Mission Sustainment: The ability of an organization to maintain critical mission continuity of operations for a duration set by the **senior commander or higher headquarters** based on timeframes to accomplish, curtail, or relocate the critical mission(s). When the duration of the critical mission(s) has not been stipulated, the Army will plan to sustain energy and water for a minimum of 14 days. (Army Installation Energy and Water Strategic Plan, DEC 2020)

FHL – Microgrid At a Glance

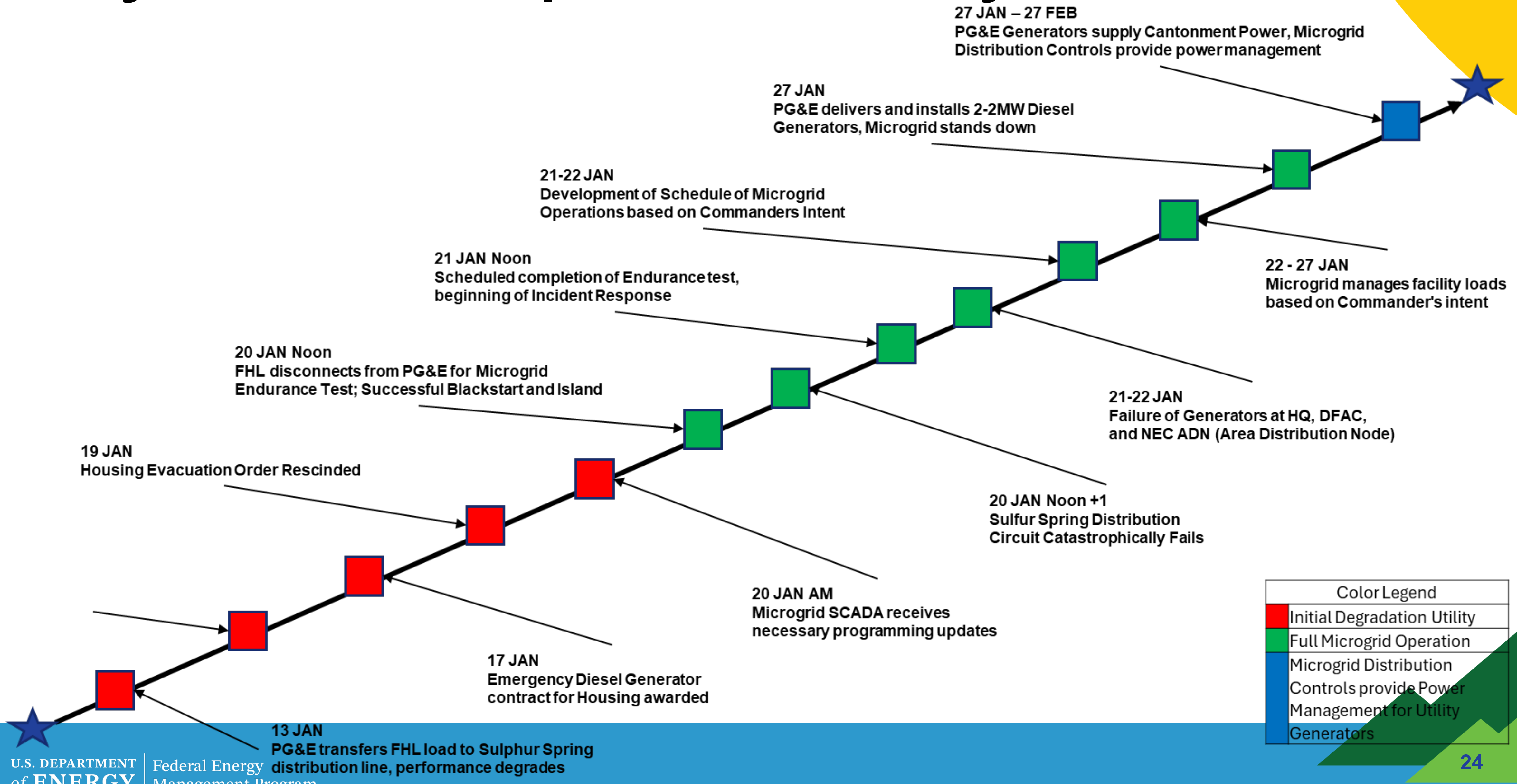
- In April 2019, a $21M ERCIP project was awarded to Ameresco for construction of a campus wide microgrid

Includes:

- 3.75MW of PV Generation
- 2.15MW Truckport
- 1.6MW Ground Mount
- 2.5MW/5MWh BESS
- 1 SCADA System to Rule Them All
- 13 Managed Distribution Switches
- 5 Barracks Buildings with low voltage switchgear controls



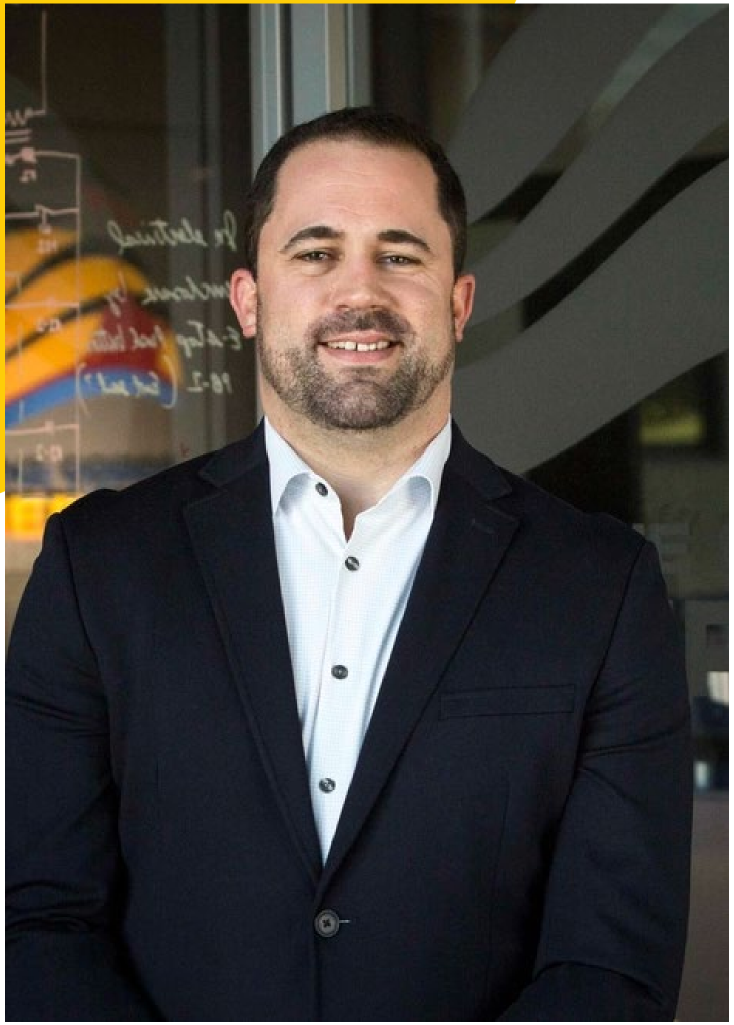

7-day Incident Response - January 2025



7-Day Incident Response

Schedule of Microgrid Operations						
Load Priority	Load Name	Building name	Switch	Schedule	Comments	Load Average
1A	Headquarters	B238	sw104 - way 5	Always on		36
1B	NEC Node and Access control point	3002 - ACP	swPE1 - way 1	Always on		18
2A	DFAC	B206	sw104 - way 4	0500 - 1900		40-100
2B	Child Development Center/CDC	B178	sw102 - way 2	0600 - 1800		14.6
3	Barracks	B229	sw104 - way 3 LVSG	1700 - 0800		55
4	IHG - Hacienda	B128 - B101	SW1 - way 2	0500 - 0800 1700 - 2300	Shedable if resources low	60
5	Barracks	B207	sw104 - way 3 LVSG	0500 - 0800 1900 - 2300	Shedable if resources low	
5	Barracks	B208	sw104 - way 3 LVSG	0500 - 0800 1900 - 2300	Shedable if resources low	
6	Gas Station/Valero	B116	sw103 - way 1	1100 - 1700		7.6
7	PX - Post Office	B80 - B79	sw102 - way 5	0900 - 1700	Shedable if resources low	16
8	Rec Center	B287	sw104 - way 2	1700 - 2100		36
9	Fuel Point	B311	sw202 - way 5	as requested,		
99	Gymnasium	B219 et all	who knows	can't turn it off if we wanted to	New Utility Manager is researching circuit	?

- **Expanding the definition of critical mission infrastructure**
  - Child Development Center
  - Gas Station
  - Dining Facility
  - PX/Post Office
  - Hotels
  - REC Center
- **Maintenance and Sustainment**



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Energy Program Overview

OBJECTIVES

RELIABILITY (Improve readiness)
Modernize infrastructure to ensure an adequate and dependable energy and water supply to support the operating forces.

RESILIENCE (Enhance warfighting capabilities)
Reduce dependence on external suppliers, increase on-site storage and generation assets, and implement exercises to test utility emergency response plans, infrastructure configuration, and equipment condition.

EFFICIENCY (Reduce operating costs)
Minimize energy and water consumption recognizing an austere fiscal environment and allowing limited resources to be applied to readiness and modernization.

CAPABILITIES

1. Operationalize installation energy security plans (IESPs) to identify and develop:
   - Holistic solutions addressing mission critical requirements with sufficient capacity and duration.
   - Microgrids coupled with multiple on-site energy sources.
   - Efficient technologies and best management practices.
2. Leverage available energy authorities to include:
   - Energy Resilience and Conservation Investment Program (ERCIP)
   - Energy Savings Performance Contracts (ESPC)
   - Utility Energy Service Contracts (UESC)
   - Power Purchase Agreements (PPA)
   - Enhanced Use Leases (EUL)
   - Utilities Privatization (UP)
   - Federal, State, and Local Grants
3. Execute energy resilience readiness exercises (ERREs) to test an installation's ability to conduct critical and essential missions while disconnected from the commercial grid.
4. Maintain a data environment that collects, stores, analyzes, and visualizes qualitative and quantitative energy and utility data to enable data-driven decisions.
5. Coordinate strategic communications on high visibility issues addressing program priorities and optimizing information sharing across Congress, OSD, and ASN.

Energy Program Execution

PLAN	**Installation Energy Security Plans (IESPs)**	• Identify energy requirements for critical missions • Evaluate current source of energy provided to support critical missions • Determine duration needed in the event of a disruption or emergency
INVEST	**Project Development and Deployment**	• Use all available vehicles, including Energy Savings Performance Contracts (ESPC), Utility Energy Service Contracts (UESC), Enhanced Use Leases (EUL), and OSD's Energy Resilience and Conservation Investment Program (ERCIP) • Utilize multiple and diverse sources for energy generation • Deploy advanced micro-grids to dispatch power to critical requirements • Adopt full-time, installed energy sources vice emergency generation
TEST	**Energy Resilience Readiness Exercise (ERRE) Program**	• Determine ability of backup systems to start independently, transfer load, and carry load until energy from off the installation is restored • Align organizations to coordinate in meeting critical mission requirements • Validate mission operation plans, such as continuity of operations plans • Identify infrastructure interdependencies • Verify performance of backup electric power system

Plan

USMC's standardized IESP approach assesses critical energy needs across all installations

Mature IESPs into roadmaps and project plans

Mission Assurance
- Vulnerability Assessments
- Mission Dependency Index
- Identify Critical & Essential Functions
- Critical Infrastructure Program
- Installation Protection

Energy & Utilities
- Annual Energy Management & Resilience Report
- Performance Contracts Reports
- Metering Plans
- Facility Efficiency Audits
- Annual Energy & Water Management Report
- Energy Projects
- DUERS Consumption Data
- Utilities Preventive Maintenance Program

Operations
- COOP Plans
- Mutual Aid Agreements
- Emergency Management Plans
- Readiness Exercises
- Refueling Plan Priorities

Communications
- Cybersecurity Assessments
- Control Systems Network Requirements
- Communications Services
- Authority to Operate Control Systems

Asset Management
- Real Property Inventory Data
- Utilities Ownership Data
- Installation Master Plans
- Facility Condition Assessments
- Geospatial Maps
- USMCmax Data
- Forecast Requirements
- Non-energy Investment Projects

Financial & Administrative
- POM & Budget Inputs
- Financial Execution Reports
- Common Output Levels Reports
- Resourcing
- Labor & Staffing Data
- Reimbursable Service Agreements
- Utility Billing Processes

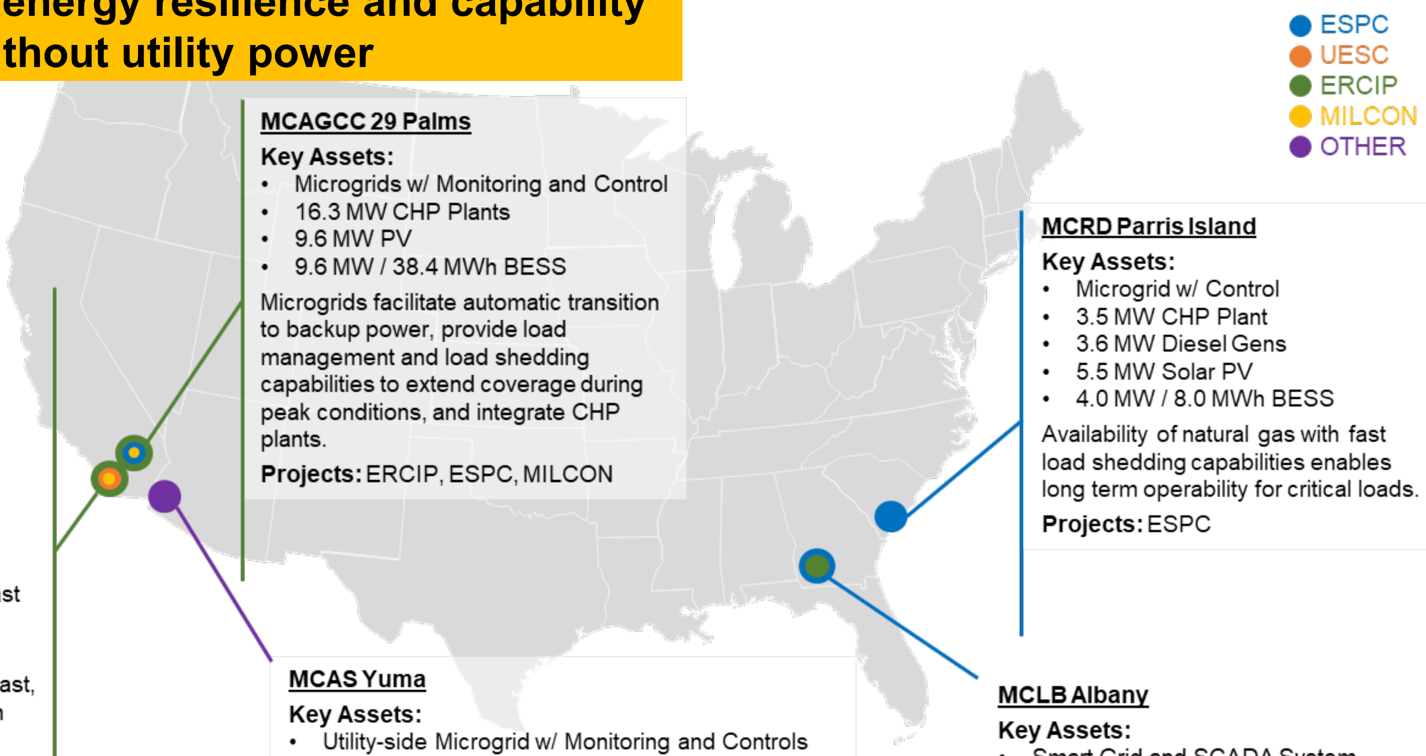
Resilience Program Guide

Installation Resilience Roadmap

Preliminary Project Development

Invest - Operational

Microgrid Projects deliver energy resilience and capability to operate without utility power



MCAS Miramar

Key Assets:
- Microgrid w/ Monitoring and Control at Central EWOC
- 2.8 MW Natural Gas Gens
- 5.6 MW Diesel Gens
- 3.2 MW Landfill Gas Gens
- 1.8 MW Solar PV
- 1.8 MW BESS
- 1.6 MW Load Management
- Water supply connection to East Miramar

Four modes to operate Microgrid provide flexibility to monitor, forecast, integrate, and optimize generation assets for economic benefits and extended energy resilience.

Projects: PPA, ERCIP, MILCON, CEC, UESC

MCAGCC 29 Palms

Key Assets:
- Microgrids w/ Monitoring and Control
- 16.3 MW CHP Plants
- 9.6 MW PV
- 9.6 MW / 38.4 MWh BESS

Microgrids facilitate automatic transition to backup power, provide load management and load shedding capabilities to extend coverage during peak conditions, and integrate CHP plants.

Projects: ERCIP, ESPC, MILCON

MCAS Yuma

Key Assets:
- Utility-side Microgrid w/ Monitoring and Controls
- 25.0 MW Diesel Gens (utility side)

Utility-side sensors detect power quality events/outages and automatically starts plant in <9 seconds. Over 200 power quality events mitigated since 2016.

Projects: EUL

MCRD Parris Island

Key Assets:
- Microgrid w/ Control
- 3.5 MW CHP Plant
- 3.6 MW Diesel Gens
- 5.5 MW Solar PV
- 4.0 MW / 8.0 MWh BESS

Availability of natural gas with fast load shedding capabilities enables long term operability for critical loads.

Projects: ESPC

MCLB Albany

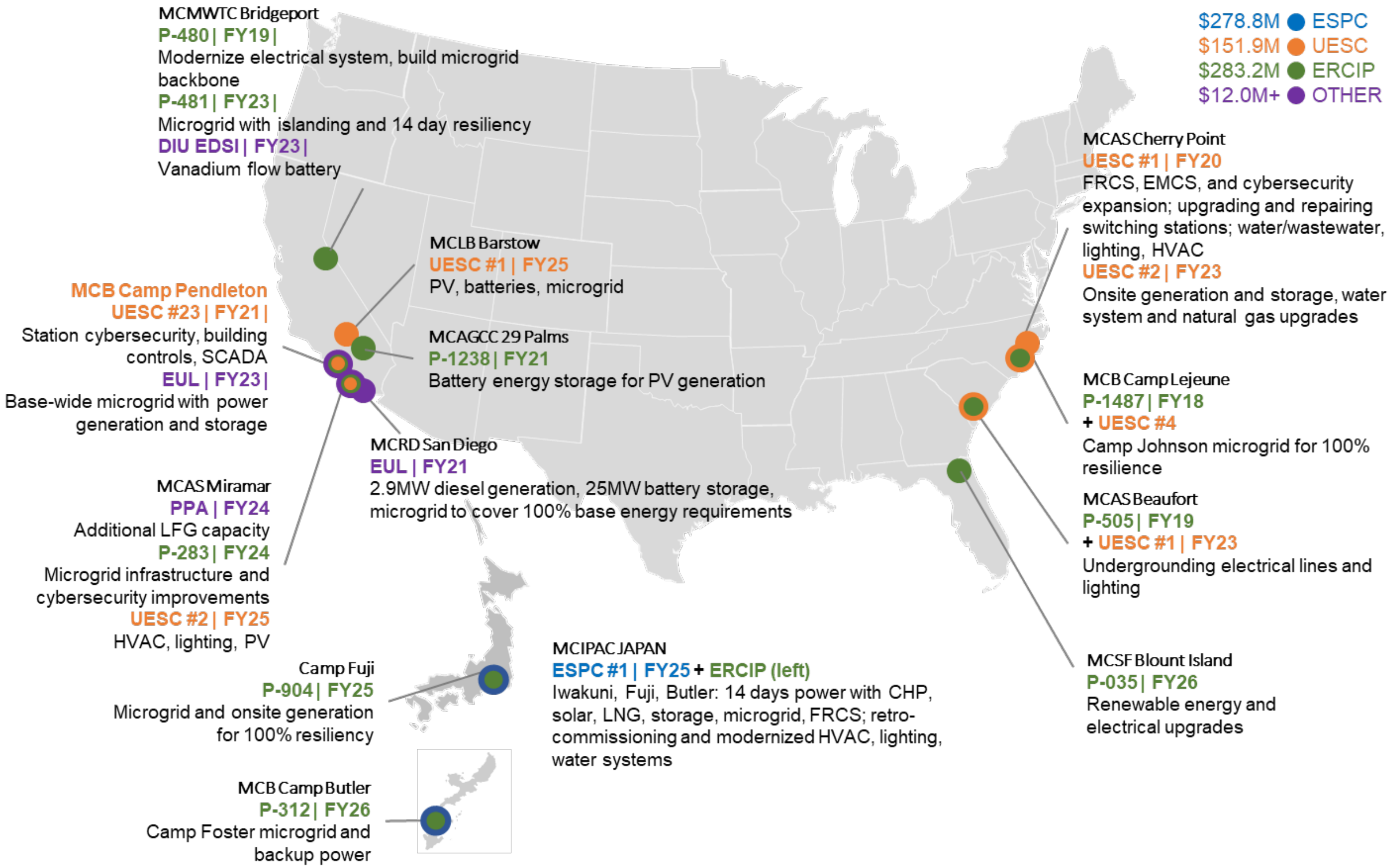
Key Assets:
- Smart Grid and SCADA System
- 8.5 MW Biomass-fueled Steam Turbine
- 1.9 MW and 2.1 MW LFG Gens
- 1.6 MW Diesel Gen

Local partnerships leveraged to achieve resilience requirements.

Projects: ERCIP, ESPC

Invest – In the works

Energy Program is building resilience leveraging alternative funding mechanisms



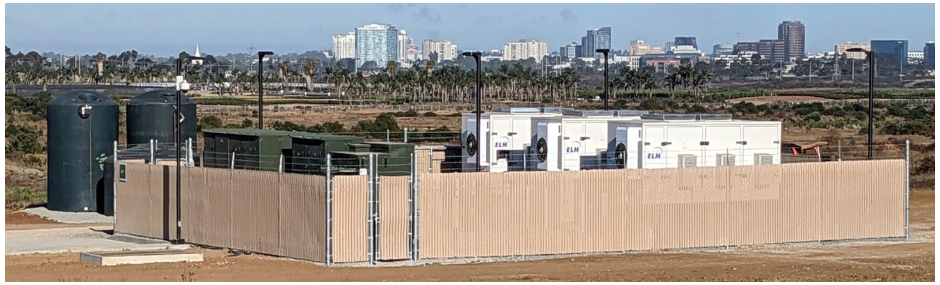
MCAS Miramar Microgrid

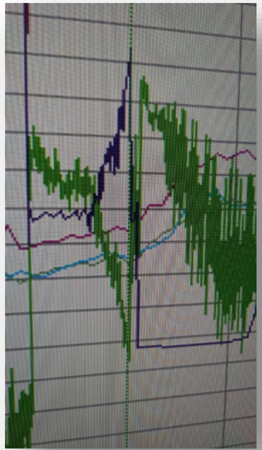
<u>Base Load</u>
- 7-8 MW average
- 14 MW peak
- Est 3-6 MW critical loads

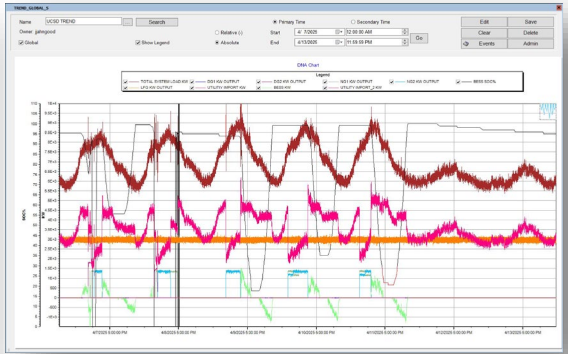
<u>Currently Operational</u>
- 3.2 MW Landfill Gas
- 3.6 MW Tier 4 Diesel
- 2.8 MW Prime Nat Gas
- 1.9 MW Photovoltaic
- 2 MW B7777 Generator (emergency use only)
- 1.5 MW / 3.3 MWH BESS

<u>Full Future Capability</u>
- 4.8 MW Landfill Gas
- 3.6 MW Tier 4 Diesel
- 2.8 MW Prime Nat Gas
- 3 MW Photovoltaic
- 2.9 MW Building Diesel Generators (emergency use only)
- 3 MW / 6 MWH BESS

Total = 17+ MW







Test – ERREs

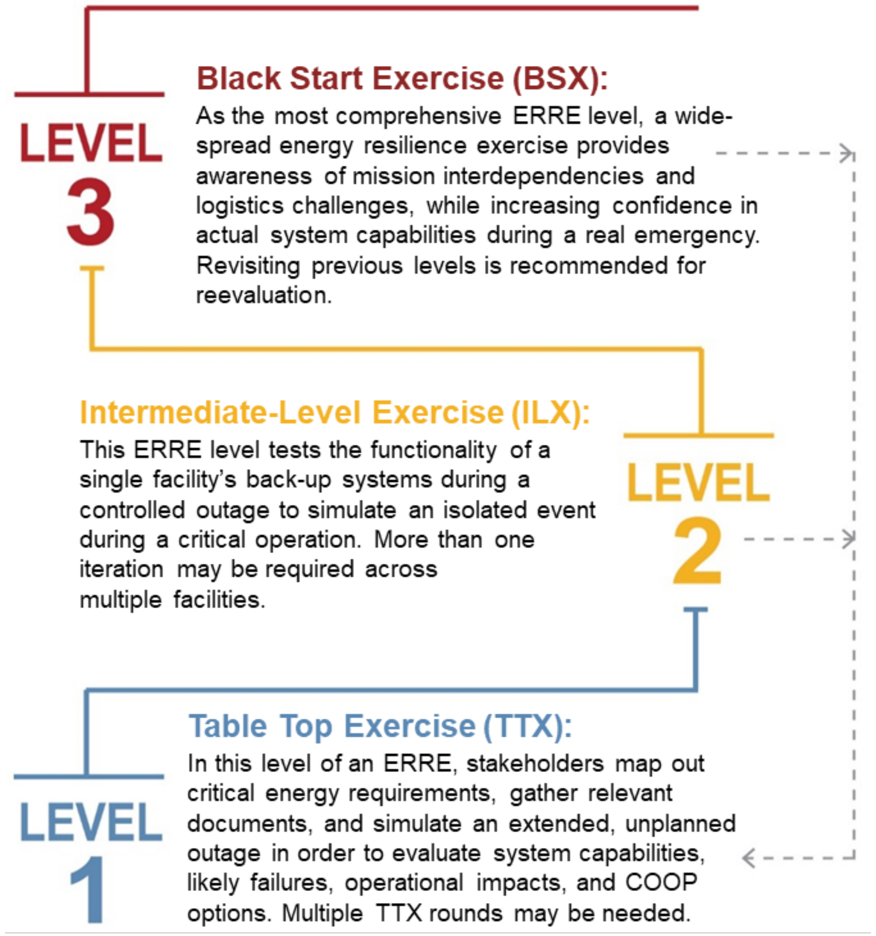
Energy Resilience Readiness Exercise (ERRE) Program develops capability for installations to test the ability to conduct mission essential functions during energy disruptions

<u>Drivers:</u>

- 10 USC 2920
- DoDI 4170.11
- OSD Black Start Guidance

<u>Objectives:</u>

- Verify backup power system capabilities, <u>including microgrids</u>
- Evaluate COOP and emergency response plans
- Increase coordination among stakeholders
- Identify repairs and investments
- Prepare Marines and civilians for emergency operations



Microgrid Considerations and Lessons Learned

Sustainment

- Understanding new real property assets and costs to sustain, manpower requirements, etc.
- Regular contracts for sustainment of microgrid systems and software are unlike other more common technologies such as HVAC or specific standalone plant operations.
- Microgrid operations require expertise in electrical, mechanical, and communications – these individuals are hard to come by and difficult to train.
- Sustainment through third party financing (long term contracts)

Planning/Design/Technical

- Electrical studies to validate energy resource abilities to island defined electrical boundary – presents challenges with funding and process
- Standard contract templates do not anticipate complex system requirements such as network designs, existing electrical and control system integration, and detailed operational commissioning for a microgrid that doesn't exist yet

Conceptual

- Reliability vs Resilience – Reliability is upgrading infrastructure and resilience is building microgrids. A microgrid does not prevent outages from our inability to maintain our electrical utilities. Microgrids are operational capabilities built for contingency situations.
- Existing infrastructure is a major concern when building microgrids. Upgrades are either needed or recommended.
- Contingency situations – if the target is 14 days and the regional grid is out of power, will civilians or contracts be available to operate microgrids that we build.

Housekeeping Items

- This session will be recorded
- Please keep yourself on mute
- Policy does not allow AI notetakers, we will kick them out
- If you joined using a phone number, a different email address than your WBDG registration, or an unverified Teams account (e.g., missing first and last name), please email KLAjmo@energetics.com to ensure you're added to the attendance list and receive CEU quiz access. Include the following in your email:
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