



Department of Defense Installation Energy Resilience



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DoD Energy Resilience (ER)

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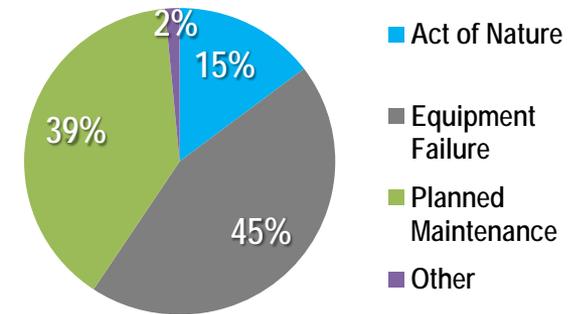
□ Policy Drivers

- Multiple requirements through FY2017 NDAA;
- DoD Instruction 4170.11(updated 16 Mar 2016), Installation Energy Management, Energy Resilience
- Title 10, Section 2925(a) (modified thru FY2016 NDAA);
- ASD(EI&E) Memorandum on Power Resilience;
- Unified Facilities Criteria (such as Electrical Series)

□ DoD Policy Initiatives

- ✓ DoDI 4170.11 change on energy resilience (complete)
 - ✓ Ensures performance against existing requirements
 - ✓ Encourages cost-effective solutions to improve mission assurance
- Implementing guidance
 - ✓ Operations, maintenance, and testing (OM&T) (complete)
 - ✓ Energy resilience, mission integration, metrics (in-progress)
- Budgetary execution
 - ✓ Business case analyses (BCA) framework (MIT-LL) to prioritize budget resources or alternative financing projects for energy resilience (complete)
 - ✓ Rating alternative financing projects to accelerate adoption of energy resilience projects – Defense Energy Resilience Bank (DERB) (in-progress)

FY 2016 Utility Outages



- *Utility disruption data is required under Title 10, 2925(a)*
- *Disruption data informs on-going metrics guidance*

Details on OASD(EI&E) Energy Resilience Initiatives:
http://www.acq.osd.mil/eie/IE/FEP_Energy_Resilience.html

DoD energy resilience is the ability to prepare for and recover from energy disruptions that impact mission assurance on military installations.



DoD Energy Resilience Base-Level Critical Loads Example – Base Grid

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Example Case – Not an actual installation (solutions will vary based on mission requirements of military installations)

DoD Installation Energy Resilience is both technology and authority agnostic. It is about mission and economic performance.

- ▲ Substation
- ◆ Critical Loads
- Distributed Gen
- Spot Gen / UPS
- ▴ Mobile Gen

A = Availability – Is the availability at my critical loads in alignment with what my mission requires?

- OM&T and right-sizing (generation)
- Consider upgrading/improving distribution system, equipment, and fuel for critical loads (not typically industry system standards – but mission-based standards)
- Consolidated/distributed generation at the critical feeder on the base
- Spot generators/UPS at specific critical facilities could still be required
- Essential to ensure mission-specific security requirements are met (resilience requirements allows for lower surface area protection)

Current authorities were developed for alignment to industry, not mission-based metrics and standards.

Generally, this was found to be a good option to improve resilience affordably (MIT-LL study).

- Renewable energy options can also be considered to help offset fuel related costs and vulnerabilities (however, based on local resource constraints and batteries beyond UPS generally difficult to support thru LCCA)
- Typically, we look at “fixed” energy systems – evaluation of flexible options (e.g., dual-fuel) and even mobile generation (lowers vulnerability surface area further)



Cost attribute: life-cycle costs (\$/kWh)
 Mission attribute (availability): annual unserved energy (MWh)

Bottom-Line Up Front (BLUF) Study Results Overview

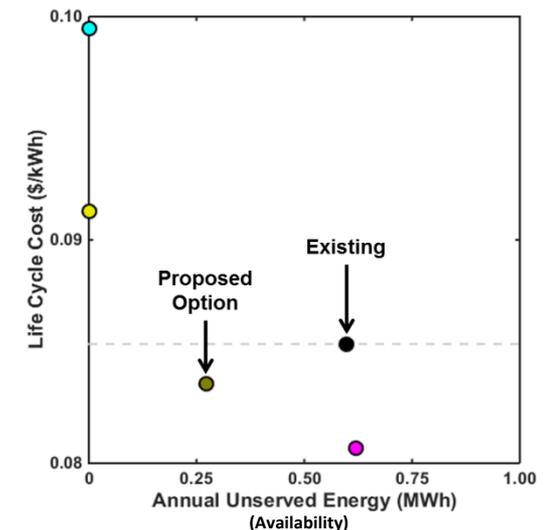
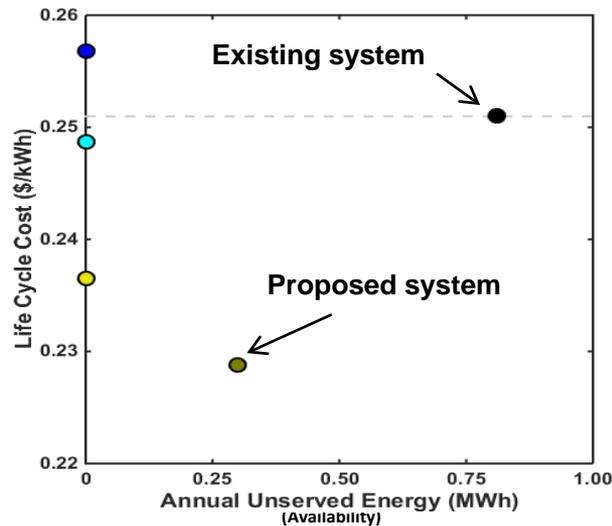
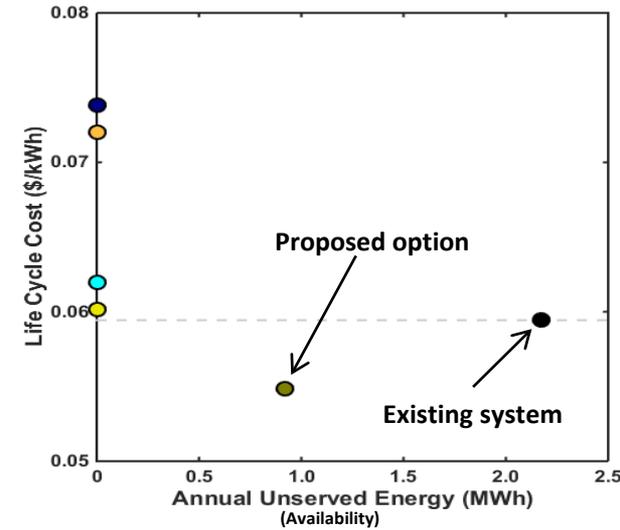
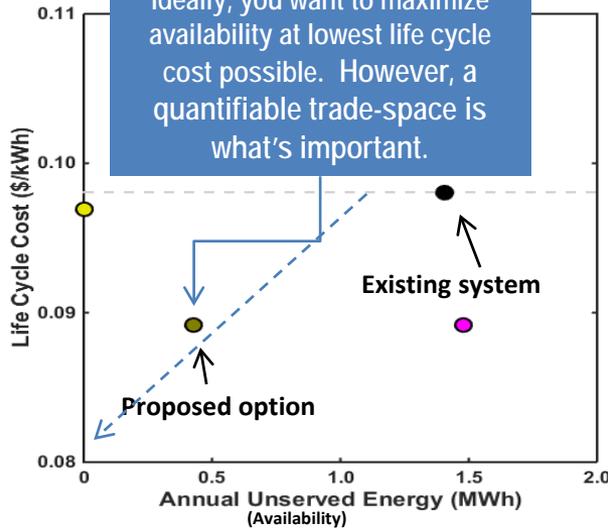
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Findings/Results (generalized)

- Critical Energy Loads: 6 MW to 21 MW
- Generators: 50 to 350 generators
- Reductions in costs: 0.2¢/kWh to 2.2¢/kWh,
- Availability improvements: 0.3 MWh to 1.2 MWh
- Base characteristics: Isolated location with frequent outages, integrated/urban base with reliable power, etc.

	Generator	Microgrid	UPS	PV	CHP	FC
●	X					
●	X	X	X			
●	X	X	X	X		
●	X		X	X		
●	X			X		
●	X	X		X		
●	X	X	X	X	X	
●	X	X	X	X		X
●	X	X	X	X	X	X

Ideally, you want to maximize availability at lowest life cycle cost possible. However, a quantifiable trade-space is what's important.



Framework allows for quantifiable tradeoffs between cost and mission assurance attributes.

Results across diverse bases indicate that more cost-effective and reliable energy resilience solutions exist to support critical mission operations on our military installations.

Energy Resiliency Approaches for DoD Installations



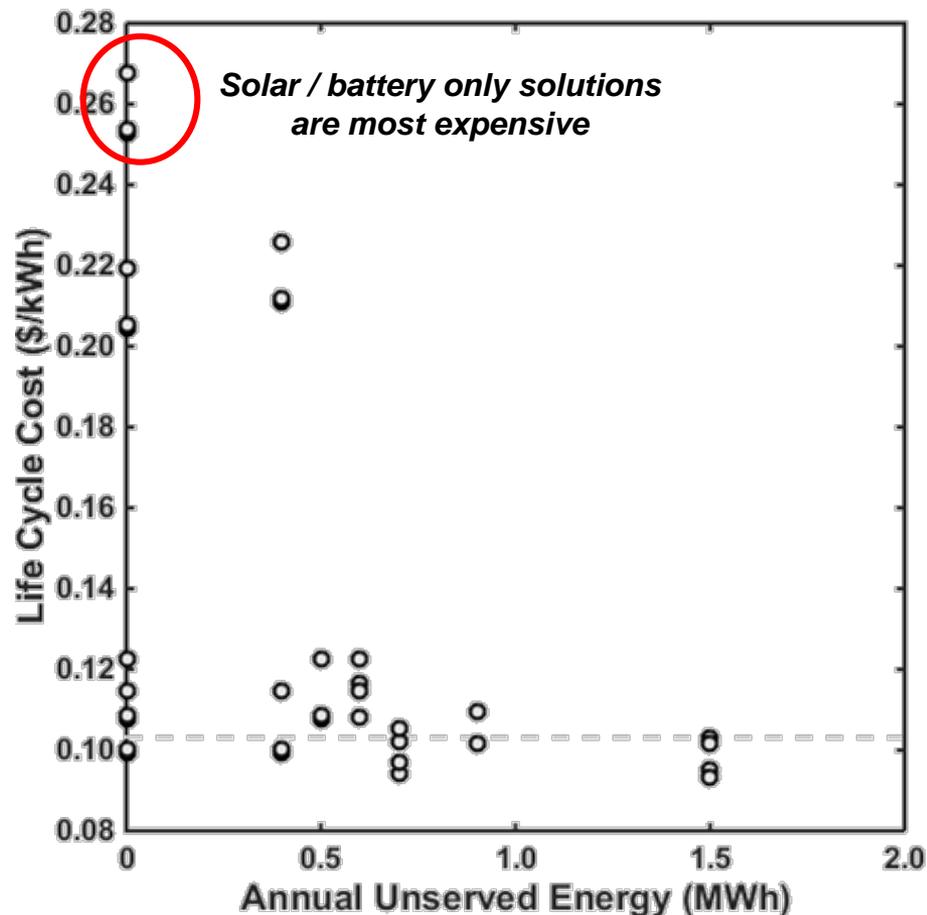
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Model Results

- 1000 annual Monte Carlo simulations performed
- Life-cycle cost (LCC) is calculated over 10 years
- Unserved energy is based on typical outages experienced by the installation
- High-cost options typically include batteries and/or fuel cells
- Low-cost options include generators, microgrids, and/or solar

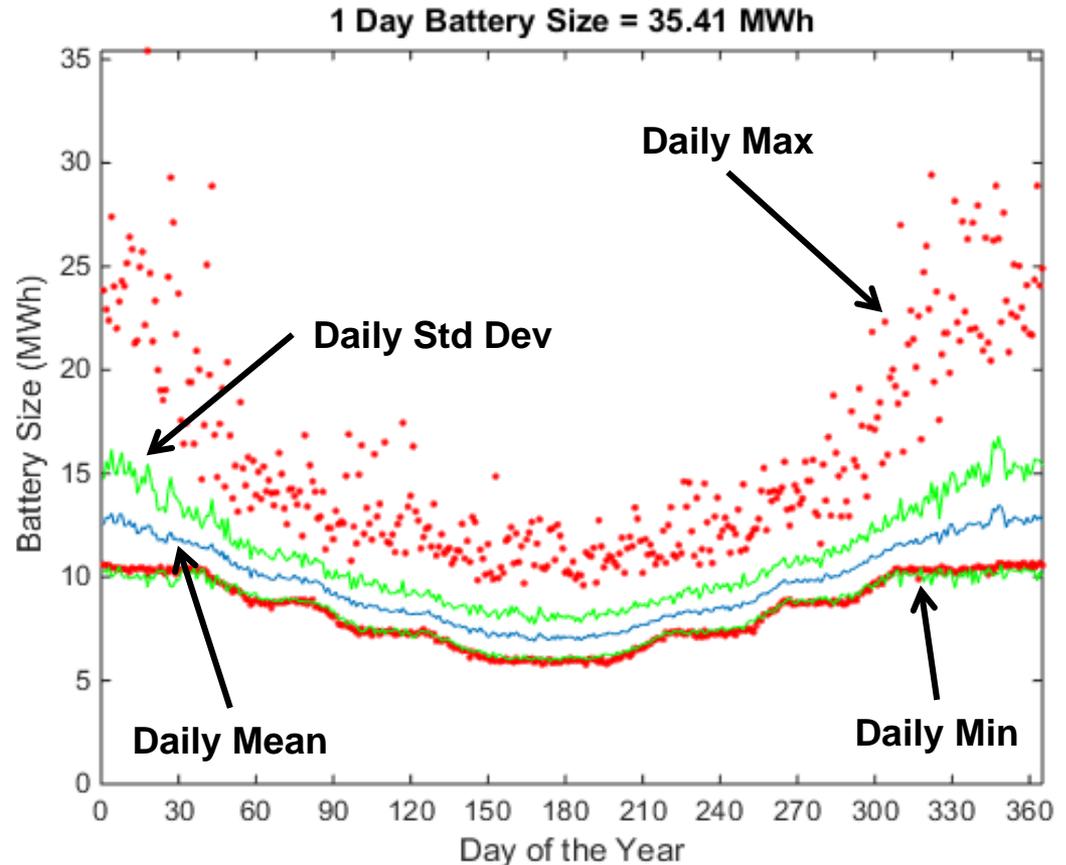




Battery Size for 1-Day Outages

Assumptions:

- Located in Boston, MA
- 2MW annual peak load
- 20MW solar capacity
- 1000 annual simulations with randomization on demand, solar output, and grid availability
- Global maximum represents the battery size needed for the grid outage duration specified



A very large energy storage system is needed to meet critical load requirements assuming worst-case solar insolation



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Backup



Energy Resilience Overview

Inclusion of Mission-Based Decision-Making

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Critical Mission Operations (Sample - For Training Purposes Only)

Global Intelligence, Surveillance, and Reconnaissance (ISR)

Power/Force Projection – Mobilizing, Deploying, and Demobilizing

Strategic Command Communication - Command and Control

Life, Health, and Safety Operations

❑ Step 1 – Criticality of mission and supporting functions

- Services and Defense Agency provided during Power Resilience review in 2014
- Validated through MIT-LL was the need for broader and strategic energy resilience framework, inclusive of:
 - Service and Defense Agency Warfighting Missions
 - Emergency, Recovery, and Response Missions
 - Supporting Installation Infrastructure (those needed based on outage risks and interdependencies)

❑ Step 2 – Mission requirements of those critical mission operations

- In terms of 'resilience' – what disruption risk is appropriate? (e.g., availability, downtime, etc.)

Important questions:

- Mission operator coordination?
- Were mission dependencies evaluated?
- Were mission-to-mission solutions reviewed and identified?
- Were risk-based mission requirements developed and considered?
- Is an infrastructure solution required or needed?

DoDI 4170.11 requires alignment to critical energy requirements (critical mission operations) and allows for expanding solutions beyond standby generators.

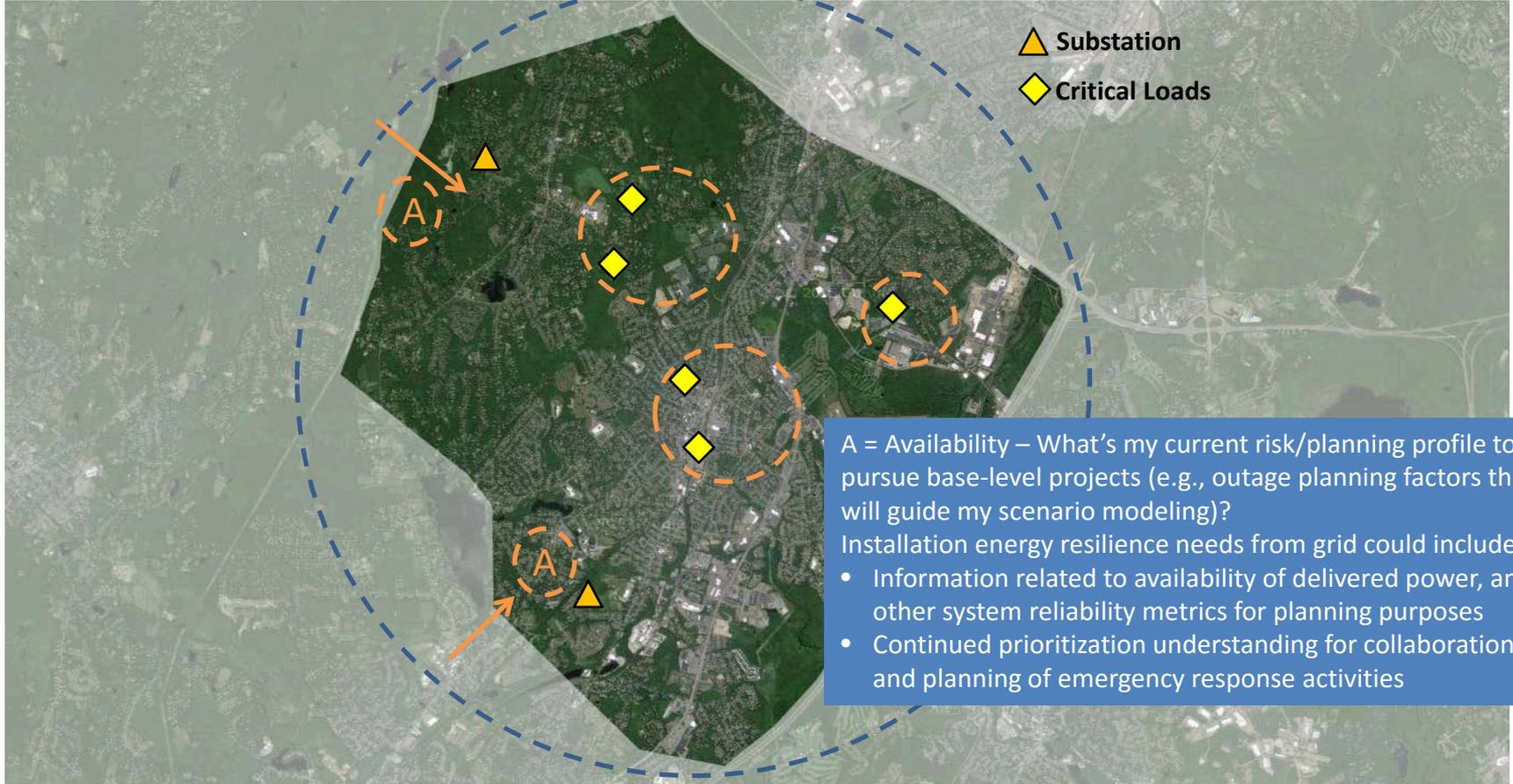
Resilience allows for a comprehensive, strategic framework and extends beyond traditional “building-by-building” or “generator-by-generator” designation for resilient designs. Important to establish a holistic and strategic resilience framework that integrates mission and installation stakeholder communities that encourage mission-based decision-making.



DoD Energy Resilience Base-Level Critical Loads Example – Commercial Grid

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Example Case – Not an actual installation



There is no requirement in our installation energy resilience framework to pay a “premium” or develop a “value” for additional delivered power to the installation, given we are prioritizing critical loads on our military bases and that resilience assumes disruptions have occurred on the commercial electric grid. Guidance does encourage inclusion of appropriate reliability savings, and tariff & security savings/cost avoidance in life-cycle cost analysis (LCCA). LCCA is required for project-level decisions on military installations.



DoD Energy Resilience Base-Level Critical Loads Example – Base Grid

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Example Case – Not an actual installation

Conceptual Example:
Critical Mission Operation: Global
ISR
Critical load for critical mission
operation: **3 MW**
Mission Energy Required for
continuous annual operations:
8760 hrs
Mission Downtime Requirement
(annual-min): **≤6 minutes**
Mission Availability Requirement
(annual-hrs): $(8760 - .10) / 8760$
 $= .999989 =$
99.9989%
Mission Requirement for
Unserviced Energy - Annual
(MWh): 300kwh

Lots of guidance on the calculation
piece already explained.

DoDI 4170.11/UFCs and Mission
Doctrine Requirement / Capability
Measure Requires these inputs

- ▲ Substation
- ◆ Critical Loads
- Distributed Gen
- Spot Gen / UPS
- ▲ Mobile Gen

Title 10 Requirement, 2925(a)
Requires these inputs

Total Measured Availability Impacting Critical Load
(annual): $(8760 - 6) / 8760 = .999989 = 99.9315\%$
Unserviced Energy - Annual (MWh): 18MWh

Gaps:

**Availability: .0674% below mission
requirement**

Unserviced Energy (MWh) = -17.7 MWh

Is the measured availability gap an appropriate
level of capability risk for the mission and
installation community?

What are the most cost-effective solutions to
remediate this capability risk (LCCA)?



Yes, lessons learned! We started the effort back in Dec 2012.

DoD Lessons Learned

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1. Collaboration of critical mission operations and mission requirements is a necessary first step to achieve energy resilience (don't assume a technology or execution path)

- Mission operator commitments?
- Were mission dependencies evaluated?
- Were mission-to-mission solutions reviewed and identified?
- Were risk-based mission requirements provided by mission operators?
- Do you need an infrastructure solution?

Resilience is a function of mission inputs, without grounded mission inputs you cannot move to an infrastructure solution (whether energy or another).

2. Determination of critical loads is important to assign prioritization, reduce vulnerability risks (and security costs), and to consider cost-effective options that align to what our mission requires

- What exactly are my mission requirements and the level of performance I expect at those critical loads?
- Are my current backup systems sized appropriately to my critical loads?

3. Existing availability/reliability of distribution system and current energy systems at critical loads that support my mission requirements require consideration prior to implementing any new energy system or generation options (also assists in establishing baseline metrics)

- Am I operating, maintaining, and testing (OM&T) my current systems and equipment?
- What is current level of availability performance at critical loads (i.e., current resilience)?
- Is further resilience required? What types of resilience options are possible on my base?
- What are my options? (e.g., upgrade current systems, pursue new systems, etc.)
- What are the most cost-effective options to deliver the required level of resilience (i.e., align to existing LCCA and economic requirements for budget and/or alternative financing – analysis of alternatives (AoA))?

Think about costs/tradeoffs as you increase complexity of solutions.



DoD Lessons Learned

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4. Consideration of various technologies, inclusive of fossil and renewable energy options are necessary when considering distributed and continuous power to ensure mission performance
5. “New” upgrades, distributed energy resources and other technologies can provide an installation greater flexibility in servicing critical loads, however, the Component must understand their current level of resilience and if the mission requires additional resilience. Examples:
 - ❑ Consider upgrading/improving distribution system, equipment, and fuel for critical loads (not typically industry system standards – but mission-based standards)
 - ❑ Consolidated/distributed generation at the substation/critical feeder level on the base
 - ❑ Spot generators at specific critical facilities can continue if additional resilience is required
 - ❑ Renewable energy options can also be considered to help offset fuel related costs and vulnerabilities (needs to tie back to mission requirements and capabilities)
 - ❑ Remember, you are remediating disruption risks, so fuel is likely still needed
 - ❑ Difficult to consider a renewable “only” option since fuel outcompetes batteries when considering cost/technical tradeoffs in a disruption scenario (difficult to size batteries to MW-level critical loads and LCCA requirements are difficult to meet with batteries)
 - ❑ Typically, we look at “fixed” energy systems – evaluation of flexible options (e.g., dual-fuel) and even mobile generation can also be considered to remediate disruption risk (lowers vulnerability surface area)
6. Energy resilience metrics (cost and technical) are needed to help move toward executable projects which align to what our mission requires
 - ❑ How do we know if we are getting the right resilience levels of resilience from existing contracts today?
 - ❑ Are we building in energy resilience performance metrics into our contracts? What types?
 - ❑ LCCA – Am I including reliability/efficiency savings and avoided costs (e.g., reliability/efficiency improvements, tariff/demand charge cost avoidance, security cost avoidance through risk reduction measures, etc.)?

Continue to think about costs and tradeoffs as you increase complexity of solutions.

Whatever the solution, don't forget about mission performance.



Energy Resilience Guidance Overview

Metrics Example – Availability for Critical Energy Loads

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- **Availability** – the ability of an item-under combined aspects of its reliability, maintainability, and maintenance support-to perform its required function at a stated instant of time or over a stated period of time. (IEEE Gold Book)
- Availability comprehensively takes into account all disruptions (threat agnostic/mission relevant: reliability, quality, maintenance, and unknown/unknowns that could impact mission) that impact mission performance
- Availability also allows a direct connection between energy/mission to help enable mission capability (e.g., developed by understanding mission requirement)

Questions that help shape metrics and solutions:

1. What is the length of time the mission requires power (cyclical or continuous)?
2. What is the disruption/risk/downtime tolerance during that period of time?

An example:
Mission x performs its function qtrly for 3 weeks at a time on an isolated part of the base. Its downtime requirement is no more than 1 hour over that 3 week period of time. What is the availability requirement?

Total Time	Actual Downtime	Actual Uptime	Measured Availability	Max Mission Downtime Requirement	Mission Availability Requirement
504	10 hours	494	98.0159%	1 hour	99.8016%

	Tier 1-2	Tier 3	Tier 4
Availability	X%	X%	X%
Type of Resilience	Susceptible to disruptions from both planned and unplanned activity.	Allow for planned infrastructure activities without interrupting supplies; some unplanned outages may occur.	Able to withstand at least one unplanned capacity component failure with no load impact.

Mission or capability gap quantification important to reduce associated risk to mission

What is right level? Depends on mission and risk profile. Services should look to understand risk tolerances based on mission requirements.

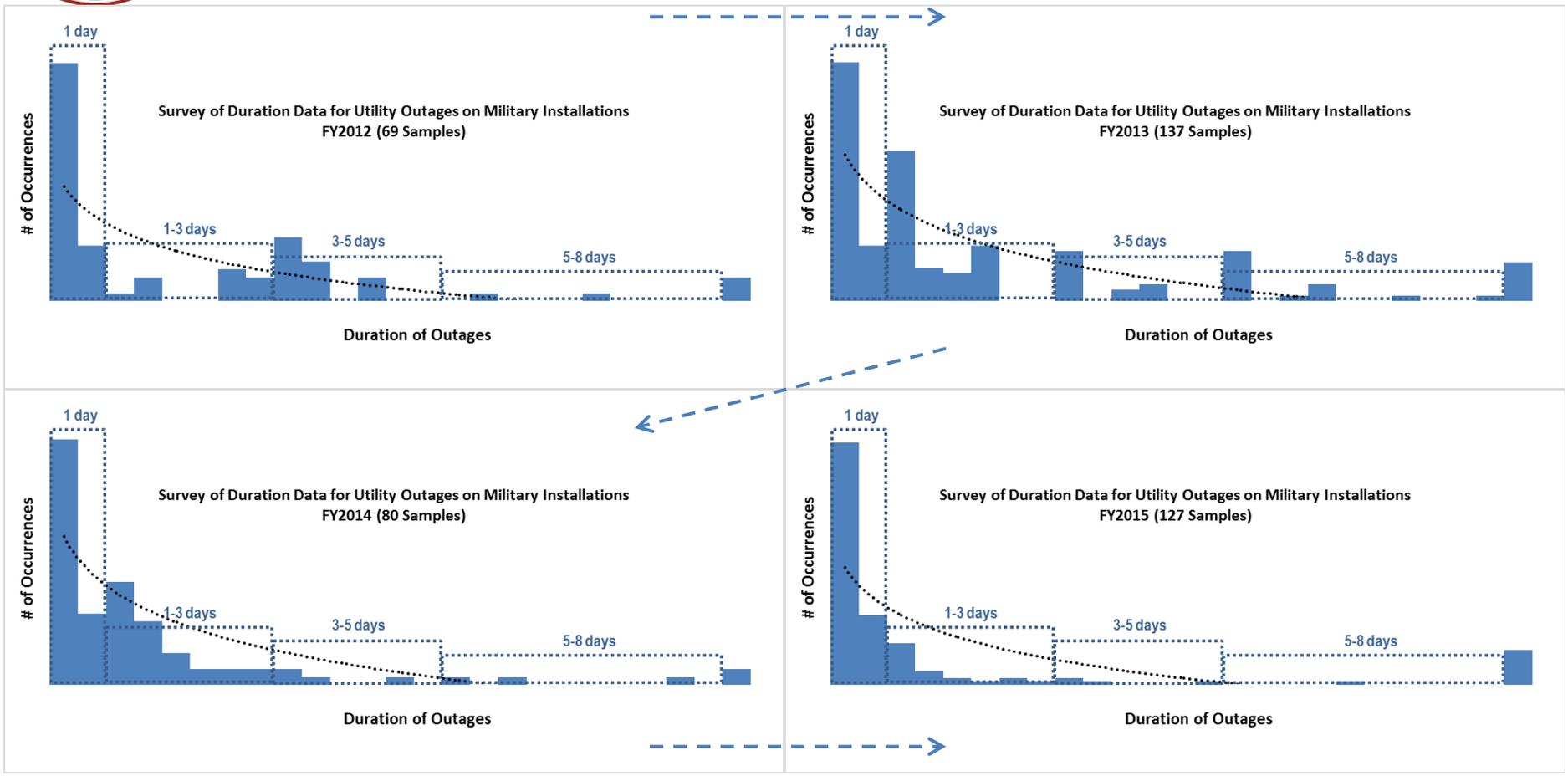
$$A = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}}$$

Guidance will provide discussion/benchmarks to consider for energy resilience decision-making. Services and Defense Agencies will be responsible for identifying the level of availability required based on their mission needs, resource availability, and changing conditions.



Duration Data (downtime) for Utility Outages on Military Installations FY2012-FY2015

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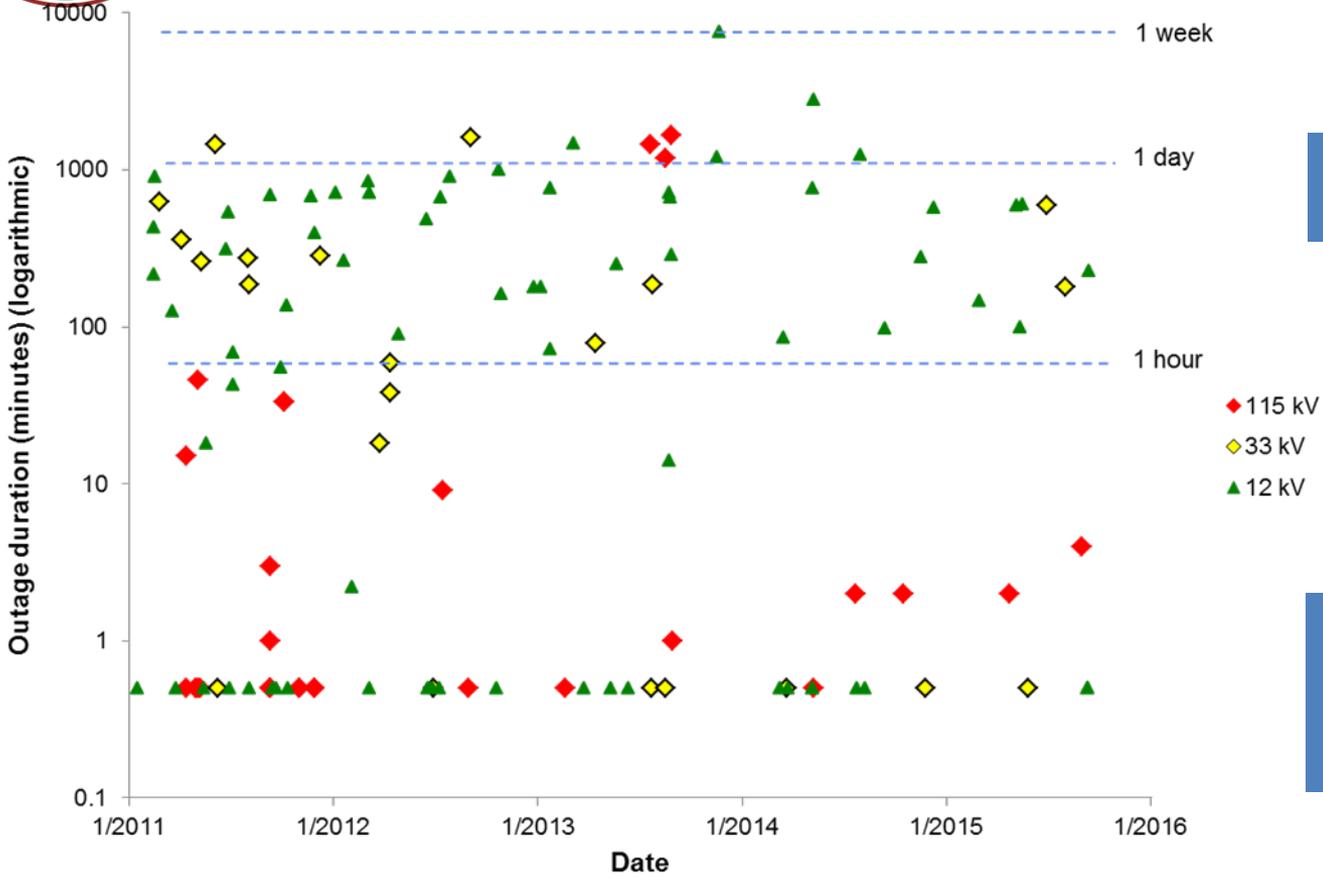
Data characteristics:

- Past Title 10, 2925(a) requires collection of commercial outage data
- Currently captures outages caused by off-base, commercial outages
- All outages caused by natural or reliability-related issues
- Modification to Title 10 requires all associated outages, including on-base



Sample of Historical Installation-Level Outages (Availability Information)

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How does availability align to critical energy loads?

Is current level of availability sufficient to meet mission requirements at those critical energy loads?

Outage information at the distribution level on the installation helps to align availability to critical energy loads and to mission requirements. Baseline of availability is important to address whether there is a mission capability gap.



Application of DoDI 4170.11 Policy MIT-LL Study Example



DoD Energy Resilience Study Problem Statement

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Study Problem Statement: How does DoD meet current requirements for cost-effective and reliable energy resilience solutions for critical mission operations?

- To implement energy resilience solutions, DoD requirements include:
 - Prioritization of energy requirements to critical mission operations (in partnership with DoD mission assurance communities)
 - Pursuit of life-cycle cost-effective energy resilience solutions that provide the most reliable energy to critical mission operations
 - Reviewing energy solutions beyond typical backup or standby generators
- How does MIT-LL study help DoD address this problem?
 - Primary focus is to review cost-effective and reliable energy resilience solutions
 - Technology agnostic – focus on quantifying and optimizing cost and availability/reliability to critical mission operations
 - Aligned energy resilience solutions to prioritized critical energy loads for the military installations
 - Analysis of alternatives comparing current baseline (generators) vs. over 40 potential energy resilience options



DoD-Wide Recommendations

Sampling of Findings

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These are not necessarily new requirements – further prioritization and awareness is required in the installation energy portfolio.

- **Communication**
 - Encourage routine meetings between installation energy leads and mission operators to determine and prioritize 'critical' mission operations and energy requirements across the entire base
 - Improve guidance to determine prioritized energy load calculation for critical mission operations
 - Coordinate with the community (inside and outside of the base) to ensure critical interdependent mission requirements are met during energy outages
- **Technical**
 - Understand your current energy systems and infrastructure; do not site energy systems on unreliable grid
 - Prioritize/ensure energy resilience systems are only placed on critical energy loads and not oversized
 - Standardize a process to ensure O&M of energy systems (e.g., generators, UPS, etc.) for full reliability picture
- **Cost and Performance Data**
 - Encourage tracking of the appropriate cost data (capital, operation, maintenance, and testing) of energy generation and infrastructure to replicate and justify the business case for future energy resilience solutions
 - Encourage tracking of performance data that aligns to mission and availability/reliability of energy systems and infrastructure (outage data, failure rates, etc.) to assist in tradeoff decisions between cost/mission
 - Helps to identify cost-effective and prioritized remediation for reliability risks on the base's electrical distribution system

Collaborating with Services and Defense Agencies to raise awareness through future guidance across the DoD.