Draft

Energy Planning for Resilient Military Installations

Resilience of Energy Systems: Metrics and Evaluation

December 5, 2017

Avinash Srivastava, *Principal, Design + Planning + Economics*
Calum Thompson, *Associate, Building Engineering*

AECOM

Overview

1. Definition of Energy Resiliency
2. Attributes of Energy Resiliency
3. Measuring Resiliency – two case studies
   - Bronzeville Resilience & Performance Metrics – perspective of ComEd (Utility)
   - Navy Energy Security & Readiness Scorecard – an Installation Perspective
4. Using Resiliency Metrics
   - For identifying priority projects at enterprise level
   - For guiding Installation Energy Planning
5. UFC for Energy Resiliency – On Going Effort

Defining Energy Resilience

re·sil·ience

/rəˈzilyəns/

noun

noun: **resiliency**

1. the capacity to recover quickly from difficulties; toughness.
2. the ability of a substance or object to spring back into shape; elasticity.

The Office of the Secretary of Defense defines resiliency as:

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

Source: DoD Instruction 4170.11, Change 1, 16 March 2016.

Energy Resiliency Metrics

Energy Resiliency Attributes

Reliability
Hardness
Redundancy
Risk
Recovery
Diversification etc.

Data

Availability
Accuracy
Maintainability

Scale and System Boundaries

Component
System
Installation
Community
Region
National

Considerations Influencing Metrics

Objectives

Strategy / Planning
Conceptual Design
Detailed Design
Implementation

Users

Executives
Planners
Engineers
Maintenance/Service

Example: Bronzeville ComEd Study

Developed resilience performance metrics to track and measure the impact of the microgrid and other grid modernization efforts for a community

Energy Resilience

- Reliability
- Power quality
- Islanding capability
- Distributed resource deployment and optimization
- Load balancing
- Energy efficiency and demand response
- Renewable and battery storage

Community Resilience

- Holistic View
- Ability to bounce back from shocks
- Minimization of chronic stresses
- Infrastructure and critical service preparedness
- Overall community socioeconomic condition
- Public and environmental health

Critical Infrastructure Resilience

- Emergency planning, preparedness, response and recovery
- Infrastructure and emergency service dependency
- Targeted service to vulnerable populations
- Cyber Security

Integrated Resilience Metrics, Benefits, Synergies

Energy Resilience Metrics:
Example: Bronzeville ComEd Study

Resilience Score 1-100	Area	Area Weight 1%-100%	Area Score 1-100	Indicator	Indicator Weight 1%-100%	Indicator Score 1-100	Metric		Metric Weight 1%-100%	Metric Score 1-100
$=\sum(area\_weight_i * area\_score_i)$, where *i* is each area	Energy Resilience (E)	33%	$=\sum(indicator\_weight_i * indicator\_score_i)$, where *i* is each indicator	E1 Power Delivery Resilience and Performance	33%	$=\sum(metric\_weight_i * metric\_score_i)$, where *i* is each metric	E.1.1	Sustained Average Interruption Duration Index (SAIDI)	5%	
							E.1.2	Maximum allowable transition time (voltage dependent) when changing from grid connection to island mode	5%	
							E.1.3	Frequency difference criteria for transition from island mode to electric power system grid connection	5%	
							E.1.4	Frequency and voltage deviation events	5%	
							E.1.5	Grid connected microgrid fault current interruption time	5%	
							E.1.6	Grid connected microgrid unintentional islanding prevention	5%	
							E.1.7	Unmet electricity demand due to power outages	5%	
							E.1.8	Unmet critical electrical load (Tier 1A/B) due to power outage	5%	
							E.1.9	Electrical service total harmonic distortion events	5%	
							E.1.10	Tier 2 electrical components that are worst performers	5%	
							E.1.11	Electrical transmission and distribution equipment damage and exposure prevention	5%	
							E.1.12	Redundant sources of electricity	5%	
							E.1.13	Distribution redundancy and automated restoration	5%	
							E.1.14	Mitigation of common risks and threats	5%	
							E.1.15	Identification of infrequent risks and threats	5%	
							E.1.16	Failure identification and elimination	5%	
							E.1.17	Islanding capability	5%	
							E.1.18	System Average Interruption Frequency Index (SAIFI)	5%	
							E.1.19	Customer Average Interruption Duration Index (CAIDI)	5%	
									5%	
									5%	
									5%	
									5%	
									20%	
									20%	
									20%	
									20%	
									20%	
									25%	
									25%	
									25%	
									25%	
									25%	
									25%	
									25%	
									25%	
									25%	
									25%	
									25%	
									10%	
									10%	
									10%	
									10%	
									10%	
									10%	
									10%	
									10%	
									10%	
									10%	
									10%	
									17%	
									17%	
	Critical Infrastructure Resilience (I)	33%	$=\sum(indicator\_weight_i * indicator\_score_i)$, where *i* is each indicator	I1 Reliable Communication & Mobility	33%	$=\sum(metric\_weight_i * metric\_score_i)$, where *i* is each metric	I.1.3	Public Transit Service Providers	17%	
							I.1.4	Public Transit Safety	17%	
							I.1.5	Building Ratings/Multi-Hazard Vulnerability of Existing Buildings	17%	
							I.1.6	Multi-hazard Vulnerability of Proposed Microgrid Components	17%	
				I2 Continuity of Critical Services	33%	$=\sum(metric\_weight_i * metric\_score_i)$, where *i* is each metric	I.2.1	Disaster Management Enhancement	13%	
							I.2.2	Streetlight Outages	13%	
							I.2.3	Protecting Critical infrastructure providers (police, hospital heating and cooling centers, schools)	13%	
							I.2.4	Protecting Commercial Centers (Grocery Stores, Gas Stations)	13%	
							I.2.5	Emergency Response Time (Police, Fire, Ambulance, etc.)	13%	
							I.2.6	Building Ratings/Multi-Hazard Vulnerability of Existing Buildings	13%	
							I.2.7	Flood Risk	13%	
							I.2.8	Multi-hazard Vulnerability of Proposed Microgrid Components	13%	
				I3 Critical Infrastructure Security	33%	$=\sum(metric\_weight_i * metric\_score_i)$, where *i* is each metric	I.3.1	Cyber Security	33%	
							I.3.2	Building Ratings/Multi-Hazard Vulnerability of Existing Buildings	33%	
							I.3.3	Multi-hazard Vulnerability of Proposed Microgrid Components	33%	

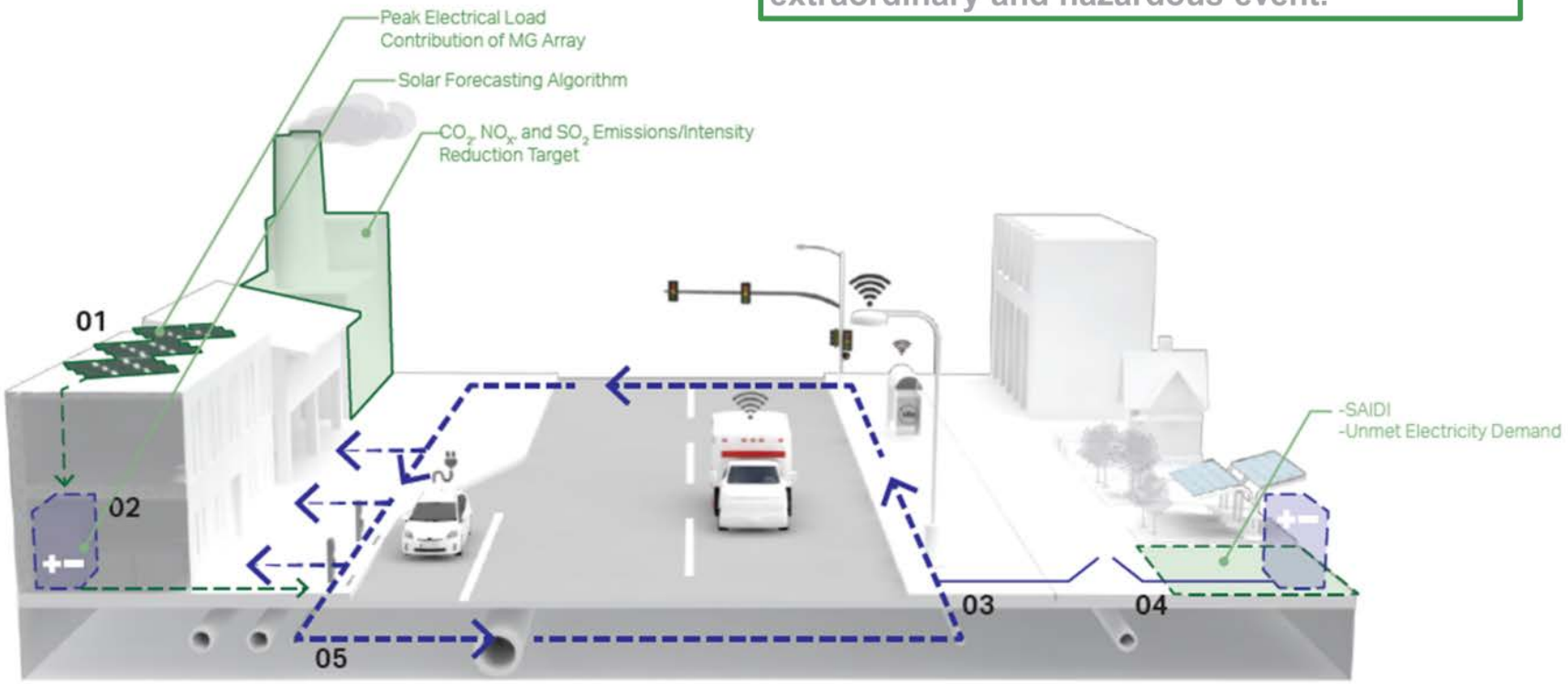
Example: Bronzeville ComEd Study

ENERGY SYSTEM RESILIENCE

01 Distributed Generation
02 Battery Storage (In building or district scale)
03 "Islanding" Switchgear to enable MG
04 Local Substation with two way power flow
05 Smart Grid

DEFINED AS:

Robustness and recovery characteristics of electric utility infrastructure and operations, which minimizes outages of service during an extraordinary and hazardous event.

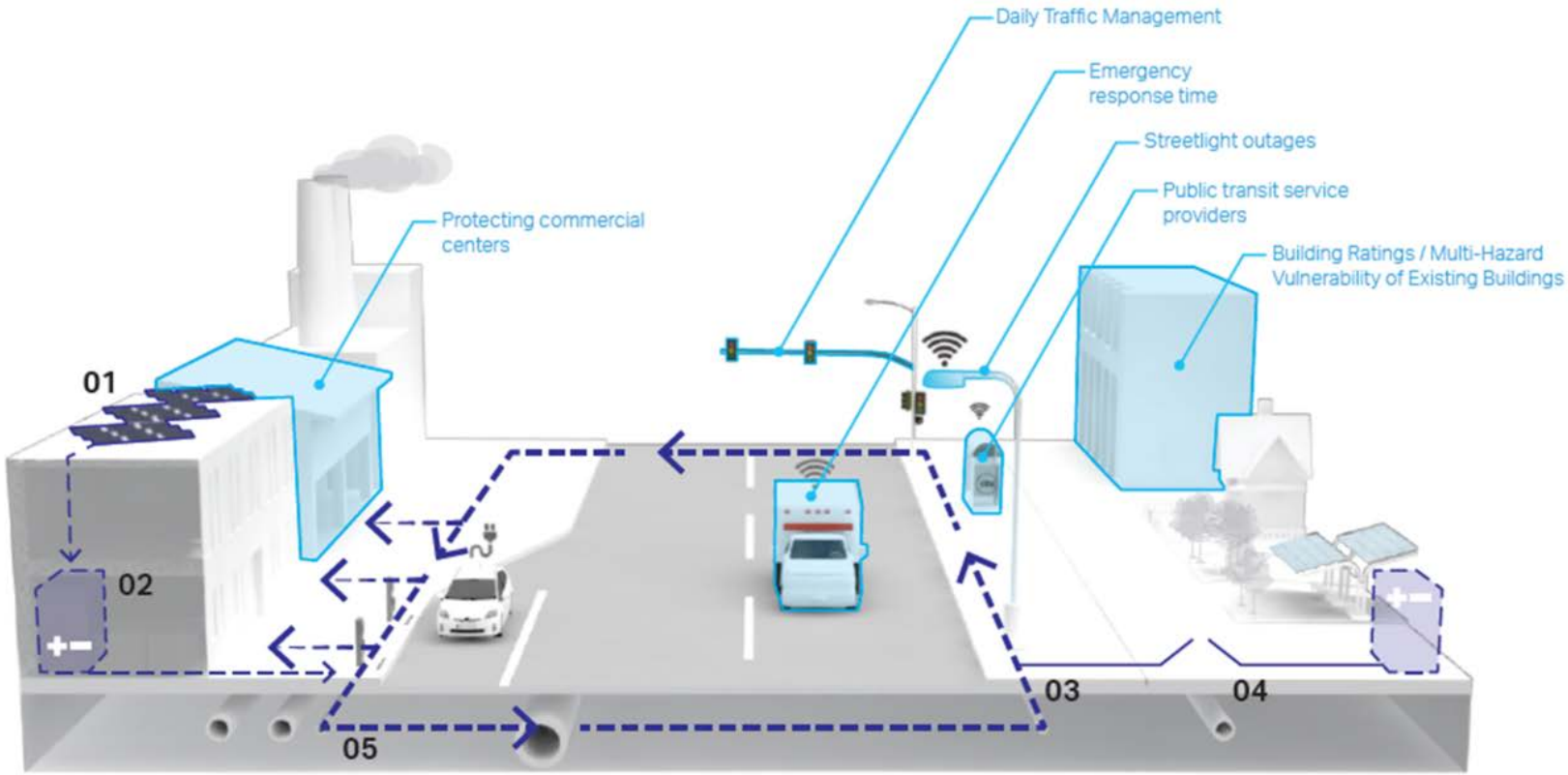


CRITICAL INFRASTRUCTURE RESILIENCE

DEFINED AS:

The ability of critical infrastructure to prepare for and adapt to changing conditions and to withstand and recover rapidly from disruptions.

01 Distributed Generation
02 Battery Storage (In building or district scale)
03 "Islanding" Switchgear to enable MG
04 Local Substation with two way power flow
05 Smart Grid



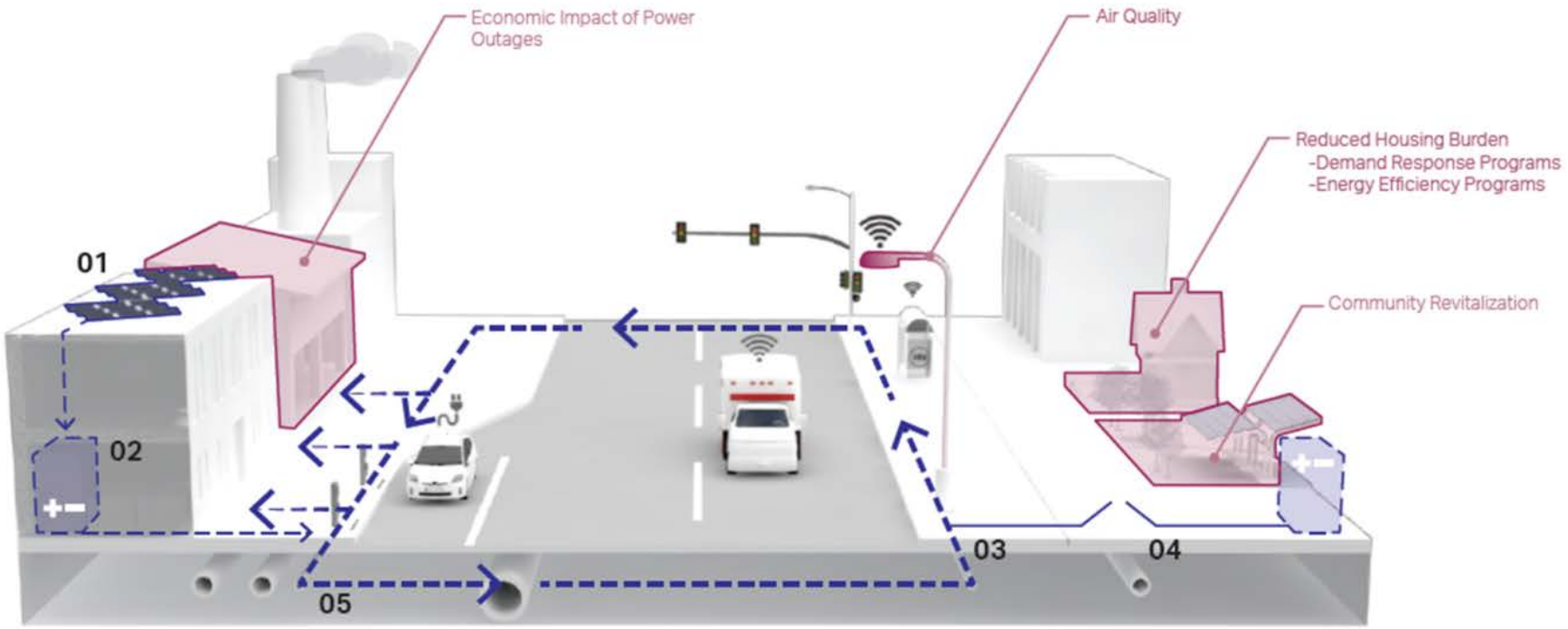
Example: Bronzeville ComEd Study

COMMUNITY RESILIENCE

01 Distributed Generation
02 Battery Storage (In building or district scale)
03 "Islanding" Switchgear to enable MG
04 Local Substation with two way power flow
05 Smart Grid

DEFINED AS:

The ability to adapt to changing conditions and withstand and recover from shocks in a manner that minimizes impact on populations and communities.



Example: Bronzeville ComEd Study

Scorecard Example

The Resilience Score will be a weighted average of the **Resilience Areas**

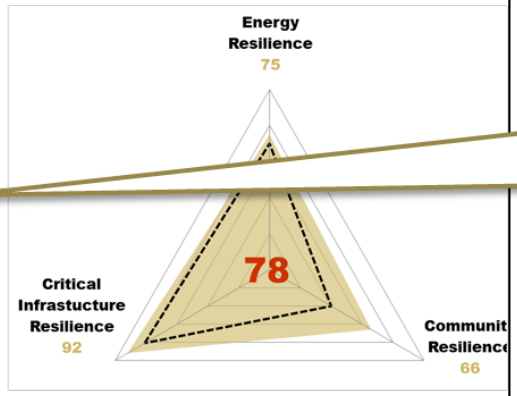
Each **Area** will be a weighted average of its **Indicators**

Allows **comparison** of scores across years

Each **Indicator** is a weighted average of its **Metrics**

Resilience and Performance Scorecard

Current Resilience & Performance Score	78
Baseline Resilience & Performance Score	64



Energy Resilience	75	Indicators	Power Delivery Resilience and Performance Score	80
			Energy Efficiency Performance Score	71
			Emissions Performance Score	74
Community Resilience	66	Indicators	Community Economic Resilience Score	72
			Community Health Score	68
			Community Livability and Safety Score	59
Critical Infrastructure Resilience	92	Indicators	Reliable Communication & Mobility Score	98
			Continuity of Critical Services Score	83
			Critical Infrastructure Security Score	95

Example: Navy Energy Security & Readiness Scorecard

NAVY
ENERGY SECURITY & READINESS

Reliability is the capability of energy systems to deliver energy within acceptable regulatory standards and quality.

Resiliency is the ability of energy systems to anticipate, resist, absorb, respond, adapt, and recover from a disturbance.

Efficiency reduces the amount of energy needed, enabling operational, capital and O&M savings, and eliminates inefficient and unreliable infrastructure

Source: DoN Energy Security, Guide to Best Practices, 17 March 2016.

Example: Navy Energy Security & Readiness Scorecard

Primary reasons for developing a scorecard:

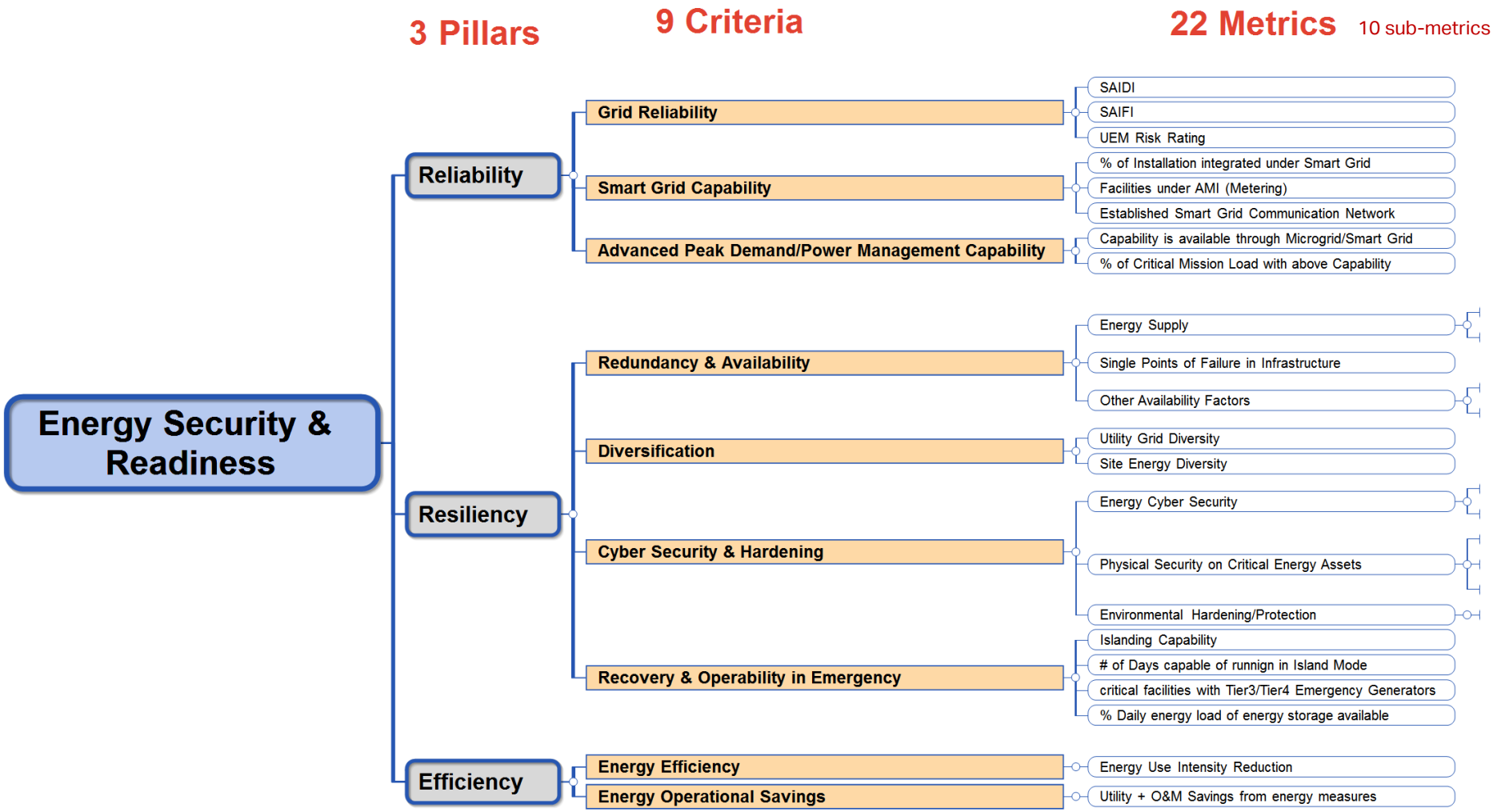
1) Demonstrate progress towards energy security and readiness at the installation level – rather than individual project-by-project level.

2) Create an easy to understand visual graphic that captures the various key aspects at a glance, with the right level of detail to be informative and actionable while not overly burdensome to calculate.

3) Develop a framework of metrics and indicators that allows flexibility in adjusting weights and priorities based on locational and regional situations.

Example: Navy Energy Security & Readiness Scorecard

Components of the Scorecard



Example: Navy Energy Security & Readiness Scorecard

3 Pillars → 9 Criteria → 32 Indicators

Overall metrics are measured in reference to critical facility energy loads at the installation

Each major metric under the three pillars has an adjustable weight

Energy Security & Readiness Scorecard

Critical Mission Energy Demand Component — 30% — based on MDI>80
% of total annual energy demand for installation

R1 Reliability
Reliability is concerned with the delivery of energy systems within acceptable regulatory standards and quality. It has 3 main metrics:

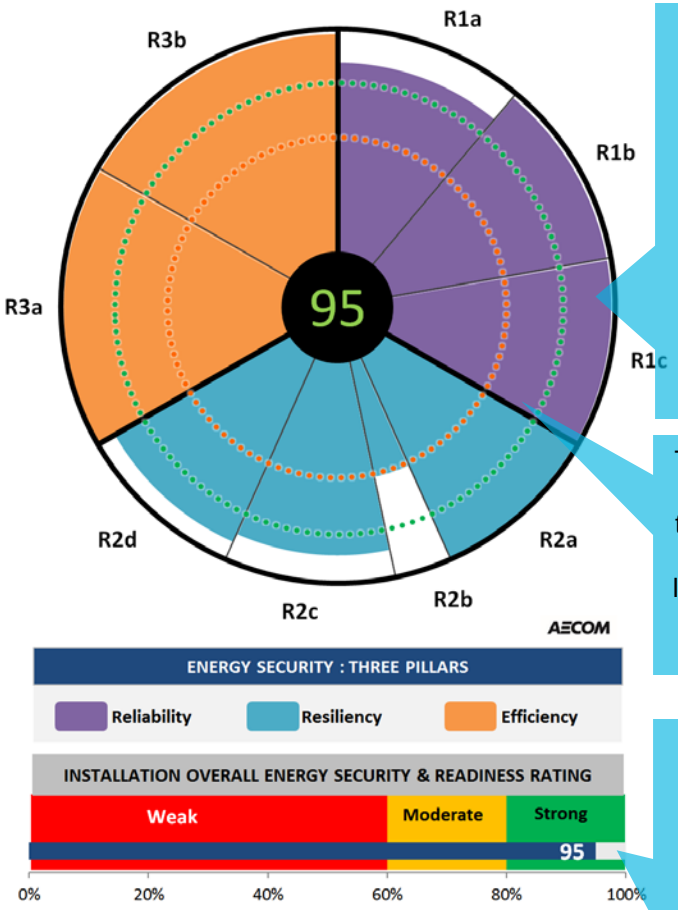
- **R1a Grid Reliability** — 33%
  Reliability of energy distribution systems
- **R1b Smart Grid Capability** — 33%
  Visibility and automation or operations
- **R1c Advanced Peak Demand/Power Management Capability** — 33%
  Active load and power quality management

R2 Resiliency
Resiliency is defined as the ability of Energy Systems to anticipate, resist, absorb, respond, adapt, and recover from a disturbance. It has 4 main metrics:

- **R2a Redundancy & Availability** — 30%
  Avoidance of Single Points of Failure (SPOF) in energy infrastructure and ensuring that there is adequate supply of energy in emergency situations.
- **R2b Diversification** — 10%
  Capability of receiving energy through a variety of sources in order to ensure stability in supply and pricing.
- **R2c Cyber Security & Hardening** — 30%
  Mitigating risk from cyber attacks; hardening infrastructure from physical damage.
- **R2d Recovery & Operability in Emergency** — 30%
  Ability to restore operational capacity of critical facilities post an emergency that disrupts normal energy supply, and sustain operations in emergency mode.

R3 Efficiency
Efficiency contributes towards operational savings and reduction of loads that directly impact other resiliency and readiness aspects. It has 2 metrics:

- **R3a Energy Efficiency** — 50%
  Reduction in energy use intensity
- **R3b Energy Operational Savings** — 50%
  Lifecycle reduction in energy utility bills and maintenance operations



Circular chart shows three pillars representing 1/3rd of the circle and major sub-metrics with weights represented by slices

The amount of fill represents the score for a metric. Dotted lines represent 'weak' to strong ratings

Overall Rating is at Installation level

Example: Navy Energy Security Assessment (On-Going)

3 Pillars → 9 Criteria → 23 Indicators

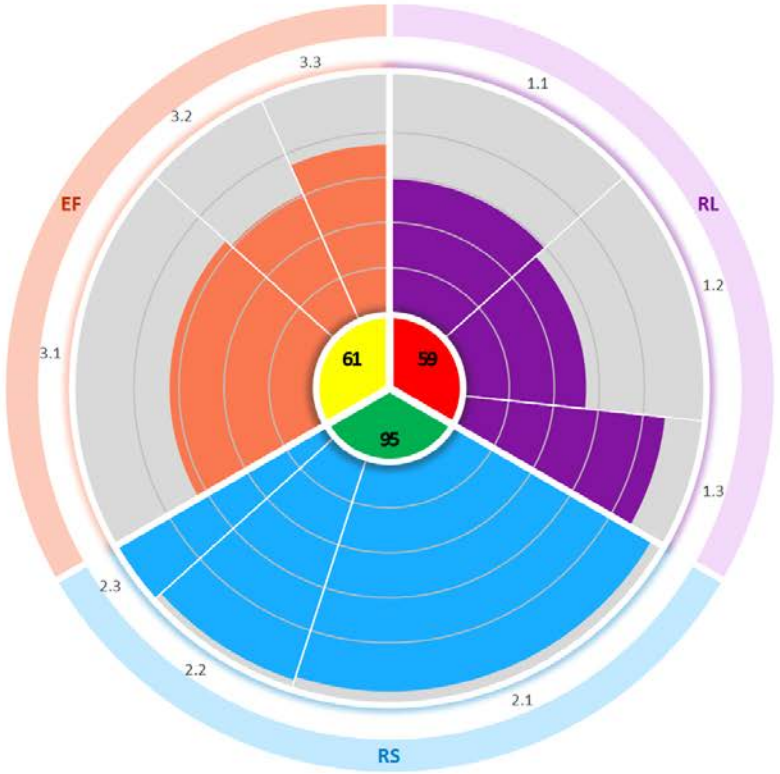
Select Installation:

NAVSUPPACT HAMPTON ROADS VA

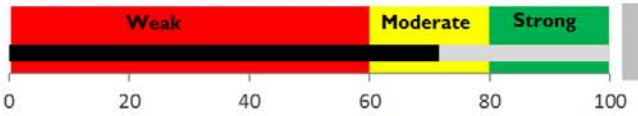
Installation UIC	CNIC Region
N57095	CNR MIDLANT
PWD or USMC Base	**Facility Engineering Command (FEC)**
PWD NSA HAMPTON RDS	Mid-Atlantic

	Score	Weight
1. RELIABILITY (RL)		
1.1 Utility Grid Infrastructure	55	40%
1.2 On-site Electric Infrastructure	50	40%
1.3 Condition and Configuration	83	20%
(RL) Reliability Score and Weight	59	33%
2. RESILIENCY (RS)		
2.1 Backup Generation Capabilities	94	65%
2.2 UPS Capabilities	96	25%
2.3 Supported Missions Resiliency	100	10%
(RS) Resiliency Score and Weight	95	33%
3. EFFICIENCY (EF)		
3.1 Energy Efficiency	60	60%
3.2 Electric Demand Management	57	20%
3.2 ICS Inventory Sufficiency	69	20%
(EF) Efficiency Score and Weight	61	33%

View Details | Recalculate Score



INSTALLATION OVERALL ENERGY SECURITY & READINESS RATING



72

Records last updated:	11/21/2017
Form last saved:	10/25/2017

Example: Navy Energy Security Assessment (On-Going)

Navy's Energy Security Assessment Tool (ESAT)

UNCLASS//FOUO

Installation Energy Security Checklist	
Installation Name (select from drop down menu)	NAVBASE SAN DIEGO
Installation UIC	N00245
CNIC Region / USMC	CNR SOUTHWEST
PWD or USMC Base	PWD SAN DIEGO
Facility Engineering Command (FEC)	Southwest

Is this workbook complete? NO

All scores based on a 0 to 100 scale.

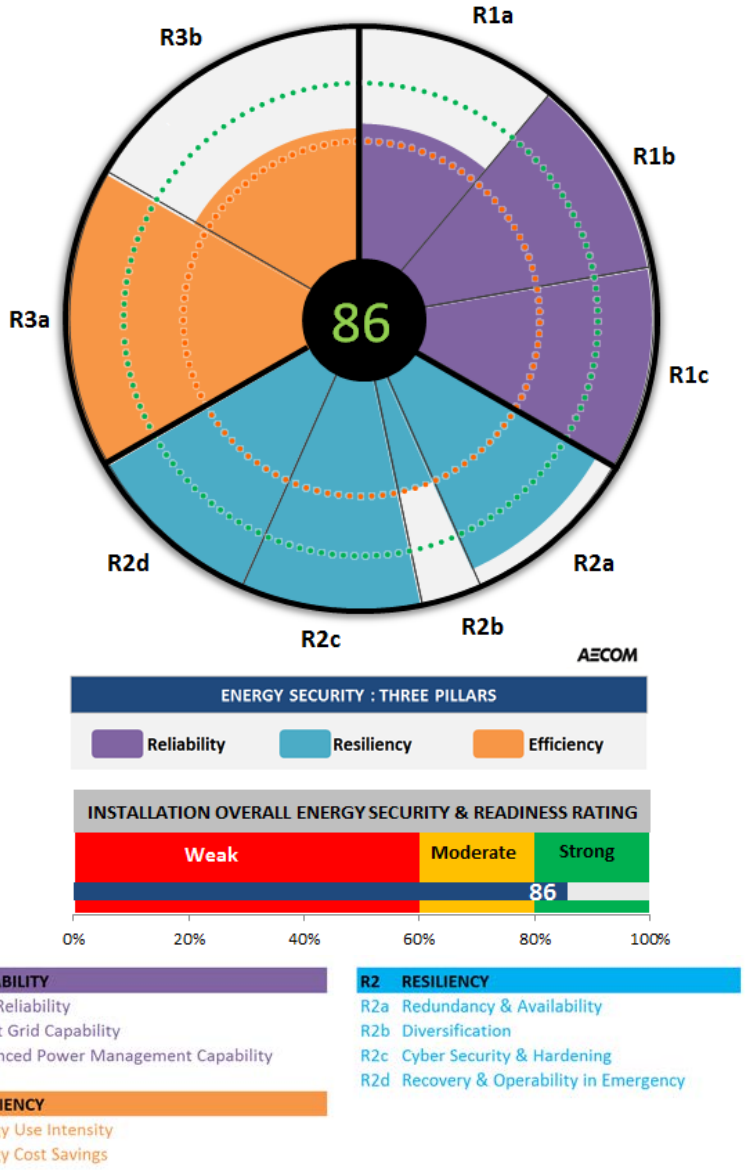
1. RELIABILITY

Reliability is determined by the adequacy, security, and quality of two primary elements: supply (e.g. generation availability) and delivery.

1.1	**Is the utility grid infrastructure servicing this installation reliable?**	**Score** 55		***Sub-Question Scores***		
		Answer	**Units**		**Weight**	**Policy Reference**
1.1.1	What is the commercial utility's SAIDI score? Does it meet the 3 pillars standards?	823.9	Minutes	0	0.45	Standard IEEE Guide for Electric Power Distribution Relia Shipyard SAIDI 60 min; All Other Installations SAIDI 120
1.1.2	What is the commercial utility's SAIFI score? Does it meet the 3 pillars standards?	0.1	Count	100	0.45	Standard IEEE Guide for Electric Power Distribution Relia SAIFI 1; All Other Installations SAIFI 2.
1.1.3	How many commercial electrical feeder lines supply the primary location? (exclude special areas)	3.0	Count	100	0.1	Information only
1.2	**Is this installation's on-site electric infrastructure reliable?**	**Score** 50		***Sub-Question Scores***		
		Answer	**Units**		**Weight**	**Policy Reference**
1.2.1	What is the internal electrical SAIDI score? Does it meet internal 3 pillars standards?	585.0	Minutes	0	0.5	Standard IEEE Guide for Electric Power Distribution Relia Shipyard SAIDI 60 min; All Other Installations SAIDI 120
1.2.2	What is the internal electrical SAIFI score? Does it meet internal 3 pillars standards?	0.1	Count	100	0.5	Standard IEEE Guide for Electric Power Distribution Relia SAIFI 1; All Other Installations SAIFI 2.
1.3	**Is the installation's infrastructure in good condition and configured for Resiliency?**	**Score** 79		***Sub-Question Scores***		
		Answer	**Units**		**Weight**	**Policy Reference**
1.3.1	What is the installation utility electrical power Condition Index (CI)?	78	Index	78	0.3	
1.3.1.1	What is the average utility electrical power Condition Index for the CNIC region?	80		43	0.05	
1.3.2	What is the electrical distribution system's general configuration (radial, loop, etc.)?	Loop - Primary Selective	N/A	60	0.25	
1.3.3	Is the majority of the electrical distribution system underground?	Underground	Y/N	100	0.2	
1.3.4	What is the age of the installation electrical infrastructure?	36	Y/N	60	0.15	

Scorecard Limitations

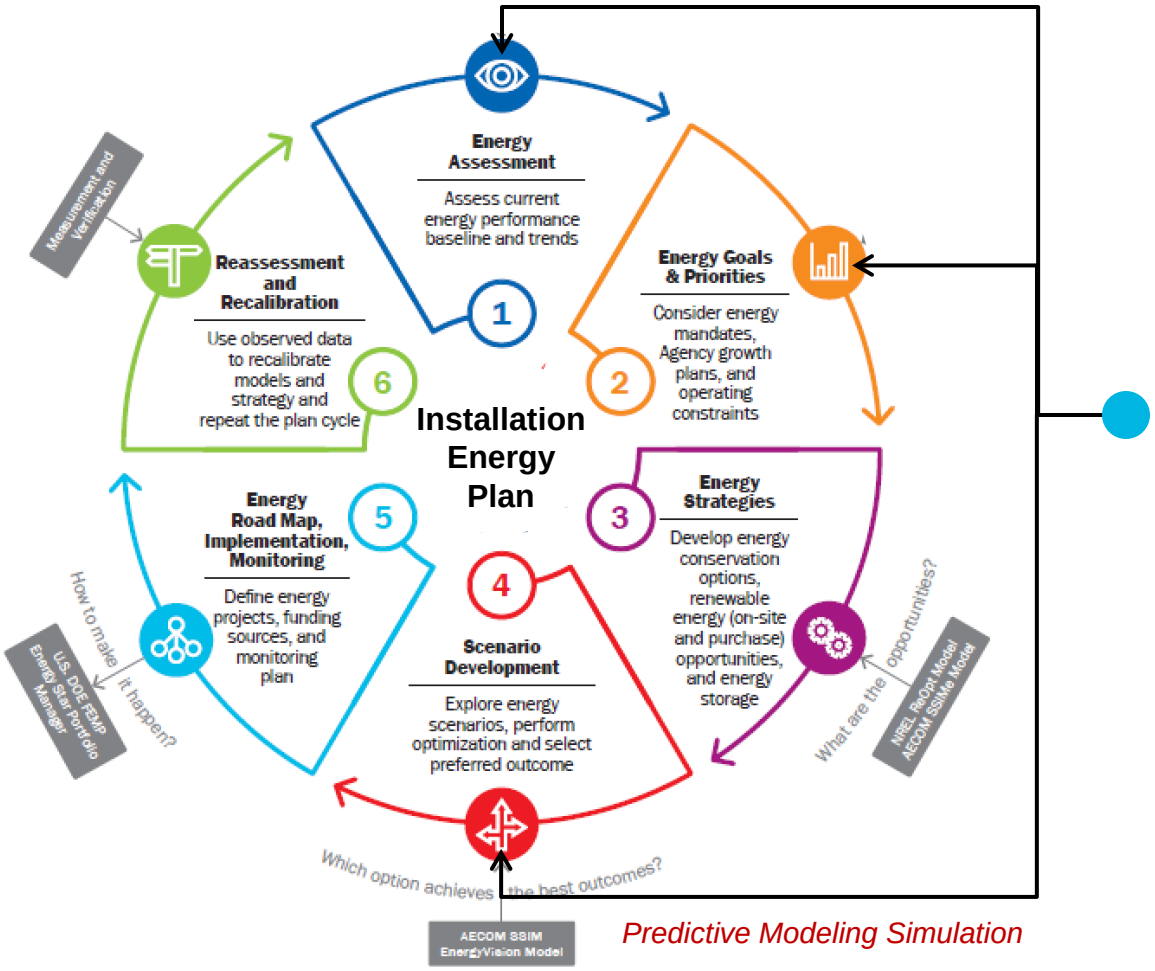
- The scorecard is intended for installation level evaluation and not for individual projects. It is a planning tool and should be used as such.
- The scorecard metrics are generalized and 'rolled-up' to an installation level.
- As a default, the three pillars are equally weighted and should not be adjusted. The contributing metrics within each pillar may be adjusted.



Using Resiliency Metrics

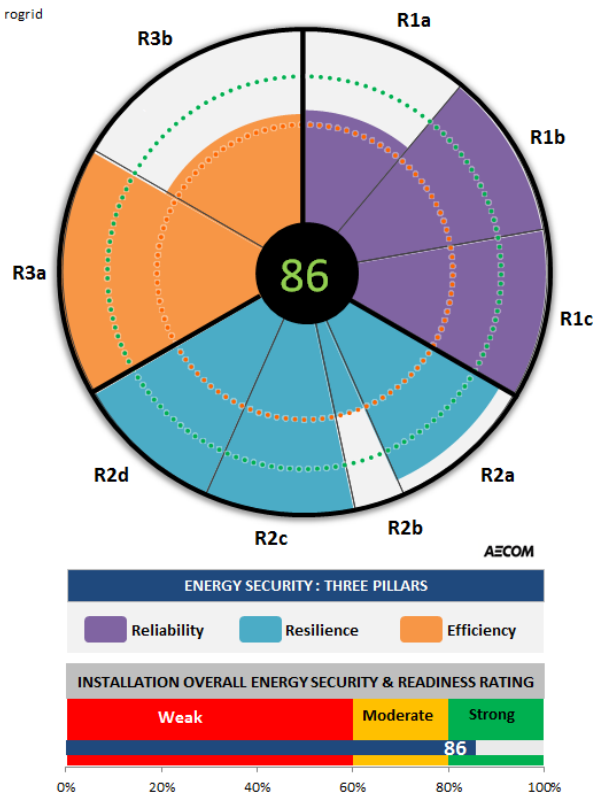
Using Resiliency Metrics for Installation Energy Plans: Guam Pilot

Existing Conditions Assessment



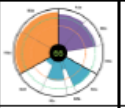
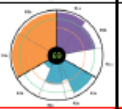
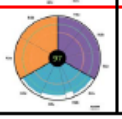
Predictive Modeling Simulation

Energy Security & Readiness Assessment Model & Scorecard



Using Resiliency Metrics

The Guam IEP process used the Energy Security & Readiness Scorecard and Assessment to guide selection of a preferred scenario and associated energy project implementation plan.

JRM Energy Scenarios		Energy Security and Readiness Scorecard				EO 13693 Mandates*			CNIC Goal*	SECNAV Goals*		Cost Metrics				
Scenario Number	Scenario Description	Reliability	Resiliency	Efficiency	Energy Security and Readiness Scorecard Snapshot[5]	Energy Intensity Reduction - 25% by 2025	Electric Renewable Energy - 30% by 2025	Renewables Mandate - 25% by 2025	Energy Consumption Reduction - 50% by 2020	Energy from Alternate Sources - 50% by 2020	Net-Zero (Utilizing Additional Sites[3]) - 100% by 2030	Cost ($M)[6]	By 2035 Projects Will Save ($M)	Net Balance by 2035 ($M)	Cost $ / MBTU Saved	Positive Cash Flow
1	Business as Usual + Government Planned Projects[1]	57	48	95		48%	84%	84%	26%	35%	28%	$394	$667	$273	$679 /MBTU	14 Years (2029)
2	Mandate Compliance[1]	60	52	96		49%	100%	100%	26%	50%	44%	$398	$674	$276	$542 /MBTU	13 Years (2028)
3	Resilient with Net-Zero MCBG[1,2,3]	100	87	100		62%	113%	113%	26%	54%	42%	$655	$844	$189	$826 /MBTU	17 Years (2032)
4	Resilient Plus[1,2,3,4]	100	90	100		65%	138%	138%	26%	55%	66%	$1,059	$911	($148)	$1,060 /MBTU	22 Years (2037)

Notes:
Red Values indicate a Mandate or Goal is not being met.
Green Values indicate that a Mandate or Goal is being met or exceeded.
*Performance against mandates and goals is projected to target year and covers the full installation load.

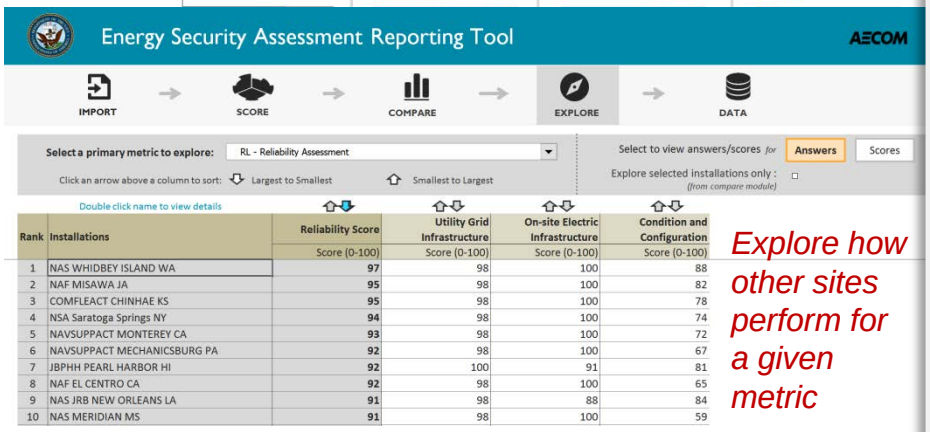
0-59	Weak - needs improvement
60-79	Moderate - improved
80-100	Strong - approaching the intent of guidance
	The Recommended Energy Scenario

[1](UFC 1-200-02 High Performance and Sustainable Buildings 2014)+(NAVFAC ECB Sustainability and Energy Building Requirements 2016) = 30% better than ASHRAE 90.1 2013 design for new construction.
[2]Microgrid includes Tier IV (primary) generator facility and energy storage (battery) sized appropriately for associated PV generation. MIT-LL study on-going to inform JRM Microgrid way forward for implementation.
[3]Ground-Mount PV is integrated into Microgrid with underground utility line (MEC and UXO costs included) and contributes toward reducing energy bills with integrated battery storage utilizing Power Purchase Agreement for some sites. Additionally, sites are being considered outside of the currently planned REPO and installation sites currently programmed for JRM.
[4]SWAC costs for NBG are from cancelled NORESCO ESPC proposal and include MEC/UXO and environmental costs. SWAC costs for MCBG are from 2014 feasibility assessment
[5]Energy Security and Readiness Scorecard covers the critical installation load and not the full installation load based on the Microgrid studies performed and DD1391s developed as part of a separate effort.
[6]Costs assume 3rd party financing for some ground-mount PV sites.

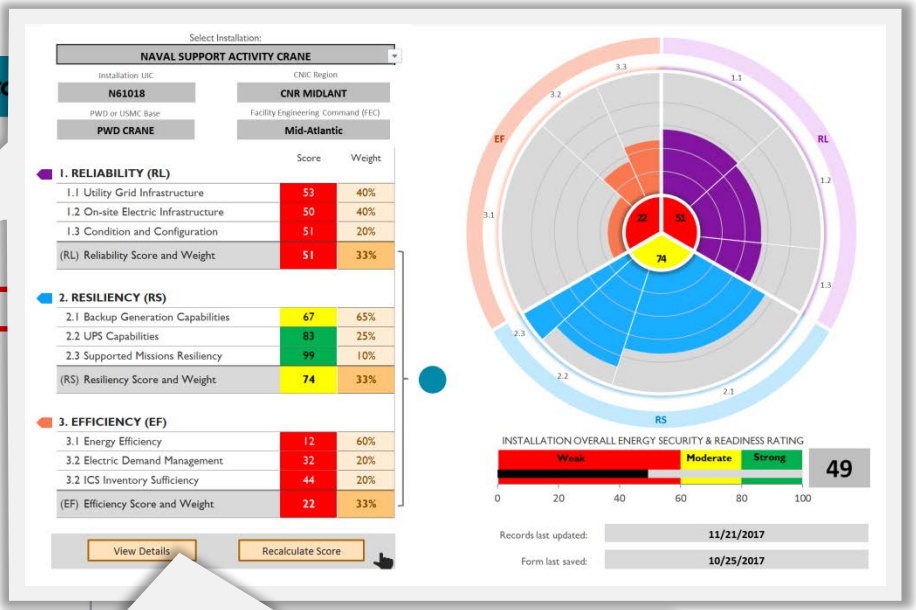
Using Resiliency Metrics

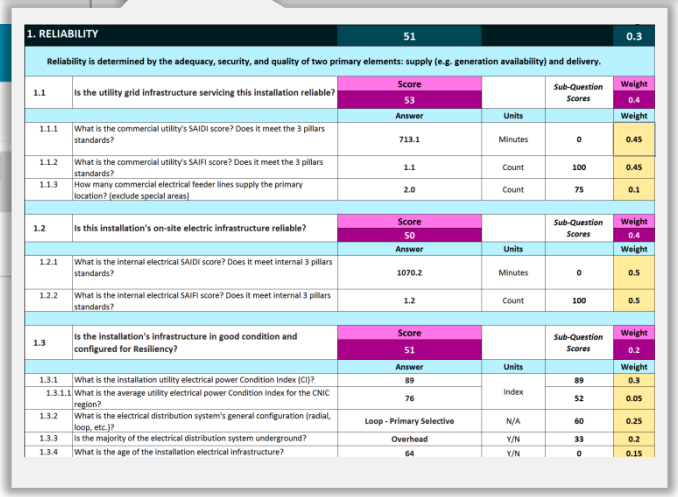
Navy Enterprise Level Energy Project Prioritization: ESA Reporting Tool

Compare Sites and Identify Gaps



Explore how other sites perform for a given metric





Drill-down ability for detail

Energy Resiliency Planning UFC 3-550-03

On going work: Expected Completion by September 2018

Discipline Working Group (DWG)
- Tarone Watley (AF) *(Chair)*
- Chris Thompson, PhD (Army)
- Steven Phillips (Navy Rep)
- Cdr Walter Ludwig (OSD)

Technical Proponents
- Tarone Watley (AF)
- Rex Bellville (AF)
- Daniel Carpio (Army)
- Mike Savena (Navy)
- Steven Phillips (Navy Rep)

Technical Representatives
- Ariel Castillo, PhD (OSD Policy)
- Doug Tucker (AF Policy)
- Maj Brian Low (AF Reqt's)
- Kathleen Richardson (AF)
- Mike Rits (AF)
- Alexander Zhivov (Army)
- Erik Limpaecher (DOE-MITLL)
- Nicholas Judson (DOE-MITLL)

Item	Section	Team Lead
7	• Tiered Structure Approach o Summary o Tier I, Basic o Tier II, Component Redundancy o Tier III, Concurrently Maintainable o Tier IV, Fault Tolerant	**Frank McBride** Frank.McBride@aecom.com
8	• System Categorization o CAT I - Mission Failure/Loss o CAT II - Mission Degradation (Loss Mission Capability o CAT III - Mission Degradation (Loss Mission Redunda o CAT IV - Mission Degradation (Loss Back-up System) o CAT V - Alternative Means (i.e. Fly-Away, Pick-up by	**Greg Ault** Greg.Ault@aecom.com
9	• Measuring Level of Resiliency (RAND Report 2015 (Willis 8 o Strategic o Regional o Local o Installation o System o Subsystem o Component	Avinash
10	• Resiliency Applications & Techniques o Microgrids for Electrical/Mechanical Systems ▪ Concept Approach ▪ Elements (Energy Sources, Distribution, Control System, Storage Application (Optional)) ▪ Suitable Architectures o Water/Wastewater o Natural Gas o Energy Monitoring and Control System (EMCS)/Utility Monitoring and Control Systems (UMCS)/Automation ▪ Cyber Security o Physical Security o Lessons Learned o Industry Best Practices	Calum.Thompson@aecom.com
11	• References	
12	• Component Specific Appendix	
13	• QA/QC	Alastair

Item	Section	Team Lead
1	• Overview	**Fran Ascolillo** Fran.Ascolillo@aecom.com
2	• Summary	**Fran Ascolillo** Fran.ascolillo@aecom.com
3	• Resiliency Attributes o Redundancy o Hardening o Diversification o Reliability/Availability o Recovery	**Cal Thompson** Calum.Thompson@aecom.com
4	• Energy Systems o Electrical o Mechanical/HVAC o Water/Wastewater o Natural Gas o Fuels	**Frank McBride** Frank.McBride@aecom.com
5	• Threat Analysis o Mission Decomposition/Kill-Chain (FOUO) o Component Parts o Interdependencies o Demarcations o Strategic/Global - Major Grids/Supplies (e.g. Nat o Regional - Major Hubs & Operators (e.g.) o Local - Cities, Municipalities, etc. o Installation - AFBs, Stations, etc.	**Greg Ault** Greg.Ault@aecom.com
6	• System Analysis o Identify SPFs ▪ Inspection, Testing and Techniques ▪ System Data, Equipment Data, and Documentatio ▪ Testing Intervals ▪ Risk Management Analysis ▪ Life Cycle Cost Analysis ▪ Tools and Equipment o Configuration Management ▪ Asset Inventory, Asset Management ▪ Manuals, Diagrams and Drawings	**Chris Kiefer/Ryan Kiefer** Chris.Kiefer@aecom.com Ryan.Kiefer@aecom.com

Draft