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Energy Master Planning for Resilient Public Communities—Best Practices from U.S. Military Installations

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ABSTRACT

Until recently, most planners at military installations addressed energy systems for new facilities on an individual facility basis without consideration of community-wide goals relevant to energy sources, renewables, storage, or future energy generation needs. Building retrofits of public buildings typically do not address energy needs beyond the minimum code requirements making it difficult, if not impossible, to achieve community-level targets on a building-by-building basis. Planning on the basis of cost and general reliability may also fail to deliver community-level resilience. For example, many building code requirements focus on hardening to specific threats, but in a multi-building community, only a few of these buildings may be mission-critical. Over the past two decades, the frequency and duration of regional power outages and water utility disruptions from weather, man-made events, and aging infrastructure have increased. Major disruptions of electric and thermal energy have degraded critical mission capabilities and caused significant economic impacts. In 2016, the U.S. Department of Defense issued guidance that each Service (Army, Navy, Air Force, Marines) complete comprehensive energy plans for the installations that consumed 75% of total building energy. Guidance was updated in 2017 to include metrics for energy resilience, and in some cases, water. This paper describes how community level quantitative and qualitative resilience analysis and metrics have been incorporated into community energy and water planning best practices for military installations in three geographically diverse locations. It is based on research performed under the International Energy Agency's "Energy in Buildings and Communities Program Annex 73," focusing on development of guidelines and tools that support the planning of Net Zero Energy Resilient Public Communities as well as research performed under the Department of Defense Environmental Security Technology Certification Program project EW18-D1-5281, "Technologies Integration to Achieve Resilient, Low-Energy Military Installations." The first case study reviews progress made on an energy and water planning study conducted at Fort Bliss, Texas. The second and third describes planning conducted at Fort Bragg, North Carolina and the Joint Region Marianas, Guam, respectively, under the updated guidance from 2017 regarding energy and water resilience. Analysis methods, key metrics, and key infrastructure and operational constraints are described, as well as technical, economic and business concepts used during the planning process.

INTRODUCTION

The increasing frequent occurrence of severe natural and man-made events, combined with the effects of aging infrastructure, makes it imperative to consider resilience at the whole community scale. Military installations offer a distinct opportunity for evaluating critical infrastructure and mission sustainment for energy and water resource resilience planning at the community-wide scale. Installations are similar to small cities; they make up a heterogeneous mix of building types and, at some of the largest installations, may serve a daily population of nearly 250,000.

Army Directive 2017-07, Installation Energy and Water Security Policy (DA 2017), establishes requirements to sustain critical mission capabilities and mitigate risks posed by energy and water disruptions affecting military installations. Assessing vulnerability and risk from potential failures and planning for adequate mitigation response are require-

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ments. Ultimately, Army installations must be capable of providing necessary energy and water for a minimum of 14 days for critical missions. Other requirements include identifying mission critical energy and water needs, defining energy and water security risks, prioritizing mitigation actions, and developing projects that close energy and water security gaps and risks.

Before energy resilience became a point of emphasis, energy planning was scoped more traditionally, with a building-by-building or generator-by-generator approach. Consideration of alternative energy sources, renewables, storage, or future needs was not fully addressed until recently when energy and water planning were more fully integrated into the master planning process. The greater emphasis on resilience closely aligned with the master planning process will enable installations to strategically maintain critical infrastructure. It will also foster adaptive response to and quick recovery from adverse events. All of this will support mission continuity and overall mission success.

INTEGRATION OF RESILIENCE INTO ENERGY MASTER PLANNING

U.S. Department of Defense (DoD) policy requires that the Installation Energy Plan should be an integral part of the Installation Master Plan. The objective is to produce a holistic road-map that enables the installation to work constructively towards achievement of energy goals within defined installation specific constraints.

The energy master planning concept [ESTCP 2019] described in this section is built on previously developed concepts (OSD 2016, Zhivov et. al, 2014, IEA Annex 51), but differs in such a way that, in addition to meeting an installation's energy goals, it integrates development of a highly resilient "backbone" of energy systems that allows maintenance of critical missions and service operations during extended outages over a range of emergency scenarios caused by weather, man-made events, and aging infrastructure.

Figure 1 shows an integrated approach that results in cost-effective operation of energy systems under normal conditions (blue sky) and in a less vulnerable, more secure and more resilient energy supply to the community's critical mission functions during emergency scenarios (black sky). It provides a framework for the planning process and outlines the main steps. These steps include: 1) establishment of energy framing goals and constraints; 2) assessment of a community's critical missions and functions; 3) assessment of community specific threats; 4) calculation of energy requirements for normal and mission critical functions; 5) assessment of the current situation (Baseline) to understand existing gaps against framing goals and constraints; and, 6) development of future alternatives, including "business as usual" (Base Case) and more advanced alternatives of energy systems. Quantitative metrics should be used to compare Baseline, Base Case, and future

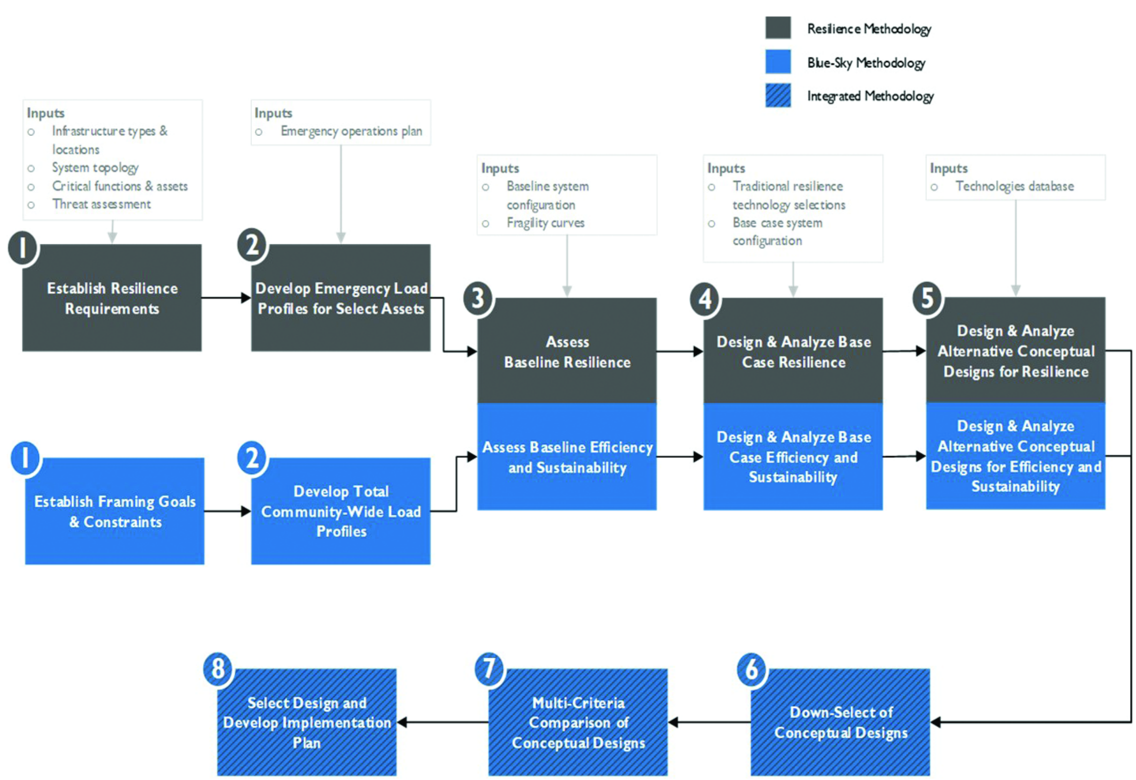

Figure 1 *Integration of Energy Systems Resilience Analysis into the Energy Master Planning process.*

alternatives. "Blue sky" and "black sky" alternative architectures can be built upon the database of technologies and architectures summarized from internationally available best practices.

Steps presented in Figure 1 using blue boxes outline the part of the energy master planning process that considers energy goals, constraints, loads and operation of all buildings and systems under normal conditions (blue sky). However, selection of architecture for alternative energy systems may already consider implications of their characteristics and function on resilience of systems serving mission critical functions under emergency conditions.

Steps illustrated using black boxes show the planning process for mission critical buildings and functions that address only critical loads under emergency conditions (black sky). This part of the process includes steps that allow narrowing down the scope of buildings and operations and their loads to those that are mission critical, assessing threats specific to locality and function of the installation and their impact on energy systems' degradation, and calculating energy requirements for mission critical functions. Planners will evaluate gaps in existing systems resilience, develop future alternatives of systems providing required level of energy assurance to mission critical functions, including "business as usual" (Base Case) and more advanced alternatives of energy systems with consideration of, but not limited to, those developed under the "blue sky" scenario. At this point of analysis, there is an opportunity for iteration between alternatives developed under these two scenarios.

Final steps of the integrated energy master planning process include comparison of different alternatives against the framing goals established earlier using quantitative and qualitative metrics. At this point, iteration may be required to modify or create new alternatives if the goals were not met. Once a preferred alternative has been selected by decision makers, an implementation plan is prepared that includes an investment strategy and projects that will be required to achieve the plan. More details regarding each of these steps are provided in subsections below. Based on the situation at specific installations, the breadth and depth of improvements under different alternatives may differ to reflect existing plans and timing for new construction, major and minor renovation of the building stock and utilities, criticality of their missions, and availability of resources. Also, the quality of the data available for development of the baseline and the Base Case and energy requirements for mission critical operations at specific installations vary. This may result in differences in realization of the described concept at specific installations. Though the integrating process described above is evolving and undergoing pilot demonstration at several military installations, its elements (especially for the "blue sky" scenario) have been implemented in multiple Energy Master Plans at DoD installations (ESTCP, 2019 and 2015; OSD, 2016; Zhivov et al, 2014).

ESTABLISHING A FRAMEWORK

Military installations are similar to cities, and while military planners share considerations with their civilian counterparts, there are additional factors that must be prioritized. Military, civilian, regional, state, and local community planners should find a foundational framework. All community planners should consider resilience goals set forth in the public community framework, and strive to meet rigorous federal, state, and local mandates. Military planners must also prioritize DoD drivers, which in fact may also broadly shed light on framework considerations that could benefit all robust and resilient community-wide efforts (Zhivov et al 2014; Sharp et al, 2020).

Design Constraints

Energy master planning (EMP) is highly dependent on a thorough understanding and early identification of design constraints. These constraints may be natural, such as the availability of fuels to the region, or imposed, such as mandates set by local building code. Once all of the limitations are identified based on a common framework, alternative solutions and technologies should then be considered. The potential constraints for master planning of buildings and communities (campuses, military installations, cities, etc.) are presented in Sharp et al. (2020). These constraints are categorized into natural and imposed areas at the local, building, and equipment level. The constraints cover many topics such as emissions, sustainability and resilience goals, regulations and directives, and regional and local conditions.

The limitations for each constraint that are applicable to the EMP should be identified, evaluated, and applied early in the planning process to narrow the many technology options down to those that offer an optimized fit to the local conditions and goals for the building or community. Early identification allows the planner to avoid inconsistencies that do not fit in the overall framework, which will in turn increase the effectiveness and efficiency of the master planning and evaluation process. It is also important to note that factors influencing EMPs are constantly evolving. Energy- and emissions-related policies, directives, and mandates are changing at this very moment and will continue to impact the master planning process.

Locational Variability. Besides imposed variables, natural or locational threats and resources are areas to explore in further depth. Location of the building or campus and the local infrastructure are absolute considerations, but may not completely eliminate a technology.

Natural, locational constraints can typically be categorized as either threats or resources. Threats to building equipment are different from the other types of constraints since they do not rule out certain technologies or solutions, but simply limit the efficiency or design of the technology installation. For example, where flooding is a locational threat, there may be a need to elevate or add a berm around equipment. Where wind is a threat, equipment may require structural reinforcement. A building equipment threat may include, for example, a building requirement that a boiler or chiller meet a local minimum efficiency limit. Note that none of the examples eliminates a given technology although they do reinforce down-selection or a need to consider alternatives.

Fuel and water resource limits should be identified through local utility providers. Chilled and hot water, and steam limitations should be recognized by the capacity of the local central plants that supply them. These resource limits must be considered in light of the demand from any users on the district system outside of the building or campus.

The availability of insolation, wind, and biomass resources could be limited depending on the location, but there are often tools available to assist in the evaluation. Taking into consideration the size of land and roof area required to support such alternative technologies is crucial.

Limits on the distribution system and energy storage constraints should also be identified. These are locally dictated by the design and existence of systems in the local infrastructure. They must be quantified and populated, by the master planner to ensure that a comprehensive list of limits are identified early for technology screening. Building and facility level constraints and limits are, of course, normally identified for the EMP by country, state, or local code requirements or mandates.

This paper presents three case studies that show how this design process can be adapted to geographic limitations, and describes some of the tools that are available.

Equipment Down-Selection. Besides locational differences, there are several environmental and operational factors to consider in regards to specified technologies and equipment. Some examples include:

- Air quality index
- Natural gas availability
- Wind strength and consistency
- Existing distribution line capacity.

For example, in a location that already has a high air quality index, large fossil-fuel, combustion-based technologies would be eliminated. This would in turn eliminate solutions that might be considered more cost-effective in other locations, such as a combined heat and power plant or the installation of a boiler technology.

Air quality, natural gas and wind are considered hard limits, but a distribution line would be considered a soft limit. The reason is that this latter limitation could be overcome. For example, the line pressure or size could be increased, or a secondary line could be installed. Assessing each consideration to determine whether it is a hard or soft limit is a useful tool in down-selection. More information on applicable national constraints, their limits, soft and hard limit determinations, and applying constraint limits to EMP is available from Sharp et al. (2019).

Mission Critical Facilities

Military installations require a consistent and systematic method to identify concerns, assess risks, analyze opportunities, and prioritize solutions that enhance installation energy and water security and resilience. A mission is determined critical if its incapacitation would severely impact the ability to execute essential functions. As defined by the U.S. Army Continuity of Operations Program (HQDA 2008), a mission essential function includes those tasks or functions that have been required by statute or Executive Order, or others that have been deemed essential by the command of the organization, having continued operation without interruption despite potential blockage from a disaster. Several examples of facility types include fire and police stations, hospitals and medical clinics, sewer lifts and water treatment plants, electric generating facilities, and facilities that store hazardous materials.

Once a facility has been identified as critical due to its core mission or for life, health, and safety purposes, energy requirements are identified for each. Efforts to reduce energy use to only what is required, while optimizing energy quality of the critical load is a priority. Unified Facilities Criteria (UFC) 3-540-01 (NFEC 2017) outlines that a standby power load analysis must be performed following a power outage to classify each load to the required power.

There are three classifications:

- *Uninterruptible Loads.* Those mission critical buildings that require continuous power and cannot experience even a momentary power disruption. These building types are usually essential because, for example, they house hazardous processing equipment or data communications systems, or because their mission is related to life safety.
- *Essential Loads*. Buildings in this category require standby power but can be de-energized for brief periods to be supplied with an engine generator. Loads would typically include Heating, Ventilating, and Air-Conditioning (HVAC) systems for vital facilities that would not experience severe consequences from short term loss of power.
- *Nonessential Loads*. Buildings in this category can have the loads be de-energized for extended periods of time without severe consequences. The loads are still capable of being energized from engine generators, but it is not required. Depending on electrical energy requirements, mission critical facilities, and operations functions can be characterized into categories, 1-5, from uninterruptible without a disruption in power to the nonessential that can be de-energized for extended periods.

Resilience Requirements

As defined by the Urban Land Institute and adopted from experts across disciplines, resilience is the ability to prepare and plan for, absorb, recover from, and successfully adapt to adverse events. The Department of Defense (DoD) has embraced the concept that planning for installation resilience allows for a comprehensive framework that is holistic and strategic in nature by integrating mission-focused decision making with the needs of stakeholder communities. Department of Defense Instruction (DoDI) 4170.11 (DoD 2009) further elaborates on the definition of energy resilience as, "the ability to prepare for and recover from energy disruptions that impact mission assurance on military installations." Army Directive 2017-07 (DA 2017) further specifies requirements to, "continuously sustain critical missions," which include:

- At least 14 days of available energy to critical missions
- Redundant and diverse sources of energy supplied
- Flexible and redundant distribution networks
- Trained personnel for system planning, operations, and sustainment activities.

INTRODUCTION TO CASE STUDIES

Three case studies were developed by separate teams, each of which has a different approach to planning for resilience. Difference in use, size, history, and climatic conditions are of note. These efforts did not develop solution designs but instead focused on planning. Design development will be overseen by the installation as part of future Installation Energy and Water Plan (IEWP) solution implementation. An assessment and planning approach to meet essential requirements was developed by the Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability (ODASA E&S). Drivers for conducting energy and water-related assessments include the Army security goals outlined in Army Directive 2017-07 (Installation Energy and Water Security Policy) and other federal, DoD, and Army policies and regulations.

Once the goals had been established, pilot installations were identified to test different approaches to resilience planning and mission critical infrastructure and operations with the goal to modify based on lessons learned and tool comparison studies. Since the requirement is set for IEWPs to meet a target of 75% total Army energy use by 2019, decision makers must continue to address and enable comparison studies as the approaches are implemented.

The targeted stakeholders were the installation's Directorate of Public Works (DPW), who are ultimately responsible for distributing energy and water throughout the installation and ensuring that energy and water needs are met. Additional relevant stakeholders included Garrison leadership, mission owners, Installation Real Property Planning Board, Directorate points of contact, privatized utility owners, master planning, and other support operations. Stakeholder engagement was critical for success. Without mission owner input, for example, the criticality of different facilities and their energy and water requirements might not be well understood, defined solutions may be inadequate, or energy and water resilience opportunities may be entirely overlooked.

Preparation of a U.S. Army IEWP involves a comprehensive and risk-based approach to planning infrastructure upgrades and supply enhancements for all utilities serving military installations. This content of the IEWP is derived from DoD requirements for Installation Energy Plans and existing Army utility planning requirements into a single, updated format. The primary purpose is to reduce risk to mission accomplishment from utility disruptions. Improved resilience is possible by reducing demand and reducing risk through an integrated and strategic planning process.

Even though planning for resilience is still in its infancy, this paper showcases three pilot locations that represent three different planning agencies and toolsets that are taking significant steps to establishing robust and resilient installations.

FORT BLISS, TEXAS—HOT, DRY (3A)

Installation Background

Fort Bliss, Texas, is the largest U.S. Army Forces Command (FORSCOM) installation and is home to multiple training and deployment missions. The installation is a Power Project Platform and Mobilization-Force Generation Installation (MFGI). Both of these designations indicate the critical role Fort Bliss plays in training, preparing, and mobilizing Armed Forces in response to National Security requirements. Commands stationed at Fort Bliss include the 1st Armored Division, 32nd Army Air and Missile Defense Command, the 11th Air Defense Artillery Brigade and Joint Task Force North. The installation provides anti-aircraft and missile defense capabilities and accommodates live fire exercises of nearly every type of Army weapon system. Fort Bliss includes 1.1M acres in western Texas and extends north into New Mexico to the border of White Sands Missile Range. The main cantonment is in El Paso, Texas. Fort Bliss is home to 39,000 military personnel and 39,000 family members and employs 13,000 civilians.

The planning process was initiated in April 2018 and the draft plan submitted in February 2019. Fort Bliss agreed to be a pilot site for the updated planning method and received technical support from Pacific Northwest National Laboratory and Concurrent Technologies Corporation through a contract with Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability. At the time this case study was prepared, the installation DPW was just beginning the process of implementing IEWP projects and management actions.

Drivers included the Assistant Secretary of Defense for Energy, Installations, and Environment memorandum dated March 31, 2016, and revised on May 30, 2018, requiring all DoD installations to develop Installation Energy Plans by September 2021. The Assistant Chief of Staff for Installation Management also released a memorandum on December 6, 2017 that required Army installations to develop Installation Energy and Water Plans, or IEWPs that address both energy and water security and resilience to meet the Assistant Secretary of Defense requirement. A third driver that was instrumental in facilitating Fort Bliss staff and mission owner cooperation was the official Order that the Garrison Commander signed and issued in support of this project, which required staff participation. Opponents in the process were limited, but there were barriers and challenges, with the main challenge discussed below.

Financing Challenges. Army installations are constantly operating in a state of constrained resources. The solutions developed for the (Fort Bliss) IEWP needed to leverage existing Utility Privatization contracts, existing Operations and Maintenance (O&M) budgets, military construction (MILCON), or potential third party funding sources such as a recently awarded Utility Energy Savings Contract (UESC). The completed IEWP included a suggested funding approach for each Course of Action. The installation will need to prioritize based on existing needs and those provided by the IEWP to reduce risk. For instance, planned utility upgrades may be shifted to address distribution to certain facilities based on the results of the risk assessment. Larger projects sent to Headquarters, Department of the Army (HQDA) for competitive funding, such as the Resilience and Conservation Investment Program (ERCIP), will need to be supported by strong mission risk reduction and cost effectiveness data.

This project was unique in that it was funded as a pilot project by ODASA E&S. The purpose was to develop an installation energy and water (E&W) security and resilience assessment approach for identifying recommended E&W solutions and documenting a solution implementation plan in an IEWP. Fort Bliss agreed to serve as the pilot installation for this effort. All Army installations are required to develop an IEWP by September 2021. ODASA E&S does not anticipate funding any additional IEWPs. Therefore, traditional funding channels will apply to the remaining Army installations. Likely, either the individual installations or their Commands will fund IEWPs leveraging O&M budgets. The majority of IEWPs due in September 2019 are underway via these funding channels.

Technical Challenges. This project did not result in system designs; instead, it resulted in the development of a Fort Bliss IEWP to serve as a roadmap for achieving increased security, resilience, readiness, and mission assurance. The major challenge of assessment and plan design was developing an assessment process and plan that evaluated risk at both the installation-level and facility-level, which are both important considerations when evaluating the impacts of energy and water disruptions. The assessment process consisted of three risk assessment approaches with specific goals, which included: Critical Mission Sustainment (ensure that critical missions have the energy and water needed to sustain operations under any operating conditions), Critical Mission Risk Reduction (reduce risk of critical mission disruption from energy and water system deficiencies), and Installation Risk Reduction (reduce risk to all installation missions from energy and water disruptions and improve performance where lifecycle cost-effective).

Solution concepts were then developed in response to the high risks identified from each of the three risk assessment approaches. An additional challenge was integrating those solution concepts into one prioritized list of solutions based on risk reduction potential. Because the Army and the installation indicated that reducing risk to the MFGI mission was highest priority, this criteria was applied first when prioritizing solutions. Additionally, many solutions could reduce high risk identified in two or three of the risk assessment approaches, which also increased the solution priority.

To address areas of high risk identified in the risk assessments, a number of solution concepts were identified for energy and water generation, storage, and load management. Energy generation solutions identified include campus and building microgrids, substation centralized backup generators, gas turbine islanding, main substation generator islanding, and locomotive power. Water generation solutions include installing additional wells to provide redundant water supplies. Energy storage solutions include adding energy storage to existing photovoltaics and adding on-site liquid natural gas storage. Water storage solutions include installing additional water storage at buildings with critical water needs. Energy and water load management solutions include building controls optimization, metering critical facilities, and ensuring appropriate cybersecurity controls on existing energy and water management systems.

Existing Infrastructure and Demand

All utilities on Fort Bliss are privatized. Electric utility service to the Fort Bliss main cantonment and ranges is provided by El Paso Electric (EPE). The main cantonment is served by five primary substations, which step down the 115-kV (1.2^5 V) EPE feeds to 13.2 kV (1.3^4 V) for local distribution on the Rio Grande Electric Cooperative (RGEC) wires.

Texas Gas Service supplies natural gas to Fort Bliss and owns and maintains the gas distribution system on the garrison. Texas Gas delivers natural gas to two primary regulator stations at the installation. The main pipeline supplies natural gas at pressures ranging between 300 and 375 psig (2068-2586 kpa). At the regulator stations, the pressure is reduced to pressures ranging from approximately 150–170 psig. Lower pressure distribution lines and service laterals (ranging from 15–60 psig, or 103-413 kpa) extend throughout Fort Bliss. Both the mains and distribution lines are stepped down via various other regulator stations located throughout the cantonment.

American States Utility Services, Inc., through its regulated subsidiary, Fort Bliss Water Services Company, owns, operates, and maintains the water and wastewater systems at Fort Bliss. The majority of the installation is supplied by a series of wells located on military property, and other portions of the installation are served via wholesale purchase from El Paso Water, an off-site water supplier. The water production, treatment, and distribution facilities consist of 16 active water production drinking water wells, nine booster stations, eight chlorination stations, 16 elevated storage tanks, 25 ground storage tanks, and approximately 370 miles (595 km) of water transmission and distribution mains. These water components comprise as many as 12 different waters systems and subsystems, some of which share water supplies and some of which do not.

Note that, while overall energy usage has increased, water conservation measures related to irrigation have caused a significant decrease in water usage over time. Costs have continued to rise for both energy and water. Tables 1 and 2 list general quantitative information.

The rate schedule includes demand billing as well as seasonal and time-of-use components. The rate structure also includes firm and interruptible components. The marginal rate, which includes interruptible demand and energy charges, is extremely low (2.6¢/kWh). As a result, there is little economic incentive to reduce energy consumption through efficiency. On the other hand, on-site dispatchable generation projects can result in significant savings through reduction of contracted firm demand.

Table 1. Utility Demand

	Fort Bliss Site	Critical Facilities
Electricity Demand (GWh)	322 (1.2^9 MJ)	171 (6.2^8 MJ)
Gas Demand (1000 Therms)	4,966 (5.2^5 MJ)	1,409 (1.5^5 MJ)
Water Demand (Mgal)	1,143 (4.3 L)	153 (0.6 L)
Building Area (ksf)	22,721 (1.1^6 kpa)	10,144 (4.9^5 kpa)

Table 2. Rate Schedule

Utility	Average or Blended Rate
El Paso Electric	$0.056/kWh
Texas Gas	$0.53/CCF*
New Mexico Gas	$0.44/CCF
Fort Bliss Water Services Company: Water	$1.94/kgal
Fort Bliss Water Services Company: Wastewater	$2.537/kgal
El Paso Water: Water	$1.58/kgal
El Paso Water: Wastewater	$4.24/kgal

* CCF= Centum Cubic Feet [100 cu ft]

Goals and Strategies

IEWP Goals. Ensure the ability of Fort Bliss to sustain critical missions in the event of an energy and/or water service disruption

- Reduce the risk to all critical missions from energy and water (including wastewater) disruptions, with priority given to the MFGI mission
- Reduce use of energy and water resources
- Increase operational efficiency

IEWP Strategies. Provide cost-effective alternatives to generators (e.g., storage, photovoltaics, demand-response)

- Help to manage responses from the electric utility to reduce load under an interruptible tariff notice
- Leverage alternative funding to support project implementation
- Leverage Privatized Utility Capital Improvement Plan projects for smart modernization
- Consider the O&M requirements of recommended solutions

Innovative Risk Assessment

The most innovative technical element of the Fort Bliss planning process was the risk assessment approach applied. Standard risk assessment approaches exist in the critical infrastructure risk management and mission assurance community. The intent was to mirror these approaches in a manner that was practical and feasible for support of the IEWP. One important goal of the development process was to ensure that the assessment method could be completed within reasonable level of effort by the installation staff themselves. The Army Headquarters proponents did not want to develop a process that would be entirely dependent on outside consultants and costly to support. It is understood that certain technical expertise will be required and necessary, but the optimal assessment method and guidance would be basic, repeatable, practical and as feasible as possible, while still obtaining the desired results. ODASA E&S developed a risk assessment process that was practical given time and budget constraints and also do-able by the current installation staff (given the typical background, clearance and training the individuals would have).

The method piloted at Fort Bliss actually consisted of three risk assessment approaches with specific goals (Table 3). The first step in this entire process is to identify and list all facilities that support critical missions as risk assessment approaches apply to different footprints. This is dependent on first identifying critical missions themselves and then the Critical Mission Footprint. To define the Critical Mission Footprint, the team reviews the installation's real property list and identifies each facility and piece of infrastructure according to its criticality. Several sources of information were used to establish the initial Critical Mission Footprint:

- Critical infrastructure lists
- Facility Readiness Drivers (prioritizes poor and failing facilities)
- Risk assessments performed by personnel in the Directorate of Plans, Training, Mobilization and Security

Table 3. Risk Assessment Approaches and Goals for Fort Bliss

	Critical Mission Sustainment	Critical Mission Risk Reduction	Installation Risk Reduction
Goals	Ensure that critical missions have the energy and water needed to sustain operations under any operating conditions.	Reduce risk of critical mission disruption from energy and water system deficiencies.	Reduce risk to all installation missions from energy and water disruptions and improve performance where life-cycle cost-effective.
Assessment Approach	Establish energy and water resource demand for critical mission sustainment. Establish baseline capability to meet Critical Mission Sustainment requirement (14 days or other). Identify opportunities to reduce resource demand. Generate and prioritize solutions to sustain missions (e.g., backup, storage, generation) and reduce demand.	Establish baseline condition of facility-level systems and procedures. Conduct detailed facility-level risk assessment. Identify opportunities to reduce resource demand. Generate and prioritize solutions to address critical facility and infrastructure deficiencies (e.g., lack of redundancy) and reduce demand.	Establish installation energy and water resilience baseline and validate root causes (via Installation Status Report – Mission Capacity). Establish facility efficiency baseline. Identify opportunities to reduce resource demand. Generate solutions to reduce installation risk (e.g., exercises, plans) and improve facility efficiency.

- Coordination with emergency response personnel/plans
- Maps and diagrams showing energy and water infrastructure lines and locations
- Generator lists
- Mission-Essential Vulnerable Area list
- Real Property Master Plan.

The initial Critical Mission Footprint was refined with mission owner input. Further coordination with mission owners was conducted to complete mission decomposition and determine which of the mission-essential functions and tasks support mission accomplishment. Mission decomposition considered all planned capabilities of the mission set (i.e., capability to meet troop surge requirements), not just baseline operations.

The team then identified facilities and infrastructure that are necessary to support these functions located within the installation boundaries. The team also established dependencies on facilities and infrastructure across missions, as those that support multiple missions are considered more critical than others. Interview protocols were used to ensure that specific information needed for the risk assessment was collected during the data collection and site visit elements of the planning process.

Critical Mission Sustainment. The risk assessment for Critical Mission Sustainment quantified shortfall between energy and water needs and availability as provided by current solutions aimed at mitigating the impacts of disruptions. The risk assessment involves:

- Estimating energy and water needed for critical facilities and infrastructure
- Calculating duration each facility can be sustained with existing supplies of electricity, natural gas, water, and fuel
- Calculating energy and water needed by each facility to meet Critical Mission Sustainment requirement (i.e., 14 days or other documented by the mission)
- Calculating the shortfall
- Analyzing opportunities to address the gap through:
    - Energy load/use analysis and reduction potential via whole-building modeling and building controls optimization
    - Water conservation assessment tools
    - On-site backup and storage sizing and capacity analysis
    - On-site renewable energy/alternative water-production feasibility tools
- Calculating contribution of solutions toward Critical Mission Sustainment requirement
- Estimating costs/benefits.

Critical Mission Risk Reduction. The risk assessment for Critical Mission Risk Reduction involves scoring facilities with a Mission Impact Index. Scoring of risk at the facility-level is necessary to identify critical missions vulnerable to energy and water disruption and to prioritize solutions to reduce this risk. Risk is based on the presence of deficiencies in the supporting utility systems and the mission sensitivity to energy and water disruptions. A deficiency is a flaw affecting the integrity of an infrastructure that, when compromised, causes the degradation or failure of a critical mission. The Mission Impact Index scores facilities using a qualitative scale adapted from standard risk assessment approaches (Figure 2). The "score" is qualitative and the only math used is addition to keep the scores as "buckets" for comparison with other facilities, creating a "1 to n" list. The results document facilities, deficiencies and risk score and are considered sensitive material. The assessment team members had the appropriate level of clearance to analyze these data and brief the installation.

Figure 2 *Mission Impact Index.*

Installation Risk Reduction. The risk assessment for Installation Risk Reduction aims to define potential projects and best management practices (BMPs) that would reduce overall risk and improve operational efficiency. Installation Risk Reduction solutions include those that address deficiencies in access to energy or water, the overall condition of energy and water infrastructure, and installation-level operations and planning. Solutions will also include those that reduce energy and/or water demand in facilities across the installation. Installation Risk Reduction is based on the installation's energy and water security posture as measured by Installation Status Report – Mission Capacity scores. Data collected and validated through on-site interviews, supporting documentation review, and inspection of systems was used to adjust these scores and identify areas where risk reduction measures are needed.

Decision and Design Process

Fort Bliss has access to energy and natural gas. There is also solar power potential. The installation has on-site capability to generate power through limited solar panels and an on-site natural-gas turbine. Fort Bliss is uniquely situated over a freshwater aquifer and has its own on-site water wells. Potable water is constrained in this region due to lack of surface freshwater. The aquifer is fresh with saltwater intrusion that must be carefully managed to meet future water demand. Climate change adds additional stress to the aquifer as surface water will become less available and demand will continue to increase.

At the time this case study was prepared, the installation DPW was just beginning the process of implementing IEWP projects and management actions, so the single most crucial parameter for go/no-go decisions had not yet been established. The installation did express concerns about constrained resources and funding availability for new energy and water projects in addition to other projects they were also trying to implement, suggesting that project cost and funding availability are high on the list of parameters for funding decisions. There are a number of other criteria that Army installations apply go/no-go decisions on energy and water projects, including those identified by the IEWP. The criteria considered when prioritizing projects for implementation include: Contribution to Risk Reduction, Operational Efficiency, and/or Energy and Water Demand Reduction; Availability of Funding Options; Change in O&M Burden; Project Implementation Feasibility.

Resilience Defined

Each Task outlined in the IEWP is designed to increase resilience of Fort Bliss to prevent, prepare for, and respond to future energy and water disruptions. Energy and water resilience is defined by four attributes: (1) Critical Mission Sustainment – ability to reduce risk to critical missions by being capable of providing necessary energy and water for a minimum of 14 days; (2) Assured Access – availability to redundant and diverse sources of supply, including renewable energy and alternative water, that meet evolving mission requirements during normal and emergency response operations; (3) Infrastructure Condition – access to infrastructure capable of on-site energy and water storage along with flexible and redundant distribution networks that reliably meet mission requirements; and, (4) System Operation – availability of trained personnel who conduct required system planning, operations, and sustainment activities for energy and water security. The Army uses an annual data call, titled Installation Status Report – Mission Capacity, to assess the energy and water resilience posture of its installations (Table 4). The data call is structured around these four attributes. The measures provide the basis for assessment of current resilience posture as well as the impact of the IEWP on improving the resilience into the future.

FORT BRAGG, NORTH CAROLINA—HUMID (2B)

Installation Background

Fort Bragg is located in Cumberland County, which lies between the Sandhills and Coastal Plain regions of North Carolina (Figure 3). Projections from 2017 approximate there are 10,273,419 residents in North Carolina, and by 2030, it is projected there will be 12 million. The region where Fort Bragg lies takes up 45% of the state's total land area and is mostly made up of wetlands. Population estimates indicate that Cumberland County has over 300,000 residents, and that the installation itself contains 145,092 residents. The region has also been subject to several localized droughts over nearly two decades, but it has not prevented Fort Bragg's ability to meet Army water use reduction targets.

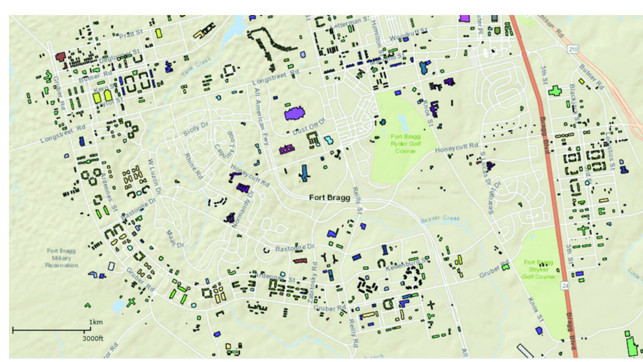

Figure 3 *Overview of Fort Bragg.*

Table 4. Example Installation Status Report

Task #	Task Title	Responsible Party	Funding Type
1	**Enhance Operations and Plans**		
1.1	Establish Generator Refueling Plans	DPW-Electric	O&M Budget
1.2	Ensure Cyber Security of Utility Control Systems	DPW-Electric/Water/Gas	O&M Budget and UP* Contract
1.3	Augment Deployable Backup Power Systems	DPW-Electric	O&M Budget and UP Contract
1.4	Prepare Emergency Response Plans and Conduct Readiness Training Exercises	DPW-Electric/Water/Gas	O&M Budget and UP Contract
2	**Improve Infrastructure Condition**		
2.1	Improve Electric System Infrastructure	RGEC/Fort Bliss Water	UP Contract, ERCIP or SRM**
2.2	Improve Water System Infrastructure	Fort Bliss Water Services Company	UP Contract
2.3	Leverage substation project to enhance capacity		O&M Budget, UP Contract or SRM
2.4	Install water storage or air-cooled HVAC in critical facilities with cooling towers		O&M Budget or SRM
3	**Increase Capacity**		
3.1	Investigate Utility Scale EPE Asset	DPW-Electric/EPE	O&M Budget or Power Purchase Agreement
3.2	Implement Campus-Scale Microgrid	DPW-Electric	O&M Budget, UP Contract, UESC or ERCIP
3.3	Install Substation Centralized Backup Generators	RGEC	UP Contract or ERCIP
4	**Reduce Demand**		
4.1	Meter Critical Facilities	DPW-Electric/Water/Gas	&M Budget, UP Contract, or SRM
4.2	Install and Optimize Building Controls	DPW-Electric	O&M Budget or UESC
4.3	Implement Energy Conservation Projects	DPW-Electric/Gas/Water	O&M Budget or UESC
4.4	Implement Water Assessment and Conservation Projects	DPW-Water	O&M Budget or UESC

* UP = Utilities Privatization

**SRM = Facilities Sustainment, Restoration and Modernization (SRM) program.

Fort Bragg identified a need to update the current energy and water security plans to comply with new DoD directives regarding energy and water security and resilience. Updated plans were required to integrate and contribute to the sustainability and resilience goals at Fort Bragg, and to consider the interconnections between critical infrastructure systems (energy, water, wastewater, etc.) and the installation's ability to complete its mission and maintain readiness now and into the future.

Goals and Strategies

The objective of this project was to evaluate and improve energy and water security at Fort Bragg, North Carolina through development of an IEWP. After determining the projected future energy and water needs of the installation in the baseline case, the energy and water consumption and management is compared with the installation's initial planning vision and goals; possible alternatives are developed for addressing the identified gaps. The analysis quantifies the energy savings needed to meet the goals and produce savings, as well as identifying the constraints and opportunities inherent in each alternative.

Development of the Baseline

Infrastructure is interdependent on other critical and high-use systems, such as water infrastructure, electric power, and transportation systems. Failures in any one system can create a cascade effect, causing an increase in vulnerability to other infrastructure. In the baseline phase, the installation's current energy and water use, resource availability, system operations, missions, and tenants were identified. This baseline was created from the installation's real property inventory (RPI), resource consumption data, energy and water profiles, modeling outputs, and the evaluation of the existing state of the utilities infrastructure. Individual buildings were then combined into facility groups based on properties that affect energy and water use, such as facility function and age. Figure 3 displays a visual representation of the RPI and facility groups that were uploaded in the modeling tool.

Through a year-long process, mission critical facilities were also identified through discussions with stakeholder organizations on post. Four categories were ultimately determined: Life, Health, and Safety; Command and Control; Deployment; and Life Support. Total demand for water required was then determined and calculated at over 100,000 gallons per day. The calculated energy use intensities (EUIs) included:

1. Number of Facilities: 1,621
2. Total Conditioned Area: 36,533,928 sf (339,411,151 m^2)
3. Site Electricity: 674,984,396 kWh (2,429,943,826 MJ)
4. Site Electricity Intensity: 63.04 kBtu/sf (715,915,651.2 J/m^2)
5. Site Gas: 15,436,431 therm or 461,481,979 kWh (1,628,543,471 MJ)
6. Site Gas Intensity: 43.10 kBtu/sf (489,466,443 J/m^2)
7. Energy Cost: $44,796,048/yr
8. Total Site Energy: 1,136,466 MWh (4,091,277.6 gigajoule)
9. Total Site Energy Intensity: 106.14 kBtu/sf (1,205,382,094 J/m^2)

Innovative Approach in Modeling Resilience

System Master Planner/Net Zero Planner Tool. The System Master Planner/Net Zero Planner (SMPL/NZP) Tool is a web-based modeling tool that provides an installation-wide overview of energy, water, and waste planning capabilities. By analyzing baseline and future priorities with this tool, better utilization and optimization of supply, load, and cost savings capabilities can be achieved (Case et al. 2015 and 2014).

For Fort Bragg, the model first extracts historical data to determine typical energy use for each facility based on a number of inputs (i.e. age, function, and conditioned area of each building and climate of the installation). The baseline calibration step then adjusts the calculated predictions to better represent the actual usage based on utility bills and consumption reports collected in the Army Energy and Water Reporting System (AEWRS). It should be noted that installation-wide consumption data may not match the model exactly, since the study may include a slightly different set of facilities and there is limited building-level metered data available for calibration. This calibration step, however, ensures that the model is valid for planning level analysis.

The energy breakdown by percentage is shown in Figure 4, along with a comparative analysis of the baseline monthly electricity and natural gas distribution. The end uses for the building are shown with energy consumption for building internal equipment loads, domestic hot water, and lighting.

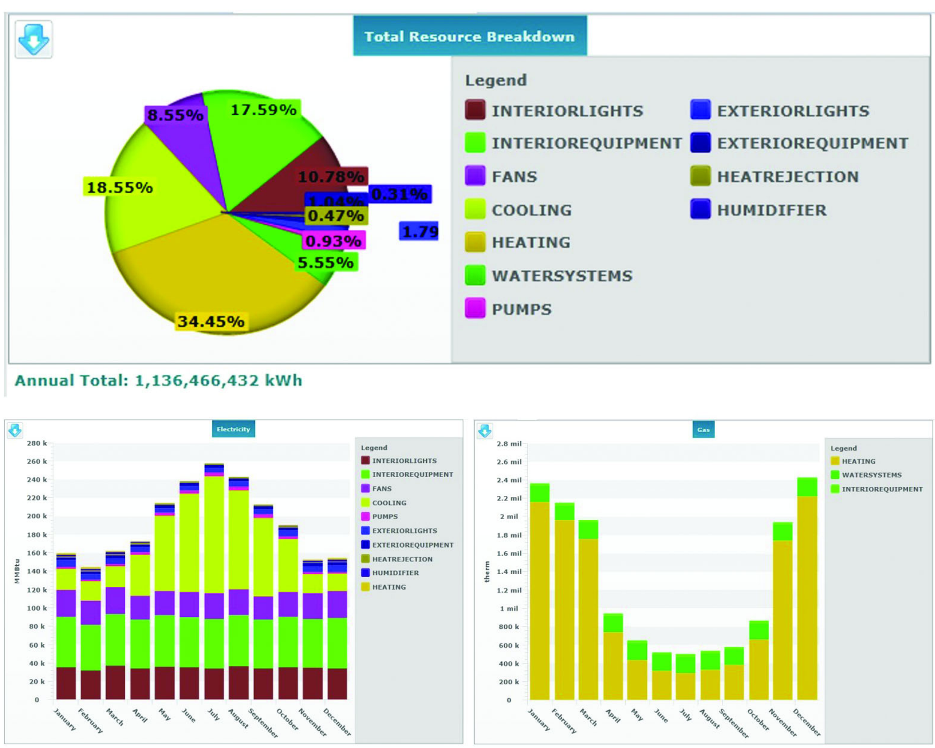

Figure 4 *Energy Breakdown of Baseline Energy and Natural Gas Distribution. Source: SMPL/NZP, U.S. Army Corps of Engineers*

The energy to condition the building is then shown with large amounts for heating, cooling, and ventilation (Fan Energy). The heating load is in two components, a) building heat and b) domestic hot water (or water systems as shown in Figure 4).

Energy Resilience Analysis (ERA) Tool. The Energy Resilience Analysis (ERA) Tool, which was included in the baseline and future scenario modeling, was assessed during the Fort Bragg study to better determine the utility of the tool and to enhance the capabilities of SMPL/NZP (Judson, 2016). The ERA tool was developed by Massachusetts Institute of Technology Lincoln Laboratory [MIT-LL] specifically to support DoDI 4170.11(DoD 2009). As intended, the automated framework tool provides energy and planning personnel with the ability to perform energy resilience assessments with a focus on availability and reliability of energy life cycle cost comparisons. The current ERA methodology has the following high-level steps:

- Define the baseline (existing) energy architecture in the ERA Tool.
- Define alternative energy architectures (this step is automatic in the Web App version).
- Compare the baseline energy architecture to the alternative energy architectures to determine the architecture that is the best option.

At Fort Bragg, the ERA Tool was tested with the electrical infrastructure and then again with a combination of the electrical and thermal infrastructure. By adding thermal in the second run, the ability to see the impact of the outputs became a factor. Of the first nearly 40 architectures that were analyzed, 10% stood out from the baseline in reduction of factors such as costs and resilience. In the second run, over 60 alternative architectures for both electrical and thermal were analyzed. The incorporation of the thermal central boilers with the same 10% having the lowest life-cycle costs showed that those architectures previously identified resulted in an increase of 15% in life-cycle costs compared to the existing on-site system. The bar chart in Figure 5 shows that the alternative architectures, which are 43%-52% more effective in reducing energy than the existing systems, have the same in effectiveness as the electric-only versions.

Establishing the Base Case and Future Alternatives

After developing the energy and water baseline, the future base case is then established. The base case is a future "business as usual" scenario that includes existing and planned facilities, but excludes facilities scheduled for demolition. Similar to developing the baseline, the development of the base case and future alternatives involves careful coordination efforts with installation resources. The installation's master planning portfolio is taken into consideration, to include any planned or programmed energy and water projects. The base case projects the total installation annual and peak daily energy and water needs to meet the facility portfolio. The base case provides a gauge to which other potential future scenarios can be compared when determining the preferred course of action.

Figure 5 *(a) Life cycle cost and (b) unserved energy of various electrical and thermal alternative architectures for typical grid outages, along with 4-day and 14-day black sky outages.*

Once projected future energy and water needs are determined in the base case, the energy and water consumption and management is compared with the installation's initial planning vision and goals. Possible future alternatives are then developed to address any identified gaps. The analysis quantifies the energy savings needed to meet the goals and produce savings, as well as identifying the constraints and opportunities inherent in each alternative. The various courses of action were reviewed with the stakeholders and a preferred alternative was chosen. Table 5 lists the energy efficiency measures (EEMs) that were evaluated for the facility groups.

Each facility group was analyzed with the implementation of a collection of EEMs, while weighing factors such as implementation cost and energy savings. When selecting the EEMs, it is important to assess both the economic and sustainability impacts. Suggestions were made to improve energy and water efficiencies for the intended usage needs, which would save an estimated 1 billion kBtu (thousand British thermal units or 1.13565E+16 J/m2) per year and reduce costs by $7.3 million in total annualized cost savings. It is necessary to assess both the economic and sustainability impacts to achieve

Table 5. EEMs Evaluated for the Facility Groups

Package Name	Goals to Increase HVAC Efficiency	Example Measures to be Taken to Achieve Package Goals
Lighting Package	Reduce Lighting Power Density (W/sf)	High-efficiency electric lighting. Replace inefficient T-12 or incandescent lamps with higher efficiency T-8, T-5, Light Emitting Diode (LED), or compact fluorescent lamps. Improve ballasts. Minimize redundant or excessive lighting. Installing advanced lighting controls such as occupancy sensors and timers.
Equipment Package	Reduce Equipment Power Density (W/sf)	Use high-efficiency, Energy Star® certified appliances and equipment with sleep or standby modes. Minimize redundant equipment. Reduce number of printers, refrigerators, personal heaters, etc.
Infiltration Package	Reduce Air Leakage Rate (cfm/sf) Implement Vestibule Entrances	Reduce infiltration with a tighter building envelope Install continuous air barriers. Caulk and weather stripping to seal existing leaks.
HVAC Package	Increase Chiller Coefficient of Performance (CoP) High-Efficiency Boiler High-Efficiency Pumps Supply Temperature Reset Controls Reduced Duct Leakage	Install high-efficiency chillers. Upgrade high-efficiency boilers. Install Condensing boilers. Install high-efficiency boilers. Install high-efficiency domestic hot water heaters. Install high efficiency chilled and hot water pumps. Supply temperature reset controls. Install air system supply temperature reset controls. Install hot water system supply temperature reset controls. Reduce upstream and downstream duct leakage fraction to return plenum.
Daylighting Package	Install Daylighting Controls	Install Daylighting controls to automatically dim electric lights. Install tubular daylighting devices and light shelves.
Cool Roof Package	Increase Roof Reflectance Increase Roof Emittance	Install a white painted or granular coated metal roof.
Envelope Package	Increase wall base cavity and continuous insulation (R-value) Increase Roof Base Insulation (R-value) Increase Slab Vertical Insulation (R-value) Decrease Window U-Value Decrease Window Solar Heat Gain Coefficient	Improve insulation levels of roof, walls, floor, and windows Install tinted, double-pane windows
Domestic Hot Water Package	Reduce Domestic Hot Water Usage (Gallons per Minute [GPM])	Install low flow fixtures

a balance and to ensure that the installation achieved its end goals. Figure 6 shows an example cost optimization curve for a Battalion Headquarters building, which clearly shows that if all EEMs, including the HVAC Package, are implemented, the installation will enjoy the greatest energy reduction while still reducing the annual cost as compared to not selecting any EEMs in the baseline.

Measuring Resilience

For critical missions, key buildings were identified with specific plans of action, cost benefit analyses, storage requirements and minimum operation levels for essential emergency personnel. Operational efficiency of existing systems, including leak detection and repair on existing systems, was also identified as a resilience measure.

Specific hazards and threats were then divided into three categories: intentional (e.g., acts of terrorism or vandalism), unintentional (e.g., accidents or infrastructure failures), and natural events (e.g., hurricanes, floods, fires, etc.). Risks and vulnerabilities to critical mission energy and water systems were assessed, including supply resources, delivery networks, and end-use systems. Cyber incidents were of particular highlight.

By identifying best management practices (BMPs) for future studies, an outline has been created for measuring resilience to include program measures to reduce demand for energy and water, increasing program efficiency, security, and identifying other resilience-enhancing measures.

Moving forward, the following BMPs were identified:

- Set an overarching policy and goals for the long-term operating objective of the installation and its facilities;
- Assess current energy and water uses and costs to establish a baseline;
- Develop an energy and water balance through metering, auditing, and estimating consumption to compare the total supply baseline, determined in step 2, to end-uses;
- Assess efficiency opportunities and economics to identify retrofit, replacement, and maintenance options;
- Develop an implementation plan, including education and outreach efforts for building occupants;
- Measure progress and review goals; and
- Plan for contingencies, such as a drought, blackout or other emergency scenarios.

JOINT REGION MARIANAS, GUAM -- MARINE, TROPICAL (2 OR 3C)

Installation Background

Unique to the geographic region of Guam, there are actually three installations collocated (or planned) on the island—the Naval Base Guam (NBG), Andersen Air Force Base (AAFB), and a future new installation for the Marine Corps.

The Joint Region Marianas Comprehensive Energy Investment Plan (CEIP) was developed as a pilot study to assess, improve and integrate energy infrastructure and achieve regionally prioritized goals within a timeframe of 20 years. The pilot study was unique in many respects, but two aspects were particularly noteworthy: first, the study expanded the typical focus of energy plans from conservation to include energy security and resilience as the primary goal; and second, the study integrated efforts across three bases – NBG, AAFB, and a future new base for the Marine Corps into a regional plan (Figure 7).

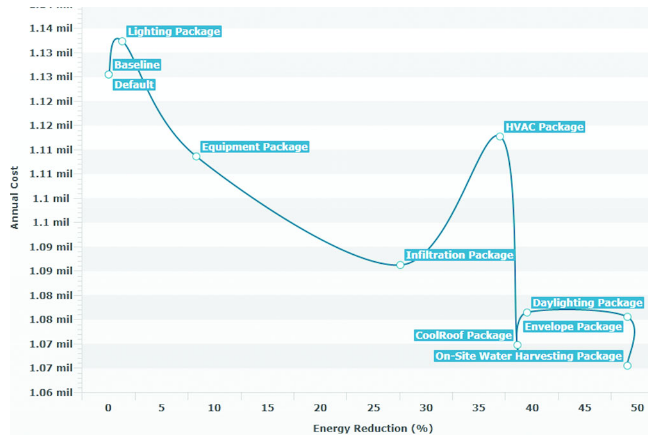

Figure 6 *Cost optimization Curve.*

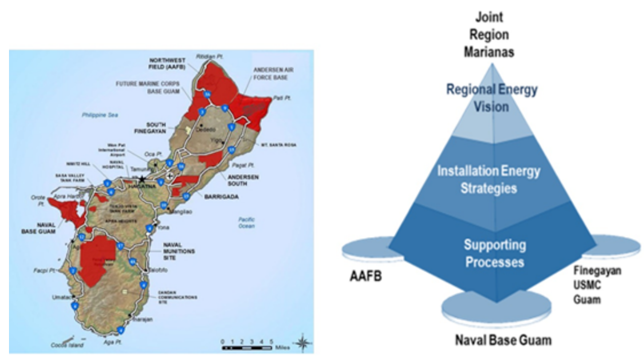

Figure 7 *Guam DoD Installations and the Joint Marianas Region CEIP.*

Modeling Energy Assessment and Energy Projects

The Joint Region Marianas (JRM) footprint on Guam accounts for around 15 million square feet (Msf or 1.4 km^2) of facilities in 2016 that have an average daily peak of around 50 MW (180,000 MJ) and a critical load of around 11 MW (39,600 MJ). With significant expansion of missions on the island, including the construction of a brand-new base for the Marines, this footprint is projected to increase by 5 Msf (465 m2) to nearly 20 Msf (1,858 m2) by 2035 and correspondingly increase the peak energy daily load by 30 MW (108,000 MJ)

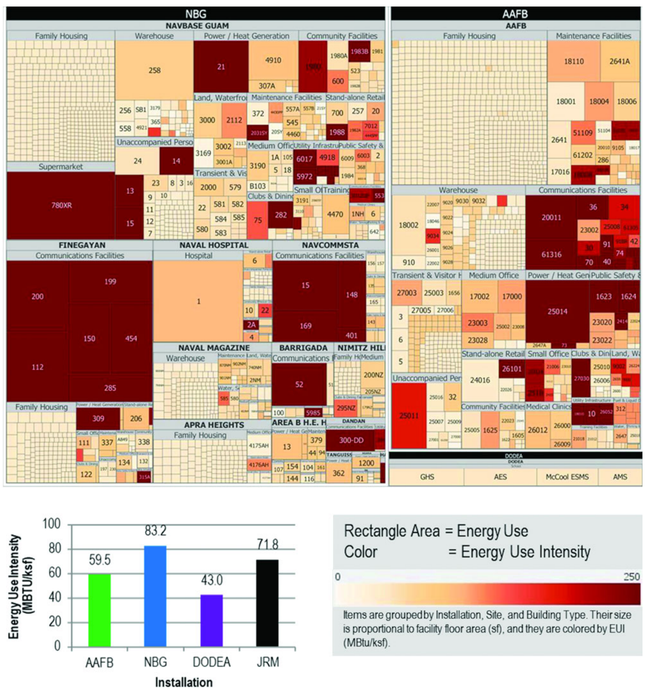

Figure 8 *Facility Energy Use Intensity Pattern. Source: AECOM analysis.*

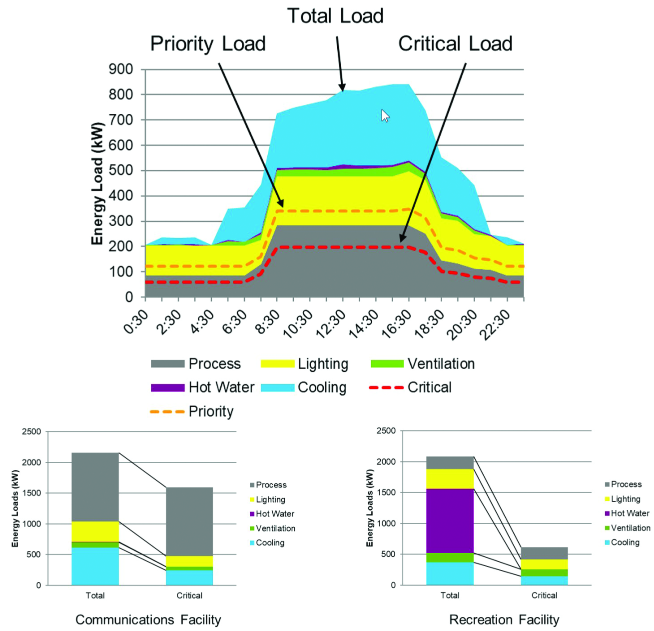

Figure 9 *Total and Critical Energy Load Estimation using Modeling. Source: AECOM Energy Modeling.*

to 78 MW (280,800 MJ) with a critical load of 21MW (75,600 MJ). The new demand was projected using the Navy's UFC for Sustainable Buildings (NAVFAC 2014) that set a 30% improvement over ASHRAE 90.1 2013 standard for different building types.

An analysis of EUIs across each installation indicated that there was considerable variation as per the mix of building typologies within each base (see Figure 8). The analysis also revealed that, out of the 2,700 individual facilities, the top 100 energy-consuming facilities account for 50% of the total energy use and represent only 25% of JRM total facility spread across the different installations. This underscored the importance of using a regional prioritization approach to planning energy projects that would result in optimized 'biggest bang for the buck' outcomes.

Using energy models of prototypical buildings, typical Total Loads, Priority Loads, and Critical Loads for various buildings were analyzed (Figure 9). This information was essential in identifying energy conservation opportunities and estimating the impact of renewable technologies or district-based solutions such as central cooling systems and/or micro-grids.

Goals and Strategies

Among the primary goals of the plan was to address energy resilience in support of mission assurance efforts. These included:

- Provide durable energy solutions
- Avoid single points-of-failure
- Ensure sustainable maintenance
- Use cost-effective energy strategies
- Meet required energy mandates and goals.

While Resilience did not have any prescribed performance benchmarks, the plan was required to meet specific Federal and DoD Energy Mandates such as the reduction of EUI by 25% by 2025 and increasing the renewable energy use component to 25% as per the Executive Order 13693 (White House 2015). In addition, the Secretary of the Navy's aspirational goals of reducing energy consumption by 50% by 2020, using 50% alternative fuel sources (U.S. Congress 2017), and a base Net Zero energy by 2030 were also to be seriously considered.

The CEIP was set against a background of increasing need for reliability and resilience due to a failing infrastructure on the island of Guam and the significant risk of super-typhoons with winds exceeding 175 mph (282 km/h). Between 2010 and 2015, there were more than 400 power outages recorded and the local utility, Guam Power Authority (GPA), had lost nearly 80 MW (80,000 KW of generation capacity. With the DoD bases accounting for over 20% of the island's energy demand, all stakeholders prudently recognized that piecemeal efforts taken by individual entities were insufficient; a coordinated "One Guam" approach was needed to benefit the entire island's energy infrastructure. Note that GPA has since embarked on a multi-phase extensive grid modernization effort including the addition of 120 MW (120,000 KW) of renewable solar energy to their capacity by 2025.

The CEIP development followed a 12-step energy planning process (Figure 10). The process included a robust energy assessment of existing conditions and implications of future development, followed by use of simulation models to evaluate energy outcome scenarios that meet energy and resilience goals. Finally, the process used an optimization model to generate funding and investment constrained year-by-year project action road-map for implementation.

Innovative Energy Scenario Planning

The CEIP used an innovative simulation model to integrate the extensive facility level data with conditions gathered and to generate various energy scenario outcomes that could be tested against the goals and performance targets set out by the CEIP Vision. The scenario process involved adjusting the model inputs and timing of proposed actions in accordance with various drivers or goals that a particular scenario pursued. Typical scenario drivers included:

- *The Ability To Develop a 'Strong' Rating for Energy Security and Readiness Scorecard for JRM.* This means that all aspects of Readiness, Resilience, and Efficiency would have to be considered to maximize the scores. In particular, the decision to implement a Microgrid solution, the availability of the right amount of redundant renewable power to cover the critical facility loads at each installation, and the size of energy storage greatly influence the scores.
- *The Need To Meet or Exceed Energy Mandates and Goals.* JRM is subject to various energy mandates and goals dictated by federal authority (Executive Order 13693 [White House 2015]), Department of the Navy (DoN 2011), and Commander, Navy Installations Command (CNIC). Although Energy Security is considered the primary driver, JRM is still obligated to show a best effort toward compliance with the targets. These goals have performance benchmarks at specific timelines that directly influence decisions on implementation timing of certain projects.
- *Cost and Funding Level.* Overall capital investment and impacts on long-term operating budgets are also important drivers that influence choices in the scenario development process. The amount of funding per year for conservation projects is controlled to simulate current trends in funding of such projects or reflect anticipated lowering in funding availability in later years (after 2020). Decisions on whether renewable power is available as model 2 (feeding internal base demand) or model 3 (feeding back to the utility grid), or whether it is sourced from a power purchase agreement or directly owned and operated also influences the cost savings potential.
- *Priorities for Individual Installations.* For JRM, the scenario development incorporates not only the perspective and targets of regional stakeholders, but also the priorities of the component installations. In this case, such development would include for example, NBG exploring rebuilding of the Orote Power Plant as part of its Microgrid solution or AAFB (which has limited land availability) being open to a more aggressive rooftop solar implementation.

Using AECOM's Vision Simulation Tool, four scenarios were developed for the JRM leadership to decide on the road-map forward (shown in Figure 10). These scenarios ranged from a Business-As-Usual approach using current planned actions only, to highly resilient installations targeting Net-Zero Energy status by 2035. Each scenario implemented a combination of energy conservation measures, energy infrastructure projects such as smart-grid capabilities, district-cooling, microgrids managing back-up generation and battery storage, and renewable energy projects inside and outside the fence.

Designing for Reliability, Resilience, and Efficiency

Another innovation used in the JRM CEIP was the Energy Security and Readiness Scorecard that provided a measurable way to assess the reliability, resilience, and efficiency posture of each scenario. The scorecard was developed in accordance with the Navy's Three Pillar approach and included nine categories of metrics and 22 individual Key Performance Indicators (KPIs) as shown in Figure 11.

The Energy Security and Readiness scorecard was used in conjunction with a range of additional performance metrics that the CEIP Vision Scenario Planning Tool generated. These metrics evaluated whether the scenario met each of the many energy mandates for reductions or renewable energy generation, as well as cost performance metrics (Figure 12, top). The interactive scenario building model allowed adjustments to various inputs such as project selection and implementation timeframes while simultaneously producing the various visual outputs for comparison. This process facilitated the fine-tuning and development of the scenarios.

After the scenario development and exploration, a decision matrix was developed for the JRM leadership to facilitate selection of a recommended scenario and course of action. The matrix combined the projected resilience posture, energy mandate compliance, and the cost implications into a single table (Figure 12, bottom). The referenced 'Decision Matrix' clearly showed that meeting energy mandates did not automatically translate to improved resilience and that substantial additional effort would be needed to achieve both resilience and energy conservation goals. Based on the evaluation, Scenario 3 (Resilient with Net-Zero at the new Marine Corps Base) was selected as the recommended scenario. A more detailed implementation plan with specific year-by-year project implementation plan was generated based on the selected scenario.

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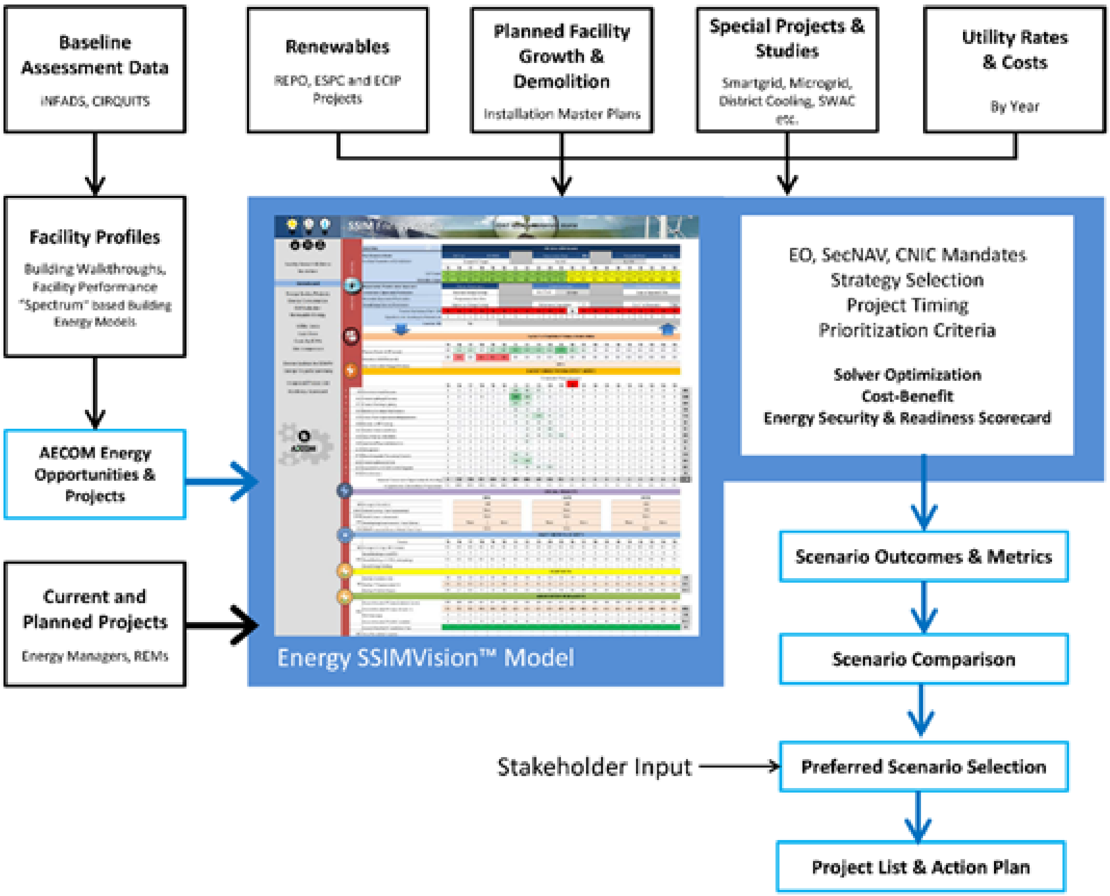

	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4
Name	Business As Usual (BAU) + Government Planned Projects	Mandate Compliance	Resilient with Net-Zero MCBG	Resilient Plus
Description	Implements currently planned projects as per intended timelines, with future conservation projects at current investment levels.	Implements only current and future planned projects that meet various mandates.	Implements current planned projects and addition projects that maximize Regional Resiliency while being cost-effective.	Implements Scenario 3 plus additional projects to maximize energy savings towards a goal of Net-Zero.
Scenario Goal	Demonstrate Current Path Outcomes for JRM.	Demonstrate what it would take to simply meet SecNAV, CNIC, EO 13693 Goals.	Determine key projects that cost-effectively help maximize Resiliency Scores as per the Energy Security and Readiness Scorecard.	Demonstrate implications of implementing SWAC and additional renewables towards Resiliency and Net-Zero.
Measures & Key Actions				
Energy Conservation Projects (ECMs)	Implements numerous separate facility level actions over 9 years across AAFB and NBG. Includes currently planned projects through 2020 and then new projects at an average investment of $19M per year from 2021-2024. Average payback is set at < 10 years for each year bundle.	Implements numerous separate facility level actions over 8 years across AAFB and NBG. Includes currently planned projects through 2020 and then new projects in years 2026, 2030 at investments of $6M/yr, and 2032 and 2034 at $11M /yr.	Implements numerous separate facility level actions over 11 years across AAFB and NBG. Includes currently planned projects through 2020 and then new projects at diminishing investments of $15M in 2021 to $6M by 2025.	Implements numerous separate facility level actions over 12 years across AAFB and NBG. Includes currently planned projects through 2020 and then new projects at diminishing investments of $15M in 2021 to $6M by 2030.
Smart Grid	Implements Smart Grid across all three bases. Costs for MCBG is assumed to be included as part of site development.	Implements Smart Grid across all three bases. Costs for MCBG is assumed to be included as part of site development.	Implements Smart Grid across all three bases. Costs for MCBG is assumed to be included as part of site development.	Implements Smart Grid across all three bases. Costs for MCBG is assumed to be included as part of site development.
Microgrid	No Microgrid projects are implemented in this scenario.	No Microgrid projects are implemented in this scenario.	Implements Microgrids across all three sites connected to renewable power and battery storage.	Implements Microgrids across all three sites connected to renewable power and battery storage.
District Energy	Implements District Cooling at MCBG as per Jacob Engineering study.	Implements District Cooling at MCBG as per Jacob Engineering study.	Implements District Cooling at MCBG as per Jacob Engineering study.	Implements District Cooling at MCBG as per Jacob Engineering study.
SWAC	SWAC is NOT considered for this scenario.	SWAC is NOT considered for this scenario.	SWAC is NOT considered for this scenario.	SWAC is implemented by 2030 at both MCBG and NBG.
Rooftop PV	Implements currently planned Rooftop PV projects. NBG: 5.5MW over 390 ksf (19% of rooftop) AAFB: 10MW over 750 ksf (35% of rooftop) MCBG: No Rooftop PV	Implements currently planned Rooftop PV projects. NBG: 5.5MW over 390 ksf (19% of rooftop) AAFB: 10MW over 750 ksf (35% of rooftop) MCBG: No Rooftop PV	Adds to currently planned Rooftop PV projects. NBG: 5.5MW over 390 ksf (19% of rooftop) AAFB: 15MW over 1 Msf (50% of rooftop) MCBG: 9MW over 570 ksf (56% of rooftop)	Adds to currently planned Rooftop PV projects. NBG: 12MW over 820 ksf (40% of rooftop) AAFB: 15MW over 1 Msf (50% of rooftop) MCBG: 9MW over 570 ksf (56% of rooftop)
Ground Based PV	Implements all 5 REPO projects as Model 2s at 38MW and another 9MW as model 3 built with ESPC funding.	Implements all 5 REPO projects as Model 2s at 38MW and another 9MW as model 3 built with ESPC funding.	Includes 9MW (ESPC) at NBG. Implements 4 REPO projects as Model 2s at 22MW and 27MW at South Finegayan site as Model 3 built by third party with a PPA. PV is sized to achieve Net-Zero at MCBG.	Includes 9MW (ESPC) at NBG. Implements 4 REPO projects as Model 2s at 22MW and 27MW at South Finegayan site as Model 3 built by third party with a PPA. Also includes 15MW dedicated PV at AAFB Site and Andersen Landfill (by 2030). Gets Net-Zero at MCBG.
Battery Storage	Does not include any Battery Storage.	Does not include any Battery Storage.	Includes Battery Storage connected to Microgrid at each site (30MWh at MCBG, 60MWh at AAFB, 30MWh at NBG).	Includes Battery Storage connected to Microgrid at each site (30MWh at MCBG, 60MWh at AAFB, 30MWh at NBG).

Figure 10 *Energy Scenario Planning Tool Process and Proposed Scenarios.*

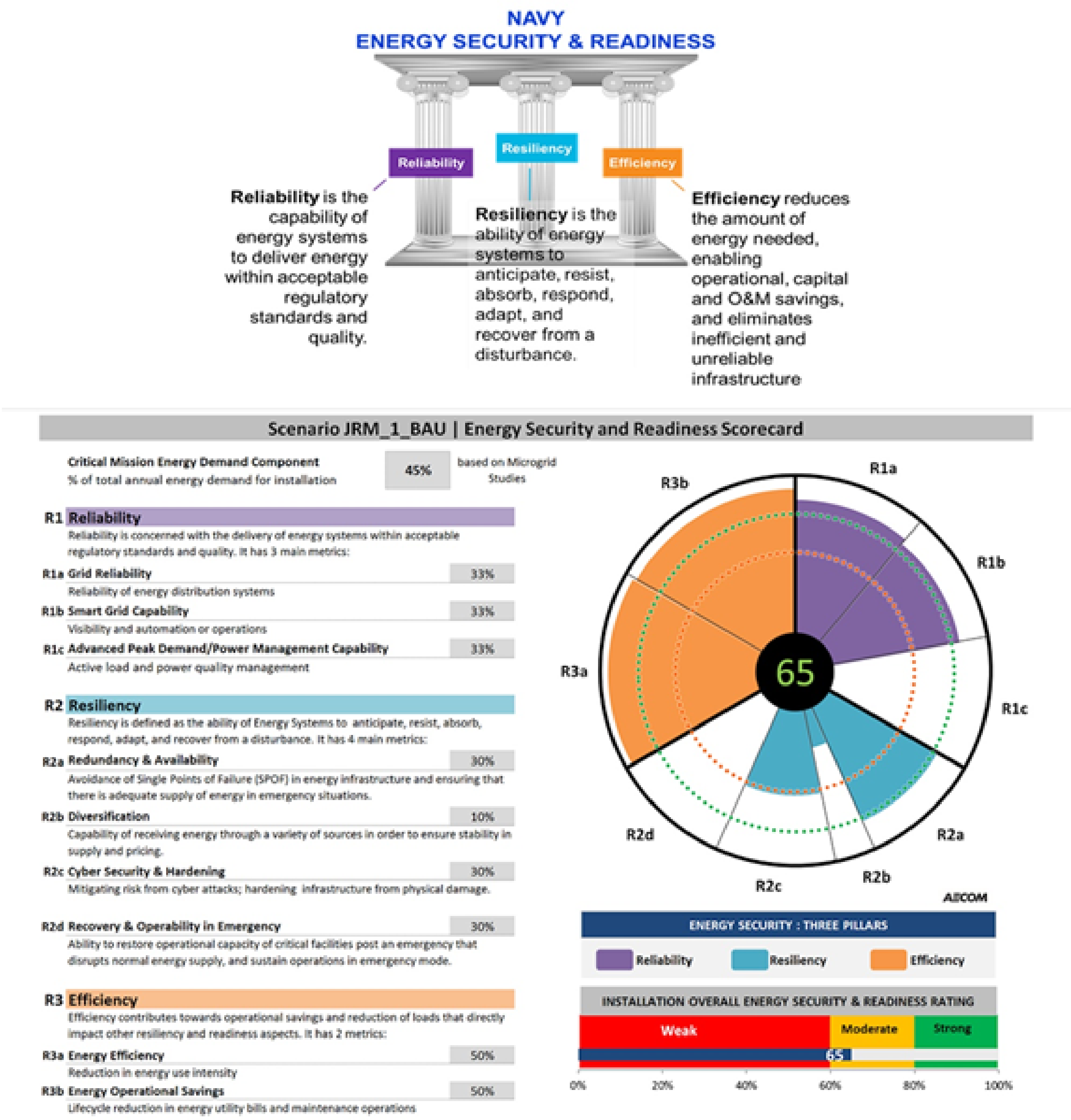

Figure 11 *Energy Security and Readiness Scorecard and Criteria.*

LESSONS LEARNED

Fort Bliss

The project team found that the single greatest barrier and challenge in completing the assessment and plan development was lack of available data to conduct risk analyses to the required level of detail. It was very challenging to obtain data from the privatized utility contractors that own and operate the installation's utilities. For example, one-line drawings of the power system serving the installation could not be obtained from the privatized electrical system owner; therefore, redundancy of installation circuits could not be evaluated.

Interaction with the mission owners at Fort Bliss was an important contribution to the success of the planning process. This interaction provided the basis for the list of critical missions and inputs into the risk assessment. It was also important for providing a basis for proactive interaction between mission owners and installation DPW going forward.

Two major bottlenecks were experienced. First, privatization of utilities creates a bottleneck for access to system information. Non-disclosure agreements were needed and, even after that, some information important for risk assessment was not available. Proxies were used, but this limited the ability to prioritize deficiencies effectively as many facilities scored similarly in the analysis. The second bottleneck was scheduling and conducting interviews. This process takes some time. Especially for an installation the size of Fort Bliss, the team needs to account for identifying the correct individuals, accommodating their schedules, and performing follow-up if the information requested is not available on the first attempt.

Major lessons learned:

- Provide cost-effective alternatives to generators (e.g., storage, photovoltaics, demand-response)
- Help to manage responses from the electric utility to reduce load under an interruptible tariff notice
- Leverage alternative funding to support project implementation
- Leverage Privatized Utility Capital Improvement Plan projects for smart modernization
- Consider the O&M requirements of recommended solutions
- Prepare for generation and management of Classified information
- Many solutions to reduce risk are operations-based and low cost
- Strategies to manage the number of critical missions (and associated facilities) may be needed

Fort Bragg

Utilizing the ERA Tool without existing SMPL/NZP baseline modeling was found to be potentially problematic. The baseline architecture did not initially include resilience measures required by the mission. For example, there may be no alternatives that have both a life-cycle cost and annual unserved energy that are lower than that of the baseline architecture; however, the baseline architecture may still not be resilient enough to sufficiently protect critical infrastructure from power failures. In this example, the ERA Tool alone would suggest that the installation keep its current insufficient infrastructure.

To rectify this issue, the team found that the combined tools could be configured to establish a base case in addition to the baseline. In installation master planning, the concept of a base case is the baseline plus any improvements planned to meet a minimum requirement. For example, an installation may have 10 existing buildings in their baseline, but they might need two more buildings over the next 5 years to accommodate an expected increase in personnel. The 5-year base case would then have 12 buildings.

To ensure that the combined modeling strategy is appropriate, it makes sense that the installation should define a minimum resilience requirement and create a base case architecture that is comprised of the equipment that would most easily meet this minimum requirement (e.g., minimum power quality requirements, minimum downtime requirements, and uninterruptible Power Supply [UPS] systems, minimum renewable energy requirements, etc.). Then, when the alternative architectures are created, it is then compared to the minimum resilience requirements defined in the base case rather than what currently exists at the installation. The resilience of the energy supply system in the base case scenario would be brought up to minimum requirements and the life cycle cost would increase compared to the pre-renovation baseline to meet the resilience requirement. This new life cycle cost would set a new standard. In the rare case where an installation's current energy infrastructure is sufficient to meet their minimum resilience requirement, the baseline will be equal to the base case and no further work would be necessary.

Guam

Feedback from the installation indicated that the outside assistance enabled a far more detailed and thorough assessment and plan that could have been possible without the extra help. The DPW point of contact also felt they now have the data, tools and knowledge to keep the plan current going forward. Although this result is to be expected, it also shows that the approach is manageable by the installation personnel. The level of detail will be less when the installation is required to complete the plan without outside assistance. Going forward, it is possible for other assessment teams to use the Assessment Guide and for the Army to move to a more standard method for assessing risk and prioritizing its investments based on risk.

The JRM CEIP Pilot was developed as a comprehensive framework to address the Navy's priorities for Reliability, Resilience, and Efficiency in a cost-effective way. The study highlighted a number of key lessons learned for the Guam situation in particular, but also for extending and adapting the process to other installations. These can be summarized as follows:

- *Resilience as Mission Assurance*. Guam has several environmental and mission requirements that drive the demand for resilient energy systems. While the mission assurance aspect resonates with all missions without exception, there is still apprehension about putting a cost on mission continuity. The concept of 'buying down risk' becomes an effective tool used in conjunction with scenario-based outcomes. For Guam, using the Energy Security and Readiness Scorecard to quantify the degree of resilience improvement proved effective in guiding decision making.
- *Demand Reduction is Still Critical.* While improving and adding more resilient infrastructure (grid improvements, storage, microgrids etc.) are directly beneficial to improving resilience, it was clear from the CEIP scenarios that reducing the demand played a significant role in reducing the size of infrastructure improvements, the size of load to the island, and consequently the costs of resilience.
- *The Resilient Role of District Systems.* Within the context of Guam (and possibly other Island systems), District Energy solutions prove to be highly favorable in improving resilience, provided they are carefully

R1 Reliability Metrics

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

R1a Grid Reliability (Inside the Fence)
- R1a.1 SAIDI (Avg. Outage duration per Yr (minutes)
- R1a.2 SAIFI (Avg. Interruption Freq. per yr)
- R1a.3 UEM Risk Rating (combination of CoF + LoF)

R1b Smart Grid Capability
- R1b.1 % of installation integrated under Smart Grid
- R1b.2 % of facilities under AMI Metering
- R1b.3 Established Smart Grid communications network
- R1b.4 Energy Management (BAS & SCADA) capability
- R1b.5 Automation of power distribution system
- R1b.6 Integration of on-site generation capability

R1c Advanced Peak Demand / Power Management Capability
- R1c.1 Capability is available through Microgrid/SmartGrid
- R1c.2 % of Critical Mission Facilities with above capability

R3 Efficiency Metrics

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

- R3a Energy Use Intensity Reduction
- R3b Utility Savings from Conservation+ Renewables and operational/ maintenance savings compared to No Action Projection

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 criteria:

R2a Redundancy & Availability
- R2a.1 **Energy Supply**
  - R2a.1.1 % Daily Energy Peak Capacity from on-site Renewable Energy sources
  - R21.1.2 % Daily Peak Energy Capacity from on-site emergency Generators
- R2a.2 **Redundant Infrastructure (Single Points of Failure)**
- R2a.3 **Other Availability Factors**

R2b Diversification Metrics
- R2b.1 **Source Energy (Utility Grid) Diversity**
- R2b.2 **Site Energy Diversity**

R2c Energy Security & Hardening Metrics
- R2c.1 **Energy Cybersecurity**
  - R2c.1.1 % of Energy SCADA Network on secure PSNET fiber
  - R2c.1.2 % of Energy Microgrid on secure PSNET fiber
- R2c.2 **Physical Security on Critical Energy Assets**
  - R2c.2.1 % Utility Transmission Underground
  - R2c.2.2 % Utility Distribution Underground
  - R2c.2.3 % Energy Comm Network Underground
- R2c.3 **Environmental Hardening/Protection**

R2d Recovery Metrics
- R2d.1 Islanding Capability
- R2d.2 # of days capable of running in Island Mode
- R2d.3 % critical facilities with Tier3/4 Emergency Generators
- R2d.4 % of daily energy load of energy storage* available (includes battery, thermal & other sources)

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[1]) - 100% by 2030	Cost ($M)[3]	By 2035 Projects Will Save ($M)	Cost $ / MBTU Saved	Positive Cash Flow
1	Business as Usual + Government Planned Projects[1]	57	48	95		48%	84%	84%	26%	35%	28%	$	$$	$$	14 Years (2029)
2	Mandate Compliance[2]	60	52	96		49%	100%	100%	26%	50%	44%	$	$$	$	13 Years (2028)
3	Resilient with Net-Zero MCBG[1,2,3]	100	87	100		62%	113%	113%	26%	54%	42%	$$	$$$	$$$	17 Years (2032)
4	Resilient Plus[1,2,3,4]	100	90	100		65%	138%	138%	26%	55%	66%	$$$	$$$	$$$$	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

Figure 12 *Cost Performance Metrics and Decision Matrix.*

planned. The maintenance, flexibility and future-readiness of district cooling and district microgrids connected to centralized generation and storage not only reduce long-term costs but add a layer of resilience and redundancy to the mission needs.

- *Blue-Sky Resilient Infrastructure.* Cost-effectiveness of resilient energy systems comes from considering 'blue-sky' operations, i.e., by leveraging resilience infrastructure such as Battery Storage or on-site generation, not just during emergencies but on normal operational days.
- *Using Efficiency to Pay for Resilience*. It is important to integrate resilience into energy planning to maximize cost-effective opportunities. The cost avoidance from reducing demand and promoting efficiency in energy systems can provide much-needed funding for investing in resilience. This is particularly relevant for engaging third-party financing, which would need to bundle cost-saving conservation projects with cost-only infrastructure improvements to be financially viable. The JRM CEIP effectively identified potential project bundles that could engage public utility investment (GPA Solar projects with energy storage) and private investments through Energy Service Performance Contracts (ESPCs).

CONCLUSION

Military installations are constantly operating in a state of constrained resources, and implementation of an integrated resilience approach to energy and water planning is still in its infancy. Military installations vary dramatically by size, mission, energy and water requirements, climatic conditions, and the status of the building stock. Some installations have more newly built and renovated facilities and utilities, while others are operating with aging building stock and limited means for improvement. There are no one-size-fits-all solutions for IEWPs. The implementation of resilience measures in the form of BMPs will allow vulnerability and risk assessments to become part of the scenario modeling done for installation master planning. When used as tools to evaluate critical infrastructure and mission sustainment, resilience measures can increase energy and water system efficacy not only on the installation, but in the wider community as a whole. The case studies described here highlight the importance of implementing a newly evolving framework that allows planners to institute resilience measures into energy and water master planning early in the development process. Many locations are yet to be analyzed, and while some installations are still awaiting funds to develop IEWPs and development of others are under way, the methodology and case studies described in this paper can provide some helpful guidance to planners and end users. Installations will need to continue to prioritize resilience measures based on existing and future needs, critical missions, and risk reduction.

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