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SUSTAINABLE ENERGY AT COASTAL FACILITIES

by

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ABSTRACT

This research seeks to identify pathways and remove obstacles to the adoption of renewable energy systems at coastal installations. Renewable energy generation is viewed as a promising means to increase installation resilience against disruptions caused by cyber-attacks or extreme weather, and is a key component of complying with executive orders issued to address climate change. The research team found that renewable generation assets are best paired with microgrids and/or energy storage in order to improve installation resilience, as traditional renewable generation depends on a functioning external power grid. Researchers studied the challenges facing renewable energy and microgrid integration and broke these challenges into technical, financial, law and policy challenges. This study concludes with an analysis of those challenges, proposed means to address them, and a collection of resources to help installation energy and facility managers through the process of designing and acquiring renewable energy and microgrid systems.

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I. SUMMARY

This research effort examined the paths to further adoption of sustainable energy at coastal facilities including current technical, financial, legal, and policy challenges that have hindered past efforts to incorporate more renewable energy and that are priorities to be considered for future renewable energy projects. The research team gathered data and information through an examination of literature and interviews with subject matter experts familiar with coastal facilities and with experts in the renewable energy sector. The team applied the research and analysis through case studies of US Coast Guard Station Monterey (California) and Naval Air Station Corpus Christi (Texas) to provide context for the adoption of sustainable renewable energy at coastal facilities. Additionally, research was conducted on mechanisms for microgrid financing to demonstrate how a facility may finance microgrid installation and adoption of renewable energy and microgrids. Researchers found that there are common core challenges for installing and using microgrids. These challenges include zoning issues, environmental considerations, infrastructure barriers, financing issues, safety standards, technical obstacles, and administrative hurdles. Some challenges can be lessened, avoided, or accounted for with advanced awareness and preparation. Further analysis of region-specific challenges would provide more context for consideration of sustainable energy and implementation of microgrids. Further study will also help to understand the details of an appropriate financial acquisition agreement with a quantification of the benefits and costs of microgrids over time. Finally, the processes for contracting out microgrid design and construction and identifying suitable contractors is recommended.

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II. BACKGROUND

This project was originally proposed as an effort to reduce energy costs and improve readiness through lowering the barriers to acquisition of renewable energy at coastal facilities. Energy costs are expected to continue to rise, and DoD facilities' reliance on the aging civilian electrical grid creates vulnerability towards outages caused by adversary kinetic or cyber actions and extreme weather events. Renewable energy is now cost-competitive with traditional energy sources and new mandates require increased resilience and investment in renewable systems, but improvements are needed to reduce hurdles and increase expertise for the federal government and DoD to take advantage of the opportunities to use renewable generation assets.

Additionally, past experience has revealed that renewable generation assets by themselves do not support key DoD readiness objectives. They can help lower energy costs and potentially free up funding for other efforts, but by themselves, they do not support energy resilience at DoD installations. Rather, they rely on an operational civilian power grid to yield benefits. In order to improve resilience, renewable generation must be paired with grid-forming energy storage or microgrids that are able to continue operating and supplying power to facilities even if the main grid is not functioning.

The research team originally set out to create a do-it-yourself approach to implementing small facility-scale microgrids at naval facilities, but it quickly became apparent that many facilities lacked personnel with the skills and experience necessary to build and maintain their own microgrid. Many facilities were unable to maintain renewable generation assets that had been professionally designed and installed by contractors. In light of these findings, the research team explored alternative means of acquisition and ownership.

One of the key obstacles that must be overcome to acquire new generation or storage assets is financing. One of the easiest paths to acquisition of renewable generation assets is the Power Purchase Agreement (PPA), where a contractor will own and operate a renewable generation asset located on federal land and sell the energy generated at a price that is lower than that of power provided by the grid. In this way, the installation receives less expensive energy without significant upfront cost. In this model, the contractor is also responsible for the upkeep of the renewable asset, so the installation does not need to have staff on hand who are capable of servicing it. PPAs have been successful on military installations such as Naval Air Weapons Station China Lake and are part of our recommendations for further adoption and acquisition of renewables and microgrid technologies. An Enhanced Use Lease (EUL) is an alternative method for adding renewable energy sources to an installation. An EUL funds construction or renovations on federal property through a private developer who leases underutilized property with payment in the form of funds or in-kind services.

The project also includes analysis of the law and policy related to microgrids. The intent of this analysis is to contribute to the development of policy that overcomes legal and regulatory hurdles and gaps related to microgrids. Researchers identified a common set of challenges related to microgrid development and their use in private and public sectors. Using this set of challenges, researchers applied them to two facilities as case studies – Monterey Coast Guard Station in California (USCGM) and Naval Air Station Corpus Christie in Texas (NASCC) to demonstrate how these challenges apply depending on the facility use, geographic location, environment and climate, applicable laws, and relationships between local, state and federal entities. The analysis culminates in a list of considerations for facilities that are considering use of microgrids which is available in Appendix 1.

III. METHODOLOGY

The research team originally set out with the intention of preparing a do-it-yourself guide to implementing facility-scale renewable generation and microgrids with storage on installations. This would have consisted of guides to identify critical facilities, calculate generation and storage needs, acquire components, understand technologies available, and analyze legal and policy challenges to be addressed. The researchers consulted with stakeholders at Port Hueneme, the USCGM, and NASCC to learn their challenges and experiences with implementing renewable energy and microgrids. The stakeholders reported that they had experienced significant issues with funding, acquisition, and maintenance of renewable energy systems. Challenges were not limited to technical or budgetary issues; bureaucratic, legal, and workforce challenges were also prevalent. Based on the information gathered from these sources, the research team concluded that a do-it-yourself approach to microgrid and renewable integration would be ineffective as installations would have a difficult time in acquiring and maintaining these systems.

Because the key stakeholders had communicated systemic challenges in purchasing and maintaining renewable energy and microgrid systems, the research team sought to explore alternative means of acquisition and ownership. The research team explored alternative funding and ownership models that had been used to acquire other technologies at DoD installations and base a proposed solution off of what has been successfully applied elsewhere. There is a precedent for installations lowering their energy costs through mechanisms such as a Power Purchase Agreement (PPA) or Enhanced Use Lease (EUL). Under a PPA, a contractor will install, own, and maintain a renewable generation system on an installation and sell the energy to the installation at a cost lower than the energy from the local utility provider. An EUL is a method for funding construction or renovations on federal property through a private developer who leases underutilized property with payment in the form of funds or in-kind services.

While these mechanisms are useful for securing renewable energy assets and lowering utility costs for an installation, they do not, on their own, improve resilience. The stakeholders expressed that resilience upgrades are difficult to fund because it is hard to quantify a return on investment. In light of these findings, researchers determined that it would be necessary to identify and confirm the viability of an acquisition model that allows installations to acquire microgrid, renewable generation, and energy storage technologies with little to no upfront cost and pay off the system over time.

The researchers sought to explore case studies for the aforementioned facilities at NASCC and the USCGM. These case studies explore the site-specific challenges and offer challenges that installations may encounter when considering the acquisition of microgrid systems. The researchers also took data from these sites to develop a financial case study to demonstrate the viability of our proposed acquisition model when applied to example microgrid designs provided by the private company Northern Reliability.

IV. FINDINGS

Technical Challenges

The primary technical challenges of implementing microgrids with renewables are the design of the system and challenges associated with energy storage. Implementing renewable generation by itself is a mature process, but implementing storage adds design and technical challenges. There are additional design constraints associated with different means of energy storage, and most NAVFAC personnel do not have experience in working with these constraints (R. Nordahl, General Engineer, PW6 – Microgrid Power Systems Team Lead, Microgrid Workshop, June 3, 2021).

One of the key challenges in the implementation of renewable energy and microgrid systems is that these systems are often custom designed for each facility. The one-off nature of most microgrid systems means there is a lack of one-size-fits-all solutions; this can increase the cost of system design and procurement. Additionally, most DoD facilities do not have personnel with the proper training or experience to design these microgrid systems from the ground up (R. Nordahl, General Engineer, PW6 – Microgrid Power Systems Team Lead, Microgrid Workshop, June 3, 2021), so they must rely on contractor expertise.

Even after a system is designed at the component level, there are additional constraints to ensure that the energy storage system complies with applicable rules and policies. Most commercial-scale energy storage comes as a form of lithium battery system which is considered a significant safety concern. Once started, there is no reliable means to put out a lithium battery fire other than to let it burn out. For this reason, most battery energy storage systems (BESS) must be placed at a minimum distance from any occupied facilities and require extensive fire control and prevention mechanisms (R. Nordahl, General Engineer, PW6 – Microgrid Power Systems Team Lead, Microgrid Workshop, June 3, 2021). Additionally, installation firefighters must be properly trained on how to deal with a lithium battery fire, and installation electricians must be trained on how to properly handle the batteries to minimize risks.

Even after a system is designed and implemented, there are still considerable technical challenges . Most installations do not have personnel on hand with relevant experience in maintaining renewable generation systems or a BESS, which can lead to systems falling into disrepair (R. Nordahl, General Engineer, PW6 – Microgrid Power Systems Team Lead, Microgrid workshop, June 3, 2021). Even installations with experienced microgrid R&D personnel may need assistance from contractors in maintaining or troubleshooting acquired equipment. Findings indicate that DoD installations have had trouble maintaining renewable generation systems (S. Foreman, PE, UEM Branch Head, Personal Communication, August 3, 2021; R. Nordahl, General Engineer, PW6 – Microgrid Power Systems Team Lead, Microgrid Workshop, June 3, 2021), and this problem likely will be compounded when a BESS is integrated.

In order to minimize the technical challenges associated with the design, implementation, and maintenance of microgrid systems with renewables and BESS, it is recommended that installations involve experienced contractors such as Caterpillar or Northern Reliability as early as possible in the design process, and write contracts that include maintenance agreements. Contractors like these have considerable experience in designing and maintaining robust renewable generation and BESS microgrid systems in the commercial sector. While it may be more expensive to pay for a contractor to maintain and operate a microgrid system, this overcomes the challenge of safely and efficiently maintaining the systems with the current DoD workforce.

Financial Challenges

Microgrids with energy storage are particularly difficult to fund due to the high cost of energy storage and the difficulty in quantifying an expected return on investment. Unlike renewables by themselves which can be expected to pay for themselves over time through reduced energy costs, the benefits of microgrids with battery systems come in the form of resilience or other capabilities that are difficult to assign a dollar value. As explained in the NASCC case study below, Winter Storm Uri in Texas 2021 revealed that while resilience may be expensive, a lack of resilience can prove even more costly.

Several programs exist within the DoD to finance the acquisition of installation energy technologies, but these programs are often geared towards efficiency improvements with an expected payback period. Historically, these programs have funded improvements such as replacing incandescent lights with LEDs or replacing outdated AC units. But microgrids are difficult to fund under these programs because they are an energy improvement that represents a new capability rather than an easily quantifiable savings. While there are programs that fund installation improvements that lead to new capabilities such as microgrids, these programs are typically more oriented towards individual R&D efforts, rather than widespread adoption of the technology.

Even after acquiring a microgrid system, there are financial challenges associated with owning and operating the system. Microgrids require periodic maintenance to keep the batteries in good condition and to ensure the renewable generation systems are functioning properly. This maintenance not only costs money and time, but there can be bureaucratic challenges in allocating the funds for the maintenance. Contacts at Port Hueneme and NASCC reported that a significant portion of the solar panel systems installed on base were inoperable. At Port Hueneme, funding for repairs had been delayed because there were challenges in deciding which department was responsible for the maintenance costs (R. Nordahl, General Engineer, PW6 – Microgrid Power Systems Team Lead, Personal Communication, June 3, 2021).

One potential solution to these financial challenges is an alternative funding and acquisition model similar in nature to a Power Purchase Agreement (PPA). Under a traditional PPA, a contractor will own and operate a renewable generation asset on a federal facility and sell the energy produced back to the installation. Under this type of agreement, the contractor is responsible for system maintenance and there is no upfront cost for the installation, although the energy cost is slightly higher than if the installation owned the equipment outright. If microgrids with renewable generation and energy storage are funded through an agreement similar to a PPA, installations may avoid the problems associated with high upfront equipment costs and contractors would be responsible for system maintenance. It is possible under such an agreement that energy costs would be higher than energy provided by local utilities, but facilities personnel agreed that an increased energy cost would be permissible if the rate could be locked in and bought additional capability (S. Foreman. UEM Branch Head, NASCC, Personal Communication, September 21, 2021; LT Gunderson, Personal Communication, August 5, 2021).

Legal and Policy Challenges

While microgrids have been in use for many years, they often are seen as an emerging technology and laws and policies rarely keep pace with technology as it changes. With the rapid changes in energy technology, microgrids can be subject to greater legal and regulatory challenges based on a rapidly changing energy sector. With different systems in use and under development, even defining microgrids can be a challenge (Wood, 2016, para. 12; Wouters, 2015).

The common set of challenges identified for microgrids includes the following:

- Zoning issues such as setback requirements and noise ordinances;
- Environmental considerations including location in a coastal zone or sensitive area or discharges associated with its use;
- Power and interconnection such as infrastructure barriers or the need for a power purchase agreement;
- Safety standards including fire and labor standards; and,
- Site-specific challenges.

These categories are not exhaustive; for example, facility staff also may experience administrative impediments or market barriers that may inhibit the implementation of microgrids. In addition, because microgrids are tailored to a specific location, they must also meet local requirements (Wouters, 2015). Advance awareness of these challenges enables facilities to address common challenges early in the process rather than as they arise or after commitment to a microgrid is made.

Placement of a microgrid at a facility can depend upon land use requirements in the home city or town. Facilities generally have existing relationships with land use boards and an understanding of the restrictions of placing certain infrastructure. Facilities in the coastal zone or those wishing to locate a microgrid near, adjacent to or over water (such as on a pier) may need to consider additional plans such as local or state coastal management plans or park and sanctuary management plans. As technology advances, zoning laws often do not keep pace and may be antiquated for the new uses under consideration. Facilities may need to pursue zoning exceptions to position a microgrid in the most beneficial location. In addition to zoning, environmental considerations need to be incorporated early in the process. If a facility has a microgrid and/or renewable energy sources, then an existing environmental review may cover the addition of new microgrids.

With climate change as a driver, state and federal emissions targets may support the introduction of renewable energy and microgrids at a facility. An installation may be able to take advantage of a state or regional programs designed to encourage renewable energy and energy efficiency (King, 2005). Similarly, safety considerations must be considered to manage safety related to the installation and use of microgrids. As an evolving technology, facilities must ensure there is awareness and skilled personnel training with the microgrid. Necessary training has been identified as a gap for many facilities.

Facilities also will need to incorporate the microgrid into their existing energy infrastructure, addressing the facility's relationship with the utility, whether private or public. In addition, staff will need to address challenges such as infrastructure barriers to connecting or interconnection issues (Saadeh, 2015). PPAs and EULs are mechanisms that can help address this interconnection and enable a facility to design an energy portfolio – including renewables and microgrids – that allows for efficiency and reliability. Finally, in addition to institutional and administrative barriers such as complicated, slow or non-transparent permitting procedures or the lack of funding opportunities, there may be other site-specific challenges to address. The two case studies included in this report address a combination of these challenges and present site-specific issues and recommendations.

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V. CASE STUDY: UNITED STATES COAST GUARD STATION MONTEREY

California has invested in its power network over the last two decades, producing significant amounts of geothermal, wind, and solar energy. The state leads the nation in non-hydroelectric renewable electricity generation and is now home to the largest battery energy storage system in the world in the form of the Vistra Zero Moss Landing Energy Storage Facility (California Energy Commission [CEC], 2020; Vistra, 2021). California has also battled the effects of climate change on its grid as transmission-impacting droughts, heatwaves, and wildfires have grown in size, duration, and intensity. Overall, changing climate conditions have affected the energy system in several ways including risks to infrastructure, changing energy demand, and changing performance of the energy delivery system (Bedsworth et al., 2018).

In response to increasing lawsuits and increased damage from wildfires, California's utilities have tried to reduce the risk of sparking further fires by shutting off transmission lines during storms. 2020 saw the state’s first rotating outages in nearly two decades and energy rationing was encouraged as blazes rendered power plants useless. Additionally, a significant problem with California’s power grid is meeting the demand during extreme heat at peak evening hours; as solar power drops off and little wind has been brought online, California relies heavily on dispatchable generation such as natural gas power plants and imports to meet the surge on the grid (CEC, 2021). These factors affect the resiliency of over 30 military bases in California which are reliant on this vulnerable grid, making independent sustainable renewable energy generation attractive, and in some cases, critical.

The USCGM is a coastal facility home to a 40+ member crew under the operational control of Coast Guard sector San Francisco. The Station’s area of responsibility covers 120 nautical miles of coastline between Point Año Nuevo and the Monterey-San Luis Obispo County line and extends 50 nautical miles offshore, including 5000 square miles of Monterey Bay National Marine Sanctuary.

Critical loads for the Station consist of IT and communications equipment to facilitate search and rescue at the main building, as well as shore power to motor life boats and a small response boat at the pier. Two power shutdowns have occurred over the past two years with other outage to shore power caused by marine mammal damage. The Station is equipped with a backup generator which consumes 100 gallons per hour but does not currently power all needed equipment due to outdated wiring and a 60kw capacity. There is also a dockside diesel generator used to keep ship batteries charged and ready, and the USCGC Hawksbill, which requires a minimum 68kw generation, is equipped with two 60kw generators each consuming about 10 gallons per hour (S. Gunderson, Executive Officer USCGM, interview with author, August 5, 2021).

There are currently two pending projects to improve resilience at the Station. These projects will renovate the wiring of the administrative building to power critical loads with generators and provide uninterruptible power supply (UPS) to IT, communications, and radar. There is space for setting up renewable generation and containerized battery systems, and the critical loads are clearly defined and concentrated. Additionally, the National Oceanic and Atmospheric Administration has a weather Station in place for solar and wind data on the pier near the candidate location for a microgrid. However, there has been little discussion to implement a microgrid (S. Gunderson, Executive Officer USCGM, interview with author, August 5, 2021).

According to LTJG Amy Kimura of the Civil Engineering Unit (CEU) Oakland, the Coast Guard tends to install building-level backup power generation to provide additional resiliency for its Stations; microgrids are not typically considered a viable solution for smaller sites, due to high cost and complex operations and maintenance (email to author, September 28, 2021). In addition, the federal System for Award Management requires a single contracting spend of over $25,000, which immediately makes any renewable energy project for a small Station such as Monterey a much larger, and possibly unnecessary, undertaking. The Station would need to show a demonstrated business and resilience case for this level of expense (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021). Furthermore, for bigger projects, contractors would likely be brought in from some distance triggering bureaucratic hurdles delaying the start of projects. In fact, the timetable to get a project approved, funded, and underway, can often take longer than the duty tour of the personnel trying to implement it (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021).

CEU Oakland California, provides infrastructure support services to the Coast Guard, managing all construction projects, including all National Environmental Policy Act (NEPA) reviews, permitting, real property, legal, safety, state historic preservation, and public notice requirements for USCGM (A. Kimura, email to author, September 28, 2021). Yet, CEU Oakland, despite not being a government agency, is made up of a team of active-duty personnel with similar frequent turnover and less consistency than similar facility asset managers elsewhere made up only of civilians (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021).

In terms of changes to infrastructure, USCGM has a significant amount of flexibility as administrative buildings and the pier are Coast Guard owned federal property. (see Figure 1. for an overview of ownership in the area. A, C, & H being Coast Guard). Assuming the property in question is under the ownership of the Coast Guard and they coordinate with the City of Monterey if there is a project overlap, the Coast Guard via CEU Oakland generally has the ability to approve its own projects (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021; A. Kimura, email to author, September 28, 2021; C. Sabdo, email to author, September 29, 2021).

Figure 1. Ownership at Coast Guard Station Monterey

A APN 001-044-001-000; USA; Zoning PC-LH
B APN 001-042-003-000; City; Zoning PC-W
C APN 001-042-001-000; USA; Zoning PC-W
D APN 001-042-004-000; City; Zoning PC-W
E APN 001-042-005-000; City; Zoning PC-W
F APN 001-042-006-000; City; Zoning PC-W
G Parcel: APN 001-042-007-000 , City, Zoning N/A
Pier/Docks: APN GOV000005; Owner GOV000005, Zoning N/A
H APN GOV000004; Owner:GOV000004; Zoning PC-W

Source: City of Monterey, 2021

However, Christy Sabdo, an Associate Planner with the City of Monterey clarified that City submerged lands are owned by the people of California and the State Lands Commission gives the City certain rights under the State Lands Act. Furthermore, there are potential safety concerns with the Coast Guard being within the airport safety zone. Any significantly tall structure, for example, would likely not be possible due to being in the airport flight path with subsequent approvals and safety analysis potentially needed from the Federal Aviation Administration (FAA) and Monterey County Airport Land Use Commission (email to author, September 29, 2021)

Additionally, the City can comment on political and aesthetic concerns as well as NEPA documents and Coastal Permits, and the Coast Guard may consult the City for issues such as the Army Corps Permits, Regional Water Quality Control Board permits and encroachment permits (C. Sabdo, email to author, September 29, 2021). So, there are circumstances where projects may require certain cooperation between the Coast Guard and the City.

Although the Coast Guard has more leeway by operating on federally owned property, there has been no new construction since the 1970s at USCGM due to lengthy and competitive approval processes (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021). For any changes in general, the Station would have to follow the standard Coast Guard Procurement, Construction & Improvement (PC&I) process for consideration of infrastructure and facility change, reconfiguration, or recapitalization, which would have to be based on an actual requirement or existing facility gap. The PC&I process is about 8 years or more, depending on priority amongst the many other shore infrastructure needs (A. Kimura, email to author, September 28, 2021).

Specifically, for installing renewable energy such as photovoltaic (PV) or other energy conservation measures, an existing Station could compete such projects at the annual Energy-POP which considers candidate projects for funding and execution two years out in a highly competitive ~$3M pot of annual dollars executed by the regional Civil Engineering Unit (A. Kimura, email to author, September 28, 2021).

Some Coast Guard Stations have made, or appear to have made, more progress in microgrid acquisition in comparison to USCGM; however, this may be due to a few unique circumstances. First, locations that have experienced damage (such as from severe storms) have to rebuild and receive funding quicker. It is easier to build new infrastructure to accommodate a microgrid than retrofit old buildings (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021). Second, larger stations have more engineering capabilities with personnel able to maintain equipment. At USCGM, the engineering capacity is limited. It is seen as cheaper to outsource maintenance which can create a knowledge and skills gap (S. Gunderson, Executive Officer USCGM, interview with author, August 27, 2021). Third, renewable energy (e.g., PV) may be installed at new Stations in an effort to reduce energy costs and make progress towards Coast Guard Net Zero goals. However, it is not likely that they will be connected to a microgrid or to a battery energy storage system and therefore do not significantly attribute to resiliency (A. Kimura, email to author, September 28, 2021).

There is progress in the region: Central Coast Community Energy's UPS Program for critical infrastructure has allocated $25 million to accelerate the adoption of reliable backup power for eligible public and private entities operating critical facilities. Eligible technologies include backup fossil fuel generators, battery energy storage systems, solar, wind, and combinations of technologies that provide energy resiliency (C.Sabdo, email to author, September 29, 2021).

It would require significant structural reorganization by the Coast Guard, but if the parallel nature of infrastructure change procedure between the City and CEU Oakland, particularly when it comes to energy projects, could be reimagined, there seems to be scope to achieve smaller scale microgrid implementation at USCGM as a necessary operation central to the City of Monterey's maritime safety. There is clear need for an alternative financial acquisition model and approval process to significantly speed up the start of a smaller project at USCGM that doesn't require the Station to compete for larger projects than necessary with unlikely approval odds within the Coast Guard system.

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VI. CASE STUDY: NAVAL AIR STATION CORPUS CHRISTI

Moving from a California case study to a Texas case study means moving from a regulated system to a deregulated system. One of the unique aspects of energy in Texas is that the energy grid is predominantly independent. The Texas Interconnection is maintained as a separate grid but it can draw some power from other grids. The grid is, in most respects, not subject to federal regulation; thus, it is referred to as a deregulated system and is, in effect, a market-based system.

The market-based nature of the energy grid in Texas impacts rates and becomes particularly significant in extreme weather, for private parties and for DoD and other federal installations. During the week of February 13-17, 2021, a record-setting winter storm named Uri brought plunging temperatures to Texas (National Weather Service, 2021). The independence of the energy grid and market-based systems showed vulnerabilities; it also exposed an aging energy grid unprepared for a changing climate. Nearly 50% of Texas is powered by natural gas, 20% by coal, another 20% by wind and solar, and 10% by nuclear energy (NOVA, 2021). With summer temperatures regularly soaring above 90 degrees F, Texas energy systems often safeguard against heat but generally are not optimized for freezing conditions.

Navy bases in Texas, including NASCC, NAS JRB Fort Worth, and NAS Kingsville, were under market-based pricing. Surrounded on three sides by water -- Corpus Christi Bay, Oso Bay and the Laguna Madre – NASCC trains Navy, Marine Corps, Coast Guard and foreign pilots and is home to the Corpus Christi Army Depot and dozens of other tenant organizations.

During Uri, the cost per megawatt hour (MWh) for NASCC rose from approximately $9/MWh to $9000/MWh. The base is on a critical list in which it is not subject to rolling blackouts so it maintained operations during that time and was billed at this much higher rate for its energy use during freezing temperatures throughout the storm. In order to meet as least some of these unexpected costs, NASCC raised the energy rates for its tenants. While the energy costs during Uri was an extreme example, this wasn't the first time the cost had risen dramatically. Extreme heat in the summer of 2019 caused costs to rise to $3000/MWh. The Navy has since modified the contracts to switch to a firm fixed price and, at least for the next several years, will maintain a contract with a set rate of approximately $40/MWh (K. Martin, PW8 Energy Program Director, NAVFAC Southeast, interview with author, September 22, 2021). This allows the Navy to accept greater costs during the normally low-priced months to avoid huge unexpected increases. In this way, a budget can be built for future years with more confidence.

NASCC is also unique because energy is privatized on the base. Nueces Cooperative maintains the lines and repairs outages. NASCC has a natural gas generator available on the facility but it is not currently considering renewable energy. The facility had solar panels onsite but they were damaged during Hurricane Harvey in 2017. Because of costs, they were removed rather than repaired (K. Martin, PW8 Energy Program Director, NAVFAC Southeast, interview with author, September 22, 2021).

Other considerations related to the introduction of microgrids at NASCC include staffing, zoning and environmental concerns. There are NASCC personnel to maintain and repair its existing generators and emergency personnel stay on base during extreme weather events. NASCC has portable generators; in September 2021, these were in New Orleans to assist following Hurricane Ida. If there is a power outage, NASCC has personnel that will move those generators to where most needed on the base (S. Foreman, UEM Branch Head, NASCC, interview with author, September 21, 2021). Even though new technology such as a microgrid would require training including maintenance, repair and the use of any applicable software, there is precedent for areas affected by storms to rely on microgrids. The Center for Climate and Energy Solutions notes that "While surrounding areas went dark during the 2011 earthquake, the 2012 Derecho event, Hurricanes Irene and Sandy, and numerous other storms, the FDA center's microgrid remained online" (Center for Climate and Energy Solutions [C2ES], 2017).

As a Naval Air Station, there are special considerations including the location and angle of solar panels (if used) to eliminate glare interference with pilots. Any new installation is also subject to FAA regulations, especially those related to air fields, for safety. Furthermore, NASCC is one of the most corrosive environments in the country. Metals must be pre-treated which triggers both environmental and budgetary considerations. Further environmental considerations depend upon what materials are considered and taking into account the waters and protected areas around the base (S. Foreman, UEM Branch Head, NASCC, interview with author, September 21, 2021).

According to Martin, for the Southeast region, there are other facilities with renewable energy and unique mechanisms to answer site-specific energy challenges. For example, Guantanamo Bay is self-sufficient as the facility makes its own power and useable water and is therefore considered a microgrid. In addition, there is a Readiness and Environmental Protection Integration (REPI) project at the Naval Construction Battalion Center in Gulfport, Mississippi, in which the facility uses an EUL of approximately 25 years to allow the utility company to build a solar array on portions of base. The in-kind consideration was a microgrid of 5 backup generators with battery storage and access to 1MWh capacity of solar array. There is an emergency grid to feed a portion of the base in a utility outage. Because lease payments do not directly benefit the facility, the EUL with in-kind payment benefits the installation more. In addition, at Naval Submarine Base Kings Bay in Georgia, there are redundant generators that can power most of the base in a utility outage. At that installation, there also is an EUL for a solar array with in-kind consideration. Mechanisms like the EUL allow for a facility to advance new energy sources like renewables and microgrids while working within a resource-restricted financial environment. This type of public-private effort is gaining popularity because they allow for sharing of project risks and management while making projects more viable (C2ES, 2017). These options may be useful to a facility like NASCC as it considers energy options that can withstand the challenges of severe weather, a corrosive environment, and an independent energy grid.

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VII. CASE STUDY: MICROGRID FINANCING

One of the biggest challenges in acquiring energy resilience technology is that it is difficult to secure funding for energy projects that don't have a clear fiscal return on investment. For this reason, the research team explored the possibility of pairing microgrids including energy storage with renewable generation assets and a financial model similar to a PPA. Although commands may not be able to allocate funds for the large upfront acquisition cost of a system, paying a few extra cents per kwh of energy could be budgeted if it also provided resilience benefits. To demonstrate that this approach was economically viable, the research team solicited a small sampling of prefabricated microgrid designs from Northern Reliability and Caterpillar to calculate how much generation capability would be needed to realistically finance the acquisition and upkeep costs of different microgrid systems. Under our proposed acquisition model, an installation would form an agreement with a contractor to install, own, and operate both a microgrid with storage and renewable generation assets; the energy generated by the renewables would be purchased by the installation at a price per kwh equal to or slightly higher than energy purchased from the local utility company.

To determine the financial feasibility of financing a microgrid through paying a premium for renewable energy generation, we solicited example microgrid configurations from Caterpillar and Northern Reliability. Northern Reliability provided example microgrid systems that were available at the sizes and price points shown below.

Microgrid Size	Initial System Cost	Total 10 Year Ownership Cost
500kw / 1088kwh	$636,000	$791,000
1Mw / 2.176Mwh	$1,000,000	$1,155,000
2Mw / 4.352Mwh	$1,903,000	$2,058,000

The ten year total cost of ownership above includes the initial purchase price of the system, an allowance for training sessions, and regular maintenance performed by the contractor.

To determine how much solar generation would be needed to pay off the microgrid system over the life of its batteries (10 years), we made assumptions regarding what installations would be willing to pay for energy and what the solar system itself would cost. Based on market data, we assumed a solar system installation cost of $2.50 per watt, and that an installation would be willing to pay no more than $0.40 per kwh of energy generated from the solar system. With these assumptions, the amount paid for energy is shown in the table below. The column on the far right shows how much of that energy cost can go towards funding the microgrid after paying for the solar system itself, assuming a ten year payback period.

Solar System Size (kw)	Solar System Cost	Yearly Generation (kwh)	Annual Energy Cost (at $0.40/kwh)	Annual Energy Cost Put Towards Microgrid (10 Years)
10	$25,000	13,600	$5,440	$2,940
25	$62,500	34,000	$13,600	$7,350
50	$125,000	68,000	$27,200	$14,700
100	$250,000	136,000	$54,400	$29,400
200	$500,000	272,000	$108,800	$58,800
300	$750,000	408,000	$163,200	$88,200
500	$1,250,000	680,000	$272,000	$147,000

For a 300kw solar system, an installation could finance a 500kw / 1088kwh, or for a 500kw solar system, an installation could finance a 1Mw / 2.176Mwh microgrid system to provide backup power to their critical loads. These numbers can vary drastically depending on what assumptions are made for maintenance costs, financing timelines, and procurement costs. When considering the longer term, the numbers are even more favorable because most solar systems have an expected life of 25 years, and the batteries are typically the only component of the microgrid that needs to be replaced after 10 years.

The case studies show a common set of challenges that may inhibit development, installation or use in general. They also show that it is vital to understand the unique nature of the environment in which the microgrid will be placed and the unique relationships between local, state and federal entities at that location. Finally, using PPAs, EULs or other proven mechanisms to overcome financial and administrative hurdles can enable installations to introduce (or re-introduce) renewable energy assets and microgrids.

VIII. FOLLOW-ON STUDY RECOMMENDATIONS

Further study is needed to refine the processes for contracting out microgrid design and construction, to identify suitable contractors, and do a deeper analysis into region-specific technical, legal, and policy challenges. In this study, researchers identified two potential contractors, Caterpillar and Northern Reliability, but a larger sample will be needed to get competitive bids for microgrids across the country or at OCONUS installations. The research team recommends an acquisition agreement, similar to a PPA, but more work is needed to iron out the details in order to ensure it is greatest value to installations. In addition, a comparison of the benefits of a PPA compared to an EUL would assist installations in selecting the mechanism best suited to their needs and location. Further work also is needed to determine what these microgrid systems will cost over time and what DoD considers an acceptable cost for the resilience they provide. Installations across the country face different regulatory and policy challenges and further case studies can enable policy changes that ease the burden these projects sometimes face and encourage use of microgrids at DoD installations.

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APPENDIX A – LIST OF LEGAL/POLICY CONSIDERATIONS

Based on the analysis of challenges in implementing microgrids, this appendix provides considerations for facilities that are considering use of microgrids.

Zoning/Siting

- What is the Facility relationship with the city/town in terms of land use?
- What does the facility have control over in terms property and what can be placed there?
- If the microgrid will be placed over water and submerged lands, are there special considerations or permissions needed?
    - Who owns the submerged lands or structure (such as a pier)?
    - Are the structure or submerged lands permitted/leased through the city or state?
- What are the site-specific zoning laws such as set-back requirements?

Environmental Considerations

- Is there currently a microgrid on the facility?
    - If so, revisit the environmental review for consistency with review criteria.
- Is there renewable energy incorporated at the facility?
    - If so, revisit the environmental review for consistency with review criteria.
- Was a microgrid or renewable energy considered but declined?
    - If so, revisit for an understanding of the hurdles that prevented project from moving forward. Are those hurdles still there?
- Is the facility located in the coastal zone? Are there special considerations related to a state or local Coastal Plan?
- Are there existing environmental reviews that cover the addition of a microgrid?
- Consider social acceptance and environmental barriers linked to experience with planning. Are there challenges in that locality such as regulations and/or public acceptance of renewable energy?
- Are there federal or state emission reduction targets that may act as drivers for the introduction of a microgrid?

Power/Interconnection

- Are there infrastructure barriers to connecting?
- Are there any existing interconnection issues to be aware of?
- Consider infrastructure barriers that mainly center on the flexibility of the energy system, e.g., the power grid, to integrate/absorb renewable energy. This includes interconnection rules and perceived or real intrusion on the utility.
- Can your facility own and/or transfer the Renewable Energy Certificates (RECs) for energy creation? Is a third party allowed to maintain RECs and can the facility benefit from the savings?

- Is a power purchase agreement (PPA) or enhanced use lease (EUL) allowed and/or necessary for the facility? Would it facilitate use of renewable or microgrid technology?

Safety Standards (fire/etc.)

- Who at facility would manage safety related to the installation or use of the microgrid?
- Are there specific safety standard or requirements specific to your site and/or use of a microgrid?
- Consider the lack of awareness and skilled personnel relating to insufficient knowledge about the availability and performance of renewables and/or microgrids.
- Is personnel training necessary and available?

General/Other

- Are microgrids adequately defined? If so, does the microgrid under consideration meet this definition?
- Are the policies and laws sufficiently clear and transparent? If not, what support is needed to understand their applicability?
- Are there institutional and administrative barriers, such as the lack of strong, dedicated institutions, lack of clear responsibilities, and complicated, slow or non-transparent permitting procedures?
- Are there financial barriers associated with an absence of adequate funding opportunities; i.e., who pays for it?
- Are there challenges because this is a developing technology? Would adding parts change the regulatory status of the unit?

Site-Specific

- How would you obtain information on local/county/state policy related to microgrids?
- How would a microgrid provider be identified and who facilitates the discussion?
- Will there be staff trained to run the microgrid?
    - If not, what would the process be in contracting local assistance?
- What are the contacts for the site related to public works, financial assistance and contracts?

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